WOLFGANG RUNGE

TECHNOLOGY ENTREPRENEURSHIP

A Treatise on Entrepreneurs and Entrepreneurship for and in Technology Ventures

Volume 1 & 2

KIT Scientific Publishing

Wolfgang Runge

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by
Wolfgang Runge

Scientific
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Dedication

To my spouse Gisela and our daughters Diana and Sarah recognizing their enrichments, stimulations and support for my life.

Acknowledgements

I thank Professor Dr. Stefan Bräse and Dr. Thierry Muller of the Institute of Organic Chemistry of the Technical University of Karlsruhe branch of the Karlsruhe Institute of Technology (KIT) for their continuous interest, support and time spent in many discussions to make the Technology Entrepreneurship curriculum continuously happen.

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Finally I appreciate also the contributions of those students of the curriculum who asked tough questions and raised discussions whose answers and conclusions could add to shape this book's content.

About the Author

Wolfgang Runge is an independent scientist and consultant for various areas of innovation and research in the chemical industry. He is a chemist by education with a doctoral degree from the Free University of Berlin (Germany) and subsequently the additional particular German degree of a "Habilitation" (Dr. rer. nat. habil.) from the Technical University of Munich (Germany), which is usually one prerequisite to become a professor in a science discipline at a German university.

After working for eight years in *academic research*, he turned for eleven years to *applied research* in the "Society for Information and Documentation" (in German Gesellschaft für Information und Dokumentation – GID), a governmental research organization which eventually was incorporated into the "Fraunhofer GMD National Research Center for Information Technology," and then he worked for eighteen years in *industrial research* in a German Research Center and in Corporate Research of The Dow Chemical Company as "R&D Operations Manager," "Information Project Leader" and "Specialist."

He published widely in leading scientific journals and books in Germany, the US and UK in organic and physical organic chemistry, physical chemistry, chemical physics and quantum-chemistry, information science and sociology of science.

Technical reports in the organizations he worked for included topics in chemical information and computer science, innovation research, "electronic publishing," document architectures and markup languages, General Systems Theory (GST), information economy and information systems development.

Major recent thrusts with Dow included "intellectual asset management" (IAM), "competitive intelligence" activities for R&D and new business development, the XML computer (markup) language and its use for Web services, development and implementation of a "technology intelligence" system having a "patent system" as a core. Simultaneously, he further developed and applied "Knowledge Discovery in Text Databases" (KDT) methodologies and techniques for various "intelligence activities."

Since several years he fills the role of an adjunct (in German Gastdozent) at the Karlsruhe University branch of the Karlsruhe Institute of Technology (KIT) leading the Technology Entrepreneurship Curriculum. [1]

CONTENTS

PREFACE

Theoria cum Praxi
Gottfried Wilhelm Leibniz (1646 - 1716)

The current effort to grasp, organize and present knowledge and thinking about the special phenomenon of “technology entrepreneurship” has practical origins. Intelligent questions and controversial discussions with students during corresponding courses over the last six years and discussions with the technology entrepreneurs who gave guest lectures as part of the related course let me re-assess what I think to understand about the topic. The result was disillusioning – not with regard to common knowledge. But my conclusion was: I have to dig deeper into the subject.

Entrepreneurship means *change* in many facets of society. And as technology is ubiquitous in modern societies and represents a large portion of the “real economy,” technology entrepreneurship contributes significantly to national and global economic wealth and growth.

In a recent book of the author [Runge 2006] on the German and US chemical industry some history of the industry, significant contributing firms and entrepreneurship was dealt with in a restricted context of industry dynamics, innovation and research. Furthermore, new technology-based firms (NTBFs) were discussed essentially with regard to the roles they play currently for innovation by existing large companies. Concerning i*nnovation* the emphasis was on *people, change, uncertainty and risk* and on *“innovative” behavior* in the context of individuals founding innovative endeavors or firms and innovation in organizational and inter-organizational contexts.

Even more than in the previous book the present treatise relies on principles and concepts of *Applied General Systems Theory* (GST) [Van Gigch 1974; Skyttner 2005]. In particular, GST has turned out to provide the proper concepts to consistently treat entrepreneurship in existing firms (“intrapreneurship”) as a specialization of entrepreneurship to found new firms within the same theoretical framework.

Since the “discipline” of entrepreneurship is a young one (relative to many other fields) with contributions from many scientific disciplines, we are not seeing rapid convergence towards a unified theory of entrepreneurship, and seeing even less agreement on competencies required to do so.

Due to their many connection points to different scientific disciplines or sub-disciplines, respectively, *entrepreneurship is not a homogeneous field of research and inquiry*. And the entrepreneur and his/her decisions, actions and practice are embedded into situations which do not allow caring how mankind has spread the requirements of “homogeneity” over various heterogeneous disciplines.

Moreover, corresponding incumbents and the public opinion take for granted that entrepreneurship is essentially a domain of business administration (mapped to “Betriebswirtschaft" in Germany) or economics. However, we share the opinion of A. Gibb who is cited by Faltin [2007:33]:

> "It seems that the importance of intense work on an idea has been subsumed by the dominance of teachings of business knowledge. What is necessary is to remove entrepreneurship from this narrow confine and the often close association with business administration, a too narrow paradigm for entrepreneurship."

Bhidé [2000:5-9] has focused the role of economics for entrepreneurship by the statement: "Many of the variables studied in this book lie outside the domain of modern economics." And Johnson [2011] provides a harsh critique of professional economists "They purport to know about trade and finance, about markets and credit, but I struggle to identify the actual benefits of all their expensive advice and esoteric debates. The only response I know to this nightmare is to encourage entrepreneurs to start new companies."

Bhidé [2000:xiii] cites the opinion that "education in business administration [was], at best, a minor factor in successful business start-ups." We hear also that business schools providing training in entrepreneurship "usually succeed in imparting only the skills of the manager." [Bhidé 2000:9] And Schramm [2006a] added:

> "The curriculum in most MBA schools is all about skill sets – there's very little that's taught about the larger economic context. The degree has become exactly what it is named, training in the administration or management of business as opposed to the generation of business."

Over the last decade entrepreneurship has become "big business" driven considerably by policy, in terms of for-profit consulting and training – and higher education by universities or schools with business administration or economics grasping the opportunities and grabbing university chairs and related departments. This is a perplexing situation which has been spelled out recently:

> "Considering that, as the present study has shown, a large proportion of founders of high-tech ventures have an engineering- or natural science-based education, it is astonishing that education of founders in Germany is targeted primarily at economists." (Translated from [Gottschalk et al. 2007:65])

And in the US even the role of "green" MBAs for venture capital firms has been critically assessed (Box I.6).

And what do we hear in this regard from successful technology entrepreneurs, such as (the German) Niels Fertig, the founder of Nanion Technologies GmbH who is highly rewarded by several prestigious German entrepreneurship and innovation prizes?

> "Today, I am convinced that you can get on with a competent financial service provider like the Savings Bank Munich Starnberg and a good tax consultant without an education in business administration."
>
> (in German "Heute bin ich der Überzeugung, dass man mit einem kompetenten Finanzdienstleister wie der Kreissparkasse München Starnberg und einem guten Steuerberater durchaus ohne betriebswirtschaftliche Ausbildung zurecht kommen kann."

And in the US we hear from Chad Hurley, a co-founder of YouTube, with a degree in art from Indiana University of Pennsylvania after having studied design how he remembers his days with the Internet company PayPal (Appendix A.1.7) as an education in business [O'Brien 2007]:

> "You may not have a business degree, but you see how to put the process into effect. The experience helped me realize the payoff of being involved in a startup."

As we shall see later, a very large proportion of scientists and engineers found their firms after they have gained experience in industry (ch. 2.1.2.4) having grasped the essentials of business and project proposals on-the-job or by special trainings (on demand) – without any needs of a formalized business administration education.

Furthermore, though not representative, but indicative is the fact that for the set of ca. sixty new technology ventures used as cases in this book only three of them had economics degrees (MBAs) as co-founders. And in these cases the idea for foundation and demonstratable results or prototypes were already in place.

And finally even for the ca. five percent proportion of the venture capital (VC)-based new firms of all NTBFs most management teams implemented by venture capitalists consist of people with two decades of management and industrial experience rather than "green MBAs."

There is no question about the necessity and importance of business administration. It is indispensable for a company's structured growth and long-term success. A basic question is whether, when and in how far (technology) entrepreneurs need to take the role or even the job of having to execute activities and processes in terms of proven tools provided for practicing business administration.

As a natural scientist by education with years of practice and years of practicing applied and industrial research and management I have been concentrating on finding out when, during the technology entrepreneurship process, business administration will add indispensable and important contributions and how long some basics of business administration and learning-by-doing of firm founders will suffice.

For all these contexts the author's "Technology Entrepreneurship" curriculum for scientists and engineers at the Technical University of Karlsruhe, Germany (now part of the ca. €800 million budget Karlsruhe Institute of Technology – KIT) has played an important role. This curriculum is not primarily addressed at MBA majors and minors, but scientists and engineers. [1] However, MBA majors and minors are welcomed.

Following the above outlines this book presents the differentiated view that business administration or economics or particular parts of them, respectively, become relevant after founding a new technology venture, when the firm has passed a particular stage of development.

The author thinks that, at least with regard to technology entrepreneurship, a very differentiated taxonomy based on various criteria is necessary for understanding the subject which will emerge in the various chapters of the book.

On the most general level, such taxonomies can serve as a teaching tool. By discussing these different taxonomies in entrepreneurship classes, the instructor can help students to become aware that there are many different types of technology entrepreneurship, each calling for different skills of and investments by the entrepreneur, and each presenting different risks and rewards. The practical issue associated with this complexifying view is to evaluate the level of significance for understanding and explaining, that is "all criteria being equal, but some criteria being more equal than others."

To overcome the dilemma of scientific heterogeneity and complexity the current book does not aim to overlay the diversity of discipline-oriented foundations of entrepreneurship with a meta-theoretical shell. Instead, we use GST as the framework and backbone to deal with technology entrepreneurship and we put more emphasis on people, their decisions and activities than on "standardized" processes for the subject.

The essence of GST induces a direction to look for *generic features of entrepreneurship* which are independent from spatial and temporal factors. This means, for instance, there are structures and processes to be revealed and made explicit that are (largely) independent from time, cultural factors, the socio-economic system, technical or non-technical conditions etc. and there are features which are bound to such factors and conditions. Overcoming simply describing situations the current book, having in mind the separation of generic and specific factors, deals with *technology entrepreneurship in the US and Germany via a contemporary comparative approach*.

Additionally, a *historical approach* to the subject let emerge features of technology entrepreneurship that are independent from temporal conditions. In Runge [2006:397-402] the Berlin Blue (Prussian Blue) innovation from 1704 and the related birth of inorganic chemistry has been mapped against current notions, concepts and thinking of innovation and entrepreneurship. Correspondingly, the re-invention of porcelain in the state of Saxony (Germany) in 1708 associated with re-engineering and issues of scale-up for large-scale production has shed light on "production-engineering" oriented entrepreneurship [Runge 2006:402-405] – on "producing technology ventures."

In this book (Appendix A.1.2) the same approach is complemented by the birth of organic chemistry and the organic dye industry in 1856. And an extensive discussion of the current entrepreneurial activities in the field of biofuels (A.1.1) again reveals another significant role of history for technology entrepreneurship.

Emphasizing the time factor in this book represents a response to some observed issues of research. Integrating findings from factors of growth studies covering different time intervals of growth has proved to be a challenge. Different samples and time frames have come up with contradictory or inconclusive results.

The response in this book will be based on "theory" referring to some basic cybernetic principles and concepts in the sense of Gartner's [2006:331-332] analysis of the status and facts of entrepreneurship research. "The kinds of relevant facts that appear to be of more interest in the entrepreneurship field are those facts tied to some kind of theoretical construct, that is, "theoretical facts": facts that offer some sense of 'why' something occurred are to be preferred."

> "I suggest that the entrepreneurship field needs more descriptive research, rather than less. Descriptive facts as those facts that may, or may not, have an ability to answer 'Why', but these facts do provide more information about the phenomenon, itself." [Gartner 2006:331-332]

Theory building interconnected with "measurement" will evolve successively after presenting more of the phenomenon by descriptive facts and empirically derived typologies of new technology-based firms (NTBFs) which make sense out of non-quantified observation.

Simultaneously, I also want to derive some practical lessons about starting new technology ventures. Being descriptive I focus much on "winners," deal much less with "losers" and concentrate generally on mistakes and pitfalls to be avoided. In a continuously changing world the notion praxis has an important explicit time dimension.

"Praxis" means "current practice," practice established during the previous fifteen to twenty years. And "praxis" must clearly differentiate the specific structures and processes used presently from those which are independent from time (and location) – the *generic* structures and processes.

Entrepreneurship research based on selecting samples and statistics has a built-in contradiction: it provides often results and statements about medians and averages, often as the basis of suggesting "how to," but disregards "*outliers*." On the other hand, practicing entrepreneurship, in particular, very successful entrepreneurship, is also interested in what is not common and shared by a majority, is not being "average" but above or far above average.

The "*theory-into-practice*" approach of the book is in line with the motto "theoria cum praxi" of Leibniz [Runge 2006:210]: It aims to combine the "what and why" with the "how" in the sense of *recommendations* (or proposals) rather than instructions. Making recommendations requires consolidations of details (from cases) and practicing means differentiation. In particular, for technology entrepreneurship, one does not fit all! Making recommendations or proposals may mean that the author suggests something which is different from the one viewed by others as "best practice."

The emphasis on the *present* situation of entrepreneurship requires to critically assess "elder" research results with regard to their "generic content" and directs tackling the *current realities* with an emphasis on cases for rather new firms and industries. Practice then means decision and action in the *presence* which has developed over the last two decades!

Consequences of the focus on "real-time events, situations and behavior," means much references to information on the Internet and current business literature (business magazines and business newsletters or newsfeeds, as differentiated from scientific business literature) and even newspaper information, and putting this into the context of generic structures, functions and activities. This is furthermore complemented by many cases of current startups/NTBFs, accessible via the Appendix (B.2). It means also lifting an economic axiom-like approach which is taking a broad set of not necessarily reality-prove assumptions for granted.

To support the practical side the approach makes use of a large number of cases which serve as examples for learning. Furthermore, the focus of the cases is on the entrepreneurial personalities, why and how they start their firms. However, from a scientific point of view, it has a certain built-in bias; it focuses on new "successful" and "promising" (and "high expectation") firms and considers almost entirely only "failures" of high expectation, highly "prized" NTBFs.

And there is another bias. The approach has a certain bias on chemistry, biotechnology and the chemical industry [Runge 2006]. As, however, chemistry acts as an "enabling technology" for many other industries the current treatise incorporates cases from many other industries – but often those with connections to chemistry and the chemical industry.

The "theory-into-practice" approach focuses on "*needs-to-know*," as expressed concerning strategy by Rumelt [1996], but also applicable to many other areas of the various contributing disciplines and sub-fields of entrepreneurship.

> "A great deal of business success depends on generating new knowledge and on having the capabilities to react quickly and intelligently to this new knowledge. … I believe that *strategic thinking* is a necessary but overrated element of business success. If you know how to design great motorcycle engines, I can teach you all you need to know about strategy in a few days. If you have a PhD in strategy, years of labor are unlikely to give you the ability to design great new motorcycle engines." (Emphases added)

In the same sense, for instance, Pocket Technology Management ("PockeTM") is put forward as a holistic technology and innovation management system, which integrates new technology-based ventures' internal and external aspects on the normative, strategic and operational management level [Luggen and Tschirky 2004].

This book focuses primarily on individuals ("entrepreneurs") in the realities of their societal and socio-economic environments and the process *what technology entrepreneurs actually do*. This is necessarily a multi-facetted exercise encompassing various technical, but also non-technical aspects, for instance, from psychology and cognitive science, economics and business administration etc. (Figure I.1).

I address issues which transcend boundaries of disciplines and rely on concepts and theories drawn from many fields. Few of us have a deep understanding of all these theories and constructs and can relate easily to their specialized terminology. I have, therefore, worked with just well-accepted ideas and concepts from these fields.

We see consistently used language, terms and concepts as a prerequisite for an *interdisciplinary* approach. Therefore, I have tried to give notions and terms with different meanings and uses in the various disciplines and seemingly controversial ideas a "precise" meaning or operational definition in the context of entrepreneurial behavior, activities and functions. I admit that, as is frequently the case in research, the question for a precise and generally accepted definition does not have a simple answer.

I think also that such an ambition with regard to theory and language is needed for optimal usage of General Systems Theory (GST). Our effort is to *integrate*, within the framework of GST, the insights and knowledge generated by the disciplines that are relevant to our domain of inquiry referring to the findings of the various disciplines and approaches and thus to contribute to *understanding and explaining* entrepreneurs and entrepreneurship.

In view of the tremendous bulk of stuff this treatise is not a comprehensive or critical literature review and, as entrepreneurship covers very many different scientific disciplines, it cannot even be one. It is an intentionally targeted and critical selection of views, concepts and theories that fit the overall GST approach to the special sub-field of technology entrepreneurship and is critical and discriminating in how far related literature results and observations fit into a treatise aiming to present a coherent and, at least, largely consistent presentation of the subject.

Cases are usually put into the context of research results of statistical samples of technology ventures. In so far they may be in line with particular findings of entrepreneurship research or complement the findings or raise questions for further research.

As an effort, the current approach will use the best and well-accepted ideas available to explain the important, but complex phenomenon. In the end, the book offers often plausible conjectures rather than firm conclusions drawn from literature studies, own research and using the theoretical framework of GST that itself is not without criticism.

It is hoped that it can be taken for education and as a guide for “practitioners” of entrepreneurship and intrapreneurship. Additionally, it should raise richer questions to be considered around the subjects. This is in line with C. West Churchman (a General Systems Theory guru) who once stated that “creativity sprouts and thrives on the soil of good questions.”

GST is also used as a means to overcome or, at least, reduce communication barriers and facilitate interdisciplinary entrepreneurship between engineers and natural scientists, especially from physics, chemistry and biology, making their ways of thinking and reasoning explicit and between scientists and researchers from “hard” and “soft” sciences.

Fundamental communication problems arise from the fact that most people with higher education in the classical sciences are trained and familiarized with views of reductionalism, explaining the whole from the parts and thinking linearly in terms of causes and effects and closed systems. The GST perspective is on *human-activity systems*, which are social systems and open systems, and dealing with *goal-seeking subjects* and *purposeful* systems.

One key methodological issue for research is reflexivity. In social sciences **reflexivity** means circular relationships between cause and effect. A reflexive relationship is bi-directional; with both the cause and the effect affecting one another in a situation that renders both functions causes and effects. Reflexivity is related to the system concept of feedback and positive feedback as well as self-reinforcement (cf. also Bhidé [2000:74-75]).

In social theory reflexivity may occur when theories in a discipline should apply equally forcefully to the discipline itself, for example, when the subject matter of a discipline should apply equally well to the individual practitioners of that discipline. More broadly, reflexivity is considered to occur when the observations or actions of observers in the social system affect the very situations they are observing, or theory being formulated is disseminated to and affects the behavior of the individuals or systems the theory is meant to be objectively modeling.

Social science is a very strong contributor to research of early-state entrepreneurship. Thus, for example, an economist (or a group of economists) teaching students in entrepreneurship at a university may affect the behavior of students that he or she is studying when the students or graduates of that university are founding firms directly or via the university’s incubator. The observations are not independent of the participation of the observer! Reflexivity is, therefore, a methodological issue in the social sciences.

An example of the reflexivity issue is provided by Mauer and Brettel [2008], both of the Technical University of Aachen (RWTH) and Brettel being Professor of Business Administration and Entrepreneurship at the RWTH. For a study they "{We} collected data from 8 technology ventures that have based their activities on technologies from Germany's two leading technology universities, starting with 6 cases from RWTH Aachen University and replicating 2 cases from the Technical University of Munich." "We examined the early-stage development process starting from the research work before the decision for commercialization."

Finally, utilizing the fundamental approach of GST to explain or even describe quantitatively (by related formulas, actually equations of state) a phenomenon under consideration by searching for analogies and metaphors in other disciplines the book presents a new theoretical approach to new technology venture growth. Based on principles of self-reinforcement and cybernetic processes, for instance, verbalized by the saying "growth breeds growth," redefining principles of "bracketing" from social theory and sociology as well as metaphorical references to the very basics of quantum theory and physics of light for quantifications "A Bracket Model of New Technology Venture Development" (ch. 4.3.5) has emerged and illustrated by many examples.

One of the key issues of technology entrepreneurship is the focus on one person, the entrepreneur, and his/her role and activities for most sub-processes viewed as central to entrepreneurship. Technology entrepreneurship is definitely an individual level phenomenon, but also a small group-level ("team") phenomenon. And some key features or activities, such as idea generation, revealing opportunity and risk taking associated often with what makes the difference between an entrepreneur and non-entrepreneur, more than often show up as a combined expression of a system of two, three or more persons.

The author uses often quotes of Johann Wolfgang von Goethe (1749-1832), the world-famous German writer, artist, and politician as mottos of chapters or subchapters. Having become the chief adviser of the Duke of Saxe-Weimar-Eisenach, Carl August, Goethe held a succession of offices. In particular, he was in charge of matters of mining. As the leader of the mining committee he actually followed an approach which can be characterized as entrepreneurial in the current sense [Schwedt 2009:36-44].

How to Read and Use this Book

Reading this book requires attention, not very special knowledge. But basic knowledge and curiosity of understanding natural sciences and business administration is helpful. As a formal and systematically written discourse on the subject, it can be read sequentially from start to end or read by piece for specific topics of technology entrepreneurship, as it presents many perspectives for an anticipated rather broad audience.

The book is designed for entrepreneurship chairs and respective professors, teachers and lecturers, researchers as well as graduate (major and non-major) students of various disciplines (such as, natural science and engineering, business administration, management, economics, organizational psychology, organizational behavior, sociology). Further addressees include to-be technology entrepreneurs, consultants and civil servants (from various ministries or public agencies and services) dealing with innovation, science and education and SMEs/SBA (small and medium-sized enterprises; Small Business Administration) as well as economy and energy (CleanTech entrepreneurship).

As this book is interdisciplinary and additionally cuts across "hard sciences" and "soft sciences" a GLOSSARY is added. To provide consistently used language and terms for the interdisciplinary approach special definitions used in this book for important terms, notions and concepts which may be used with differing meanings in the various disciplines a *"local" definition or understanding*, respectively, *in the text is* marked *by bold face characteristics*. Many of these marked terms occur also in the GLOSSARY, sometimes with additional or examplary explanations. However, also other relevant terms, notions and concepts are emphasized in the text by bold face.

There is a special section for "Notes" presented in addition to References. Notes will be used for explanations or short descriptions that do not fit into the GLOSSARY or into the running text or are simple Internet addresses (URLs).

Adapted to the interdiciplinarity the writing style of the book is recurrent, which is, it contains many forward and backward references to text (sub-chapters), figures, tables, and equations to facilitate readers to follow a "slow" build-up of the book's subjects and content. Furthermore, to help readers it uses some redundancies in the text. Direct access to specific topics of interest in the book is possible through a "Subject Index" and a "Company Index."

The book is "*Web links enhanced*." This means references to information in paper-based documents are enhanced through a Web address whenever there exists a corresponding Internet address for that resource. This may also be a Web address of the information provider or publisher. It may also be an address using or referring to a Google cache.

Typically a reference to an article of Susan J. Ainsworth in volume 82 and issue 15 of the journal “Chemical & Engineering News” given on pages 17 to 19 will show up as given below (title in italics). Several authors will be separated by semicolons.

Ainsworth, S. J. (2004): *Nanotech IP. As nanometer-scale materials start making money, intellectual property issues are heating up.* Chemical & Engineering News 82 (15), 17-19. http://pubs.acs.org/cen/coverstory/8215/8215nanotech.html (last access month/day/year) – cited in the text as [Ainsworth 2004]. Reference to a specific page or pages will be added after the year using a colon as a separator like [Runge 2006:423,501-502].

Additions in citations to facilitate understanding or complete sentences are given in braces.

A critical remark concerning the use of Internet resources is given in Runge [2006:x-xi].

Figures, tables etc. in case documents (B.2) use straight notations, such as Figure 1 or Table 1. As these will sometimes be referenced in this book, corresponding captions of this book will use modified captions like Figure I.1, Table I.1 etc.

Dislaimer:

At the time of writing this book the given Web addresses (URLs) were active, but during the final editing some turned out to be no longer accessible or were transferred to a “subscriber-only” location which will sometimes be indicated in the citation.

APPROACH

The essentials of a phenomenon are best understood
if one tries to explore their rise from the very beginnings.
Aristotle

The present book deals with why and how technology entrepreneurs start and grow their businesses. The *very great variety we find in new businesses and approaches to NTBF foundations* is a fundamental challenge to understand technology entrepreneurship ("one does not fit all") and make it difficult to go beyond trite generalizations.

Using General Systems Theory (GST) – in particular, Applied General Systems Theory [Van Gigch 1974] – as a framework for description and explanations (and sometimes "predictions") has important implications for an *interdisciplinary* approach to technology entrepreneurship. Concerning *content* it requires a common language with a consistent use of terminology, notions, definitions, and concepts. Therefore, the multitude of existing definitions, notions and terms used in the various disciplines will be fixed by redefinitions in this book in such a way that they allow further expansion or specification and can be accepted (largely) by the various specialists.

With regard to *interdisciplinarity* I address subjects of importance that lie outside traditional boundaries of economics and business administration. Few of us have a deep understanding concerning current states of research of the particular involved disciplines (Figure I.1). Therefore, I sought out to work with just those well-accepted ideas, concepts and notions and results from the fields that are directly/explicitly or, at least implicitly, in line with GST principles. And I used related research results on special subjects only if they are absolutely necessary and can be clearly related to (technology) entrepreneurship.

Furthermore, GST adds different *ways of thinking, reasoning and explaining* which is totally different, for instance, from the typical way of physicists' and engineers' (and chemists') thinking in terms of linear causality and reductionism. Using GST means that instead of relying exclusively on analysis and deduction deeply ingrained into Western thinking we proceed also with synthesizing and being inductive [van Gigch 1974:147].

Centrally to GST focusing on human-activity systems is to deal explicitly with the often *different perspectives of representatives of all the involved sub-systems* when they come into contact, when they interact, such as the innovator (supplier) and adopter (customer) or the firm founder and financial backer.

> Therefore, the "Introduction" of this book provides an overview emphasizing those parts of GST which are important to fit the intentions of the book. For those familiar with GST it is just a refresher.

On the operational level of individual NTBFs we follow Faltin [2007:32-34] and Bhidé [2000] *separating entrepreneurship from managing, management science and business administration*. The rationale is different levels and fields of activities associating these activities to a certain degree with roles during the early state of firms after foundation, but emerging into (professional) jobs as firms develop and expand.

However, we will always be aware that most contributions of business administration originate from requirements of large firms to manage organizational complexity. This means, principles and prescriptions of management science and business administration must always be assessed whether and in how far they are transferable to just founded and small firms.

As one *methodological characteristic* the current book takes an *inter-cultural* direction and deals with technology entrepreneurship in the US and Germany in a *comparative* way. This serves to separate "generic" and specific factors and processes of entrepreneurship. Identification of generic effects and behavior means revealing features which are independent from the cultural, socio-economic, political etc. context and let specific factors of entrepreneurship in the two countries emerge more clearly. The book will emphasize major country-specific differences.

By the same token including *historical considerations* (dating back to around 1700) reveals time-independent behavior, processes and effects which are also generic to the phenomenon. Such a method means, find constants and similarities looking into differences.

Explicit consideration of time as a parameter of entrepreneurship has important implications for many of the existing macro-studies based on statistical samples. As will be shown, it makes a significant difference for the birth and growth of a new firm whether its birth is, for instance, during (or immediately after) an economic recession or not, whether it has to survive a recession during its first three to four years of existence or whether the firm does not suffer from a recession at all during the whole first seven to eight years of its existence.

This does not only affect results of macro-studies. It, moreover, may make comparisons between studies' results difficult or even impossible. And with regard to the current situation of technology entrepreneurship and *current practice*, as mentioned in the Preface, "elder" research results requires critical assessment with regard to their "generic content" and directs the emphasis to tackling the *current realities* to new firms founded within the last two decades.

And there is another role of history for technology entrepreneurship. In particular, the past and history is important for technology entrepreneurship as it turns out that often current technology entrepreneurship, ideas and problem-solving, are based on technical solutions provided 30 - 120 years ago and activities are a repetition, continuation or start over from the past utilizing recent technical developments to respond to current market or societal requests.

The book presents technology entrepreneurship as an *interwoven interplay* of *descriptions and explanations on the macro- and micro-level* (going inside the "black box" – the firm, but also the industry segment the firm is active in) and epistemologically similar to relating classical thermodynamics and classical statistical thermodynamics.

This means, using available research results from selected statistical samples of entrepreneurial firms and "group" them for prototypical entrepreneurial descriptions or focusing on selected groups of individual firms (entrepreneurship cases) and match them to statistical results. Hence, instead of the disconnect often found in the literature between research on development processes of individual firms and generalizations about development rates in populations of new firms, analysis at the two levels can be mutually supportive.

In this sense, the efforts to approach the subject required some additional systematic original research of related firm's foundation and NTBFs, respectively, in addition to those already discussed in Runge [2006]. For instance, for the special situation of biofuels the considered group of individual new firms and players in the field is so large that their descriptions and analysis for entrepreneurship and intrapreneurship presented in the Appendix (A.1.1) comes very close to an example of "industry analysis."

This approach does not only reflect a methodological feature, but is seen as a prerequisite for understanding of the highly specialized and complex field of technology entrepreneurship. In this way, cases provide more than just "anecdotal evidence." This is not only in response to the high specializations but simultaneously raises questions not tackled so far in the field. For practical purposes this method provides the ability to "*telescope*," focusing on the details and then move back to the bigger picture (if it is available or can be created).

The relevant results considering the macro-level stem entirely from the relatively rare research literature referring only to technology entrepreneurship or from literature combining technical and non-technical entrepreneurship. For the last situation, however, validity of the related result for the technical area is always assessed and often results must be rejected as they cannot be viewed as representative for the technical field.

The book does not provide a review of the research literature. It refers selectively to that literature and its results that fit into the GST framework of entrepreneurship. That means, for selecting particular literature results sometimes the overall coherence of the presented "great picture" may be regarded as more important than a currently rather widely accepted view of a special topic or a current "vogue."

Literature means also the report literature with studies intending to serve policy purposes with regard to entrepreneurship. In particular, heavy reference is made to the extended research published continuously by the Center for European Economic Research – ZEW (Zentrum für Europäische Wirtschaftforschung GmbH in Mannheim, Germany) in reports on "high-tech foundations in Germany."

On the micro-level we use *case studies*. All the related data and information used in this book are in the public domain. Case studies are recommended when “why” and “how” questions are being asked about a *contemporary* set of events, over which the investigator has little or no control. Such studies are also useful when the aim is not generalization about populations in the statistical sense, but is for “expanding theory instead of enumerating frequencies.”

Through case study methods one is able to go beyond the quantitative statistical results and understand the behavioral conditions through the actor’s perspective, the entrepreneur’s perspective. The qualitative methodology is the rationale for a descriptive, interpretative and explanatory work to become recommendative rather than prescriptive [Yin 1994].

Work emphasizing the recent cases, new firms not elder than ten to twelve years, provide further perspective. Detailed inspection of cases, investigating contemporary real-life phenomena through detailed contextual analysis of a limited number of events or conditions and their relationships, provides insight into *current practice* of entrepreneurship which, as a time- and region-dependent phenomenon, adds insights into their inherent, generic features.

Moreover, a *multiple-case design* can be adopted with real-life events that show numerous sources of evidence through replication rather than sampling logic. According to Yin [1994], generalization of results from case studies stems on theory rather than on populations. By *replicating the case through pattern-matching*, a technique linking several pieces of information from the same case to some theoretical proposition, multiple-case design enhances and supports the previous results. This helps raise the level of confidence in the robustness of the method.

There are several categories of case study: exploratory, descriptive and explanatory case studies. It is suggested that *descriptive case studies* may be in a *narrative style.* The challenge of a descriptive case study is that the researcher must begin with a descriptive theory to support the *description of the phenomenon or story*. *Explanatory case studies* examine the data closely both at a surface and deep level in order to explain the phenomena in the data. On the basis of the data, the researcher may then form a theory and set to test this theory (ch. 4.3). Case studies must not be confused with qualitative research, but case studies can be based entirely on quantitative evidence [Yin 1994].

The notion story refers to the raw materials of situations, events, decisions and actions as they might be described and narrative structure is about two things: the content of a story and the form used to tell the story. Many researchers of educational methodology advocate narrative interpretation in entrepreneurship education to be an important epistemological approach.

For instance, Dorf and Byers [2007:50,51] suggest to entrepreneurs to create a “new venture story” (business story) to “communicate verbally the business idea and the profitable solution of the problem." This is seen as "all one needs to start working on building a business." "The story can be told to all would-be investors or employees."

The various cases of individual startups or NTBFs, respectively, referred to in this book have three different origins.

- Cases are described in the (paper-based or electronic) literature, in books to find information on Intel, Cisco, Microsoft [Bhidé 2000] or AgraQuest [Dorf and Byers 2007] or case reports on the Internet, such as Cambridge Nanotech, Inc. which sometimes are updated by the author. Sometimes even diaries are made public (for instance, by German Suncoal GmbH – B.2).
- New firms whose births were already described and analyzed in a previous book of the author [Runge 2006] have been usually updated (17 firms; Appendix B.2). Additionally, Runge [2006] provides also short stories of German and US technology ventures founded between 1860 and 1940 and in the 1960s.
- Firms for which the entrepreneurs' personalities and entrepreneurship behavior and processes were described and analyzed for the author's technology entrepreneurship curriculum or they were specifically generated for this book (ca. 41 cases listed in Appendix B.2). Some of these were complemented by interview-type targeted discussions of the author with firm founders who gave lectures as part of the author's Technology Entrepreneurship curriculum (discussions with them before and after the lecture during common dinner). Furthermore, out of these the Appendix on biofuels (A.1.1) refers to 31 cases described in more or less detail or with regard to relevant features.

Furthermore, 36 NTBFs are referred to by larger text blocks, sometimes enhanced with charts showing firm developments, to illustrate related situations or features.

Cases were generated mostly from Internet sources (documents, videos, video interviews, NTBF Web sites). Specifically for US cases the "Entrepreneurial Thought Leaders Lecture Series" (Ecorner) of the Stanford Technology Ventures Program is notable.

The selected NTBFs are clustered basically by market/industry and further differentiated by type of technology, with or with anticipated production or no production and whether or not being backed up by venture capital. In selecting the new technology ventures I paid mostly attention to "winners" (firms highly rewarded with prestigious prizes and awards in their countries and internationally) as their cases may be used simultaneously as "role models" ("learning-by-example") for to-be entrepreneurs.

The case selection process looked into "similar" NTBFs from Germany and the US to reveal cultural and socio-economic influences on entrepreneurship or into "competitive groups" within one of the countries or across countries. Cases were also selected to inquire into NTBF development of firms addressing the same markets but following organic versus non-organic growth – the last mode meaning growth by acquisition of other firms or particular businesses from other firms.

There are fundamental issues of how founders tell their entrepreneurial story referring to publications as they appear in the media as interviews, articles, reports, anecdotes or episodes [Blodget 2009]. How it appears through a detailed journalist's investigation over several years may be quite different, as can be seen in the case of Mark Zuckerberg/Facebook [Carlson 2010]. One often hears or reads a narrative that people tell as a true story, but in essence, it is a legend a founder is about to create. Even structured interviews may be biased in this way; entrepreneurs may tell their subjective view of their firm.

Consequences of "recycling" or "reviving" old technical ideas as a very important part of idea generation (ch. 3.1, 3.3, A.1.1) is that "technology entrepreneurship" has to cover "historical technological developments and technology trajectories" intrinsically.

As a reminder:

- There is a difference between *running* a large firm or *developing* a startup or NTBF (from scratch).
- A *stable, established firm* is different from a *startup or NTBF* – they represent *different entities*.
- An established firm exhibits *complexity*,
a startup/NTBF exhibits "*organized complexity*"
- For a new venture loosing an "element", for instance, a researcher, has usually much more serious consequences than for an established firm.
- Describing and understanding a *startup/NTBF* require to deal with reasons or motivations, respectively, of the entrepreneur(s) *why the firm exists or is founded*.
- There is a difference between *initial financing* and *following financing(s)* of a startup/NTBF.

As a final remark, an intended low level of redundancies in this book shall facilitate the reader to track chunks of content in different contexts. That means, the presentation of content follows a recurring (revolving) style of writing. Furthermore, many forward and backward citations in the book will expand a particular topic or concept into a broader context or help understanding referring to illustrations or further details.

A condensed outline of the book will be given in the introductory part (ch. 1.1.2).

TECHNOLOGY ENTREPRENEURSHIP

Entrepreneurs and Entrepreneurship for and in Technology Ventures

1. CONTEXTUAL SETTINGS

1.1 Setting the Stage

1.1.1 Technology Entrepreneurship and New Technology-Based Firms

"*Technology entrepreneurship*" is a particular sub-field of entrepreneurship focusing on how science and technology is or is intended to be converted into "value." In particular, it relates to technical innovation and behavioral or organizational innovation based on technical means. Basically, it is assumed, but also more generally shown, that entrepreneurship for technical areas to found new technology-based firms (NTBFs) requires specific approaches according to the scientific and technical discipline and related industry, respectively.

Education and training are major factors that distinguish the founders of NTBFs from other (non-technical) entrepreneurs (ch. 2.1.2.4). For instance, in Europe 87 percent of NTBF entrepreneurs believe that *training for technology entrepreneurs needs to be specialized* to reflect the *unique challenges* of the discipline [European Commission 2003; Gangemi and DiMeglio 2005; Mitchell and McKeown 2004]. Correspondingly, one reads:

> "We argue, therefore, that high tech entrepreneurship is a unique phenomenon that needs to be researched, distinct from other forms of entrepreneurship." [Kirchhoff and Spencer 2008]

Dorf and Byers [2007:xv] have defined technology entrepreneurship as follows:

> "Technology entrepreneurship is a style of business leadership that involves identifying high-potential, technology-intense commercial opportunities, gathering resources such as talent and capital, and managing rapid growth and significant risks using principled decision-making skills."

They focus on exploiting breakthrough advancements in science and engineering and refer to "high technology" covering information technology (IT) and electronics companies, life science and biotechnology businesses (and those service firms where technology is critical to their missions). And additionally, they emphasize firms whose leader(s) strive for "rapid growth," which, as will be seen (ch. 4), is a particular restriction not intrinsic to the subject. Furthermore, their focus on "principled decision-making skills" raises the question in how far technology entrepreneurs' decision-making rely on skills – which can be taught and follow rational approaches (ch. 4.2.2).

Most current discussions and work on technology (or technical) entrepreneurship – whether on paper or electronic on the Internet – put the emphasis on information and communication technology (I&CT). And concerning education and teaching in the US technology entrepreneurship is often viewed as a rather narrow field focusing on Silicon Valley-style of entrepreneurship and I&CT and consumer services as expressed by Chuck Eesley [2012].

"This course introduces the fundamentals of technology entrepreneurship, pioneered in Silicon Valley and now spreading across the world."

On the other hand, while keeping IT as one aspect, the author [1] has shifted the emphasis from IT more towards science and engineering in his Technology Entrepreneurship curriculum. Therefore, concerning the subject and content, the current book is a certain complement to Dorf and Byers [2007] and the Stanford Technology Ventures Program (STVP) and its ECorner with regard to scientific and engineering disciplines.

In recent studies confined to Germany [Niefert et al. 2006; Gottschalk et al. 2007; Metzger et al. 2008; Heger et al. 2009] "**high technology**" has been classified into four areas according to related technology-based industries and by a *link between technology and research* (Table I.1).

On the one hand, technology-based industries are differentiated according to the research and development (R&D) intensities of the associated firms in particular industry branches. The **R&D intensity** is the proportion of R&D expenses in relation to the overall revenues (sales) of the firm in percent.

With respect to the averages of R&D intensity (RI) of all firms belonging to given industry branches the following kinds of R&D-related technology are defined as follows.

- Top value technology – **TVT** (in German "Spitzentechnik") for RI $\geq$ 8%
- High value technology - **HVT** (in German "Hochwertige Technik") for 3.5% $\leq$ RI < 8%.

On the other hand, due to their current importance, firms in Information and Communication Technology (I&CT) are treated as providing separate areas with the subfields I&CT Software and I&CT Services. However, firms engaged in I&CT Hardware usually fall into the realms of top or high value technology. Typical industry branches or segments based on top/high value technology are given in Table I.1.

The I&CT Software sector refers typically to software development including "Internet firms" (including those with consumer services) and software consulting. The I&CT Service sector comprises areas such as telecommunication services, database developments and I&CT system developments as well as computer and telecommunication center operations services.

In Germany and expected to be similar in other developed Western countries firms' foundation in the high technology segments account for 6 – 8 percent of all firms' foundation [Metzger et al. 2008]. The German studies [Metzger et al. 2008] indicate that in this segment currently roughly 17 percent of all the high-tech NTBF foundations occur in the top/high value technology sectors and ca. 83 percent belong to the I&CT Software and I&CT Services data area.

Though I&CT Software and I&CT Services which have special characteristics concerning entrepreneurship will not be neglected in this book (ch. 3.4), the emphasis will be on entrepreneurship in the top value and high value technology areas.

Due to co-evolutionary material-oriented developments with other industries the chemical industry plays a central role for the top/high value technology sectors [Runge 2006]. Chemical science and technology are interwoven with very many other industries and, hence, chemical technology often plays the role as an "*enabling technology*" (Table I.12; [ACS 2011]). In the same regard, concerning biotechnology the current book focuses on "white (industrial) biotechnology" (cf. biofuels, A.1.1) and "blue biotechnology" focusing on algae (A.1.1.4).

Admittedly, particular areas of I&CT act also as enabling technologies for TVT and HVT and R&D.

Table I.1: Selective non-I&CT *) representative high technology industry branches or segments.

R&D-Related Technology Classes	Industry Segment
Top Value Technology (TVT)	Pharmaceuticals ("pharma"); Agricultural chemicals ("Ag"); Biotechnology ("Red," "Green," "Blue," "White" Biotechnology) [Runge 2006:571-578]); (Micro)electronics and Organic Electronics (e.g. organic semiconductors, printed electronics); Photonics and Lighting (e.g. LED and OLED – organic light emitting diodes); Measuring Devices, Instruments, Sensors (e.g. analytical and medical instruments and devices, control and navigation instruments); Nano tools
High Value Technology (HVT)	Specialty chemicals; fine chemicals; high performance polymers and plastics including conductive polymers; Many areas from mechanical engineering and automotive, process and chemical engineering, in particular, "energy efficiency" as a notion for energy saving processes and activities in many industries

Top or High Value Technology Sectors	Chemical nanotechnology; Advanced materials; CleanTech (photovoltaic and organic solar cells, solar thermics, wind power (wind turbines), fuel cells/batteries, biofuels, biorefineries; hydrogen storage; water treatment and membranes)
R&D-Related Technology Classes	**Industry Segment**
Technology-Based Services – TBS (in German Technologieorientierte Dienstleistungssektoren – TDL)	Research and development in natural and agricultural sciences, medicine and engineering (contract R&D); Engineering offices and firms Technical, physical and chemical testing and studies, e.g. analytical laboratories; Data processing and databases, such as cheminformatics, bioinformatics [Runge 2006:210] or research or innovation support systems

*) Not generally software; software for technical devices, instruments etc. and technical processes or process control are viewed as an integral part of technological product or process development (cf. Vitracom AG, WITec GmbH, JPK Instruments AG – B.2, etc.).

In this regard, our focus on technology and related NTBFs appears as even more specific than the one suggested by Bates [1995] that entrepreneurial research be conducted in a specific industry, given the importance of the industry variables in influencing the success or failure of entrepreneurial ventures.

Contrary to activities of *pure science* and "*pure research*" aiming to gain new insights and generate new knowledge, which is mostly pursued in academic settings, *industrial research* and related *activities* are associated with *purpose*. *The objectives of industrial R&D are to create value* [Runge 2006:611]. And fundamentally, in commercially oriented organizations, one can differentiate four areas of activities of a corporate R&D Function [Runge 2006:614]:

- Basic research,
- Applied research,
- Development,
- Technical service (or technical service & development – TS&D).

With increasing complexity of the NTBFs' offerings (products, devices, instruments) the need for technical service will increase. And in its broadest sense technical service also comprises education and training of (basic and advanced) usage of the products through practicing and workshops, seminars or webinars (as do, for instance, WITec GmbH, JPK Instruments, Nanopool GmbH; B.2).

Technology has more than one definition, but it refers essentially to the body of know-how about the means and methods of producing tools, goods and services [Runge 2006:620]. Technology comprises a system of application-oriented statements about means and ends. And **technique** represents an applicable element of a technology. Technology comprises often a set of techniques and **technology implementation** means selecting techniques to target a given goal.

Techniques constitute what is also called *instructional (practical) knowledge*. Like any recipe they comprise essentially instructions that allow people to "produce" or "reproduce," respectively. The lines in the technique can be either "obligate" (do X) or "conditional" (if X, do Y), "optional" (do X or Y; do or do not X) or "mandatory" (must do X) and in this way are related to the concepts of algorithms and heuristics and programmed and non-programmable problem-solving [Runge 2006:341].

It is often impossible to specify explicitly the entire content of a set of techniques or instructions. Even a simple cooking recipe contains a great deal of assumptions that the person executing the technique is supposed to know. Such "**tacit knowledge**" and, more specifically, "**tacit technology**," is mainly ingrained in people and represents correspondingly an issue for "technology transfer" or also "licensing" of technology.

"T*acit technology*" is not codified or not documented *practical knowledge* and *experience* of people in technical fields. Tacit technology is often brought to bear as and when it is required, similar to a resource. Hence, it is an important *competitive advantage* of a firm (ch. 4.3.3) and part of its *core competencies* – as long as the firm can keep the people.

"**Core competency**" is a central variable for innovation! It is the one thing that a company *can do better than its competitors*; an area of *specialized expertise* that is the result of *orchestrating complex streams of technology and work activities and processes,* including building and keeping unique relationships with customers, suppliers, research, development or marketing partners, and operational agility or unique business practices.

It should be noted that core competencies, the bundle of skills and technologies, are dynamic. In particular, with regard to technology developments, over time some competencies get more important, others become obsolute. For non-technical competencies, for instance, management style and execution usually differ whether the firm is in growth mode during an economic boom or the firm has to fight against the effects of an economic recession.

The preceding outlines raise the general question *whether it is necessary to use and exploit science for purposes of technological progress*. In fact, many important technological innovations were initially not very well understood scientifically. And there is often a substantial lag between the time technical information is generated and the time it is used for innovation. The lag is usually 8 to 15 years, but may be decades.

> Hence, technology entrepreneurs do not have to know what they are doing to be successful, but they do have *to be able to deliver demonstrative and reproducible results* [Runge 2006:619].

Such a statement, of course, does not imply that it is not preferable to have a scientific foundation of a technology.

Furthermore, one must clearly differentiate development from research and engineering from science. Development is sometimes more an art than a science, particularly in the chemical industry. In the areas of adhesives in a review one reads, for instance, "There is a distinction between the science of adhesion and the *technology* – I was tempted to say the '*art and mystery'* – of adhesives and their use." [Runge 2006:620]). Or look at paints and coatings: "formulating coatings (paints and inks) is a science which sometimes is referred to as a bit of black magic" [Weernink 2009]. And concerning chemical nanotechnology Scott Rickert, founder of Nanofilm LLC (B.2), said "I didn't know how it worked, it just did." [Charlton 2005].

1.1.1.1 Entrepreneurship and Technology Entrepreneurship

Having set the anchors for technology entrepreneurship let us focus on a definition serving the purposes of the book. There is a proliferation of theories, definitions and taxonomies of entrepreneurship that are often in conflict and overlap with each other, resulting in confusion and disagreement among researchers and practitioners about precisely what entrepreneurship is.

There is no universally accepted definition of entrepreneurship, much less of technology entrepreneurship. Entrepreneurship means many things to many people and depends to a large extent on the context it is discussed in or on the particular scientific or technical discipline dealing with it.

Furthermore, entrepreneurship and the strategic role of *the entrepreneur as an agent of economic transformation in society* has become an important topic of policy in the context of growth and job creation of the economy. This, in particular, has led to some degree to perceptions of entrepreneurs and entrepreneurship in the public which hinders understanding and explanation of the phenomenon and thus also hinders to formulate proper governmental programs to initiate and support entrepreneurship and/or implement corresponding programs properly. Hence, the definition of technology entrepreneurship shall be re-visited.

For the current book the question is whether there is an appropriate definition of "technology entrepreneurship" fitting GST as the framework so that, after combing key aspects of existing definitions of entrepreneurship, it emerges as a specialization. In particular, we also want to be operational with the notion "technology" to lift the restriction to "high technology."

To outline our route to the definition we shall first refer to some pertinent definitions – and will emphasize two targets of inquiry, entrepreneurship as a process of change and the entrepreneur, the personality, as the "***agent** of change*" (Figure I.1). We see the change agent essentially to live in the future, not just the present. Regardless of what is going on today, a change agent has a vision of what could or should be and uses that as the governing sense of action. The change agent's actions will affect individual lifes or even economies.

A rather recent definition by Onuoha [2007] and referred to numerously on the Web views entrepreneurship as the "*practice of starting new organizations* or *revitalizing mature organizations*, particularly *new businesses* generally *in response to identified opportunities*." Important implications of this definition are the relation to a procedure or even routine for the startup phase of a new organization or renewal of an existing organization through a "New Business Development" (NBD) process.

Onuoha's definition, hence, embraces also "entrepreneurship in existing organizations ("intrapreneurship"). The relationship to "identified opportunities" may not only refer to revealing explicitly or implicitly ("latent") existing opportunities, but also to creating opportunities, for instance, through so far not existing technologies. Especially the last aspect will exhibit an interconnection to the notion of "*innovation* (ch. 1.2.5.1).

Adding to Onuoha's definition, Webster's Online Dictionary [2] states that entrepreneurship is "the organization, management, and assumption of risks of a business or enterprise, usually implying an element of change or challenge and a new opportunity." Furthermore, Collins Concise Dictionary Plus defines an entrepreneur as the "owner or manager of a business enterprise who, by risk and initiative, attempts to make profits."

As a consequence, entrepreneurship in this broader sense includes also a situation of *changed ownership of firms or parts of firms*, such as *business succession* with a fundamental change of business ("*business model innovation*") or *management buy-out* (MBO) of an existing firm or a particular business of a firm. Basically, a **business model** is an organization's *core logic for creating value*, a *hypothesis* how to create value – how to make money.

This complements the definition of entrepreneurship by Hayes [1997:16; emphases added] as an "*intentional* activity aimed at meeting a *perceived need* through the creation of *innovative methods, processes or products*; and, subsequently, envisioning, organizing, managing, and *assuming the risks* of a new enterprise or business."

The "New Business Development" (NBD) process can be seen as a generic activity of entrepreneurship and does not depend on the size (and age) of a firm. For (very) large firms NBD is an established, structured process and has been studied and put forward intensively [Morris et al. 2008; Runge 2006]. NBD with appropriate adaptation can be relevant for new, micro-sized firms when they change business direction or for medium-sized firms, when, for instance, after business succession a new business will be started.

Concerning the interconnection between entrepreneurship and innovation we learn from Peter F. Drucker, respected and admired as the most influential management thinker. He provides the following working definition of *innovation* [Drucker 1985:19]: the *exploitation of change as an opportunity* for a different business or a different service. He argues that this exploitation of change is *intentional*. In his 1985 book "Innovation and Entrepreneurship" he said the following about entrepreneurship and innovation:

...whereas much of today's discussion treats entrepreneurship as something slightly mysterious, whether gift, talent, inspiration, or "flash of genius," this book represents innovation and *entrepreneurship as purposeful tasks* [Drucker 1985:vii] . . . Innovation is the *specific tool of entrepreneurs*, the means by which *they exploit change as an opportunity* for a different business or a different service [Drucker 1985:19, emphasis added].

Furthermore, Drucker [1964:5] introduced an operational definition of entrepreneurship as follows:

> ..."*maximization of opportunities* is a meaningful, indeed a precise, definition of the entrepreneurial job.
> It implies that *effectiveness* rather than efficiency is essential in business. The pertinent question is not how to do things right but *how to find the right things to do*, and to *concentrate resources and efforts on them*."

Notably, all the definitions mentioned so far indicate a *differentiation of leadership and management*; whether as roles of an entrepreneur or separating the entrepreneur(s) and a (professional) managerial job. Furthermore, it differentiates *developing* from *running* a firm or business.

In particular for the technology entrepreneurship Dorf and Byers [2007:4] add further aspects to the definition of an entrepreneur:

An entrepreneur is a person who

- … undertakes the creation of an enterprise or business that has the chance of profit (or success),
- … has the ability to accumulate and manage knowledge and
- … seeks to achieve a certain goal.

The economist Joseph A. Schumpeter (1883-1950) took a different approach starting from the role of *innovation*. He was essentially concerned with a *special kind of entrepreneurship that, historically, has led to the creation of railroad transportation, the birth of the chemical industry and electrical industry, and the emergence of multidivisional,* *multinational firms.* In shaping his theory he connected innovations and economic development and cycles along several time scales.

According to Schumpeter [1942] the entrepreneur is someone who carries out "*new combinations"* by introducing new products or processes, identifying new export markets or sources of supply, or creating new types of organization (concerning combinations cf. ch. 3.3). Schumpeter presented an *image of the entrepreneur* as someone motivated by the "dream and the will to found a private kingdom"; the "will to conquer: the impulse to fight, to prove oneself superior to others"; and the "joy of creating" which all, through the media, entered to a certain degree the public perception of an entrepreneur.

In Schumpeter's view the entrepreneur leads the way in creating new industries, which, in turn, initiate major structural changes in the economy (ch. 1.2.4). Old industries are rendered obsolete by a process of "*creative destruction*." As the new industries compete with established ones for labor, materials, and investment goods, they drive up the price of these resources. The old industries cannot pass on their higher costs because demand is switching to new products. As the old industries decline, the new ones expand because imitators, with optimistic profit expectations based on the innovator's initial success, continue to invest. Eventually, overcapacity depresses profits and halts investment. The economy goes into depression, and innovation stops.

Invention (Table I.10) continues, however, and eventually there is a sufficient stock of unexploited inventions to encourage courageous entrepreneurs to begin innovation again. In this way Schumpeter used entrepreneurship to explain *structural change, economic growth, and business cycles*, using a combination of economic and psychological ideas. He outlined the view of a "dynamic disequilibrium" based on "*creative destruction*."

The insights of previous economists can be synthesized. Entrepreneurs are specialists who use *judgment* to deal with novel and complex problems. Sometimes they own the resources to which the problems are related, and sometimes they are stewards employed by the owners ("intrapreneurs"). In times of major political, social and environmental change, the number of problems requiring judgment increases and the demand for entrepreneurs rises as a result.

In revealing profitable opportunities *the entrepreneur needs to synthesize information from different sources*. Thus, the Schumpeterian innovator may need to synthesize technical information on an invention with information on customer needs and on the availability of suitable raw materials. A good education combined with wide-ranging practical experience helps the entrepreneur to interpret such varied kinds of information. *Sociability* also helps the entrepreneur to make contact with people who can supply such information secondhand.

Schumpeter's ideas have a broad influence on discussing the role of new businesses and firms on innovation and on long-term national economic growth. However, there is distinct critiques of Schumpeter's views and claims, particularly summarized and put forward as sometimes misleading by Bhidé [2000:319-337] when "Reexamining Schumpeter."

Long before Schumpeter, for the concept of entrepreneurship, in 1803 Say [1803] already combined person(ality) and process and the entrepreneur's role for a superordinated system, the economy/industry.. In the English translation of Say's work the term "adventurer" was used instead of entrepreneur. Say was certain that the entrepreneur was "necessary for the *setting in motion of every class of industry* whatever; that is to say, the application of *acquired knowledge* to the creation of a product for human consumption" [Say 1803:176]. Some provide land; others, capital; still others, labor. But only the entrepreneur – or the "master-agent" [Say 1803:176] as Say sometimes described him – can *combine these factors* to bring to market products that meet *human needs and wants*.

Further, an entrepreneur "requires a *combination of moral qualities*" [Say 1803:177], such as "judgment, perseverance, and a *knowledge of the world, as well as of business*." He must be a *forecaster, project appraiser*, *and risk-taker*. Finally, "in the course of such complex operations, there is abundance of *obstacles* to be surmounted, of anxieties to be repressed, of *misfortunes to be repaired*, and of expedients to be devised." In short, the entrepreneur *is the rare yet indispensable individual who actually makes the economy work*, an agent of change.

From these above definitions and statements we distilled our following view of Technology Entrepreneurship:

> **Technology Entrepreneurship** is a purposeful and goal-oriented process in a complex and interwoven scientific/technical, cultural, social, economic, legal and political situation driven by a person (or group), the entrepreneur(s), and associated with a practice of starting a new technology-based organization or "renewing" an existing technology-based organization.
>
> It corresponds to the *conversion of science and/or technology into socio-economic value* through gathering tangible (material) and intangible (immaterial) resources after having perceived a change of a situational factor as an opportunity for the creation of innovative offerings, such as products, processes or applications. It involves decision-making and assuming the risk to found and lead a new technology-based firm (NTBF) and later manage the NTBF for further development or create a new business of an existing firm.

Whereas Dorf and Byers [2007:xv] refer explicitly only to human and financial resources (**resources**:= sources of aid or support that may be drawn upon when needed) the current definition uses generic notions to account for the broad variety of, for instance, important intangible resources for technology entrepreneurship, such as a firm's Advisory Board for technical, organizational etc. advice, external networking or intellectual properties (such as patents; Table I.8) to generate revenue, for instance, through out-licensing.

Selling a license (by a provider) concerning a production process to another firm (the acquirer) may or may not be an end as a source of revenue for the provider (exclusivity; Figure I.31), but a means to an end for the acquirer to make his production more efficient or establishing a production process new to the acquirer resulting in increased revenue.

In our definition, the notion "*development*" does not necessarily imply growth or even rapid growth of the NTBF, but a viable existence over time. And the "creation of a new business of an existing firm" ("renewal") could comprise new offerings ("technical innovation"), such as products or services, or a new business as a new business unit or as a part of an existing business unit of the firm or the creation of a "spin-off" (intrapreneurship) or even an organizational (behavioral) innovation.

A **spin-off** is a new organization or entity directly formed by a split from a larger one, such as a new company formed from a large firm. The new firm is created out of one of its existing divisions, subsidiaries or subunits as a deliberate act of the parent company, and the owners of the parent are the original owners of the new firm (although these owners can normally sell their ownership stakes at market rates soon after the new entity is formed, especially if the spin-off is publicly traded).

In most of the literature the term "spin-off" is used interchangeably with "spin-out." However, we will use the term **spin-out** if a firm is formed when an employee or group of employees leaves an existing entity to form an *independent* startup firm. Particularly, this can refer to a university research group or a group of a research institute, directly or mediated by a business incubator (ch. 1.2.6).

During their early phase of development spin-outs typically operate at arms length from their parent organizations (formally and legally independent, but usually with certain ties) and have independent sources of financing, products, services, customers, etc. In some cases, the spin-out may supply the parent with products or services. Spin-outs as a source of technology transfer (ch. 1.2.6.3) and diffusion in rapidly-evolving high technology industries [3] have been examined by Franco and Filson [2006].

Entrepreneurship is closely related to self-employment and both terms are often used interchangeably. But self-employment might take on a different meaning in a different context [GiSeung Kim 2008]. One can be entrepreneurial without being self-employed (for instance, as an intrapreneur) and self-employed without being entrepreneurial, such as a physician. In the technological context we shall refer to **self-employment** as a restricted aspect of entrepreneurship related essentially to an *autonomy* orientation ("be one's own boss," perceived freedom).

The difference between an entrepreneur and the self-employed is that the former one is a founder who wants to run and develop a company whereas the latter one simply wants to make income working for him-/herself. It is seen as an alternative to paid employment to achieve economic independence (not necessarily total ownership). In the context of technology entrepreneurship it may show up as a "one-person firm," for instance, as a (freelance) management or engineering consultant, market researcher or technology scout etc. Here, self-employment often lacks initiating and controlling change. It may also be represented as a micro firm, an "engineering office" or an "analytical services laboratory."

Sometimes self-employment is an issue of "voluntariness" or "involuntariness" (like that of unemployment). As in the 2007-2009 "Great Recession" out of work people may do something totally different to survive through self-employment as "accidental entrepreneurs" (or "*necessity entrepreneurs*" (ch. 2.1.2.4)). Related activities may be more oriented to survival rather than to technical innovation.

A special situation for self-employment may occur for "inventors" by hobby or profession. Most of these persons can be characterized as "*tinkerers*." Across the globe, from Germany to the US and Japan, there are "inventors' fairs" where "inventors" present to potential buyers their inventions and ideas – from strange to interesting and sometimes usable. "Ideas, Inventions and New Products" in Nuremberg (Germany) is one of the biggest trade fairs for inventors. Particularly addressing students there exists also "Young Inventors' Fairs."

Entrepreneurship within an organization means **intrapreneurship**. We hypothesize that an intrapreneur's personal characteristics are not significantly different from those of entrepreneurs (ch. 2.1, 2.2). **Intrapreneurs** are employees with a dedicated perspective on the value of the organization, but generally they have not created the idea of the organization. And, moreover, they behave differently as corporate innovators through different conditions or constraints imposed by the firm. That means, intrapreneurship is entrepreneurship constrained by certain specific organizational factors.

Though intrapreneurs may take risk, for instance, concerning their career development or reputation in the firm, they usually have no risk to the success or failure of that organization. They may have access to the necessary resources, but usually operate through given well-defined corporate processes and routines and execution control by professional managers with little room for deviations. Their ideas or revealed opportunities are often accepted only if they provide a strategic fit with the corporate goals. Apart from lack of any form of ownership an intrapreneur's character and behavior relates to the employee's attitudes and organizational performance requirements [Bhidé 2000:114; Sasiadek 2004].

To better reflect this situation Morris et al. [2008] preferred the term "***corporate entrepreneurship***" rather than intrapreneurship. As entrepreneurship can happen in various organizational contexts the Oxford English Dictionary definition of an intrapreneur, as “an employee given the *freedom to work independently* within a company with the objective of introducing innovation to revitalize and diversify its business,” represents just a very special case of an intrapreneur.

An overview as well as “similarities and differences between corporate and “start-up entrepreneurship” emphasizing their major differences is given by Morris et al. [2008:34-36]. Though we shall use the terms intrapreneurship and corporate entrepreneurship as synonyms from a consistency point of view the last one would be appropriate for our GST approach (Figure I.17).

Modifying the definition of Wolcott and Lippitz [2007:75] we view corporate entrepreneurship as the innovation process by which individuals and teams within an established company conceive, foster, launch and manage a new offering, new business or spin-off or change a business position or processes of the parent company leveraging the parent’s assets, market position, capabilities or other resources. In particular, for large firms this is often associated with an industry-wide, largely standardized work processes, particularly New Product Development (NPD) or New Business Development (NBD), respectively.

Focusing on intrapreneurship has also a *practice-oriented rationale* when relaxing certain constraints of the specific corporate environment, such as corporate culture or routines (Figure I.17). Intrapreneurship, emphasizing innovation to increase profits and growth of large companies, is at the center of business and management research, which means initiatives undertaken by established companies. “The increased *routinized* nature of corporate initiatives suited the norms and aspirations of business scholars” [Bhidé 2000:x] for systematic inquiry, but also the interests of management consulting firms.

Hence, entrepreneurship may refer to established approaches, tools and skills (“best practice”) for managing new entrepreneurial firms when, in the course of their development, they attain the point of growth which requires “professional management” for further development (ch. 4.2.3, Figure I.118). In particular, the New Product Development (NPD) and New Business Development (NBD) processes and innovation according to a Stage-Gate® process of large companies (ch. 4.3.1, Figure I.79, Figure I.180) may serves as models for management of new technology-based firms in advanced states of development.

1.1.1.2 New Technology-Based Firms and Research-Based Startups

From the point of view of entrepreneurship and innovation policies new technology-based firms (NTBFs) are considered to be one of the most promising categories of new firms. These firms are expected to produce innovation(s), develop technological standards and to create new jobs. Not surprisingly, there is great variation in definitions of NTBFs with an emphasis on firm activities and technology orientation, but also ownership, firm development phases, age or survival probabilities (in years).

In a study by Mäki and Hytti [2008] NTBFs are defined as independent firms that are at maximum ten years of age, and their operations are based on exploiting the firm's technological resources, which means that the firm actively develops, produces and/or commercializes technology. The group of NTBFs includes also knowledge-intensive business service (KIBS) firms.

Similarly, Luggen and Tschirky [2003] stress firm age, but associate the definition with a still leading role of the original founder(s). For them an NTBF is a firm "working in a 'high technology' sector, less than 10 years in operation and which is led by the original founder team." Referral to the survival chances of NTBFs (ch. 4.2) we shall concentrate on a 12 year period of operation when investigating development and growth of NTBFs.

Finally, there is also a definition with an emphasis on technological innovations through R&D (cf. Table I.1). "An NTBF is defined as an entrepreneurial organization in the survival or growth phase, where the focus is on the creation, development and exploitation of technological innovations through a strong R&D orientation in high-technology industries." [Luggen and Tschirky 2004:1]

Summarizing the above definitions in line with our intentions we view a **New Technology-Based Firm (NTBF)** as

> an entrepreneurial organization with the goal to actively create, develop, and/or commercialize offerings (Table I.3) based on technology and/or research, particularly innovative products, processes, applications and services, which is no more than 12 years in operation and which is usually still led by the original founder or founder team or, at least, one member of founder team.

This definition connects *leadership* with the founder(s) of the NTBF, not ownership or control aspects, but allows for the case that an entrepreneur transfers his/her managerial role to a (professional) manager as a separate job.

As NTBFs are mainly technology driven ventures, technology strategies play a key role because technology issues have a major impact on all the other management issues, such as finance, marketing, human resources, etc. *Technology strategies* evolve with the maturing of the NTBF as do other management issues. The required emphasis on strategy for NTBF development differentiates them from non-technical new firms or new firms with little technical orientation which often lack strategic orientation and follow an "opportunistic" approach of entrepreneurship [Bhidé 2000].

As a special case of an NTBF the type of a so-called **Research-Based Startup (RBSU),** also called an *academic spin-out*, is mostly viewed as a new for-profit company based on the findings of a member or by members of a research group at a university or public research institution. Generally, there is a broad range of academic spin-out definitions centering around only university spin-outs [Djokovic and Souitaris 2008].

We shall specify an *academic spin-out company* as a commercial entity that derives a *significant portion of its commercial activities* from the application or use of a technology and/or know-how developed by or during a research program of a university or non-profit, usually public, research organization (ch.1.2.6.1). This can also be a doctoral thesis. For instance, how William Henry Perkin founded his firm in 1856 and became the father of industrial organic chemistry can be seen as one of the first notable examples to create an RBSU (A.1.2).

An RBSU can be created also, for instance, 1) based on a license to the related technology (patent) from the parent research organization, or 2) by providing a service using scientific or technical research-derived knowledge or expertise. In this sense, for instance, a consulting company formed by academics from natural science or engineering is no RBSU. Founding and developing RBSUs is sometimes also referred to as “*academic entrepreneurship*” (ch. 1.2.6.1).

For their study on technology entrepreneurship and firm’s foundation in Germany Egeln et al. [2002] differentiated various types of technology-oriented firms. Accordingly, “*academic startups*” comprise all firms’ foundation by persons having studied at a university. This means, there are spin-outs and academic startups comprising together the set of “*academics-based foundations*.” In Germany these account for ca. 60 percent of the foundations in research- and knowledge-intense industry branches (Table I.2).

The other part is “*non-academics-based foundations*” which is additionally characterized by their low level of R&D-orientation. Non-academics-based foundations do R&D regularly by only 10 percent and ca. 7 percent do it occasionally [Egeln et al. 2002]. They cover essentially science- or technology-oriented services, such as data processing and software, technical offices or R&D services. The proportions of founding types for Germany are presented in Table I.2.

Table I.2: Foundations of technology-based firms in Germany by type [Egeln et al. 2002].

1996 - 2000 Foundations in Research- and Knowledge-Intense Branches (64.400; a quarter of all foundations)		
Foundations by Academics (37.700; **58.5%)**		Foundations without Academics (“Other NTBFs”) (26.700; **41.5%**)
Spin-Outs (RBSUs) (6.800; **10.6%)**	(Other) Academic Startups (30.900; **47.9%**)	

Basically, entrepreneurship and commercial activities of a for-profit organization can be related to a business model. That part of the business model which describes how the firm will earn revenue, generate profits and produce a favorable return on invested capital corresponds to the **revenue model**. It specifies by which kinds of offerings the firm will earn revenue to make more money than it spends. An overview of offerings of NTBFs or RBSUs as sources of revenues is summarized in Table I.3.

Table I.3: A spectrum of NTBF offerings as the basis for their revenues*).

NTBF Offerings	Remarks
Products; instruments, devices (incl. sensors and diagnostics); systems	Single products may be standardized for the market or customized according to customers' specifications
Processes; developing and commercializing industrial processes; providing products for processes of customers, such as "process chains," "Mosaic" offerings	Groups of products and services along customers' process chains, not necessarily comprising an uninterrupted sequence along the path (Figure I.94, Figure I.95; ch. 3.2.1)
Solutions	An offering comprising all the components to provide a *solution of a problem*, often for a particular industry
Offering-related services	Technical service, education and training for offerings' usages, software development for offerings' (systems') configurations and usages – "plant layouts"; here a spectrum is observed from free-of-charge to the customer to fee-based services
"Enabling" services	Consulting, analytical services, etc.
Intellectual properties (IP), for instance, patent licenses, "rights to practice," knowledge and know-how sharing; access to information/knowledge in databases	Special information services for customers
Contract research or development, contract manufacturing (scaling-up); process development and optimization	
Other contractual services, technology-based services	For instance, special software (incl. database) developments, Web-based services, I&CT system development
Cooperation: Joint research alliance (JRA), joint development alliance (JDA)	

*) **Revenue**: Sales after deducting all returns, rebates, and discounts.

According to the previous outlines taxonomies for NTBFs have been implicitly introduced which cover types of technologies related to industries as well as levels of research and development activities (Table I.1), education of firms' founders (Table I.2) and types of offerings (Table I.3). A full taxonomy to deal with NTBFs is elaborated in Figure I.128.

Depending on the time period since foundation for which a firm is viewed as "new" as well as the growth rate of the "new firm," NTBFs may cover the whole range of micro, small and medium-sized enterprises (**SMEs**; in German: KMU, Kleinstunternehmen sowie kleine und mittlere Unternehmen) as defined by the European Commission. The classification is based on number of employees and turnover or the firm's balance sheet.

Generally, with regard to quantitative growth of NTBFs headcount (number of personnel per year) or annual turnover are used as the most important indicators (Table I.4). We shall follow this typology as it expresses to a certain degree development stages of NTBFs (ch. 4.3).

In the US the Small Business Administration (SBA) provides a very detailed explanation of what has to be regarded as a "small company" on the basis of the North American Industry Classification System (NAICS) as the standard used by the Federal Government which does not fit our current purposes. Broadly, in the US a business is small if it has fewer than 500 employees.

Concerning business policy the SBA definition of a small firm and, for instance, the German SME differentiation together with the NTBF differentiation (Table I.1) one realizes that in Germany political support of startups and mid-size firms takes into account that small businesses are incredibly diverse, technical versus non-technical firms, with very different needs, aspirations and potential of job creation. In the US to support NTBFs or RBSUs the basically one-size-fits-all approach of policy (by the SBA; ch. 1.2.6.3) would have difficulties to provide the required customized attention.

Table I.4: Definition of micro, small and medium-sized enterprises (SMEs) by manpower or financial criteria [European Commission: SME Definition].

Enterprise Category	**Headcount: Annual Work Unit (AWU)**	**Annual Turnover or Annual Balance Sheet Total**	
Medium-Sized	< 250	≤ € 50 million	≤ € 43 million
Small	< 50	≤ € 10 million	≤ € 10 million
Micro	< 10	≤ € 2 million	≤ € 2 million

The staff headcount is a crucial initial criterion for determining in which category an SME falls. This particular notion covers full-time, part-time and seasonal staff and includes the following category of personnel:

- Employees,
- Persons working for the enterprise being subordinated to it and considered to be employees under national law,
- Owner-managers,
- Partners engaged in a regular activity in the enterprise and benefiting from financial advantages from the enterprise.

The *owner-manager* is an individual business owner who manages and leads a business from any industry or service sector and exhibits a relationship to the notion "self-employment."

An enterprise is not an SME under the definition if 25 percent or more of its capital or voting rights are directly or indirectly controlled, jointly or individually, by one or more public bodies. The reason for this stipulation is that public ownership may give such enterprises certain advantages, notably financial, over others financed by private equity capital. In addition, it is often not possible to calculate the relevant staff and financial data of public bodies.

1.1.2 The Conceptual Skeleton of Entrepreneurship

The nature of the subject is not to blame
if mankind created so many branches of science and schools.

In essence, entrepreneurship deals with a person or a group, the entrepreneur(s), in a particular situation and environment and why and how they found, or even take over, a firm anticipated to be "successful." Anticipated success of the entrepreneur means "perceived" (subjective) success – perceived chances (ch. 4.1).

Mugler [1998] has presented a "configuration approach" as a concept to explain firm's foundation and development (growth), in particular, SMEs which reflects a GST view. Runge [2006] used such an approach in the context of innovation in the chemical industry basically differentiating the concepts of "*innovation architecture*" characterized by endogenous variables and "*innovation configuration*" considering architecture combined with exogenous (external) variables ("parameters"). Here, architecture and configuration means *primarily structural categories* which, however, may achieve also functional and operational characteristics if the components or their proper aggregations are associated with attributes for a multidimensional approach (A.1.6).

Basically, Mugler views a "**configuration**" as a set of interconnected factors that initiate *firm's foundation and development*. It is important to note that the factors are interdependent and interacting, such that their effects may be enhanced or diminished. "Configurations are inherently multidimensional entities in which key attributes are tightly interrelated and mutually reinforcing" [Mugler 1998: 105].

The current approach will refer to *entrepreneurial architectures* and *entrepreneurial configurations* for founder teams and new technology ventures in detail (ch. 2.1.2.5;

ch. 4.3.2, Table I.41, Figure I.71, Figure I.72, Figure I.73; A.1.6). The architectures and configurations will be related to a sophisticated taxonomy (Figure I.128).

Mugler's configuration approach searches for variables and relationships between them that initiate developments without implying certain patterns for the proceeding. Clustered occurrence of individual variables or variable indicators provides invariance which can be measured and interpreted. Interpretation of variance in terms of relationships between the variables delivers the basis for the transfer of insight to other, similar cases. Individual configurations can be grouped into "configurational types."

As a summary, the configuration approach with its interdependencies of functions views an *enterprise as a "whole"* with its own attributes which cannot be derived from its parts or components. Each enterprise is formed by its individual constellation of variables and parameters and can be related to the concept of "archetype" only concerning certain aspects. Over time this induces dynamics ("development"), which is a special form of change.

For instance, referring to entrepreneurship in the biofuels field (A.1.1) venture capitalist Vinod Khosla [2008b] introduced also a sort of configurational view into entrepreneurship and entrepreneurial firms through the notion of an "Innovation Ecosystem" solving large problems by key drivers and coordination of capital, intellect, pragmatism, and confidence so that a firm will succeed. Pragmatism refers to awareness that some approach will work and some will fail. The "configuration" (for venture capital-based) NTBFs includes

1. World class or best known academics, people with very different scientific and engineering backgrounds, from very different industries and life experiences coming together and challenging traditional industry assumptions about what is possible and what is impossible.
2. The industry's ability to attract entrepreneurial and managerial talents to run the companies from their beginnings who are often attracted by making money – and making a difference. In particular, "business veterans" are joining related (biofuel) startups in droves.
3. Intelligent capital and huge financial resources, where the "deep pockets" are with venture capitalists or existing giant companies (, and also large grants through governmental programs).
4. Finance and project development skills from other industries are now being brought to bear in a disciplined, staged approach to project design and contracting.

In this book a configuration approach with a strong focus on *startup (initial) architecture* in the above sense will be central to *characterizing NTBFs* and generally firms, for instance, the class of "Hidden Champions" in Germany (ch. 4.1.1; Box I.18) and to deal with *firms' developments* (ch. 4.3). As no two firms will have the same initial configuration and a subsequent path to growth, the further question will be, how can we tackle the desire to derive generalizations in the context of technology as a particular opportunity of entrepreneurship?

We regard GST as *the* option for a framework to progress towards a united concept of thinking with regard to explanation of entrepreneurship and providing a consistent system of regularities and patterns indicating in some cases even “kinds of laws.” We approach the subject using a conceptual skeleton separating basically the entrepreneur and entrepreneurship, a distinction which is important.

For entrepreneurship we look at the macro and micro perspectives of a process (ch. APPROACH). Focusing on entrepreneurs we concentrate on *the person in the process*. (ch. 2). We frame the content systematization according to four fundamental categories, viewed as concepts for understanding and order factors to interrelate terms and notions to judgment, as outlined in Table I.5.

Table I.5: The conceptual skeleton of technology entrepreneurship – the “entrepreneur(s) in entrepreneurship.”

<table>
<tr><td>The Entrepreneur (in German Gründerperson) and the Founder Team</td><td>The founder’s personality in the broadest sense; traits, attitudes, etc.;
demographic characteristics (for instance, age, gender) and experience;
the culture factor;
visions, goals, purposes;
foundation by a team of entrepreneurs;
entrepreneur versus intrapreneur (ch. 2).

Having and/or revealing opportunities (ch. 3);

Decision-making and risk taking (ch. 4.2.)</td></tr>
<tr><td colspan="2">Entrepreneurship</td></tr>
<tr><td>The context of the foundation
(in German Gründungsumfeld)</td><td>Basics of Applied General Systems Theory and systems thinking (ch. 1.2.2, ch. 1.2.3);
the context of systems the technology entrepreneur(s) is active in (ch. 1.2, ch. 5)</td></tr>
<tr><td>The endeavor:
key categories and processes
(in German Gründungsunternehmen)</td><td>For instance, the foundation initiatives, perspectives of “success” (ch. 4.1),
characteristics and processes (“architecture”) of the founded firm, e.g. resources, structure and activities (ch. 4.3.2); resource/input conversion; ownership and legal issues;

the foundation’s environment and conditions;
the directing “configuration” (through internal and external “drivers”);

firm’s foundation as systems design (ch. 5)</td></tr>
</table>

The foundation success (in German Gründungserfolg)	Failures and pitfalls of startups (ch. 4.2.3) Firm's development; processes and results, goal achievement, firm output, output performance; growth; theoretical descriptions of firms' development based on sociological and cybernetic concepts and principles (ch. 4.3)

(Technology) Entrepreneurship is not only an interdisciplinary exercise for those who research the subject, but it requires also for those who execute technology entrepreneurship an interdisciplinary attitude, selected "hard" and "soft" skills and dealing with resources of various types and origins.

It is one aim of this book to generate a *sufficient, "need-to-know" level* of understanding of the concepts and the language of the involved fields and disciplines (Figure I.1) so as not to be mystified, and finally to ask the right questions about entrepreneurship rather than discipline-specific questions.

Figure I.1 shows the stages of the entrepreneurship model with the various disciplines which contribute essentially to describing, explaining or practicing, respectively, relevant activities during these stages without excluding the others at the particular stage. The outline of Figure I.1, therefore, will also present some remarks in how far and by which concepts the disciplines enter into this book on entrepreneurship. Moreover, the simple notion "science" hides how the epistemology and the ways of reasoning in physics, chemistry and biology will show up (Figure I.2) and how important metaphors from physics are for dealing with new venture growth (ch. 4.3).

Figure I.1 emphasizes an approach where a *person or group*, the entrepreneur(s) or the foundation team, with given psychological and cognitive dispositions and expressions and visions and goals (ch. 2) are interconnected with the *"success" of a firm founded through a process* of entrepreneurship. The current approach considers explicitly the foundation process and early development phases, the *time before ("pre-startup") and after the foundation* ("startup": early, nascent stage and early growth and stabilization). But, the structural representation in Figure I.1 with the question mark leaves it unanswered (till ch. 4.1) whether distinct growth is a criterion of success for the entrepreneur(s) and whether innovation is a necessary or preferred or even uncommon prerequisite for firm's foundation and success.

Visions or goals of the entrepreneur (Table I.5; ch. 2.1.2.7) will enter his/her perception of success and may be associated with three situations:

- They exist *a priori*, often already in the life of the to-be-entrepreneur, without explicit interconnections with a firm as the appropriate means to achieve the goals/visions. Typical examples are described for V. Dulger of the Prominent Group [Runge 2006:74], D. Spatz of Osmonics, Inc. [Runge 2006:91], and P. Marrone of AgraQuest [Dorf and Byers 2007:24].

- They emerge out of an established idea or revealed commercial opportunity or interrelated idea and opportunity to found and lead a (new technology-based) firm. Visions and goals will and must become explicit after revealing opportunity.
- Original visions and goals are changed. They are modified after a new opportunity has been revealed, after a chance discovery or serendipity. Serendipity [Runge 2006:430] is often associated with a change of original goals of a new firm or an innovation project (re-direction).

Operationalized visions and goals are the basis to assess success (ch. 4).

A key aspect of entrepreneurship is that, for many cases, it represents the *pursuit of opportunity (and/or problem-solving) beyond the resources the entrepreneur(s) currently controls* (ch. 3).

It must be emphasized that entrepreneurship research deals to a vast amount with the entrepreneurial person rather than a team. Research on the entrepreneurial foundation team has remerged only during the last few years and contributions are almost negligible when compared to contributions to the entrepreneurial person. This is particularly true for the subject of technology entrepreneurship (ch. 2.1.2.5).

But, general systems theory for NTBFs requires to differentiate aggregation of persons striving for a common goal according to the levels given below of relevance for entrepreneurship, the individual, the group/team (ch. 2.1.2.5) and the "herd" with say less than 50 members (ch. 4.3.1).

The "Herd" (Sociology)

The Group (Social Psychology)

The Individual (Psychology)

Leadership

Management

All these three entities should be viewed as systems. In isolation they are the subjects of different scientific disciplines, but are interconnected for entrepreneurship via the notions of leadership and management.

Figure I.1 differentiates entrepreneurship from management. Both processes have different requirements with different time horizons as they refer to activities and tasks, respectively. The entrepreneur has essentially an external orientation, refers to intuition, creativity, ideas and views into the farer future; the manager is engaged in organization and administration and in efficient interconnections between the internal and the external referring more to rationality. Both differ by their psychometric profiles (ch. 2.1.2.1).

> There is a difference between *running* a large firm or *developing* a startup or NTBF (from scratch). A *stable, established firm is different from a startup or NTBF* – they represent different entities!

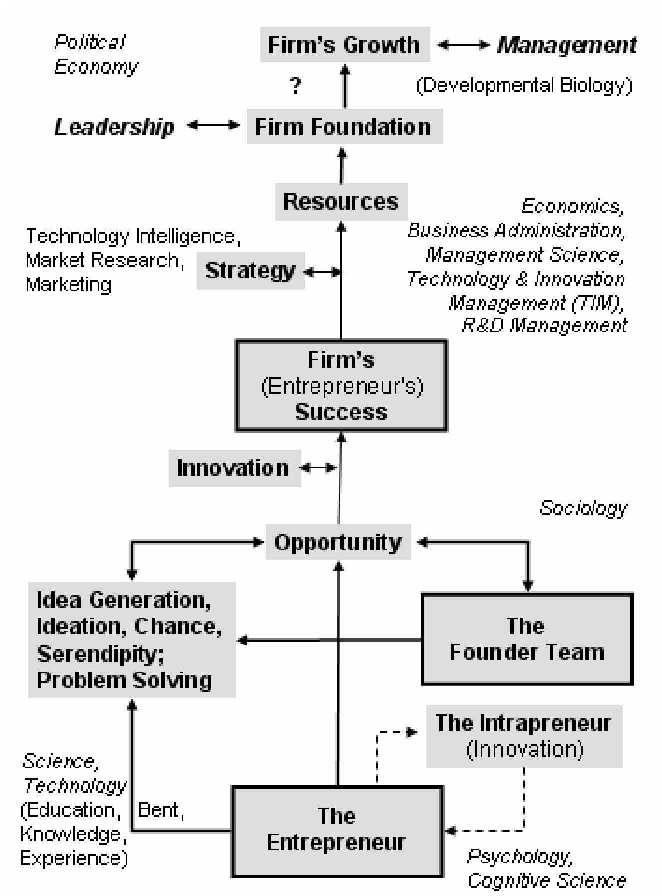


Figure I.1: The Entrepreneur and Entrepreneurship – Key categories and related research disciplines.

The question mark indicates whether insignificant, marginal or high growth is bound to the entrepreneur's view of success (goal achievement).

Management is a process and *the art, or science or practice*, of setting and achieving objectives utilizing and coordinating appropriate assets and resources including people in order to attain them with least cost and minimum waste which means attaining the best return on such assets and resources by getting things done efficiently.

It is widely accepted that entrepreneurship differs from management [Morris et al. 2008:12]. Concerning roles in NTBFs there is a difference between management and leadership, the significance of management showing up more for growth or a particular development stage, respectively, of a successful NTBF.

Repeating the already cited statement of Drucker [1964:5], the entrepreneurial job is associated essentially with *effectiveness* which, in short, means doing the right thing and contrasted with efficiency, do the things right. The focus on efficiency is essentially bound to management.

There is no generally accepted or generally applicable definition of leadership. For the context of this book we note firstly that, in the foreword to the book "The Leader of the Future" [Hesselbein 1996], Drucker provides a very condensed definition of leadership: "The only definition of a leader is someone who has followers." To gain followers requires *influence*.

Hence, we see **leadership** as a process of social influence in which one person (or a coherent group) can enlist the aid and support of others in the accomplishment of a common goal. Leadership is reflected by *a purposive collective or group process* and is ultimately concerned with fostering change directed toward some future end or condition which is desired or valued. The emphasis of leadership on social influence actually means that its expression will often emerge from national culture (ch. 2.1.2.3).

In particular, for European (German) NTBFs, which often have an international or even global orientation from early on, leading multi-cultural personnel or teams, respectively, is important.

Innovation has always been a primary challenge of leadership. There is a need for leaders to constantly work to *develop the capacity for continuous change* and *frequent adaptation*, while *ensuring that identity and values remain constant*. In doing so, it is important that these leaders recognize people's innate capacity to adapt and creativity to innovate and have their people pursuing continuous development (Figure I.120, Figure I.121).

The above discussion can be condensed into an illustrative relationship as given in Equation I.1.

Equation I.1

$$\frac{\text{Doing the right things}}{\text{Doing the things right}} \sim \frac{\text{Leadership}}{\text{Management}} \sim \frac{\text{Effectiveness}}{\text{Efficiency}}$$

Furthermore:

Leadership is about people;
Management is about business results and processes.

For entrepreneurship, addressing specific leadership behavior expected to contribute to organizational or unit effectiveness, *functional leadership* theory is particularly useful. This theory argues that the leader's main job is to see (and foresee) that whatever is necessary to group needs is taken care of. Thus, leaders can be said to have done their job well when they have contributed to group effectiveness and cohesion. Five broad functions are observed a leader performs when promoting an organization's effectiveness. These functions include:

1. Environmental monitoring ("environmental scanning"; ch. 1.2),
2. Organizing subordinate activities,

3. Teaching and coaching subordinates (Figure I.121 in ch. 4.3.2),
4. Motivating others,
5. Intervening actively in the group's work. [4]

A key leadership's characteristic is the exercise of **influence**. It is therefore worth to be aware of the difference between influence and power. Both involve a capacity to change the behavior of other individuals, to get them to do something that they would not otherwise do. However, power does not primarily affect attitudes, whereas influence does:

Influence > attitudes > behavior

Power > behavior > attitudes.

Influence is simply the capacity to affect a choice made, in other words anything that will value or devalue a certain choice (ch. 4.2.2). For planning, in particular, a firm's operation, van Gigch [1974:7] emphasizes in this context the dichotomy of "planner leader" versus "planner follower," which means "planning *to influence* trends" versus "planning *to satisfy* trends." Power over an individual is the capacity or status by declaration in an organization to make their decisions for them. Consequently, power does not require goal congruence; leadership does.

As will be seen later, if a venture's success is not only to avoid insolvency, but systematically expand market and competitive positions ("growth"), established principles of management science and business administration become essential. That means, consideration of entrepreneurship-related business administration and economics.

How Various Disciplines May Enter Technology Entrepreneurship

The transition of an NTBF or fledgling business to a well-established medium-sized or large company requires fundamental transformation rather than simple scaling-up. Entrepreneurship-related business administration (including market research and marketing) will essentially refer to Management Science and *Technology and Innovation Management (TIM).*

One must be aware, however, that the currently exploding literature on managing firm's foundation focuses essentially on heuristic recipes for processes and organizational shaping of new firms – without a theoretical basis as they rely essentially on results derived for usually large existing firms.

Related arguments concerning their basis also apply to *market research and marketing* or generally commercial intelligence which focus largely on consumers and mass markets. Therefore, *technology intelligence* [Runge 2006:816] which sprouts essentially out of research and technology, but exhibits also relationships to market research and commercial intelligence, has been put forward as a basis for technical firms and also for NTBFs. Technology intelligence as an aspect of competitive intelligence [Runge 2006:798] comprises as major components "competitive technology assessment" (CTA) [Runge 2006:802-803, 816-826] including "patent tracking and analysis" [Runge 2006:660-670].

To describe the development of new firms reference is often made to biological analogies. The discipline that is assumed to provide *metaphoric explanations* of a firm's or industry segment's growth is *Developmental Biology* [Runge 2006:7; Bhidé 2000:249]. Developmental biology exhibits also relationships to entrepreneurship architectures or configurations, respectively, via three key concepts: similarity, homomorphism, heritage and analogy (actually function-analogy).

Two structures are *homologous*, if they *look similar* and the similarity is due to descent from a *common ancestor* possessing the ancestral version of the part in question. If two structures are *analogous* there is *no common ancestry* and the parts look similar as the pressure of natural selection has forced a convergence of structure to meet the need for similar function. In biology identity of form or shape or structure is termed isomorphism.

An evolutionary approach allows growth of successful NTBFs to be described as actions of variety and selection, as has been done lucidly on the macroscopic scale, for instance, for the emergence of the organic dye industry and global dominance of German dye firms between 1860 and 1914 cited by Runge [2006:275].

As will be discussed later (ch. 2.1.2.4, A.1.6), formal descriptions of entrepreneurial architectures may rely on permutation algebra which allows comparing frequency distributions as an order relation and using strictly mathematical concepts of isomorphism (essentially one-to-one mapping between the elements of two sets) and homomorphism (essentially a many-to-one mapping of elements of two sets).

Generally, sociologists who study the institutions and development of human society are seen as the principal developers of *organizational theory*. And in *sociology*, on the other hand, an isomorphism is understood as a similarity of the processes or structure of one organization to those of another one, be it the result of imitation or independent development under similar constraints. This kind of isomorphism will be used, for instance, to deal with entrepreneurial architectures or configurations and expectations concerning growth of new firms (ch. 4.3.6).

There are three main types of isomorphism in sociology: normative, coercive and mimetic. Coercion means to attempt to enforce desired behavior on individuals or groups, or even governments – and thus exhibits relationship to power. It is practiced by compelling a person or manipulating persons to behave in an involuntary way (whether through action or inaction) by use of threats, intimidation, trickery, or some other form of pressure or force.

> An important expression of sociological isomorphism for entrepreneurship is "*role models*," in particular, considering parents and children in relation to entrepreneurship or self-employment (ch. 1.2.2, ch. 2.1.2.4, ch. 4.2.1, ch. 4.2.2). Role models are essentially mimetic.

The outline of entrepreneurship and the process of firm's foundation and leading the early-state enterprise in Figure I.1 implies that attention is not only directed toward the personality of the founder(s), referring to *psychology, social psychology and sociology*. It focuses on also the processes of emergence, revealing, evaluating and exploiting opportunities as viewed by *cognitive science*. And, for the technology area, it covers specifically how ideas, discoveries or findings and mechanisms of idea generation are related to opportunities or how research and technology provide the answer to an opportunity associated with a problem to be solved. This includes "*ideation*", a structured approach to generate ideas (ch. 3.3).

For innovation and technology entrepreneurship often having or generating an idea is separated from revealing the related (business) opportunity (ch. 3.3). For instance, the historically prototypical situation is the case of Berlin Blue (Prussian Blue) which involves two persons, one who had the finding and one who recognized its commercial opportunity [Runge 2006:397-402]. And concerning intrapreneurship in multi-industry case studies it was found as cited by Runge [2006:607] that in ten out twelve cases idea generators did not reveal or recognize the opportunities. In this regard we differ from Dorf and Byers [2007:1] who relate *the "capable entrepreneur"* with his/her ability to "*learn* to identify, select, describe and communicate the essence of an opportunity." (Emphasis added)

Apart from idea generation or ideation also the "unpredictable events" of novelty of a discovery or invention and luck are essential for innovation. Therefore, in our technology entrepreneurship approach, we interrelate the categories "idea" and "opportunity" also to "*chance detection, discovery or serendipity*." These are treated as principally independent phenomena which have to be "channeled" into further entrepreneurial actions and processes.

Whatever the approach to technology entrepreneurship or innovation is, serendipity, which is so fortuitous, but shown by history to be associated with much fortune for developments in chemistry and other areas, should be taken into account as an event of individual discovery, initiative, risk taking and achieving.

Serendipity is *finding something unexpected and useful while searching for something else* entirely [Runge 2006:430] or is planned insights associated with unplanned events. In so far, concerning the search process, serendipity shows a certain relation to the "*paradox of searching*": When you do not know what you are looking for, but you recognize it when you find it.

In the context of serendipity one must refer simultaneously to the French chemist and microbiologist Louis Pasteur (1822-1895). He was a master of experimental research and not so much interested in theory. Pasteur made many fundamental discoveries just by careful observation. In this context, he formulated in 1854, “in the field of observation, *chance only favors the prepared mind*.” Usually, only the second part of Pasteur’s statement (given in italics) is cited in the context of revealing (business) opportunities. However, the first part focused on *observation* is of equal importance as a premise.

A classical example of failure when a researcher defines his own target of observation disregarding what actually happened is the missed “Bakelite” discovery in 1872 by German chemist Adolf von Baeyer. He was investigating the recalcitrant residue that gathered at the bottom of glassware that had been host to reactions between phenol and formaldehyde. *Von Baeyer set his sights on new synthetic dyes, however, not insulators as envisioned for Bakelite*. To him, the ugly, insoluble gunk in his glassware was a sign of a dead end. The “phenol-formaldehyde” plastics (1909) with the name “Bakelite” was the world’s first fully synthetic plastic and characterized as “the material of a thousand uses” which explains its huge success [Runge 2006:423, 413, 465-467].

To summarize, the structural elements of serendipity comprise a search, a fortunate accident and a knowledge base to recognize the potential of the discovery for a given context.

> Serendipity plays a role for science/research, applied research, technology and innovation. It is suggested that serendipity may be a quite prevalent feature of entrepreneurship [Dew 2009; Chandler 2004]. This means, *serendipity is an intrinsic and recurring, though not predictable event of innovation and (technology) entrepreneurship.*

Typical examples of serendipity for entrepreneurship or innovation over three centuries include, for instance, related to chemistry the cases of Berlin Blue (Prussian Blue) dyestuff/pigments in 1704, Perkin’s mauvein (mauve) dye in 1856 (A.1.2), the copper phthalocyanine pigments as unchallenged leaders of various types of blue and green pigments during 1907 – 1930 [Runge 2006].

Serendipity showed up for polymers and plastics in cases of polyethylene, polytetrafluoroethylene (Teflon®), polyurethane plastics and flexible polyurethane foam, Styropor® and Styrofoam® polystyrenes and in adhesives uncovering the cyanoacrylate superglues. In pharmaceuticals Fleming’s discovery of penicillin in 1928 or Pfizer’s Viagra® from 1998 result from serendipity [Runge:2006: 397, 294, 310, 421, 423, 294, 420, 103, 16]. In the adhesives area also 3M’s famous Post-It® Notes product from 1980 originates from serendipity [McLeod and Winsor 2003; Runge 2006:377].

In physics, for instance, the emergence of paper batteries in 2007 [Rensselaer Polytechnic Institute 2007] or the discovery of carbon nanotubes in 1991 [Iijima] can be attributed to serendipity. The author closely observed a serendipity situation for a manufacturing process during his work with Dow Chemical [Runge 2006:215]. And the development of the flesh freezing process for food and the “Quick Freeze Machine” by the General Seafood Corp. (1926) originated also from serendipity [Birds Eye Foods; Dorf and Byers 2007: 31].

Recently, the German NTBF Vitracom AG (B.2), founded in 2000, started with a video sensor and camera for image processing in the context of IT-based security (security video surveillance). However, they soon found that the sensor unexpectedly fit exactly the requirements of marketing in retail in terms of “shop efficiency monitoring.”

Against a structured background, the Vitracom software can differentiate men and women as well as adults and children and can track paths of shopping as well as dwell times at particular offerings on the shelves and can interrelate that to purchase actions. Its systems provide real time performance figures to enhance sales and profitability of the retail business. Vitracom’s Shop Efficiency Monitoring platform is also used at airports and many places with public access. The firm views itself as the market leader in Europe in this field.

Given the separation of ideas and opportunities for technology entrepreneurship it is also meaningful to consider serendipity for discovering opportunities. This has been tackled by Marvel and Murphy [2007] based on data derived from technology entrepreneurs in university-affiliated incubators. They explain technology entrepreneurial discovery mode via general human features (essentially experience depth, experience breadth, formal education). Furthermore, they explain discovery mode using a specific framework comprising prior knowledge constructs (such as markets, customer problems, ways to serve markets, and technology). However, they do not make a clear distinction of whether all these features should be attributable to just one person, the entrepreneur, or whether they can be distributed over two or more persons (a team).

Finally, for entrepreneurship also *political economy* comes into play which is the study of the interaction of politics and economics as well as studying economic and political behaviors. Political economy thus begins with the observation that actual policies are often quite different from ‘‘optimal’’ policies, the former being defined as subject to fiscal, technical and informational, but not political constraints. If economics is the study of the optimal use of scarce resources, political economy begins with the political nature of decision-making and is concerned with *how politics will affect economic choices in a society*.

Hence, political economy provides important contributions to deal with entrepreneurship. Political economy most commonly refers to interdisciplinary studies drawing upon economics, law, and political science in explaining how political institutions, the political environment, and the economic system influence each other. When narrowly construed, it refers to applied topics in economics implicating public policy, such as, market protection, government fiscal policy, or government education, science and technology policy.[5]

In the developed and developing countries initiating, encouraging and supporting entrepreneurship is high on the list of priorities of various ministries (ch. 1.2.6). For instance, in Germany the Federal Ministry of Education and Research (BMBF – Bundesministerium für Bildung und Forschung), Federal Ministry of Economics and Technology (BMWi – Bundesministerium für Wirtschaft und Technologie) and also the Federal Ministry of Defense (BMVh – Bundesministerium der Verteidigung) are committed to pursuing an effective policy on entrepreneurship (and innovation). In the US one sees corresponding activities by the Department of Energy (DOE), Department of Defense (DOD) and the US Department of Agriculture (USDA).

To support government's entrepreneurship policy (and measure its results) in many countries political economy have undertaken numerous studies concerning entrepreneurship. The results of such essentially macro-level studies will represent an important basis of this book.

1.2 Systems, Change, Innovation and the Future

The future is purchased by the present.
Samuel Johnson (1709 – 1784)

You can't predict the future, but you can invent it.
.Dennis Gabor

The best way to manage the future is to create it.
Peter F. Drucker

General Systems Theory (GST) will make it possible to develop a more uniform abstract framework and generally understood scientific language for researchers from a variety of disciplines to better understand contexts and answers originating in another realm of discipline and conversely identify questions which are asked in one discipline, but can be (already) answered through another discipline. This requires consensus about terms, notions, concepts and tenets and their consistent uses to "systematically" organize observations and contribute to a phenomenological and theoretical approach to entrepreneurship.

1.2.1 General Systems Theory and Systems Thinking

General Systems Theory provides *a way of conceptual and general thinking as well as a methodology of change and innovation*. It emphasizes "organized complexity" [van Gigch, 1974:43] and understanding of the system in relation to all other systems larger than or interfacing with itself. As GST is central to the treatise and as it is not to be expected that readers are generally familiar with the subject Applied General Systems Theory shall be selectively summarized and adopted to the current use.

A *systems approach* considers direct and indirect effects of change in any element within a system or external to a system that have the potential to affect any element or process within the system. On the operating level for systems events, patterns and relationships between patterns are main objects of investigation. *Events* are directly observable actions and behaviors. *Patterns* emerge as comparable actions and replicated behaviors.

GST focuses on *holistic* views of an area of human-activity. In particular, the environment in which the phenomenon under consideration is observed is part of this holistic approach. Furthermore, GST considers various arrangements of *interacting subsystems* and *supersystems* with the system under consideration.

The recent dramatic consequences of discarding applied systems thinking showed up very lucidly in the so-called global “financial/credit/debts crisis” which brought the world economy down to its knees with the so-called Great Recession (sometimes also called the “Great Repression”). Much of it can be traced back to fundamentally disregarding interconnections. And fighting the “Great Recession” targeted to ease “systemic risks” which are assumed to avoid even more damage. In particular, the risk models of the financial (banking) system lacked a reliable statement on how the various risks depend on each other (“systemic relevance”).

GST has become an analytical tool when studying *interdisciplinary phenomena*. Like any other analytical tool it has advantages and limitations. In particular, GST looks to find approaches to solve new problems by reference to “earlier solutions of structurally related problems.” That means, GST emphasizes *“generic solutions” of problems* which apply across different domains and scientific disciplines.

Systems Thinking is an approach to problem-solving that views “problems” as parts of an overall system, rather than reacting to present outcomes or events and potentially contributing to further development of the undesired issue or problem.

> “There exist models, principles and laws that apply to generalized systems or their subclasses, irrespective of their particular kind, the nature of their component elements and the relations of forces between them.” [Von Bertalanffy 1968:32-33]

Accordingly, to a certain degree, systems follow a number of general principles or rules or quasi-laws which are particularly relevant for entrepreneurship.

In the context of GST the challenge to deal with entrepreneurship lies in the interplay and balance between complexity and simplicity, generalization and specification:

> How complex phenomena or architectures can arise from or be explained by simple laws or rules or patterns, and sometimes follow simple rules of their own; how much details must be necessarily described to initiate evidence and inferences leading to presented abstractions.

Systems Thinking expands the focus of the observer, whereas analytical thinking (dissect a whole into the constituting parts) reduces it: analysis looks into things, synthesis looks out of them. Essentials of GST are summarized by the German philosopher Wilhelm Friedrich Hegel (1770-1831) as cited by van Gigch [1974:49].

1. The whole is more than the sum of the part (“nonsummativity,” synergy).
2. The whole determines the nature of the parts.

3. The parts cannot be understood if considered in isolation from the whole.
4. The parts are dynamically interrelated or interdependent.

To recall and summarize the essentials of GST which are relevant for the current subject reference will be made to van Gigch [1974], Skyttner [2001] and a contextual sketchy overview in Runge [2006].

A **System** is an aggregation of interacting living or non-living entities or interacting living and non-living entities. A system is intrinsically associated with a goal, purpose or function. It is represented by a set of "*components*" and "*relations*" as "elements" and *attributes* assumed to be relevant for the system to achieve the goal, purpose or function. Attributes cannot be manipulated by researchers.

From a cybernetic point of view (ch. 4.3.4) "a system is a set of variables sufficiently isolated to stay constant long enough for us to discuss it." [Skyttner 2005: 57].

Observable and/or *measurable* attributes (properties/characteristics/behavior) are quality-like or quantity-like. This differentiation determines the approach to be used in measuring ("metrics"). The character of goal/purpose/function determines the metrics for evaluation of achieving or having achieved those (by which criteria the *system's productivity or performance* will be judged).

> A system is not something presented to the observer; it is something to be recognized by him/her.

Systems can have *decompositions* and *order* according to various criteria (like *hierarchy*, "nesting"). The issue of systems and, hence, entrepreneurship, will be how far to "compose" or "organize" the "entrepreneurial system" into larger systems. A *system's structure* relates to the kind of elements and the kind of relationships which bind the elements of the set together. System structure may refer to different decompositions, components and subsystems.

Hierarchy implies a framework that allows complex systems to be perceived from simpler ones and allows having order among subjects and objects. Given a hierarchy of systems and purpose/goals/objectives of a supersystem objectives of the subsystems can be arranged in a *hierarchy of (subsystems') objectives* to achieve the supersystem's objectives/purpose.

In the context of large companies the term *function* is used for structural (organizational) units or systems performing particular kinds of activities and processes to contribute to purpose/goal achievement of the supersystem, contributing to the firm's objectives by Research and Development (R&D), Engineering, Manufacturing, Marketing and Sales etc.

Animated ("*living systems*") are associated with goals or purpose and provide "purposeful systems." Referring to living entities biology is closest to GST. Our focus is on **human-activity systems** [Banathy 1996] and, in particular, on *business activities*.

A system's purpose is the reason for its existence ("mission"; ch. 2.1.2.7) and the starting point for measuring its success. Purposeful behavior is directed toward the achievement of a final state, the goal. Living systems are characterized by the presence of both *coordination and sub-ordination* in the system.

A system exists or is developed to produce an output or outcomes or achieve a goal. An output is the *product* of the system. By definition, without an identifiable output or outcome, there is no system. The criteria defined for purposeful behavior are summarized by van Gigch [1974:44] in Table I.6.

Table I.6: Criteria for purposeful behavior [Van Gigch 1974:44].

1.	For purposeful behavior to take place the object to which behavior is attributed must be part of the system.
2.	Purposeful behavior must be directed toward a goal.
3.	There must be a reciprocal relationship between the system and its environment.
4.	Behavior must be related to or coupled with the environment, from which it must receive and register signals which indicate whether behavior is conducive to making progress toward the goal.
5.	A purposive system must always exhibit choice of alternative courses of action.
6.	Choices of behavior must lead to an end product or result.
7.	A distinction must be made between *sufficient* and *necessary* conditions for an event. Sufficient conditions enable us to predict its occurrence, whereas the necessary conditions aim at discovering the elements in nature which are responsible for it. The former are related to physics and to cause-effect relationships, whereas the latter are better suited to biology and the social sciences and to an explanation of producer-product relationships.

Human-activity systems are basically studied on two levels:

- The level of the *individual* and
- The "*group*" level, from the couple and family, to teams and task forces etc. to end up with nations.

Correspondingly, leading disciplines for scientific studies are psychology including cognitive science and sociology (Figure I.1).

In the social sciences and, hence, also in the context of GST, there is a caveat with necessary and sufficient conditions and the symmetry of the relationship {A $\leftrightarrows$ B}. For instance, Brennan cited in Runge [2006:115] deals with truth-functional conditional sentences stating both a necessary and a sufficient condition. Moreover, he shows that natural language and reading with "if-clauses" leads to systematic ambiguity in the concepts of necessary (and sufficient) conditions. Accordingly, one cannot give unqualified endorsement to the thesis that A is a sufficient condition for B if and only if B is a necessary condition for A (and *vice versa*).

Brennan has shown that odd results would not arise in some *non-classical logics* where it is required that *premises be relevant to the conclusions drawn from them, and that the antecedents of true conditionals are likewise relevant to the consequents*. Brennan elaborated the gap between *inferential symmetry* and *explanatory asymmetry* in cases of conditionals.

Brennan's elaborations have implications concerning inferences (if X, then Y) and facultative action (do X out of Ys), particularly also for recommendations. In the end "*reason why*" and "*reason for thinking that*" conditions are introduced to help to shed light on the encountered asymmetries. And he stressed that there is need for care in determining whether reason why or reason for thinking that relations are being stated (Figure I.2).

Figure I.2 reflects, for instance, the structural shortcomings of an experimental design targeting behavior and decision-making comparing entrepreneurs (A; upper right graph of Figure I.2) with intrapreneurs or even managers in a large existing firm which should refer to the situations in the middle or lower graph rather than making inferences for intrapreneurs based on inferences valid for entrepreneurs (ch. 2.1.2.1). Inferences would also be questionable even it would be possible to confine a design to entrepreneurs in their roles as managers to relate these to corporate managers.

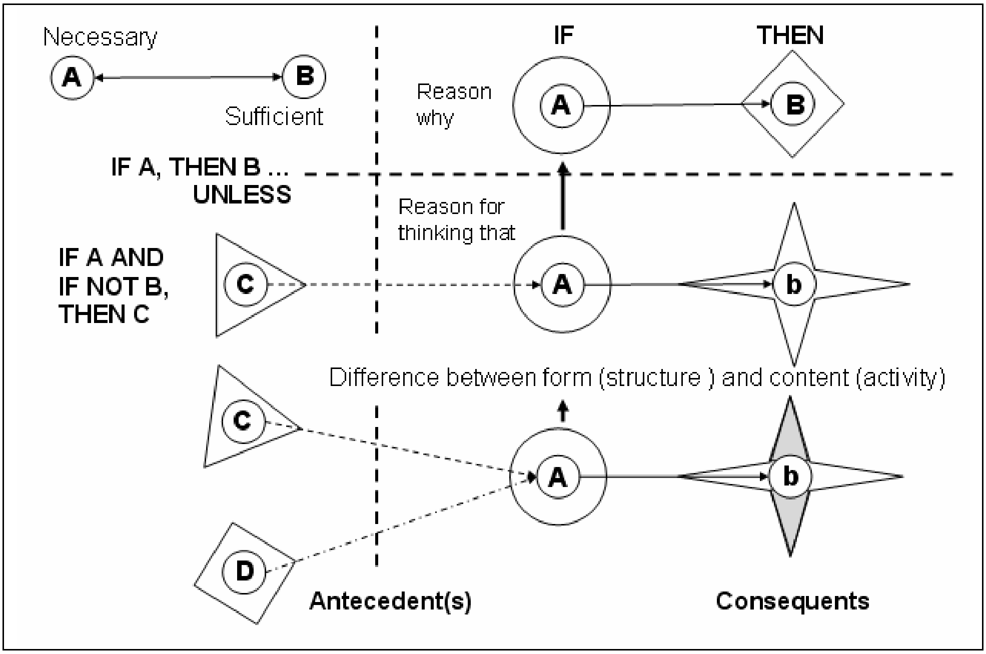


Figure I.2: Statements with conditionals: "reasons why" versus "reasons for thinking that" illustrated in terms of antecedents and consequents and different symmetries (a square to a four-pointed star, one with a fourfold the other with a twofold rotation axis).

Currently most published work on the philosophy and epistemology of science is in fact the philosophy of physics and centers around the notions of “reductionisms,” “deduction/induction,” “causality,” “explanation” and “prediction/prognosis.” What embraces all major scientific disciplines, physics, chemistry and biology, from an epistemological point of view, is the notion of causality.

Physics aims at more or less precise quantitative prediction, following closely the model of *deductive* explanations (deriving “behavior” from constituent parts). And all this works largely also in chemistry. But basically there is another root of chemistry which touches GST: For instance, the key chemical approach of mixing substances A and B focuses on *what happens*, whereas a physical approach is trying to discover *why* it happens. Another key difference lies in the style of explanations. In chemistry there is also explanation by analogy and precedent.

Prediction in chemistry refers, for instance, to properties and reactivities of molecular classes and exceptions (“single events,” “single data points”) explained *a posteriori* by a particular condition. For instance, in the case under consideration, where the (basic) rule is that molecular classes A and B react to give compounds of class C there may exist an associated “exception rule”: A and B do not react if B has a bulky substituent which prevents the reaction through steric hindrance.

This finding models a new pattern as a constraint to reactions of compound classes A and B: “A + B → C, while B does not contain a bulky group.” Similarly, physical and biological properties of molecular classes may “perturb” the regular class property through definable exceptions. In so far, in chemistry the “outlier” may be of particular interest for “reaction architectures” [Runge 2006:212-214].

> The particular situation of chemical science to deal often with incompletely defined reaction designs and to reveal reaction constraints only *a posteriori* is one of the reasons why serendipity plays such an important role for chemical research and innovation in the chemical industry.

Referring, for instance, to physics, chemistry and geosciences (“natural sciences”) versus psychology, sociology and economics (“social sciences”) and their underlying epistemology and style of reasoning the corresponding systems under investigations are generally characterized as “**hard**” **systems** versus “**soft**” **systems**.

One important difference between hard and soft systems refers to **measurement** which is the assignment of numbers (or numerals) to represent attributes (properties). Numerals possess order only because of arbitrary assignment or mere convention. One of the first requirement of measurement is the determination of the appropriate scale in which the attribute in question could be mapped.

One can assume four different scales of measurement that can be mapped to mathematical relations and transformations [Van Gigch 1974:128-134].

1. The nominal scale:
   The most basic measurement, classifications, taxonomies and “groupings”; $x = z$, $x \neq z$
2. The ordinal scale:
   Classes or taxonomies are subject to order rank; $X < Z$, $X > Z$
3. The interval scale:
   Requires the determination of equality of intervals among numbers; $(X – V) = (W – Z)$, $(X - V) \neq (W - Z)$, for instance, the Fahrenheit or Celsius temperature scale
4. The ratio scale:
   Implies the determination of the equality of ratios among numbers; all transformations intersect at an “absolute” zero point; $X/V = W/Z$, $X/V \neq W/Z$; numbers, length, weight, Kelvin termperature scale.

The vast majority of measurements in soft sciences refers to the first three of these scales.

When dealing with entrepreneurial technical firms or innovation one deals with relations of two entities, here (ch. 1.2.5.1, Table I.10) the entrepreneurial firm (the innovator, supplier) and the (innovation) adopter (customer). Correspondingly, tackling this problem requires as the basic measurement appropriate “groupings” of new firms by various criteria, such as R&D expenditures or technology (Table I.1, Table I.12) or mode of financing (Table I.29, Figure I.54), but also “groupings” of the adopter side, for instance, according to industry, industry segment (Table I.1) or markets and type of customer (ch. 1.2.5.3). This combinatorial issue gives a first impression of the need for a highly differentiated approach to technology entrepreneurship.

Once the “overall” objectives of an organization are identified, activities pursuing similar objectives or fulfilling related functions can be grouped into programs. A **program** is coded or prearranged information (“instruction”) that controls a process (or behavior) leading it toward a given end.

A common term used also here is the “*work process*.” A classification scheme relating the activities of an organization according to function they perform and the objectives they have been designed to meet is a **program structure**. The program structure may cut across formal organizational (and other) boundaries.

Attendees of the various programs, participants who play a role in achieving the objectives or changes of the system, are called **agents**. Once grouped according to the particular program or function they pursue, agents form a *component* of the system. They do not necessarily conform to traditional and/or organizational boundaries. For instance, cross-functional teams in large organizations (innovation teams, project selection teams, project teams, task forces etc.) are particular agents.

Responsibilities for the guidance of the system toward achievement of its objectives are with decision-makers, managers and agents. In this context agency is an issue of efficacy and influence contrasted to **stakeholders** (which may include shareholders) with different levels of ability to act or exert power or control for their or the system's benefit. A stakeholder (in German Einflussnehmer, Anteilsnehmer) is a person (or a group) who has a stake or interest in the outcome of a system's activities, operations and conversion process (Figure I.5), but also one who is or may be affected by a firm's projects. Stakeholders may influence programs, products, and services.

Firms and stakeholders have relationships because they need each other. Managing the relationships between the firm and its stakeholders is difficult – satisfying one stakeholder's needs may come at the expense of another one.

In GST the *management concept* in its broadest sense covers all the activities and all the decision-makers and agents involved in the planning, evaluation, implementation and control of the Systems Design [Van Gigch 1974:21]. A **decision-maker** is someone who is *internal to the system* and who *can change the performance of the parts*.

Concerning decision-making (ch. 4.2.2) connotations can be differentiated according to the *decision-maker's information* or knowledge, respectively [Van Gigch 1974:69]:

- Under ***certainty*** there is complete knowledge of the value of the outcomes and of the occurrences of the states (of the system).
- In situations of ***risk*** the decision-maker knows the value of the outcomes and the relative probabilities of the states (of the system).
- Under ***uncertainty***, the values of the outcomes may be known but no information on the probability of (occurring) events is available.

To steer a system toward its goal efficiently **coordination** of its components is required. In the business environment the competency for coordination is viewed as a "critical meta-asset of long-lived companies" [Bhidé 2000:223]. It is seen as a *source of competitive advantage*. According to Bhidé such "*integrative competency*" is embedded in the firm's culture, its values and norms that influence the behavior of employees, customers, suppliers, information handling and sharing and communication across boundaries as well as processes, routines, formal and informal reporting relationships, incentive and the control system (Table I.8).

A **state of a system** under consideration is represented by *observable attributes* for which corresponding elements show up at a point in time or period of time. For a community, for instance, one may refer to its financial state, the physical health of its members or the state of criminality.

A *development of a system's states over time* ("flow") is represented by the *rates of change of the system's attributes*, such as number of a firm's employees or its monetary revenues or change of internal processes. The growth and development of a system is usually associated with increasing specialization of system components and increasing exchanges between the system and other components outside the system.

A **Systems Approach** considers *direct and indirect effects of change in any element within* a system or *external* to a system that have the potential to affect any element or process within the system:

> "What is connected with what," "with what intensity/strength," and "what follows after what ("order," "function")?"

In the sense of the systems approach the present treatise reflects the many conceptual interconnections within the technology entrepreneurship field by excessive forward and backward links and internal references across the contents (text, figures, tables, etc.). This characterizes the organization of content as recurring rather than sequential.

Applying the systems approach concerns the purpose for the existence of the system; it requires an understanding of the system in relation to all other systems larger than and interfacing with itself. In human-activity systems these insights have led us to aspire to understanding rather than predicting.

The **Whole System** comprises all the systems deemed to affect or to be affected by the problem at hand. Within a Whole System the **environment** is defined as comprising all the systems (subsystems and supersystems) over which a decision-maker of a given system has no control.

The environment establishes performance requirements or object specifications of a particular system as well as resources employed by the system. In *Analytic Thinking*, the parts are primary and the Whole is secondary. In **Systems Thinking**, the Whole is primary, and the parts are secondary.

> A central issue of using GST is to reach agreement between those who take into account too few systems ("simplicity") and distort reality and those who take too many ("complexity") and are incapable of reaching a solution.

Boundaries, limits or scope will be defined to every system under consideration in relation to describing or explaining a subject of interest. This means, boundaries of a system are set by its (identifiable) subsystems and supersystems and the strength of systems' interactions with its environment.

The environment within which the entrepreneur operates may have certain regularities or patterns. As we focus on dynamics ("flow of systems or system components' flow) "**environmental rhythms**" [Bird 1992] are of particular interest. A rhythm exists in the environment when *patterns in the environment vary over time with some regularity*. Its recognition, however, is perhaps not simple or easy.

Lucid examples of environmenttal rhythms comprise economic downturns (recessions) or technology obsolescence, governmental policy on economic and non-economic conditions and the impact of these on entrepreneurial activity. Generally, environmental rhythms may be categorized by level of analysis of the involved systems (for instance, interpersonal, organizational, cultural, industrial; cf. also Figure I.13) and by frequency (occurrence per time unit) and amplitude/magnitude of the changes they reflect.

Dealing with environmental rhythms as a source of insight and learning requires a historical perspective which is followed in this book. Furthermore, we regard a single repetition (“déja vu”) of a significant environmental event also as a rhythm rather than as a “rhythmic unit” for more of the same kind to come. “History does not repeat itself, but in rhymes,” as Mark Twain is supposed to have said.

For learning environmental rhythms provide the following facets.

- The past changes or unsuccessful change initiatives tell us about important impact factors.
- The present informs on the basis for future developments.
- Scenario-building (Box I.19), for instance, can explore and test possible futures to assess the relative sizes of barrier forces and become a basis for decision-making.

Complexity has turned out to be very difficult to define. Basically **complexity** of a system expresses a condition of the *number of components* in a system and *the numerous forms of relationships* among the components. The numbers may be very large or even infinite, but remain *enumerable* in the mathematical sense.

Aspects of *distinction* and *interconnection* determine the two dimensions characterizing complexity. In the systems treated by GST complexity will encompass other systems interacting significantly with the one under consideration. Hence, the focus of inquiry is how the kinds of the parts and the relationships between parts give rise to a collective behavior of a system and how the system interacts and forms relationships with its environment.

In a mathematical sense complexity has “order” as a system would be characterized as *more complex* if more parts could be distinguished, and if more connections between them existed. Organizational theory has construed complexity as an objective characteristic of either the structure or the behavior of an organization. *Distinction* corresponds to variety whereas in the current context *heterogeneity* to the fact that different parts of the complex behave differently. Interconnection corresponds to constraint, to the fact that different parts of a system are not independent. Interconnection will induce order.

However, complexity may also become a relative, subjective notion of an observer, understood in terms of human cognition of structure or behavior (ch. 2.1.2.9).

Variety refers to a category of things distinguished by some common characteristic or quality and may induce choices; something differing from others of the same general kind. Variety may also emerge as a measure of complexity if it indicates the number of states of a system [Skyttner 2005:134].

Two principles of GST related to variety are notable in the context of entrepreneurship in which the first one on stability can relate to longevity of a firm.

> **The Variety-Adaptability Principle** [Skyttner 2005:100]: Systemic variety enhances stability by increasing adaptability.
>
> **The Law of Requisite Variety** [Skyttner 2005:100]: Control can be obtained only if the variety of the controller is at least as great as the variety of the situation to be controlled.

On the other hand, for entrepreneurship *human-activity systems* can be characterized by exhibiting "***organized complexity***" [van Gigch 1974:43, 272]. Its main feature is that there are only *finite, relatively small numbers of components and relationships* in the system. Organized complexity is what we usually encounter dealing with new firms, with a number of employees say less than 50. But the pragmatic sense, "given the properties of the parts and the laws of their interactions, it is not a trivial matter to infer the properties of the whole" even in case of organized complexity.

We describe human-activity systems of organized complexity at three levels [Banathy 1996].

1. A system serves the purpose of its collective entity.
2. It serves the purpose of its members.
3. It serves its environment of the larger system(s) in which it is embedded.

Description may include measurement. As in natural science measurement is confined to "*observables*." Hence, with regard to learning or other mental or psychological constructs "*behavior*" is the related observable (Figure I.3).

Effects or changes of state or behavior of a system are classified by *endogenous factors* originating from within and will be denoted as "**variables**" and *exogenous factors* (which are basically variables originating from outside) will be denoted for differentiation as "**parameters**" [Runge 2006]. Variables may or may not be under control of the decision-maker; in our context parameters are always not controllable. We use parameters often to differentiate behavior and execution. For instance, a procedure or activity might have different parameters passed depending on what needs to be done and how it is executed.

Drivers are relevant variables or parameters of a model which provide sufficient power ("strength") or influence to explain (and probably "predict") a system's state and development. Drivers, hence, are those combinations of factors which *suffice to determine the observable response of the system*. External events are special drivers. In particular, the driver concept applies also to the human personality's behavior, decision-making and actions (ch. 4.2 – think of the concept of an agent.).

Specifically, a *"value driver*" is a factor which significantly influences and defines the value for and of a company. Value drivers can have a tangible (financial) and/or non-tangible (non-financial) nature.

The concept of drivers depends on differentiation of systems' interactions in terms of

- *Tight Coupling*: Change in one component (variable, parameter) means specific and significant change in another one, or
- *Loose Coupling*: Change in one component (variable, parameter) might have some (minor) impact on another one.

For certain situations GST uses a "single-shell view" for explanation, which means one looks only at one variable or a "*collective environment*" exerting an "average" influence as a driver that generates a function or form. For instance, function-analogy means that systems/organisms with originally different forms striving for "optimized" fit to *external situations* (the "environment") with comparable external influences ultimately provide *form similarity*. The most striking example is for animals living in water or air and their forms fitting the streamline ("function forming").

In social science one often deals with so-called "**intervening variables**" ("latent variables"). Intervening variables are *hypothetical* internal states (constructs) that are used to explain relationships between observed variables, such as independent and dependent variables. They are not real things; they cannot be seen, heard, or felt. They are *interpretations of observed facts*, not facts themselves. But they create the illusion of being facts. Typical examples include personality, traits, memory, attitude, understanding, expectation, intention, intelligence and learning.

An intervening variable reflects theoretical processes that are assumed to take place between what is observed as the "before" conditions and the "after" conditions. The situation is displayed for learning as an intervening variable in Figure I.3.

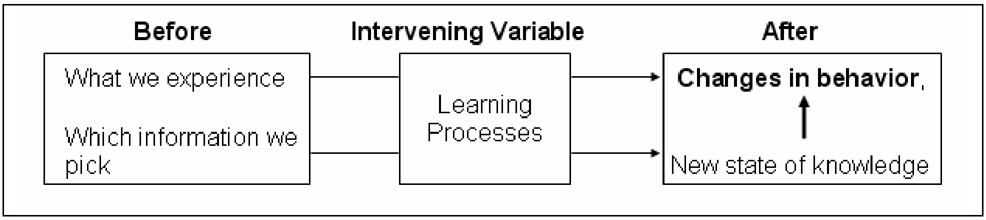


Figure I.3: Learning as an intervening variable.

The theoretical processes of learning are mostly associated with two approaches.

- Cognitive theories take an information processing approach to learning; learning as capture, storage and processing of (not inherited) information which allows or induces a change of behavior.

- Behavioral theories approach learning as an evolved relationship between units of behavior (responses) and units of the environment (stimuli). With emphasis on observable relations between specific responses and specific stimuli they are less speculative and avoid reference to internal, hypothesized processes.

Both approaches assume more or less explicitly *motivation* as a prerequisite of learning.

Rather than promoting one or the other approach, for learning we shall focus on *interpretation* of the situation under investigation. Basically, learning emphasizes a reference to oneself ("doing," "what I am subjected to") or others (what others do, have done"). This is illustrated for various types of learning in Table I.7.

Table I.7: Types of learning and their interpretations by cognitive or behavioral theories.

Learning by	**Typical Examples**	**Interpretation**
Conditioning	(Higher) Education, apprenticeship	Behavioral
Example	Observational learning: imitation, emulation, simulation	Behavioral
Insight	Theory, know why; ability to interrelate chunks of experiences, events or patterns such that new ways of problem-solving are found	Cognitive
Doing	Trial-and-Error (experience)	Behavioral
Mistake / Failure	"Adversity is the school of wisdom." (German idiom: "Durch Schaden wird man klug")	Cognitive or Behavioral

"Learning-by-doing" is based on repetition and leads to the incremental development of expertise, which makes the individual more efficient in executing tasks. Learning-by-doing is an important source of knowledge for several reasons as summarized by Dencker et al. [2007].

1. Foremost, learning-by-doing may generate a string of subsequent improvements and new knowledge.
2. Learning-by-doing is a critical source of knowledge when information is "*sticky*," that is, costly to acquire, transfer and use. When this is the case, learning can only take place in the context of engaging in a particular activity. For example, this might happen as entrepreneurs try and create a successful product line. Only in the course of introducing products and seeing how customers react to them the entrepreneur can gather information about actual and/or unarticulated customer desires that is used to make additions and subtractions to the line.

3. Entrepreneurial situations are characterized by novelty and uncertainty. New ventures often relate to a company envisioning what is unknown, uncertain, and not yet obvious to the competition. Hence, entrepreneurs must often plan and act, despite missing or inaccurate information and ambiguous information signals (ch. 4.2.2). Over time, entrepreneurs will learn about the outcomes of their early efforts, and can use this new knowledge to revise their assumptions and redirect their actions [McGrath and MacMillan 2000; Chesbrough and Rosenbloom 2002].

Knowledge acquisition through *learning-by-doing* may help an entrepreneur compensate for low prior knowledge of the business activity (which means deficits in their pre-entry stock of knowledge). There are several reasons for this.

First, "doing" is likely to require that the entrepreneur gains most of the knowledge he/she lacked when beginning the new business venture. For instance, take the case of a scientist who starts an application of a technology. The scientist-entrepreneur may develop brilliant products with a spectrum of excellent properties and performances (by chemical or physical standards), but be unfamiliar with what real customers want to get by their standards. The entrepreneur will have to learn how to handle the gap between what he/she offers and what is wanted or needed on the market (cf. overshooting; Figure I.88).

Second, learning-by-doing might provide knowledge that is more useful than pre-entry knowledge, particularly in highly uncertain and dynamic entrepreneurial situations. That is to say, learning-by-doing may be the most direct and effective method (and in some cases even the only method) for gathering accurate, up-to-date information.

Third, learning – combined with subsequent explicit actions – can also serve to transform goals, through making alterations in the way the business runs (that is, by making changes to the technology, equipment, processes, or human capital in ways that augment capabilities) [Dencker et al. 2007].

"*Learning-by-mistake*" may be by ones own mistakes and generating corresponding inferences to avoid such a mistake, and it has a cognitive aspect. The most important is not the mistake but how you react to it. On the other hand, "learning-by-mistake" may be from direct observation of others (behavioral), but also from insight, for instance, by reading about failures (of new firms' foundation) which refers to a cognitive situation. In particular, the last aspect is an important corollary for entrepreneurs:

Learn from past mistakes, preferably from those of others.

Another important mode of learning for entrepreneurs is *role* models (*learning-by-example*), for instance, through parents or relatives (ch. 1.2.2, ch. 2.1.2.4, ch. 4.2.1, ch. 4.2.2), knowing or reading about successful entrepreneurs ("business biography as a driver") as, for instance, Scott Rickert, the founder of the US firm Nanofilm LLC (B.2) had Herbert H. Dow, the founder of Dow Chemical, as an example.

Variables and parameters are the basis for a *model*. For the GST framework a general procedure to obtain a model for a particular configuration or situation is given by van Gigch [1974:208-209]. For the model, apart from finding the main variables and parameters that are liable to describe the configuration (phenomenon or event), the key effort of the procedural steps should *focus on finding the most plausible relationship among the variables* – one that explains how changes in one of the variables affects the other. “The model serves to uncover and reflect the relationships among the variables, to estimate the cost of changes, to analyze alternative strategies, and to study responsiveness of results to departures from the norm.”

In social sciences collecting data and information on systems and systems’ performance are not merely to classify, count and compare, but to *evaluate and measure progress toward specified system’s goals*. For entrepreneurs and their new firms that means:

> You cannot control that which you cannot measure!
> (You can’t manage what you can’t measure!).

“Measurement is one of the central elements of the evaluation phase of *systems design*” [Van Gigch 1974:124]. Furthermore, measurement refers to the output of “soft” systems and methods to evaluate complex alternatives. Therefore, measurement is “a decision-making activity … designed to accomplish an objective” [Van Gigch 1974:141].

> For entrepreneurship control/measurement means to evaluate whether the business idea works as quickly as possible, so that you can correct course. Correcting the course may be the key to success. You had better be sure about what you are doing,

In social sciences the decision how to relate measurement to a particular “observable” (“metrics”) induces often an operational definition which is called an **indicator** for a variable. According to Albert Einstein, “it is the theory that decides what we can observe.” An indicator may be a composition (aggregation) of several *elementary indicators*. Appropriate aggregation is often not easy. Each of the component indicators must be compatible with every other to make aggregation meaningful and the relative importance of each one must be “weighted” to build the “composite indicator.”

Indicators are generally sets of data and information used to measure change. They can utilize quantitative (raw data, comparable numbers) and qualitative (opinions, judgment, values, yes/no) information. For indicators to be of true value they must be feasible, both to collect and interpret, and they must be practical to implement.

Measurement, hence, serves description, control, prescription (recommendation) and expectation, but also “prediction.” In the context of entrepreneurship “predictions” and expectations are about the results to be obtained when the activities upon which are decided upon or are recommended are implemented. Whether or not these predictions or expectations are met depends on the underlying theory and on the model and upon whether the standard conditions prevail.

Usually measurement entails comparisons with a "*standard*" and measurement is possible when we understand and can set or predict the relevant conditions or properties of the standard. A *statement of condition* refers to the physical, situational or psychological circumstances under which action or behavior is to occur (cf. "*innovation configuration*" [Runge 2006:12]). This is part of a system (firm) under consideration and a given environment connected and joined together by a web of relationships allowing or favoring innovation.

An often occurring issue for measurement (and decision) in social sciences is the "**information dilemma**" which is associated with the need for explicit and actual and current information and states [Skyttner 2005:398]: "the precise information is not timely, and the timely information is not precise."

In the context of entrepreneurship (emphases added) "an **opportunity** is a *timely* and favorable juncture of circumstances providing a *good chance* for a *successful* venture" [Dorf and Byers 2007:28]. This definition treats the "timely and favorable juncture of circumstances" largely as a "*black box*" which is a system or object which can (and sometimes can only) be viewed in terms of its input, output and transfer characteristics without any knowledge of its internal mechanisms and workings.

With regard to the opportunity of firm's foundation or innovation *offering adoption time* is an important factor of constraint. The (relatively short) period of time in which suitable actions can lead to success is called the "**Window of Opportunity**" (Figure I.4). The window of opportunity refers to the timeliness of an offering and adopting an innovation or the offering. It is an anticipated (time-dependent and attracting) positive *relationship between an offering (by the innovator) and the adopter*. When something already existed, but was not adopted (ch. 1.2.4), it was "ahead of time."

In Figure I.4, for technology-based firms the concept of the Window of Opportunity is illustrated when the technology base for a product, process, application, market or demand may change and provide the basis for a firm's foundation and competitive advantage if seized upon. Entering the market with regard to the Window of Opportunity may become a "make" or "break" decision – not only for a product, but also for a company.

The Window of Opportunity may be determined by several systemic factors. With regard to the time factor it may be expressed as a condition which makes it fixed if for an offering the entrepreneur has to wait until a specially needed technical component is available and produced on the industrial level (ch. 1.2.2; foundation of the German Magnetfeldtechnik Resonanz GmbH) or sliding if, for instance, the input material X has to becomes cheaper than x dollars or if the oil price exceeds $85 per barrel (cf. A.1.1).

Some more factors which determine the width of the Window of Opportunity for NTBFs or technical innovations comprise:

- Trends in the financial (investment) system;
- The level of existing competition (competing firms or technologies);
- Availability of corresponding infrastructure, if applies.

Other factors which determine the width of the Window of Opportunity for NTBFs or technical innovations comprise:

- Scientific achievements;
- Economic recessions;
- Special political initiatives and programs.

In essence, the Window of Opportunity appears as a quasi convergence of various developments, possibly influenced by policy and societal effects (Figure I.92).

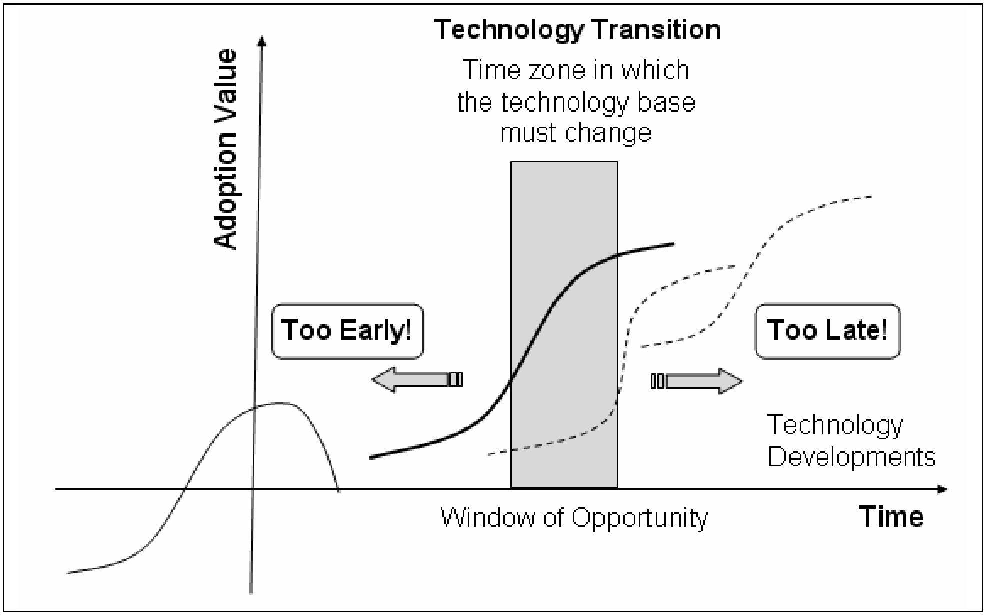


Figure I.4: The Window of Opportunity – avoiding being too early or too late.

There may be special "*opportunity-rich*" situations. Typically such situations occur in crises ("big problems"), big changes or strong policy interventions in industries. A typical example is the currently world-wide "green" attitudes and CleanTech movement initiated by the climate and energy/fuels issues which propel a hype of investments in this area (for instance, biofuels; A.1.1).

This last aspect can usually be characterized as the “*Zeitgeist*.” The **Zeitgeist** (from German Zeit-time and Geist-spirit) is usually a restricted time of general cultural, intellectual, ethical, spiritual, and/or political attitudes, behavior and climate within a nation or even nations, but also only specific social groups, leading to general ambience, socioeconomic and cultural directions, or mood or movement of a time period (cf. Goethe’s remark concerning Zeitgeist in the Glossary).

An **Open System** has an environment (Figure I.5); it possesses other systems with which it relates, exchanges and communicates (for instance, shares information) [Van Gigch 1974:40]. All systems with living components are open systems. In particular, *Man-Machine Systems* with “subjects” and “objects” are open systems. Figure I.5 illustrates that firms are open systems. **Systems Engineering** is the scientific planning, design, evaluation, and construction of man-machine systems.

Human-activity systems [Banathy 1996] often involve various natural and designed physical systems and/or abstractions (“*abstract systems*”) of the way we think about and reason related activities, such as theories of action. A special abstract system under consideration is the national “legal system.”

Human-activity systems range from families and small groups (organized for a purpose) to organizations, communities, nations, regional/international associations, and supra-national organizations. In this context an *open system* means a system that is adding or destroying, exchanging or sharing mass-related entities, energy, information, people and values (in a broad sense, including money) with other systems (Figure I.5, Figure I.13, Figure I.16).

Systems Design can be seen as a *methodology of change* which proceeds essentially from the system *outward* (ch. 5.1). According to GST it concerns the *purpose* for the existence of the system, its boundaries and the determination of the constraints imposed on the system. This requires an understanding of the system in relation to all other systems larger than and interfacing with itself. And it has an emphasis on the “predictions” of future results rather than explanations of past deviations [Van Gigch 1974:10]. Correspondingly, the role of a system’s leader is to influence trends rather than satisfying trends [Van Gigch 1974:9]. A necessary condition for design is the ability to evaluate (for instance, to judge alternative systems).

Systems Design is a creative, though formal process. Design depends largely on *constraints*. The focus is the *problem* at hand and the manner in which *problem-solving options* are considered, *ideas* are created and refined and *selections* are executed.

Option means the possibility but not requirement to take some action (now or in the future), leaving the entrepreneur (or leadership group) with an exercise of choice (ch.4.2). Tangible resources as well as human, information and other intangible resources and work processes and coordination are integrated into a system in order to facilitate its performance. Furthermore, the *future environment of the system* has to be forecasted!

If the design of the system has been set and is established, *systems improvement* “refers to the process of ensuring that a system, or systems, performs according to expectations.”

In the context of Systems Design [Van Gigch 1974:2] there is currently in the US a new wave (and probably hype) with *Design Thinking* [Dziersk 2008; Wong 2009a, 2009b]. The aim is to merge design, business, and technology. It is a catch phrase for a more multi-disciplined approach to solving problems and tapping into authentic innovation But, “Sure, it’s the latest trendy term to sweep the business world, but it’s a technique that designers and executives alike hope may help to provide a solution to some of the world’s serious challenges,” and “There’s no consensus on how to teach it.” [Wong 2009a]

System Processes and Performance

Organized (purposeful) systems are endowed with **conversion processes,** also called *throughput***,** by which elements in the system change state (“systems dynamics”). The conversion process changes *input* elements into *output* elements. In such systems the conversion process usually adds *value* and/or *utility* on the inputs as they are converted into outputs.

Following van Gigch [1974:13] in Figure I.5 the conversion process is schematically specified for a system, such as a firm, and its “closest” environment (cf. also Figure I.13). It indicates furthermore that the firm is seen as a system which means as a “whole.” Another important aspect of the conversion process is *feedback* (see below).

According to GST systems follow a number of general principles or rules or quasi-laws. With regard to input-output relationships there is the eighty-twenty principle (“**80:20 Rule**”): In any large complex system (roughly) eighty percent of the output will be produced by only 20 percent of the system [Skyttner 2005:100]. The “80:20 rule,” also termed the *principle of factor sparsity* or the “*vital few and trivial many rule*” states that for many phenomena: 80 percent of the consequences stem from 20 percent of the causes.

Concerning innovation considering the following aspects may be worthwhile:

> 80 percent of the profits made in an industry are made by 20 percent of firms. If you are not one of these, what are they doing right that you are not?

In the context of innovation this rule may, for instance, be referred to for answering the following questions for operations of a firm [Runge 2006:12].

- Do 20 percent of the products account for 80 percent of total product sales?
- Does 20 percent of the sales force produce 80 percent of revenues?
- Do 80 percent of customer complaints arise from 20 percent of the products or services?

- Do 80 percent of delays arise from 20 percent of the possible causes of delay?
- Do 80 percent of the benefits from any product or service can be provided at 20 percent of the cost?

The "80:20 Rule" applies generally to large system – large firms. With regard to output new technology startups usually have just one or very few offerings (products).

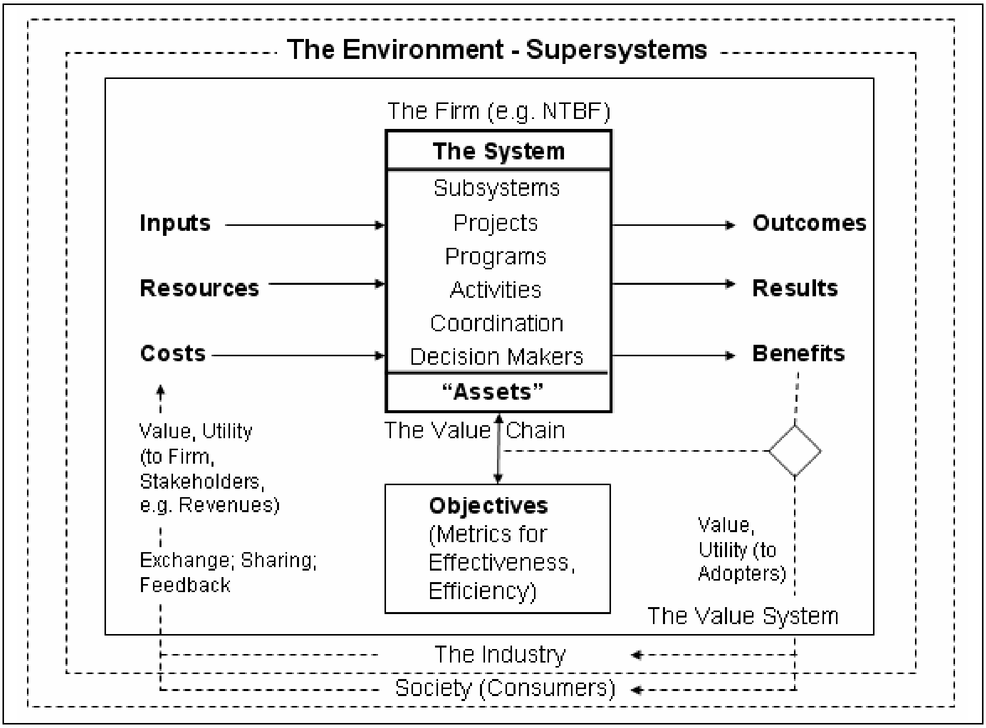


Figure I.5: A system's function via a conversion process.

On the monetary level a firm's conversion process is associated with streams-in and streams-out of money. Correspondingly, **cash flow** is the movement of cash into or out of a business, project, or financial product (note that the word cash is used here in the broader sense, where it includes bank deposits). It is usually measured during a specified, finite period of time.

Cash means "ready money" held ready for payment, or actually paid, at the time of a transaction. It is related to the concept of liquidity, which means being capable of covering current liabilities quickly (ch. 4.2.3).

Streams of money that go in and out of the firm include:

IN: All receipts, like:
- Payment made by customers
- Divestments
- Bank loans
- (For stock companies: new shares subscription).

OUT: All payments, like
- Salaries (and employee benefits, rewards etc.)
- Payment to raw material and utilities suppliers
- Rent/lease payments (rooms, equipment; facilities)
- Returns to banks
- Investments
- Taxes.

A *Cash Flow Statement* is an analysis of the timing of cash receipts and cash disbursements over a specific time period. It tells how much cash is available in a business to keep the business running – the actual cash flow. A company can fail though it is profitable. It is important for entrepreneurs to be aware of the two distinctly different concepts. Profit is created by accounting conventions and include non-cash items and does not include explicitly, for instance, time of receipts.

In economic systems the output elements refer to *offering (*essentially *product or service) markets*, the input elements to “factor markets.” A **factor market** refers to markets where the *factors of production (conversion)* are bought and sold, such as the labor markets, the capital market, the market for raw materials and the market for management or entrepreneurial resources. The buyers in the factors markets are the firms that produce the final “goods” for the offering markets. The demand for inputs is a *derived demand*. That is, the demand is determined by or originates from the demand for the product the inputs are used to produce.

The organization of the system (technology-based firm) in terms of subsystems doing the conversion processes can be classified essentially as

- Supportive Subsystems – ensure production inputs and resources are available – for instance, import of raw material
- Production (Technical) Subsystems – concerned with the throughputs – plants, assembly lines (including maintenance in the sense of proper functioning and repair of technology)
- Maintenance Subsystems – guarantee internal stability, social relations in the system, corporate culture; react to the environment by changing short-term functions, undergo long-term changes, but maintain identity and evolve
- Adaptive Subsystems – monitor the environment and generate recommendations and responses to external “signals,” stimuli, opportunities or threats
- Research & Development Subsystems/Innovation Systems (Technology-Based Firms) – explore, exploit and utilize science and technology to gene-

rate commercially applicable knowledge and offerings with benefits/value to adopters/users

- Managerial Subsystems – lead, coordinate, adjust, control, make decision and direct subsystems.

Organization provides a link of Systems Theory to management practice. According to "contingency theory," which is a class of behavioral theory, there is no best way to organize a corporation, to lead a company or to make decisions. Instead, the appropriate course of action is contingent (dependent) upon the internal and external situation, upon the nature of the environment to which the organization must relate. This is in line with the GST ***Environment-Modification Principle*** [Skyttner 2005: 103] (cf. also motto of ch. 1.2):

> To survive, systems have to choose between two main strategies. One is to adapt to the environment, the other is to change it (example in Nature: the beaver).

The difference between inputs and resources (Figure I.5) is slight and depends on the point of view and circumstance. We differentiate them essentially by relation to (regular) output. **Resources** are sources of aid or support that may be *drawn upon when needed* whereas input is sources that are continuously needed to generate output.

When identifying the inputs and resources of a system (firm), it is important to specify whether or not they come under control of the system or systems designer, that is, whether they can be considered as part of the system or part of the environment. Amit and Schoemaker [1993] specify that the firm's resources will be defined as *stocks of available factors* that are *owned or, at least to a large extent, controllable by a firm*. Resources and input exhibit a many-to-one relationship to output. A variety of input or resources, respectively, may be converted to the same output.

Inputs and resources introduce constraints which are known human and material limitations and restrictions integral to a particular input or resource. Input and resources may be mandatory or optional to achieve a particular result/outcome/benefit. Hence, input and resources represent one source of *competitive advantage*. Another one is related to the conversion process. Input and resources will mostly be counted as costs. Costs cover generally expenditures in terms of value equivalents and specifically monetary value (ch. 4.3.3).

There are two main types of competitive advantages: *comparative* advantage and *differential* advantage. Comparative advantage ("cost advantage") is a firm's ability to produce a good or service at a lower cost than its competitors; this gives the firm the ability to sell its goods or services at a lower price than its competition or to generate a larger margin on sales. A differential advantage is created when a firm's products or services differ from its competitors and are perceived as better than a competitor's products by customers.

Using a wide range of the firm's "assets" and "bonding mechanisms", such as technology and research, information and intelligence systems, decision-making, employee hiring and retaining policies, incentive systems, trust between leadership/management and "workforce," and more, a firm establishes its offerings, like products or services. But in addition to (tradable) financial or physical assets resources also contribute to final offerings. These resources provide, *inter alia*, competencies and know-how that can be traded (for instance, patents and licenses). Also tangible resources are tradable and non-specific to the firm.

Input and resources, if considered as isolated factors, do not result in conversion and productivity *per se*. Hence, *coordination of resources* is important. To achieve the targeted output (results/benefits) coordination of input and resources and assets is important. A firm's capacity to coordinate diverse assets is deeply embedded in its routines, processes, formal and tacit reporting relationships. "The capacity for coordination represents a critical meta-asset of long-lived companies" [Bhidé 2000:223].

An **asset** is an entity with *economic value* that an individual, corporation or country owns or controls with the *expectation that it will provide future benefit*. The probable future benefit involves a capacity, singly or in combination with other assets, to contribute directly or indirectly to future net cash flows.

One can refer also to a firm's "assets" when they actually can be related to their "resource providers," for instance, stakeholders or advisors. That means the firm merely uses the assets that one or more of its constituents own and may deploy.

Intangible assets are defined as identifiable assets that cannot be seen, touched or physically measured, which are created through time and/or effort and that are identifiable as a separate class of assets – differentiated from *tangible assets* (property; land, plants, equipment, etc.). How resources are utilized create *capabilities* which are firm-specific and can be viewed mainly as intangible assets (cf. also RBV, ch. 4.3.3).

When treating a startup (or any firm) in the sense of GST as a wholistic entity, then, in our context, one may *view a firm as operating through a bundle of tangible and intangible assets and resources* as summarized in Table I.8.

A firm's assets in the above sense can be "*durable*" having a specific life time or "*transient*," which means they can disappear instantaneously. The last aspect is particularly critical for *people as assets* ("human resources"), information and experience ("tacit knowledge," "tacit technology"). The typical situations for a transient asset is when key researchers or engineers leave the firm or a firm wants to acquire particular assets of another firm by acquisition and related key people of the acquired firm will leave.

For directing development of a system toward a goal control is essential. *Control* is a central concept of human-activity systems with three meanings,

- control in the sense of *compliance* with norms, rules, laws and behavior,
- control in terms of *ownership and power of decision-making* and

- control in terms of *directing and regulating actions and behavior* towards a goal when related actions are influenced by factors which are under control of the decision-maker and those which cannot be controlled by the decision-maker.

Table I.8: Examples of tangible and intangible resources and assets (of NTBFs).

<table>
<tr><th colspan="2">Tangible Assets</th></tr>
<tr><td colspan="2">"Finances"; land, buildings, machines, instruments, computers, production plants etc. (which can be "monetarized" and traded)</td></tr>
<tr><th colspan="2">Intangible Assets/Resources</th></tr>
<tr><td colspan="2">Related to human resources (for instance, corporate culture, employees' competencies, knowledge, skills, learning and work practices, competitive and technology intelligence; cooperative networking), innovativeness and discovery potential (for new products, processes and applications, services, patents)
Related to "organizational capital," which is leadership, unique organizational designs, organizational coordination and work and business processes ("systems of activities" including coordination) or strategy formation, formulation and implementation; reputation (partially overlapping with intellectual capital)</td></tr>
<tr><th>Intellectual Capital (IC)</th><th>Intellectual Property (IP)</th></tr>
<tr><td>▪ Human capital (systemic contributions) (productive qualities of people in organizational settings that support the business processes; information handling, communication, coordination, etc.)
▪ Organizational learning
▪ Corporate knowledge and competencies
▪ Enterprise innovativeness
▪ Enterprise external relationships (including R&D networking and alliances, customer loyalty, relationships with suppliers and "input/resource providers," contractual rights, permits, franchises, distribution rights, non-compete covenants)</td><td>▪ Patents (covering inventions and IPR-related business processes like licensing)
▪ Trade secrets and confidential information
▪ Designs
▪ Trademarks (including Web domain, company and business names)
▪ Copyright</td></tr>
</table>

In terms of cybernetics **control** shall be defined as the *purposive influence* toward a predetermined goal involving continuous comparison of current states to future goals ("is" versus "shall" assessment). In general terms, GST associates system control with three notions [Skyttner 2005:77-78]. In particular, emphasizing efficiency is not a privilege of business administration, but a basic principle of human will for shaping [Faltin 2007:43].

> **Effectiveness**: a measure of the extent to which a system achieves its intended conversion or its goals.
> **Efficiency**: a measure of the extent to which a system achieves its intended conversion or goals with the minimum use of resources.
> **Efficacy**: a measure of the extent to which a system contributes to the purposes of a high-level system of which it may be a subsystem.

Paraphrased, *effectiveness* means doing the right things and efficiency doing the things right (Equation I.1). In terms of political goals and means entrepreneurship (founding of new firms) is associated with efficacy, for instance, in terms of the number of jobs created by new firms for a nation's economy.

Efficacy represents, for instance, a notion that is relevant if the political/societal supersystem (Figure I.13) and its goals/programs for a nation's "entrepreneurship system" or "innovation system" assesses the level of achievements or evaluates its role in creating "policy-driven markets" (Table I.15).

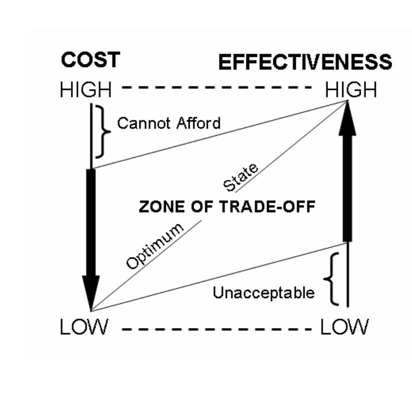
A system may employ a variety of different components to achieve an output that meets the performance requirements or object specifications of the system. Various configurations of components may all be effective, but where those components vary in cost, time, and complexity the *efficiency* of the system becomes an issue. A system is efficient when cost, time, and complexity minimums balance without compromising the effectiveness.

When measuring or stating "success" or "failure" of a venture we shall always think of the whole system, the whole firm, at a particular point in time. On the other hand, though also being related to the whole system, measuring effectiveness or ineffectiveness usually will implicitly make reference to the system's components and their contributions to success of failure.

Choices among *conflicting goals* inevitably lead to the necessity of making and accepting "trade-offs." A **trade-off** (or tradeoff) is a situation that involves losing one quality or aspect of something in return for gaining another quality or aspect. It implies a decision to be made with full comprehension of both the upside and downside of a particular choice. As the extreme one has to be sacrificed totally at the expense of the other. [6]

The trade-off between cost and effectiveness as depicted in the Banathy diagram (Figure I.6, left) is to achieve effectiveness at the lowest possible cost.

However, it may well be that widely accepted trade-offs occur with activities (or decisions) that are only seemingly incompatible. Such a situation represents an excellent opportunity for innovation. The classical example is the Japanese car maker Toyota which started its tremendous success lifting the generally accepted trade-off that cars are either of high quality and expensive or low quality and cheap. Toyota succeeded offering high-quality cars at low cost.



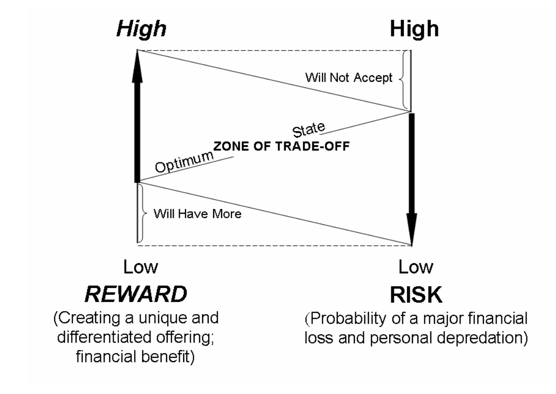


Figure I.6: Trade-off diagrams: Zone of trade-off (left, from [Banathy 1968:73] and for risk/reward of entrepreneurship.

For the entrepreneur a fundamental trade-off occurs between reward and risk, with seeking the balance for a decision between high rewards with low risk. It means that at each stage of developing his/her venture the entrepreneur should answer the following questions:

- What can go wrong?
- What can go right?

And the basic question is "what is the risk of venture failure?" However, one must keep in mind that "failure" is a relative notion as it relates the start of a firm associated with goals and requirements to a particular point in time. Failure may be the end of the firm's life ("total failure") and seriously "damaged" founders.

But a near catastrophic situation for the firm may be overcome by the founders, for instance, lifting causes of failure through a "*second chance*" or by recognizing their "*false start*" and redirecting their activities toward other goals that fit identified opportunities. After having left the trough and entering a profitable new business development the firm may become successful. The classical example for such a situation turning around a false start is the 3M Corporation [Runge 2006:446, 460].

If the conversion process of a system (Figure I.5) is split into a not necessarily sequential (linear) arrangement of sub-processes or sub-functions, respectively, the proceeding from input into output is the so-called "*value chain*." Usually, the notion is related to a firm and monetary value and an adopter. The value chain can serve as a tool to analyze the value of what a company does. For instance, a technology-based firm with internal research and development (R&D) may exhibit a linear value chain as shown in Figure I.7 (upper graph) to bring its offerings, such as products, to the "adopters of output" (customers).

The **value chain** (Figure I.5) categorizes the generic *value-adding activities* of an organization. The "*primary activities*" include: inbound logistics (procurement), operations (production), outbound logistics (distribution), marketing and sales, and services (maintenance). The "*support activities*" include: administrative including IT infrastructure management, human resource management, and R&D.

However, in line with current societal environment and sustainability attitudes it is relevant focusing not only on the customer's adoption (use) of the offering, but also including the disposal of the offering (product), for instance, via recycling or value-generating disposal. Recycling may simultaneously reduce the "carbon footprint" (carbon dioxide emission) of producing an offering.

Recycling can also become a value adding business of the firm. For instance, Dow Chemical established an innovative (recycling) business for its polychlorinated solvents used for cleaning. It is a closed-loop system to manage the risks associated with chlorinated solvents. Dow works together with the customer to determine the best customer-specific solution for his or her cleaning needs, the desired cleaning results, and the legislative environment [Runge 2006:264].

In this view the value chain extends over distribution of an offering to the customers, but, via recycling or disposal, will comprise the whole life-cycle of the offering. Disposal provides, of course, also business opportunities for other firms which means, it can become part of the value system.

Value generation of an existing firm by analyzing the value chain to identify important cost-lowering and profit-enhancement options and achieve competitive advantage will start with the question

Which activities can we do best?

This analysis, however, is not restricted to existing firms. NTBFs often perform only some of the value chain activities/functions themselves – not just due to a lack of related resources, but because others can do it more cheaply (ch. 4.3.1). For instance, an NTBF might set up larger scale production or marketing and sales through alliances with other firms which thus become components of the value system (dotted lines in Figure I.7). This situation is illustrated by Runge [2006:792-793] contrasting a staged, linear value chain with one having "cross flows" of related activities from outside into particular stages of the firm-internal value chain.

The **value system** (Figure I.5) consists of value adding components which correspond to supplier/channel-customer bunches (Figure I.7). It is an interconnection of processes and activities within and among firms that creates benefits for intermediaries and end-users (consumers). It is the network of organizations and the value producing activities involved in the production and delivery of an offering.

A value system includes the value chains of a firm's supplier (and their suppliers all the way back), the firm itself, the firm's distribution channels, and the firm's buyers (and presumably extended to the ultimate buyers ("customers-of-customers," "end-users") of an ultimate products, and so on).

The output of one firm may only be an "intermediate" or contributing part to generate or assemble a "larger" offering, such as a material, device, a module, a machine, a system, etc. This leads to the notion of a "value system" (Figure I.7; lower part). Each supplier/channel-customer bunch is associated with a corresponding market segment where added value is generated.

Valuation criteria may be different for the various components. However, the extent of the overall value addition is constraint by the ultimate adopter; the end-user determines the "*unique selling point*" (USP).

For instance, if for adhesives technology a product is described which enables objects to be securely mounted on most household surfaces and removed without surface damage or sticky residue left behind, "the unique selling point being the clean release of the product" [Runge 2006:377]. This is which sets your product or service apart from your competitors in the eyes and minds of your prospects.

Associating values for the components (suppliers) of a value system in terms of the end-use markets and the corresponding product are exemplified for the field of photovoltaic (solar cells) in Figure I.11 and Figure I.12.

The value system, formally a "supplier-to-customers value chain," is also denoted as the **supply chain** [7] if the focus is on the "actors" (other firm with generic activities): Specifically, *a supply chain is a system* of organizations, people, technology, activities, information and resources involved in moving an offering, product or service, from supplier to customer. Supply chain activities transform natural resources, raw materials, intermediates, and components into a finished product that is delivered to the end customer. In sophisticated *supply chain systems*, used products may re-enter the supply chain at any point where residual value is recyclable. We shall use both these notions, supply chain and value system, as equivalent.

> In terms of GST the position of a new firm in an existing value system provides a special aspect of its "environment."

The extent to which a firm contributes to the purposes of a high-level system of which it may be a subsystem, a component of a value system, relates to efficacy.

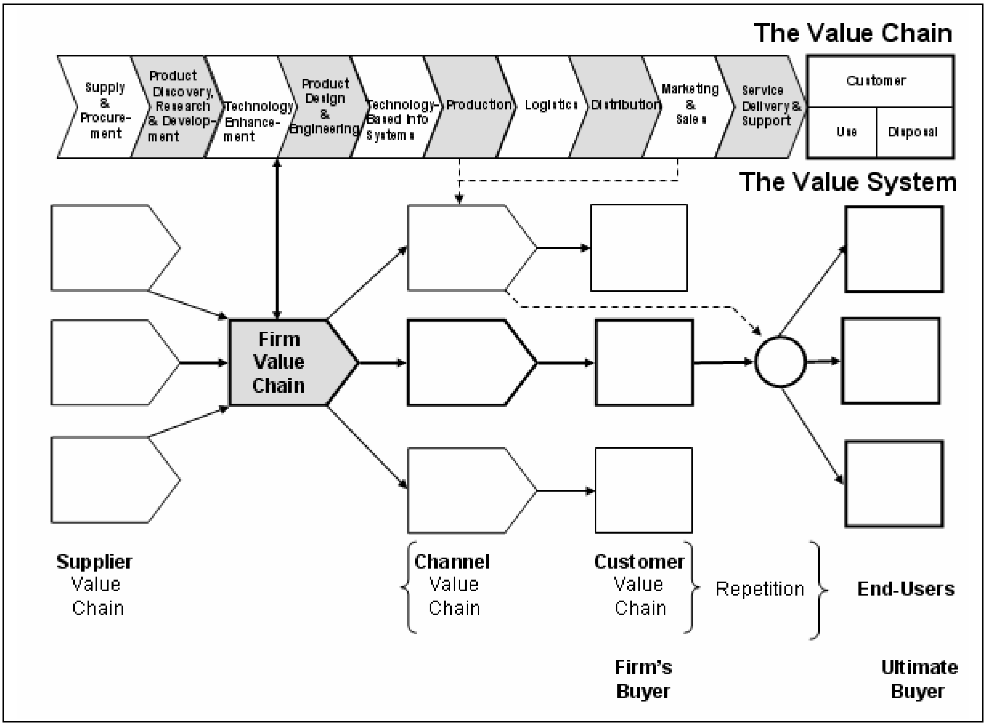


Figure I.7: A value chain of a technology-based firm with a firm-internal research and development unit and its value system.

Considering previous discussions some important aspects emerge. One can characterize the founding situation of an NTBF by the following types of scarcity.

- Scarcity of value chain components (for instance, lack of marketing and distribution activities and/or lacking larger scale production facilities)
- Scarcity of offerings (for instance, just one or very few products)
- Scarcity of resources (for instance, financial resources only from personal savings and/or through family & friends).

Such scarcities may be responsible, at least to a certain degree, that a startup/NTBF does not achieve its goals or does not achieve its goals satisfactorily. With regard to a system's performance Stafford Beer, as cited by Skyttner [2005:139], introduced three indices for *levels of achievement*. With these indices, for instance, concepts of performance and productivity can be introduced according to Equation I.2 (for operationalization see Figure I.132 and surrounding texts).

1. Actuality (A)	The *current* achievement using *existing resources* and constraints
2. Capability (C)	The *possible* achievement with *existing resources* and within existing constraints
3. Potentiality (P)	What could be achieved by developing resources and removing constraints

Equation I.2:

Performance ~ A / P	**Productivity ~ A / C**

For technology-based firms targeting large-scale production the value chain steps from "Product Discovery, R&D" to "Production" (Figure I.7) is associated with the very capital-intense sub-process of (technical) "**scaling-up**," where science is connected with engineering and "Production/Manufacturing" interrelates back to "Supply & Procurement" of input. Scale-up may refer to increase of quantities of produced material or devices, apparatuses etc. in "commercial plants" (Figure I.8) or increase in the spatial dimensions of an apparatus, device, vehicle, etc. (Figure I.9) as the ultimate offering of the firm and is usually associated with particular questions.

Scale-up for business purposes targets not only production in large quantities, but achieving production at a cost that related price ranges are accepted in the market. For NTBFs targeting at production the technical failure of scale-up and/or the commercial failure associated with not covering cost and too high prices for the product are often reasons for firm failure through bankruptcy (cf. bankruptcy of solar firm Solyndra, Inc. in ch. 4.3.5.2 and the problems of many biofuels firms in A.1.1, or Zoxy and MnemoScience – B.2).

The scale-up in Figure I.8 corresponds essentially to situations in the chemical, pharmaceutical and biotechnological and related industries. The last case (Figure I.9) refers more often to engineering-oriented industries, such as transportation vehicles, machines and devices ending up with production of prototypes which will stepwise approach the final design and will be subjected during further development to cost reductions and enhancing performance.

It should be noted, however, that constructing a large-scale commercial plant requires not only very much capital, but also also management of legislative matters for construction (regulations, standards, permits).

With the pilot plant a phase of learning how to produce is entered. The first serious contact with anticipated and likely customers during scale-up occurs on the level of the (semi-commercial) "market development unit" which is a "demonstration plant." Here production quantities are still limited, but sufficient to supply material to (potential) customers for testing and providing feedback to the producer for further refinements of the product and product processes. This is extensively seen in the discussion of biofuels development (A.1.1).

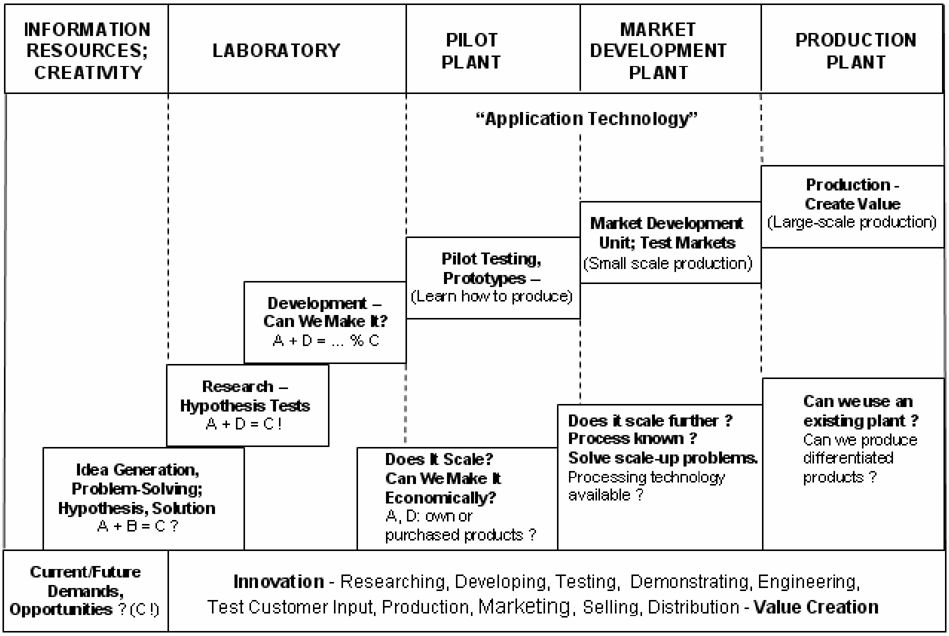


Figure I.8: Transferring science, engineering and technology from the laboratory to the world and some related questions occurring during the process of converting a technical idea into a (commercial) product [Runge 2006:519].

The historically classical case for issues of scale-up in material science is lifting the Chinese monopoly for porcelain, which the Chinese kept as a secret, by two Germans, the at that time very famous scientist E. W. von Tschirnhaus and J. F. Böttger in 1708. Von Tschirnhaus succeeded in finding the components and the way to make porcelain (the "re-invention of porcelain" in Saxony (Germany) in 1708) which was improved and ultimately "scaled-up" by Johann Friedrich Böttger (1710) for "large scale manufacturing" (ch. 3.3; cf. also the German firm SkySails – B.2).

> The route from prototype (pilot plant) to product (manufacturing) is often long and more strewn with obstacles than the conversion of the original idea (laboratory) into a prototype (pilot plant) – as illustrated, for instance, for the biofuels field (A.1.1).
>
> Scale-up is not only associated with development issues. The key is that the result, a marketable product, device, etc., must be produced at competitive cost with a price range accepted by the market, a global market with probably competition from China or India.

For NTBFs targeting mass production the technical failure of scale-up and/or the commercial failure associated with not covering cost and too high prices for the product are often reasons for firm failure through bankruptcy. But also if scaling-up takes too long impatient financial bankers and their doubts on the success may lead to stop further needed investments with serious consequences for the NTBFs.

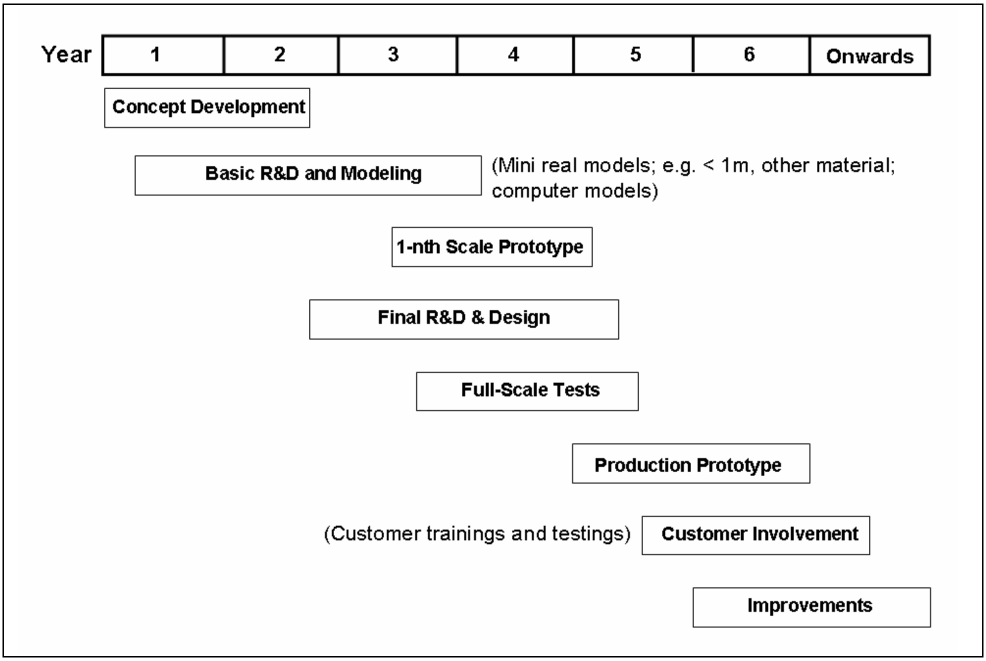


Figure I.9: Staged production prototype development with corresponding approximate stage durations.

Organizational scale-up, including I&CT-supported organization-wide working processes like information and communication systems, usually means starting with a concept, development and behavioral model (lowest scale prototype). This is implemented (including user training) and tested for a small "pilot group," taking feedback from the user group to modify the system or relevant components, respectively, or even enlarge the original approach, running a further test assumed to mimic full scale and finally implementing the "production system."

> Scale-up is associated with requirements for people with new, different skills and experiences and with large jumps in capital employed and expenses (A.1.1). For the context of producing technical innovation there is a "*cost ladder*" which positions research at the bottom. It has turned out that development costs exceed research cost by multiples and commercialization costs exceed development cost by multiples [Runge 2006:643; Griesar 2008:16-17].

There is also a market difference between progress of scientific/research advance and engineering advance (ch. 2.1.2.3; Figure I.62). Engineering advances take often existing technology and adapt it to new uses. A hybrid car is an example (Box I.10). Existing internal combustion engines, existing batteries and electrical technologies were combined to produce the hybrid cars. Usually engineering focuses more on the *economic aspects of the system*.

During the phase of transition from applied science to “application technology” a key question is whether needed processing technology, the enabling technology, is available. For instance, in the material science, although the remarkable properties of polytetrafluoroethylene (PTFE; Teflon® of DuPont; very low coefficient of friction, great chemical inertness, etc.) were soon recognized, these could not be exploited for several years because the material resisted processing by conventional techniques. It had to await the development and availability of powder metallurgy techniques [Runge 2006:21].

System performance is a measure of acquiring inputs/resources and the extent of their conversion into outputs/outcomes with particular value (Figure I.5). System structure with its internal relations among the system’s component as, for instance, shown in Figure I.7, affects the system’s performance. According to Equation I.2 performance is related to efficiency and productivity. When dealing with changing performance of an organization the basic question is *maintaining the system* or *changing the system*.

Examples of system performance of organizations are listed by van Gigch [1974:200]. According to van Gigch [1974: 201] performance of any social system, such as a firm, is related to

1. people *and*
2. non-human (tangible and intangible) resources,
3. grouped together formally or informally in teams or “communities” into subsystems *that*
4. interrelate among themselves *and*
5. with the external environment, and are subject to
6. certain values *and*
7. a central coordination and guidance system that may help provide the capacity for future performance.

The performance of any social system consists of activities, norms and guidance.

1. To satisfy the interests of various “interesteds” (stakeholders) *by*
2. producing various kinds, qualities and quantities of output and outcome,
3. investing in the system’s capacity for future output,
4. using inputs efficiently,
5. acquiring inputs, and doing all the above in a manner that conforms with
6. various codes of behavior, and
7. varying conceptions of technical and administrative (or guidance) rationality.

Present performance issues refer to outputs that are expected or planned, but that are not being reached – performance goals that are not being met (lower than expected performance and missed goals). In larger firms usually improvement in present performance and future performance requirements (to remain competitive) do not carry the same intensity as present performance problems.

Performance goals are usually the only way to bring about any changes in social structure, a target needs to exist. Assessing performance of a social system uses performance measures which comprise time and cost and are quantity- and/or quality-like (Figure I.10). Levels of an organization's performance comprise:

- Organizational (the whole system, for instance, in relation to its environment)
- Processes/activities including coordination (for instance, the value chain)
- Team(s)
- Individual(s).

For measuring performance (the extent of purpose/goal achievement; Figure I.10) corresponding variables in relation to explicit performance needs must be attributed to the performance levels and selected. Relevant output units of performance on the various component levels must be identified. And finally the performance measurement and assessment must provide an interpretable and actionable result.

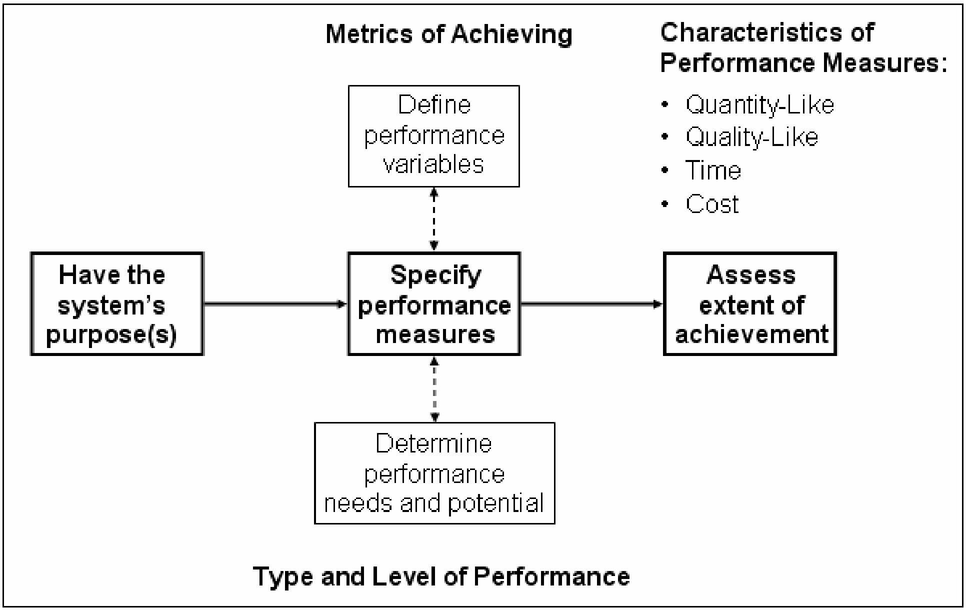


Figure I.10: Measuring a system's performance.

For large firms the **value chain** may be a root for increasing the system's performance and leading to competitive advantage. To conduct a *value chain analysis*, a company's operations need to be divided into specific business processes and grouping them into primary and support activities. Within the broad categories, companies perform a series of discrete activities that vary from business to business. These activities are nevertheless interdependent and connected by linkages, requiring the coordination of activities.

For Porter and Miller [1985:150] linkages often create *trade-offs and exist "when the way one activity is performed affects the cost or effectiveness of other activities.*" The challenge for decision-makers//managers is "to disaggregate what actually goes on into numerous distinct, analyzable activities rather than settling for a broad, general categorization" [Pearce and Robinson 1997:179]. But these crosses the issues of "systems improvement" and sub-optimization (see below).

The **value system** makes explicit the role of a company in the overall activity of providing a product to a customer and end-user and provides a reference to analyze how a company positions itself relatively to other companies (competitors). Furthermore, it opens options for a firm to grasp more value, if it is capable to become active on another, more value-adding stage of the value system ("value appropriation"). The value system shows where, how and by whom value is added. The presentation of the value system in terms of value contribution can take a demand-oriented perspective (Figure I.11) or a supply-oriented perspective (Figure I.12).

For instance, the output/offering of the various players of a value system can be related to the market size for the output as shown for the OLED (organic light emitting diode) business in Figure I.11. In this specific example the German chemical company BASF grasps value in addition to being a raw material supplier by a strategic partnership for the development of OLED displays with teco Optronics Corporation, a subsidiary of the Teco Group (Taiwan) [Runge 2006:700].

In photovoltaics, one solar cell value added system is the set of steps from sand or raw silicon to the completed solar module and photovoltaic system completion and installation. Figure I.12 transforms the players of the PV industry into the value added in percentages by these contributors. Additionally, both these figures demonstrate the option to grasp most value if industry players serve many or even all of the value steps. For instance, the chemical industry can contribute from raw material to module production (Figure I.11).

Figure I.11 emphasizes a systemic view and shows that, for instance, the input component of the PV value system (silicon, Si) is simultaneously the input component of another value system, that of the semiconductor industry. The competing demands for silicon will affect the prices for silicon.

The interdependence of both these industries shows up also by the fact that for silicon production of poly-Si based solar cells silicon can be obtained from recycled "scrap" materials generated from semiconductor grade wafer productions (pot scraps, tops and tails, broken wafers, etc.). Furthermore, any scarcity of poly-Si for the PV industry due to increased demand by the semiconductor industry may favor developments and market capture by alternative technologies for PV, such as thin-fim technology.

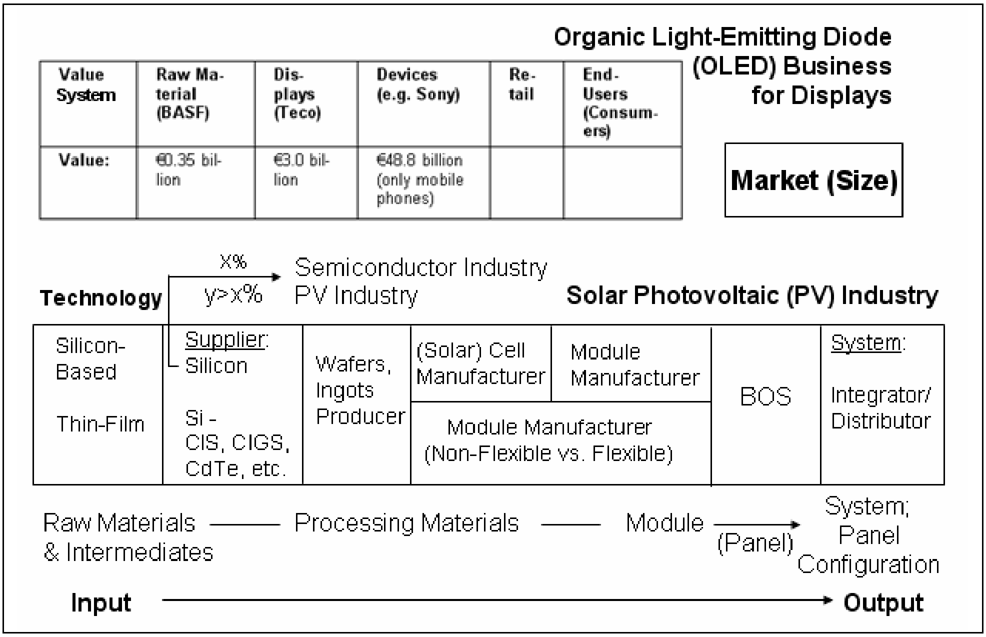


Figure I.11: Output of players of the OLED value system in terms of market size for the particular outputs (from Runge [2006:701]) and players of the solar photovoltaic industry (silicon, not thin-film-based) value system (BOS - Balance-of-System). [8]

Figure I.11. exhibits the fact that various value systems may exist for functionally the same end-product if the underlying technology is also taken into consideration. In case of the PV industry this refers, for instance, to solar cells based on mono- and polycrystalline or amorphous silicon versus, among other technologies, thin film solar cells based on cadmium telluride (CdTe), copper indium gallium diselenide (CIGS) or even thin film crystalline silicon (ch. 4.3.5.2; Box I.23).

Generally, competing technologies may emerge for several components of the value system. In Figure I.12 results of a questionnaire concerning the knowledge and awareness needed for an adhesive supplier to enter a business in the solar photovoltaic market shows the awareness of the PV value system to be very important.

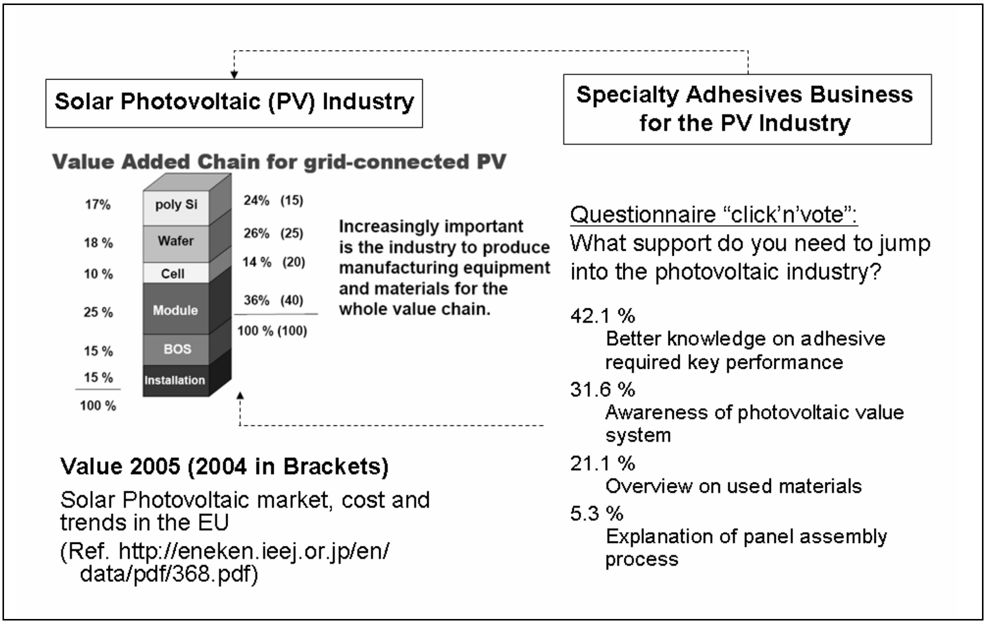


Figure I.12: Product-related value system for the solar photovoltaic industry (IEEJ, October 2006, last access 10/8/2009) and the awareness needed for an adhesive supplier to enter a business in the solar photovoltaic market. [9]

Though relevant more for large firms rather than NTBFs there are two situations of importance with regard to the value system. **Backward-integration** means the situation in which on a corporate basis a plant or business (or a firm) is interrelated to an *upstream* plant or processing facility for producing its offerings. This means, for instance, acquiring ownership of one's supplier, is often in the hope of reducing supplier power and thus reducing input costs. An example would be a wafer producer which is also a silicon supplier (Figure I.11; Figure I.12).

Forward-integration is the situation in which on a corporate basis a plant or business (or a firm) is interrelated to a *downstream* plant or processing facility for producing its offerings. This means, increasing integration by acquiring intermediaries between oneself and the end customer or otherwise moving along the value system towards customers. For instance, a wafer producer becomes also a solar cell manufacturer with its wafers (Figure I.11; Figure I.12).

Regulation (in the context of control rather than law) means that the interrelated subjects and objects constituting the system must be regulated in some way so that the goal can be achieved. Regulation implies that deviations must be detected and corrected. A human-activity system maintains sets of relations within it for attaining its purpose. The maintenance of these relations over time is of primary importance. The process by which these relationships are maintained is the system's regulation – the rules of the game. The scope and limits within which these rules can be sustained are the conditions of the *systems stability over time*.

System processes may or may not be self-regulated. A self-regulated system is called a **closed-loop system** and has its output coupled to its input. The regulatory mechanisms of closed-loop systems are called **feedforward** and **feedback**. Feedback and positive feedback play a central role for self-reinforcing processes, in particular, firm development (ch. 4.3.5).

Feedback is a prerequisite of *effective control for goal achievement*. Feedback is a basic strategy which allows a system to compensate for unexpected disturbances. This is done through feedback loops that maintain certain variables constant or regulate the types and amounts of particular components. Information concerning the result of own actions is delivered as a part of information for continuous action. As a control mechanism it acts on the basis of its *actual* rather than its expected performance. It serves to *control a system's performance*.

Feedforward is an *anticipatory control action*, intended to produce a "predicted," desired state in the future. The process uses *information from the input* in contrast with *feedback which uses information from the output*. Feedforward occurs before an event and it is part of a planning process in preparation for future eventualities and, therefore, shows relationships with scenario techniques (Box I.19).

As mentioned, control is a central concept of human-activity systems with three meanings, control in the sense of compliance with norms, rules, laws and behavior, control in terms of ownership and power of decision-making and control in terms of directing and regulating actions and behavior towards a goal when related actions are influenced by factors which are under control of the decision-maker.

Finality is a term used to describe the *goal-seeking nature of systems*, that is, achieving a predefined future state. Open systems have equally valid alternatives easy of attaining the same objectives from different initial conditions.

Equifinality means, a *system can reach the same final state from different initial conditions and by a variety of paths (the ability to reach a goal from myriad ways and beginning at various locations).* For open systems this option of finding equally valid ways is the expression of equifinality. In particular, this definition does not mean that the various paths to reach the goal are fixed, but includes the situation that new paths or branching occurs over time due to events or changed conditions (Figure I.122). Particularly for entrepreneurship we have to accept equifinality versus "one best way."

Related to finality, **teleology** represents an *antithesis to causality and linear thinking* in terms of causes and effects, which is prevalent in natural sciences. Teleology *anticipates future existence of systems*. As an analytical method it is related to *purpose*. Analytical-mechanistic approaches, typically for natural sciences, focus on antecedents of interest ("causality"). With regard to purpose and teleological implications for assumptions on systems to which GST applies consequences are of interest ("goal-oriented systems").

Operational characteristics of a system according to ("GST guru") West Churchman as cited by Skyttner [2005:52] and, hence, for a (new) firm are summarized as follows.

- It is teleological (purposeful).
- Its performance can be determined.
- It has a user or users.
- It has parts (components) that in and of themselves have purposes.
- It is embedded in an environment.
- It includes a decision-maker who is internal to the system and who can change the performance of the parts.
- There is a designer who is concerned with the structure of the system and whose conceptualization of the system can direct the actions of the decision-maker and ultimately affects the end result of the actions of the entire system.
- The designer's purpose is to change a system so as to maximize its value to the user.
- The designer ensures that the system is stable to the extent that he or she knows its structure and function.

In the entrepreneurship context equifinality exhibits association with strategy and planning. Rather than referring to one of the many definitions in the literature we shall emphasize *operational definitions* for plans and strategies [Runge 2006:703].

Plan: When you know *what you want to do* and exactly *how to do it*.
A plan is characterized by knowing what the next step will be.
Each step is designed by taking into account the next step.

Strategy: When you know *what goal you want to achieve*, but you are not sure exactly how to do it.
A strategy is characterized by not knowing what to do at the next step until you have results from the previous step. Each step of a strategy is realistically influenced by what was *learned* from the previous step.

The quality of a strategy cannot be fully assessed until it is tried! A successful strategy requires considerable information. In effect it is based on various intelligence processes.

Accordingly, cited by Runge [2006:703],

> Plans are for execution, strategies are for *learning* what plans to use.
>
> Strategic planning means changing minds, not making plans.

"**Implementation** is the use or adoption of change" [Van Gigh 1974:293], the actions of accomplishing some goal or executing some order. In this context we prefer the notion "utilizing" and do not regard this as a synonym for "use," but relate it to "make use of something, or find a practical or effective use for something; especially to find a profitable or practical use for.” [10]

In business or engineering implementation refers to a building process. The success of implementation have been found to depend on the extent to which goals are “operational,” that is (cf. Figure I.10), “when a means of testing actions is perceived to relate a particular goal or criterion with possible courses of action” [Van Gigh 1974:303]. For implementation of change to occur it has to be timely. *Timeliness* is an often forgotten variable (cf. the Window of Opportunity).

For implementation Bhidé [2000:280, 298] refers to concrete decisions and actions. While goals and rules help direct and coordinate effort, building a durable firm also requires an exceptional capacity to execute or implement strategy. Implementation also affects a firm’s capacity to coordinate multiple assets and activities.

A common experience of entrepreneurs is that, how thorough and detailed their strategy and planning may be, they often miss the mark. This is common knowledge for centuries concerning military strategies and plans and formulated by the German military strategists and thinkers Carl von Clausewitz (1780-1831) and Helmuth von Moltke (1800-1891) who is assumed to be the most brilliant military strategist since Napoleon and was Chief of General Staff of the Prussian and later German Army. Famous statements, very often cited in the context of strategic planning and management, of both men are given below.

Carl von Clausewitz	**Helmuth von Moltke**
Strategy is the first victim of any war. (Die Strategie ist das erste Opfer eines jeden Krieges.) [Hiersemenzel 2003]	No battle plan ever survived the first encounter with the enemy. (Kein Operationsplan reicht mit einiger Sicherheit über das erste Zusammentreffen mit der feindlichen Hauptmacht hinaus.)

But von Moltke added more to the concepts of strategy and planning. He wrote:

> No battle plan ever survived with some certainty the first encounter with the enemy’s main army. Only the layman believes to grasp the course of a military expedition to be the consequent execution of an original thought made in advance, reflected in detail, and kept {unchanged} until the end. … It is important, despite many special cases, to look through the factual situation wrapped by a fog of uncertainty, to appreciate the given appropriately, to guess the unknown, to make a decision and then to execute strongly and undeterred. (From author’s German translation [11]).

From Dorf and Byers [2007:465] we hear the paraphrase: “No business plan survives its ultimate collision with reality.”

Von Moltke's description is almost a blueprint for new business development and entrepreneurship. Former CEO of General Electric (GE) Jack Welsh transformed this into the business area which characterizes also the situation encountered with business plans:

> "Men could not reduce strategy to a formula. Detailed planning necessarily failed, due to the inevitable frictions encountered: chance events, imperfecttions in execution and the independent will of the opposition." … "The Prussian general staff, under the elder von Moltke, perfected these concepts in practice. They did not expect a plan of operations to survive beyond the first contact with the enemy. They set only the broadest of objectives and emphasized seizing unforeseen opportunities as they arose. Strategy was not a lengthy action plan. It was the evolution of a central idea through continually changing circumstances." [12]

And from investor-entrepreneur Reid Hoffman, the key founder of the US firm LinkedIn (ch. 3.4.2.1), we hear:

"Smart people tend to think that they can execute on a complex plan. *Executing on a complex plan is generally a recipe for failure.* If you can't make a startup work on a simple plan then your chances of success are very low." [LinkedIn, B.2]

In essence we see here a description of "***opportunistic adaptability***" as put forward by Bhidé [2000] for entrepreneurship. This relates to the fact that many ventures do not find success in their initial business idea.

On the other hand, Systems Thinking has recently entered strategic planning and management. For instance, Haines [2000] suggests "a five-phase strategic planning model that invites the leader to ask and answer five important questions." However, we shall add a sixth question (cf. GST Environment-Modification Principle) which is of particular interest to technology entrepreneurship. These six questions are:

1. Where do we want to be? (this is, our ends, outcomes, purposes, goals, destination, vision)
2. How do we want to get there; how will we know when we get there?
3. Where are we right now? (which is, today's issues and problems)
4. How do we get there from here? (which is, close the gap from 3 → 1 in a complete and holistic way)
5. What is changing in the environment that we need to take into account? *or*
6. How do we change the environment (by technology) from here?

With regard to the above outlines of von Moltke and Welsh a key is the fifth question which implies a process of *continuously tracking the environment* which is emphasized by Haines in terms of "*environmental scanning*" [Haynes 2000:93; Tidd et al. 2001: 52, 244] and by Runge [2006:798-843, 917-971] as the process and product of "technology intelligence."

The adaptability to the environment as the basis for survival and long-term competitive performance of the firm lies in its ability to build and develop firm-specific capabilities and, simultaneously, to renew and re-configure its competencies in response to key factors and conditions of the environment and is related to its **dynamic capabilities**.

> Firms are adaptive if the individual and collective behavior transform corresponding to a change-initiating event or collection of events.

If, with regard to adaptation, norms or standards for operation have been set, but the system or systems do not perform according to expectation or requirements, **systems improvement** is needed. [Van Gigch 1974:2-3] In GST, however, there is a specification of what is commonly regarded as "improvement" and how to approach it.

There is a tradition of Western thinking that *parts* of the *whole* system can be studied and improved more or less in isolation from the rest of the system. "We think it proper that each element develops its own criteria of improvement and that the elements be as free as possible from the interference of other parts of the social structure." "In considering improvement for systems we must concern ourselves not only with the problem of scope and horizon but also with that of choosing proper objectives." [Van Gigch 1974:258-259].

For open system the interest of improving or even optimizing the performance of a system will encounter the issue of **sub-optimization**. Optimization is only possible for closed systems! Open systems can, at best, only be partially optimized. Moreover, optimizing the subsystems does not guarantee that the total system's optimum is reached, whereas the optimization of the total system (if it could ever be reached) does not guarantee that all the subsystems can be optimized at the same time [Van Gigch 1974:34].

Sub-optimization, in essence, is a reflection of the traditional Western thought of reductionism. In economics neglecting the effects of one system upon another one is often referred to "**spillover effects**." They are "externalities" of economic activities or processes upon those who are not directly involved in it.

Sub-optimization from systems theory refers to the extent to which attempts to improve the performance of a subsystem by its own criteria may act to the detriment of the total system, which includes that subsystem, and even to the defeat of its objecttives. Sub-optimization is also called "*false trade-offs*" that promote "subsystems improvement" while disregarding the objectives of the whole system [Van Gigch 1974:102]. Accordingly, there is a **sub-optimalization principle** in GST [Skyttner 2005:100]:

> If each system, regarded separately, is made to operate with maximum efficiency, the system as a whole will not operate with utmost efficiency.

A firm's strategy to "maximize" shareholders' profits is a sub-optimization of a firm's stakeholder architecture, at the expense of, for instance, employees, community and even the state.

Trade-offs in strategic decision-making are often not observable. On the other hand, there are situations when the implications of existing, but disregarded trade-offs show up drastically. A very lucid case of sub-optimization in the context of entrepreneurship is the massive support of "CleanTech" (Table I.52) and particularly biofuels by policy to lift dependency on mineral oil (a fading resource) and expensive imports and simultaneously reduce carbon dioxide emissions to fight climate change (Box I.1).

Box I.1: The biofuels issue as an example of sub-optimization by policy and corrective actions – The bioethanol and biodiesel cases.

A biofuel is any fuel that is obtained from renewable resources of biological origin – or from the waste they produce. Over the last decade a biofuels industry has emerged in Europe and the US – largely initiated and supported by political programs and actions.

There are two main political drivers which are energy independence and environmentally friendly (renewable) energy. However, on both sides of the Atlantic these drivers concentrated on internal markets/projects and, therefore, development of the related industries were directed to addressing local concerns and therefore feedstocks and technologies are directed towards that.

The main political drivers for the biofuels industry in Europe were directed towards the environment, and therefore lowering carbon emissions as much as possible. As a secondary objective the Europeans aimed to reduce their dependency on petro-energy. In particular, Germany wants to change its power mix in favor of "renewable energy sources" (RESs). This perspective was closely related to the objectives and structure of the Kyoto Protocol, which was endorsed by the EU. Interestingly, in terms of concrete actions in the EU, the focus seemed to be more on developing biofuels in the member states to meet objectives. The objectives included a 5.75 percent bio-to-petrofuels blend envisaged by the European Union by 2010.

In contrast, in the US the primary objective was to reduce dependency on imported oil. More specifically, the Department of Energy's Office of Energy Efficient and Renewable Energy (EERE) invests in research to achieve the following goals:

- Dramatically reduce, or even end, dependence on foreign oil.
- Spur the creation of a domestic bioindustry.

The US orientation combines national industry, geopolitical and environmental considerations. There is a broad mix of policy objectives: reducing energy dependency, fighting climate change, helping farmers, and creating jobs. As an important aspect of lifting oil dependency the US military emerged as a very important customer and driver for developments for the biofuels industry. The net effect, biofuels advocates said, is an up to 90 percent reduction in greenhouse-gas emissions [Theil 2005]; a UK government publication declared that biofuels will reduce emissions “by 50-60% compared to fossil fuels.” [BBC 2007]

Furthermore, unlike mineral oil no country will dominate the market for biofuels. The strive for becoming independent from imported oil or, at least, reduce dependency is structurally related to the *autarky* efforts of Germany after World War I and during the Nazi regime which among many other things also focused on oil and gasoline and culminated in two successful technical processes and mass production (A.1.1) which still form the basis for some current efforts to produce ethanol or sugar, respectively, from biomass [Runge 2006:424-425, 270-272].

Berlin and Washington were backing these goals with laws, regulations and mandates particularly with tax breaks, incentives and exemptions, loan guarantees, subsidies for suppliers and users and scores of millions of euros/dollars in grants and financing options for research and startups, with more support expected in upcoming energy bills and financial support of firms’ foundation. These inducements and the vast potential market have stimulated investments of more than billions of dollars and euros and *spawned a new industry* with plenty of entrepreneurial firms (Figure I.34, A.1.1).

Political programs and actions targeting industry creation may achieve characteristics of self-reinforcement: The created industry organizes itself to etablish lobbying and pressure groups to further support or even enlarge the level of the program.

For instance, in the US under the Energy Independence and Security Act of 2007 (EISA), advanced biofuel production should rise from 2 billion gallons per year in 2012 to 21 billion gallons in 2022, and companies were pivoting to meet those goals. Fuel required to be blended into gasoline stood at 36 billion gallons by 2022.

In Germany the EEG (Erneuerbare Energie Gesetz – Renewable Energy Act; Box I.22) plays a similar role. Germany is an EU leader (and second often worldwide) in the wind energy, the photovoltaics, the solar thermal and the biofuels sectors. A stable and “predictable” policy framework was assumed to have created favorable conditions to renewable energy sources (RES) penetration.

Other regulations, which mean *mandates*, concern requirements of blending proportions of biofuels into oil-based gasoline. For instance, B20 means blends of 20 percent biodiesel with 80 percent petroleum diesel, E10 means 10 percent ethanol with 90 percent petroleum gasoline. All this was simultaneously met by an increasing societal green attitude, particularly in Europe.

The term “biofuels” suggested renewable abundance: clean, green, sustainable assurance about technology and progress. It seemed that international organizations, particularly environmental and developmental non-governmental organizations (NGOs), forced a fundamental reappraisal of biofuels policy, certainly in Europe. But this obscured the political-economic relationships between land, people, resources and food, and failed to help us understand the profound consequences of the industrial transformation of the food and fuel systems. "*Agro-fuels*" better characterizes the industrial interests behind the transformation [Giménez 2007].

"The industry is still pretty much a government creation. The reason why renewable fuels exist at all is because politicians have decided they meet policy objectives. The whole market is 100% political." [Carey 2009]

Most of Europe's biofuel comes from rapeseed and sugar beets while most American biofuel comes from soybeans, corn and sugarcane, most Asian biofuel comes from palm oil. These crops are used for so-called *first generation biofuels*, in particular, biodiesel (as its name suggest for Diesel engines) and bioethanol (for Otto engines).

Like other renewable fuels, bioethanol and biodiesel as transportation fuels are commercially not viable without subsidies. As in Europe the emphasis is much more on Diesel cars than in the US Europe leads the "biodiesel train." According to the European Biodiesel Board Europe is a major player on the global stage, responsible for 65 percent of the world's biodiesel production [Della Vedova 2009]. Germany alone has a share of 40-50 percent [European Biodiesel Board 2009].

What is the issue of sub-optimization for the biofuels case? From the environmental point of the view, the big issue is *biodiversity*. With much of the Western world's farmland already consisting of identical fields of monocultured crops, the fear is that a major adoption of biofuels will reduce habitat for animals and wild plants still further. Asian countries may replace rainforest with more palm oil plantations.

The environmental NGOs who decry the Asian biofuels actually oppose all forms of biofuel because they fear it will lead to a reduction of rainforests. Wildlife conservationists said a boom in palm oil – used extensively for biofuel and processed food like margarine – has affected the jungles in Borneo, endangering the already declining orangutan populations. If increased proportions of food crops such as corn or soy are used for fuel, that will or may push prices up, affecting food supplies for less prosperous citizens initiating social unrest [BBC 2007].

Indeed, by mid of 2007 in the US growing demand for the use of corn in ethanol had driven up the price of corn. In the US ethanol producers used 23 percent of corn crop in 2007 to make 5 percent of car fuel supply [Langret 2008]. Higher corn prices have boosted the cost of producing beef, poultry and thousands of processed products. The ethanol obsession with much more expensive food was particularly felt in Mexico where basic nutrition relies on corn meal. All told, ethanol has cost Americans an additional estimated $14 billion in higher food prices. These increases have also pushed up sugar prices on *speculation* that demand for the commodity will strengthen to help produce ethanol [Wasik 2007].

Becoming aware of these "false trade-offs" corrective actions of policy took place without giving up the idea with still powerful political support of slashing dependence on oil, creating thousands of jobs, and reducing emissions that contribute to global warming.

Growing crops specifically designed for biofuels which do not compete with the food supply has been one response. A direction was the planting of Jatropha curcas – a drought resistant, inedible oilseed bearing tree which does not compete with food crops for good agricultural land or adversely impact the rainforest – in order to make more sustainable biodiesel feedstock available on a larger scale. Identifying the most productive varieties of jatropha, cultivated in South East Asia, Southern Africa, Central and South America and in India would be a matter of research.

The other approach to such so-called *second-generation biofuels* focused on the non-grain portion of biomass (for instance, cobs, stalks or wheat straw), often referred to as agricultural stover or residues, and energy crops such as switchgrass in the US which also contain valuable components. Further targets comprise inedible sugars and lignocellulosic biomass resources (also called cellulosic) derived from wood comprising of cellulose, hemicellulose, and lignin and finally municipal solid waste and animal fats.

Consequently, a new race started focusing also on non-ethanol biofuels, such as biobutanol (A.1.1.5). The success of biobutanol startups, however, depended on whether biobutanol can attract the kind of subsidies that have already been liberally splashed about for corn-based ethanol in the US, a policy which has been severely criticized [Van Noorden 2008].

But still the time for discovery of an economic method of turning inedible plants and their residues instead of ethanol from corn or other food crops into transportation fuel could be a disaster for the world's jungles, since then people living near them would have a powerful incentive to chop them down [Langreth 2008]. Hence, the most recent target in the field focuses on algae generated oils as a source of biodiesel fuel – and we are at *third-generation biofuels* (A.1.1.4). A comparative assessment of biofuels' overall effects is presented by Jacquot [2008]: *Biofuel Comparison Chart: The "Good," the Bad and the (Really) Ugly*.

However, by the end of 2009, it was beginning to dawn on politicians and environmentalists that biofuels may be a mixed blessing, if at all. Two papers have poured cold water on the promise of second generation biofuels [Marine Biological Laboratory 2009; Sanderson 2009].

A report examining the impact of a global biofuels program on greenhouse gas emissions during the 21st century has found that carbon loss stemming from the displacement of food crops and pastures for biofuels crops may be twice as much as the CO2 emissions from land dedicated to biofuels production. The study, led by Marine Biological Laboratory (MBL) senior scientist Jerry Melillo, also predicts that increased fertilizer use for biofuels production will cause nitrous oxide emissions (N2O) to become more important than carbon losses, in terms of warming potential, by the end of the century.

Using a global modeling system that links economic and biogeochemistry data, Melillo, MBL research associate David Kicklighter, and their colleagues examined the effects of direct and indirect land-use on greenhouse gas emissions as the production of biofuels increases over this century.

The studies suggests that changes in the way land is used, as a consequence of growing crops for biofuels, is not taken into account, and if it were then those biofuels would be shown to actually cause more greenhouse gases to be released than fossil fuels. Nitrous oxide emissions from increased use of fertilizers are a big part of the problem. As a conclusion, Melillo is reported as saying in Reuters "In the near-term I think, irrespective of how you go about the cellulosic biofuels program, you're going to have greenhouse gas emissions exacerbating the climate change problem." [Sanderson 2009]

These reports deal serious damage to the belief – which up to now has been driving the biofuels bubble – that stepped-up biofuels production is an answer to global warming. This may be a further strike for the bursting of the biofuel bubble (A.1.1) associated with the very numerous foundations of new firms in the field which are bound to disappear.

Realizing that the pros and cons of biofuels were often discussed in a piecemeal fashion, the UK-based think tank Nuffield Council on Bioethics (NCB) took it upon itself recently to do an integrated analysis of all the ethical concerns of biofuel production and came up with recommendations on how to better set government policies to guide biofuels production [Mukhopadhyay 2011a].

1.2.2 Outlining Relevant Systems for Technology Entrepreneurship

There are several levels of models, respectively, for treating systems (firms):

System-environment model – Focus on the system within the context of its broader externalities; see and understand relational arrangements and dynamics between the system and its context;

Structure-functions-model – Focus on the goals and roles of the system's (firm's) components; see the system at a given moment in time and understand what it is (ch. 2, ch. 3, ch. 4.1, ch. 4.2);

Process-behavior model – Focus on what the system (firm) does over time; the development of the system's states (ch. 4.3).

None of these models provides a complete picture of the *system under consideration*. Only by integrating the three models one can grasp a comprehensive view – the wholeness of the system.

Focusing on a firm identifying other involved systems proceeds either through analysis of involved components (factors) which are known to belong to certain systems or, starting from known facts. We proceed by deduction and inductions to draw (tentative) conclusions, we "hypothesize." Figure I.13 exhibits *the suggested entrepreneurial system-environment model* emphasizing the components assumed to exert significant effects on the entrepreneur(s) and entrepreneurship and in this way also take differences of entrepreneurship in the various countries into account.

Culturally, the differences between national entrepreneurship can be night and day. Financially, the rules can be completely different. Simultaneously, the various subsystems may have various criteria to assess entrepreneurial success. All the systems in Figure I.13 are assumed to interact forwards and backwards among each others by various modes and to different extents indicated by returning ("cyclic") arrows.

Figure I.13 assumes implicitly that entrepreneurship may be subjected to influences of the supersystems with various intensities for its discernible development processes. Specifically, the interrelationships with the industry in which the entrepreneur will operate provides important mutual interconnections between NTBFs and large existing firms via their "new business development" and "corporate venturing" processes for corporate innovation and renewal (ch. 1.2.7.2).

Reference to Figure I.13 (and Figure I.16) indicates that differentiation of technology entrepreneurs from non-technology entrepreneurs comprises also access to (material and immaterial) resources in terms of additional drivers or kinds of support, for instance,

- The national culture means, the particular norms and beliefs held by every human, that impacts how individuals, groups and societies perceive, behave and interact (ch. 2.1.2.3).
- The Higher Education System via technical and scientific education and training focuses particularly on (national) university systems including its organization in terms of (research) grants, scholarships and research projects by national science organization, such as the NSF (National Science Foundation) in the US or DFG (Deutsche Forschungsgemeinschaft) in Germany (ch. 1.2.6).
- The Science & Technology System (S&T) includes, for instance, public research organizations and institutes, such as federal and state laboratories and research centers (ch. 1.2.6), and the overall *National Innovation System* including university-industry relationships and "technology transfer" (ch. 1.2.6).
- The Industrial System refers to emphases on national industrial orientations (ch. 1.2.6, ch. 1.2.7.2) and various forms of cooperation and alliances between NTBFs and large firms.

- The Legal System plays a role for entrepreneurship by the national patent system and intellectual property protection as well as legal forms of startups.
- Policy plays a key role for the Higher Education and S&T System as well as the Industry System and the national innovation system and affects entrepreneurship directly and indirectly in many different ways through policies, initiatives and legislation.
- Military enters the scene as a customer or an initiator of research projects and provider of funds and grants.

For entrepreneurship Germany and other European countries also a supra-national system plays an important role, the European Union (EU).

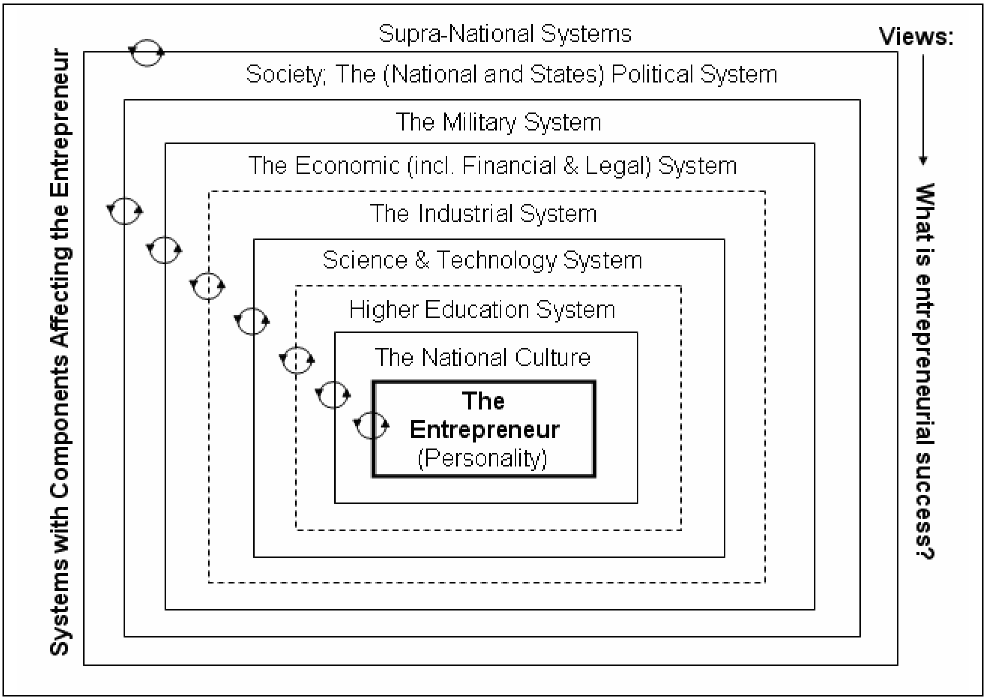


Figure I.13: System-environment model for the entrepreneur and entrepreneurship (subsystems or contributing systems emphasized by dashed lines).

There is some arbitrariness in the sequences of the (outermost) arrangement of systems. The Political System may be switched with military and *vice versa*. Industry may serve military, but innovations in military may be used in industry.

An extremely complex subsystem for technology entrepreneurship is the (National) *Innovation System* which requires consideration of interactions of almost all the subsystems given in Figure I.13. In particular the National Innovation System extends over the societal, economic (industrial) and the science & technology systems. Therefore, it is not explicitly given in Figure I.13.

As we emphasize the particular industry of the Economic System (Table I.19) we shall refer to specific scientific and engineering branches and technology fields as the relevant parts of the Science & Technology System. The S&T System may be viewed as being interwoven with the Higher Education System.

On the other hand, the Industrial System emerges as being *country-specific for entrepreneurship by industrial orientations and "natural resources"* [Runge 2006:287], such as coal, petroleum, forests/wood or farmland, but also wind and sunshine. Think of the Corn Belt in the US and "corn-ethanol" in the context of biofuels (A.1.1). This means, national advantages in natural resources and traditional industries can be fused with related competencies in broad technological fields and thus provide the basis for technological advantages in new product fields and often new and strong and innovative companies. As a corollary, this situation often induces strong political effects of the particular industry through lobbying on the federal and state level.

Generally, different facets of entrepreneurship react differently to national policy and cultural-societal environments.

Embedding the various systems does not necessarily imply strict hierarchies of the systems. Figure I.13 *represents* an onion-like model of systems or components, respectively, where each layer may or may not exert an influence on the entrepreneur and his/her entrepreneurship.

At the center of the system-environment model one will find the *entrepreneur embedded and conditioned* by the national culture and the Higher Education System as for technology entrepreneurship higher education and university and college education are important, but not necessarily a prerequisite (ch. 2.1.2.4). The model will be reduced to "*core-shell*" subsystems for describing special situations in detail (cf. Figure I.16).

The present "core-shell" model assumes that the influences of supersystems are largely transparently transferred, without essential distortion, through intervening systems to the system under consideration.

Interactions between the political and the military/industrial systems are essentially mediated by "lobbyists." An example for the transparent transfer of influences and the direct interactions between entrepreneurs (the core) and the outmost Political System are the biofuels (A.1.1.5) and CleanTech (Table I.52) industries when even lobbying of entrepreneurs may occur.

A lucid example from the US is provided by the NTBF SiGNa Chemistry, Inc. (B.2) when its co-founder Michael Lefenfeld, obtained a nearly $1.5 million federal government earmark requested by US Rep. Rush Holt, D-N.J. It is reported that Lefenfeld wanted a government grant to help fund his hydrogen car research. He even hired the

Washington lobbying firm K&L Gates to pursue those plans. SiGNa has paid K&L $170,000, records show. In general, for entrepreneuship and small firms a number of agencies or special organizations may interface the Political and the Industrial System (ch. 1.2.6).

Actually, the layered approach in Figure I.13 represents the general situation that causality of embedded or associated social systems appears (often) as cyclic: As a cause leads to an effect in the sub-ordinate system, this effect simultaneously becomes a cause affecting the super-ordinate system and, hence, the original cause initiates a reaction onto itself [Runge 2006:12]. The *dynamics of the whole system* is reflected by multiple, mutual and recursive causation. Also this effect is indicated by the cyclic arrows in the related figures.

This means, in particular, concerning a human-activity system [Banathy 1996]:

- The people in the system are affected by being in the system, and by their participation in the system they affect the system.
- The human-activity system is open and interacts with the environment; it depends on it and contributes to it. The nature of its relationship with the environment is *mutual interdependency*. This interdependency imposes constraints and expectations on both the system and its environment responsively.

In social sciences circular relationship between cause and effect is called **reflexivity**. A reflexive relationship is bidirectional; with both the cause and the effect affecting one another in a situation that renders both functions causes and effects. Reflexivity is related to the system concept of feedback and positive feedback (PREFACE).

In this context **exposure** is a key concept for systems consideration. It can refer to the emergence of reflexivity of a new or existing *entity subjecting the entity to potential reactions of its super-systems – the environment* – with forces of various strengths which may be positive or negative for the entity.

Examples refer to a person running a hazardous process (Equation I.8, Equation I.9; ch. 4.2) or founding a firm, the firm entering a market ("entrant, "exit"; Figure I.33, Table I.16 - Table I.18) thus being exposed as a new system component to the market or industry inducing competitors' reactions.

Circularity means that the actions of the entity determine the kinds and strengths of the reactions. That implicitly means for human-activity systems that decision-making with regard to subsequent activities and a new constellation for exposure has consequences for the effects onto itself.

Commerce, as a center of economy, is the exchange or share of something of value between two entities. That "something" may be goods, services, information, know how, money, or anything else the two entities consider to have value. Commerce is the central mechanism from which capitalism is derived with its focus on "markets."

For instance, in microeconomic theory, the theory of supply and demand as a market mechanism explains how the price and quantity of goods sold in markets are determined. The interaction between beliefs and observations in a marketplace provide another typical example of reflexivity: if traders believe that prices will fall, they will sell – thus driving down prices – whereas if they believe prices will rise, they will buy – thereby driving prices up.

On the other hand, military with a particular demand and as a buyer does not (or only to a certain degree) follow market mechanisms. Therefore, in the context of technology entrepreneurship it is important to differentiate "*demand*" as an encompassing notion from specifically "*market demand*."

The Military System may represent a special market for civil products, such as trucks, textiles and dyes etc., but also fuel cells or batteries or coatings – or separate areas providing demand, often without any consideration of price ("*price insensitivity*"), for innovative and entrepreneurial products for defense and war (Table I.15).

Though with a civil emphasis, due to the overlap of civil and military orientation, we consider in our context the (super)national space agencies of the US (NASA – National Aeronautics and Space Administration) and Europe (ESA – European Space Agency) as a part of the Military System. Generically, NASA and ESA have requirements for innovation and correspondingly entrepreneurship for materials which provide special properties, such as high-temperature resistant materials based on polyimides or polybenzimidazoles, now used as electronic chemicals or for fuel cells [Runge 2006:336] or processes and devices under the special aerospace conditions, such as photovoltaic (PV) and solar cells in aerospace.

Examples of entrepreneurship in aerospace through cooperation with ESA and NASA are represented by the German firms "von Hoerner & Sulger GmbH" (vH&S) [Runge 2006:482-484; von Hoerner 2008] and OHB AG (end of ch. 2.1.2.4; Table I.92).

When it comes to details of the role of the Military System for entrepreneurship in the literature one usually meets a well-measured distance from all programs involving space and the military though we are confronted very often with the impact that government programs have had in spinning off technological innovation to improve our everyday life.

The US military has blessed us with everything from the microwave oven to the Teflon pan, not to speak of ARPANET, the Defense Department project that evolved into today's ubiquitous Internet. In the US after World War II (WWII) the Korean War, (1950-1953), the "Race to the Moon" in the 1960s and the Cold War all fueled innovative and entrepreneurial activities, for instance, based on the Program of the Defense Advanced Research Projects Agency (DARPA) and DARPA funds.

And in Germany, synthetic rubber and synthetic gasoline or synthetic gas (syngas; A.1.1.3), ammonia for fertilizers and gun powders as well as the world's first jet plane all sprouted out of military aspects [Runge 2006:272, 424-425].

For well-known reasons the unprejudiced discussion of entrepreneurship and military is easier in countries other than Germany, such as the US. Entrepreneurship in military environments or initiated or financially supported by military by the Department of Defense (DOD) is not only "battlefield creativity" and to find creative and innovative solutions to battlefield problems. There may be entrepreneurship for civilian technology which is simultaneously of interest for military. And there is the special area of *defense technology conversion* (the use of military technologies for products aimed at the civilian market). And there is innovation and entrepreneurship to protect the public, for instance, against bio-terrorism.

"Military enterprise" as a notion has been introduced by Smith [1985] to describe an ongoing process in times of peace and times of conflict referring to a broad range of activities by which military (armed forces) promote, coordinate, direct technological change and thereby, sometimes directly and sometimes indirectly, the course of industry.

For instance, recently the (US) paint industry has benefited from coatings developed for space and military applications. NASA developed pad coatings that are now used to protect the Statue of Liberty. Space age hard-coats for optics developed at NASA Lewis Research Center have been licensed to protect sunglasses. And an award made by the Department of Defense through its Environmental Security Technology Certification Program (ESTCP) aims to fund research into the potential of UV powder as an alternative coating system for repairing military aircraft [Mills 2008].

The role of military for entrepreneurship is described by Mills [2008] as follows: From computer chips to lasers, the bonds between military and industrial technology continue to draw tighter. UV technology is just part of the evolutionary chain in each of these arenas. In "From Spin-off to Spin-On: Redefining the Military's Role in Technology Development" the University of California observed that "The technology base from which American firms compete in today's commercial markets is the same technology base that determines whether or not the United States is prepared to respond to the national security concerns of the future. Americans can conjure many potential threats to their well-being, but only one technological arsenal with which to meet them."

It is a widely accepted view of technology entrepreneurship that only economy, not technology will be the ultimate arbiter of success. However, as also demonstrated by the cases of biofuels (A.1.1, Box I.13, Figure I.34) or wind power and photovoltaic in Germany (ch. 4.3.5.2; Figure I.150, Box I.22), in addition to economy, policy plays a crucial role for "winner technologies."

A final remark with regard to the systemic view of entrepreneurship according to Figure I.13 concerns the time factor, in particular, historic times. The model reflects time implicitly, for instance, by the states of the particular relevant subsystems given in the figure. For instance, for the Technology Entrepreneurship context, entrepreneurship of interest in pre-industrial societies simply disregards not only the Industrial System, but also the "Higher Education System" and to an appropriate degree the "Science & Technology System."

Typical cases refer to the Berlin Blue (Prussian Blue) dye innovation from 1704 and the re-invention and innovation of porcelain in 1708, both in Germany as a dawn of science-based innovations [Runge 2006:397-405], the Aniline Purple (Mauvein) innovation (1856) in the UK (A.1.2) and the interaction of the Industrial Systems and the "Science & Technology System" in the formation of the German dye industry (A.1.2.; cf also Runge [2006:266-269, 274-276, 293-294]. In this regard, the cited examples provide also a direct *differentiation of generic from specific features of technology entrepreneurship*.

For describing current entrepreneurship on the macro-level the Global Entrepreneurship Monitor (GEM) used a model as given in Figure I.14 [Bosma et al. 2009]. GEM is a not-for-profit academic research consortium that has as its goal making high quality international research data on entrepreneurial activity readily available to as wide an audience as possible. GEM is the largest single study of entrepreneurial activity in the world.

In 2008 GEM conducted research in 43 countries. It provides an annual assessment of the national level of entrepreneurial activity in terms macro-indicators. On the basis of macro-indicators GEM does not differentiate technology and non-technology entrepreneurship and, therefore, can contribute only little to technology entrepreneurship except for basic concepts and theoretical approaches.

The GEM model actually interprets the system-environment model (Figure I.13) in terms of some selected influences and effects targeting "national economic growth" which is the essential expectation of the Political System. Furthermore, it is perceived essentially as a linear model of causes leading to effects, contrary to the circular, system-environment model.

GEM puts a special emphasis on early constellations of entrepreneurship and uses a "*phase-based view*" (ch. 4.3.1) of entrepreneurial firm's foundation (Figure I.15) associated with corresponding operational definitions.

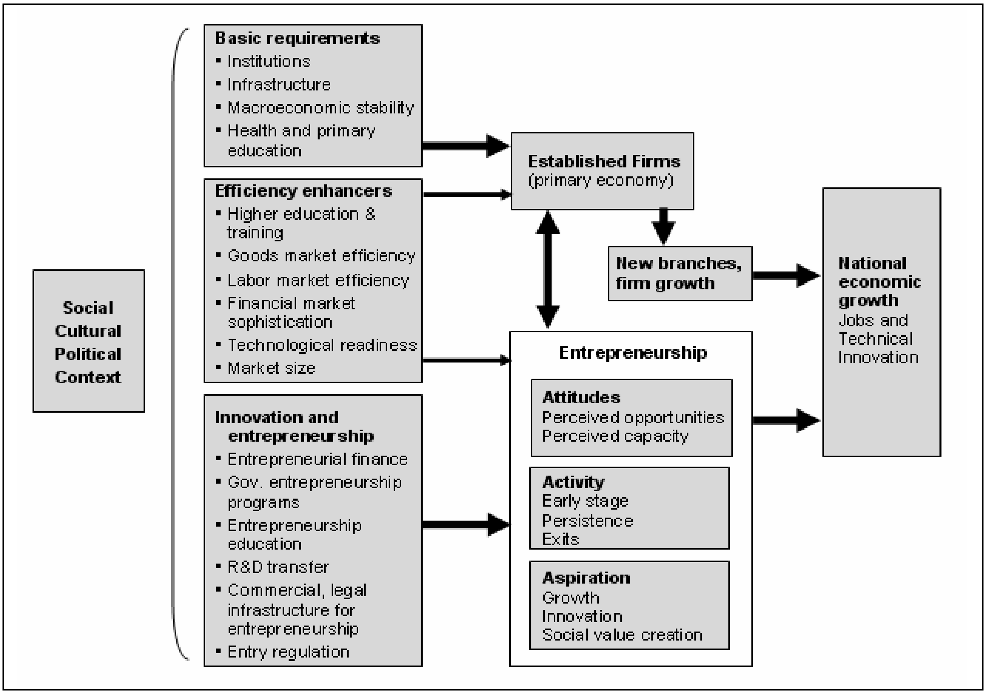


Figure I.14: The Revised GEM Model for a macroscopic description of entrepreneurship activities in various countries [Bosma et al. 2009].

The GEM model starts with "the potential entrepreneur" confronted with an opportunity, but disregarding an "idea, chance and serendipity" (Figure I.1), and who is endowed with knowledge and skills as resources or "assets," respectively. The foundation and development (and growth) of firms according to GEM is related to an evolutionary metaphor in terms of the stages of the entrepreneurial process as well as the differences and transitions between the phases.

In essence, the GEM phased model includes a "pre-startup," the "pregnancy," and the "startup phase" with the "birth" which may be the point of incorporation as a legal entity or the beginning of the operational activities in the market. The GEM model accepts the multi-faceted nature of entrepreneurship. It recognizes that a range of environmental conditions affect three important "components" for entrepreneurship: the entrepreneur's attitudes, activity and aspirations.

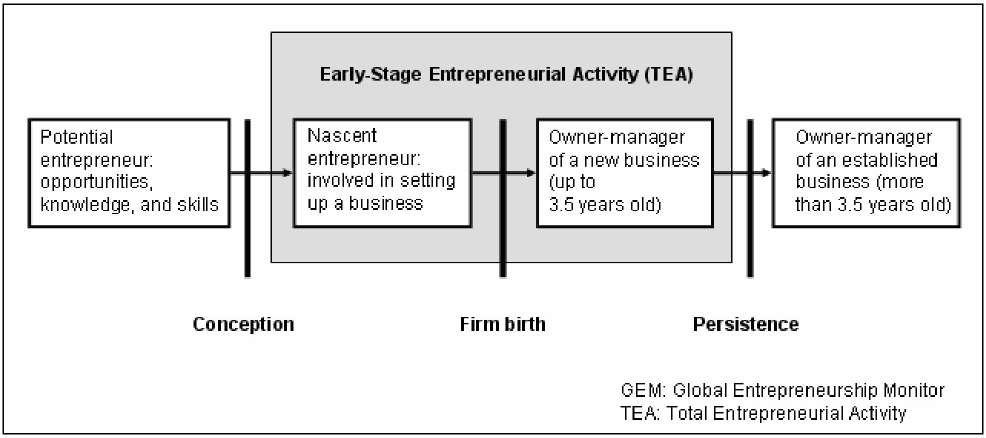


Figure I.15: GEM operational definitions of the entrepreneurial process [Bosma et al. 2009].

Formally, GEM's model resembles biology-oriented models (cf. end of ch. 4.3.2). The biology-oriented evolutionary model of entrepreneurship [Arenius and Ehrstedt: 2008, and references herein] differentiates essentially the creation of new organizational structures (*variation*), by the way in which entrepreneurs modify their ventures (*adaptation*), the conditions under which such organizational arrangements lead to success and survival (*selection*) and the way in which successful arrangements tend to be imitated and perpetuated by other entrepreneurs (*retention*) (cf. Runge [2006:275-276] for the birth and growth of the chemical dyestuff industry).

An important contribution to the evolutionary theory of the firm is the introduction of "nascent entrepreneurs." *Nascent entrepreneurs* are individuals who seriously intend to start a business and whose efforts may or may not lead to the birth of a new firm. In evolutionary terms, nascent entrepreneurs are a major source of organizational variation, beginning with their intentions and continuing through their activities oriented toward a realized founding.

Following the literature GEM uses four phases of the entrepreneurial startup process as the basis of its macro statistics (Figure I.15).

- The first stage involves the population of all individuals – all those involved in the labor force and those who are employees of existing businesses. Some of these individuals decide to pursue a new business startup (perceived opportunity versus perceived capacity; Figure I.1), which is the first transition point of the entrepreneurial startup process called "*conception*."
- Conception is followed by the *gestation* stage, during which individuals engage in action aimed at starting a firm. Individuals in the gestation phase are called *nascent entrepreneurs*. The second transition point in the entrepreneurial startup model is "*firm birth*."

- After firm birth the new business is in its *infancy* stage (operationally defined by GEM in Figure I.15 and lasting up to 3.5 years). Entrepreneurs in the infant stage are also called “baby business owners.”
- If surviving due to persistence the infant firm will enter the *adolescence* stage, in which it is considered to be an established firm.

GEM’s infancy stage of 3.5 years after firm’s foundation will, for other reasons, later be called the “startup thrust phase” (ch. 4.3.2, Figure I.125) and it is found (for German startups) that the probability of exit from the market of a young firm increases after foundation until the firm is about three years old, but then the probalility decreases again.

It is to be noted that using previous GEM data it has been shown that those who perceive themselves as possessing the necessary skills are several times more likely to be nascent entrepreneurs than those who do not believe to have the necessary skills [Arenius and Ehrstedt 2008].

While using carefully some of the related GEM findings our GST-oriented approach to NTBF foundation (Figure I.16) is more concerned with the micro level to follow changes over time taking explicitly relevant factors and drivers into consideration – often derived from or related to startup cases.

GEM’s phased-based model of entrepreneurial firm’s foundation and development serves essentially statistical purposes to allow comparisons of entrepreneurship across countries. This is the only legitimization to assume fixed durations of development phases. However, clinging to a phased model social theory and sociology provides one useful basis to deal with what can be observed with new firm development referring to the concept of “*bracketing*,” of **temporal brackets** or **spatial brackets** [Bird 1992].

The GST interpretation of *business bracketing* leads to a division of an overall development process by irregularly occurring *changes* into different range phases, with every period having certain continuity in its activities and discontinuity to adjacent periods. The relevant changes may occur from inside the system or by external influences. Each bracket will induce a particular new state of a system. Temporal bracketing is easiest to see in our ability to separate past, present, and future. We can think in the past and the future and this influences our present behavior (ch. 4.3).

A bracket serves as a *phenomenological construct* to tackle the reciprocal interactions among the processes of human action, situational structuring, and mapping of observable reality (ch. 4.3.5). In the context of entrepreneurship different temporal brackets can, for instance, be related to strategic actions or decisions taken by actors or initiated by environmental events.

Each temporal phase starts either by *revealing or cognition of an empirically founded significant exogenous or endogenous event* (Table I.76) and a related or an unrelated endogenous decision and action taken by organization's decision-makers. The venture founder (and his or her team) determines the critical occurrences in the past and anticipated future around which temporal brackets are set (Figure I.1, Figure I.16). Temporal brackets are no episodes.

A typical case initiating a spatial bracket of entrepreneurship concerns the selection of or the move to a new location by the new firm or keeping a location when a new (larger) building or facility is needed as a response to firm growth (ch. 1.2.3).

Temporal bracketing will have a start by a process or event (the *front bracket* "["; Figure I.135) and an expectation how long the process or the event will take to complete – or an event's effects become insignificantly (*end bracket* "]"). The "end," after a period of time, may also be related to the cognition of an event that will start a subsequent (new) bracket or an intentional start of a new bracket in anticipation of an event to occur. The last two cases refer to "reactive bracketing" or "pro-active bracketing," respectively.

Pro-active bracketing, on the level of the individual, would cover, for instance, the hours involved in writing a business plan or an estimate when the Window of Opportunity will close. Some of such brackets get formalized into timetables such as business plans, PERT charts, and calendars.

The temporal brackets may structure the pacing of venture development, which is at least partially controlled by the entrepreneur (this means, he or she can choose when to act and when to withhold action, when to move quickly and when to move more slowly, and when to change or resist change). Those timeframes chosen as critical to venture pacing are often communicated as goals or milestones to the venture team and external stakeholders. The achievement of these serve as symbolic marker events which serve to enhance the validity, legitimacy, or reality of the venture idea. That is, achieving a pre-set benchmark that is widely acknowledged helps to socially construct the new venture [Bird 1992].

Well structured temporal bracketing can be observed for intrapreneurship and innovation in large firms by staged processes; such as the Stage-Gate® (PhaseGate) innovation process (Figure I.79). Here a period typically is terminated by a (selection) team's decision, the gate, whether and how to proceed in the subsequent.

The GEM model in Figure I.15 is a reflection of bracketing. For the macro-oriented GEM approach it appears rather natural that the micro aspects of the "pre-startup phase" are rather loosely defined. It is also rather difficult to operationalize the "nascent entrepreneur." One can envision this bracket to comprise, for instance, the time from the conscious intention, imagination and will to the action of founding a firm.

Following strategy logics (Table I.33) the nascent entrepreneur may develop and digest a vision and ideas and concepts, have these evaluated by others, perform a self-assessment, set a time horizon with "milestones" to track development and ultimately found formally or informally a firm, for instance, in an incubator (ch. 1.2.6). The decision about the particular incubator (location selection) may represent a spatial bracket. Particularly, staying at a university (and utilizing a laboratory and infrastructure) for more experimental preparations of firm's foundation is a rather often used time bracket for RBSUs. But, "strategy formation in a fledgling enterprise is more a creative than a deductive exercise." [Bhidé 2000:302]

And even having an idea and revealed an opportunity may be associated with postponing firm's foundation intentionally for a rather long time as additionally needed technology is not available on the market. For instance, this was the case for the German firm Resonanz Magnetfeldtechnik GmbH, a 2007 Awardee of the German National Founders' Award ("Deutscher Gründerpreis"). The founder could not materialize his idea of an electromotor to increase efficiency of power generation by wind turbines commercially as the needed multiple-phase control electronics was not on the market as a purchasable component. [13]

Specifying Figure I.13 and contrasting Figure I.15 the process-related systemic view of NTBF foundation is presented in Figure I.16.

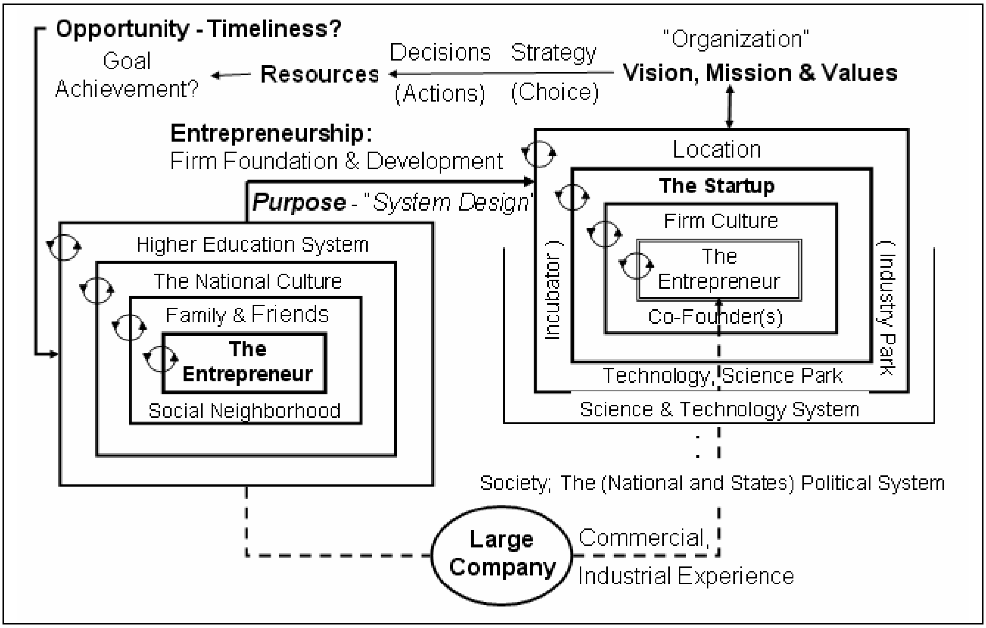


Figure I.16: A systemic (GST) view of NTBF foundation.

Figure I.16 shows the entrepreneur as a core-shell expression with a transition into a new situation in the startup which itself represents a new "wholistic entity causing a reaction onto its origin." This transition, while keeping the entrepreneur's core-shell expression (Figure I.16, left), results in a new situation for the entrepreneur who becomes a component of the "startup core," which may lead to more or less pronounced changed "organizational behavior," in particular, if the firm's foundation was done with co-founders.

It is to be noted that Figure I.16 contains the implicit assumption that assessing goal achievements of the startup is against the entrepreneur's personal goals which may be the those of the firm's decision-maker (Figure I.1) and not against the ones of the startup's *de facto* decision-makers, for instance, investors in the startup or owners.

After founding the new firm the entrepreneur will decide and act in a new situation and will be "conditioned" by a new system, the startup. The entrepreneur's behavior is determined by the context of relationships with other persons, such as co-founders, and the context of interactions with other systems. For instance, in the new environment the entrepreneur may build up a sense or feeling of responsibility for his/her employees.

But there are more factors to be considered for the entrepreneur. For instance, if he/she starts the firm after leaving a job in a large company the entrepreneur is not only "conditioned" by the related "company system," but often have gained considerable technical and commercial experiences and skills (ch. 2.1.2.4). Such formative experiences shape the worldview of the entrepreneur and play an important role in determining the entrepreneurial approach, for instance, concerning strategy, decision-making, organization and resource selection.

Finally, Figure I.16 emphasizes the general (systems) rule that, for firm formation, *structure ("organization") follows purpose/objectives ("mission")*. This corresponds also to the situation in art where there is first the idea and then the form.

It should be kept in mind, however, that the core in Figure I.16 should be complemented by a further situation, namely the entrepreneur (and his/her personality) embedded in another shell, the *entrepreneurial team*, the "co-founders," who play a very important role for technology entrepreneurship (Figure I.68; ch. 2.1.2.5).

The core-shell model actually represents the *entrepreneurial configuration* (ch. 4.3.2) covering those endogenous factors (variables) of the entrepreneur (and, if applies, his/her team) and those exogenous factors (parameters) which drive the new firm's further development. In a related way the innovation configuration and innovation architecture have been introduced (ch. 1.1.2).

The fact that an entrepreneurial person will be conditioned in the environment of a large company our systems view of intrapreneurship (Figure I.17.) attributes a key role to company culture (attitudes, work conditions including policy and politics) for the likeliness employees to become innovative or entrepreneurial. The finding of Nicolaou et al. [2008] that the entire environmental influence on entrepreneurship (regardless of operationalization of the phenomenon) was accounted for by non-shared environmental factors has important implications, for instance, for intrapreneurship (and corporate venturing) including the creation of spin-off companies.

> In short, intrapreneurship refers to an *entrepreneurial system* within a company.

The assumption (supported by the literature) that a significant component of the non-shared environment comes from a person’s work environment suggests that companies can influence the likelihood that their employees will become entrepreneurial by the type of work environment that they provide. Thus, companies can influence the tendency of their employees to engage in two activities of strategic importance: the tendency of employees to engage in corporate venturing (the creation of new companies by established companies) and the level of spin-out activity (people quitting companies to pursue business opportunities rather than pursuing them on behalf of their employers). These results support the political rationale that entrepreneurship can be influenced by proper programs of education, consultative support and financial and infrastructural support and incentives.

However, one of the barriers to intrapreneurship may be “organizational memory” and overcoming corresponding constraints (ch. 2.2.1). A common opinion is that **organizational memory** as a part of corporate culture can be viewed as an interrelated network of a group’s decisions, rationales, processes, best practices, policies and procedures that exist independently of the individuals who contributed to it (ch. 4.2.2; Figure I.129, Figure I.136).

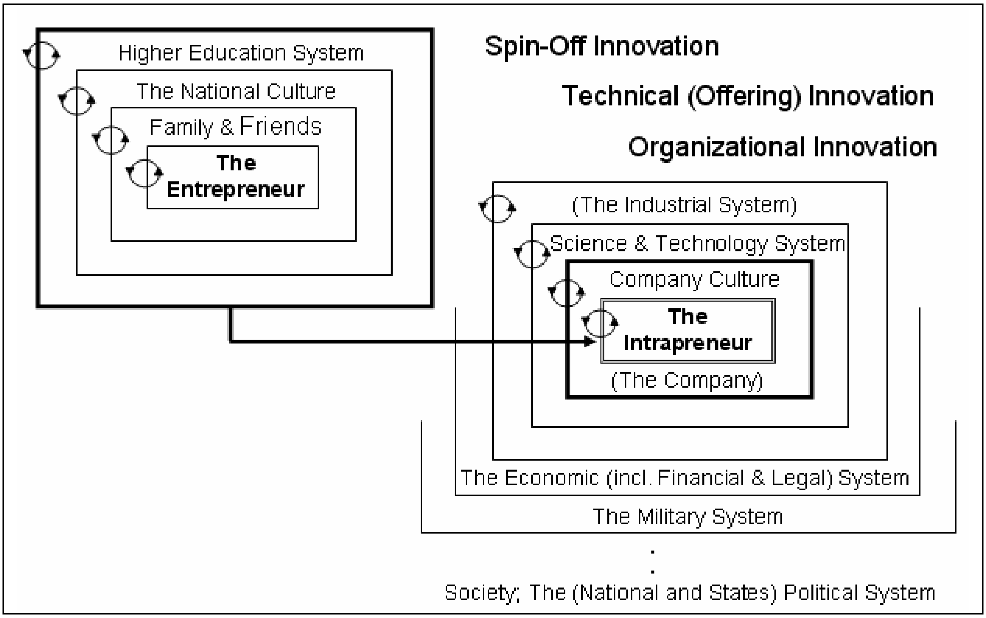


Figure I.17: A systemic (GST) view of corporate entrepreneurship (intrapreneurship).

For both cases, entrepreneurship and intrapreneurship, the "Family & Friends" subsystem is essentially responsible for socialization as well as setting values and norms of the national culture and beliefs, worldviews, ambitions etc. of the entrepreneur. It comprises essentially

- Family with parents, brothers/sisters (for instance, may found firm together),
- Spouses
- Other relatives,
- Friends with friendships generated during childhood or attending schools, high schools and universities, in sports and leisure etc. and "soul mates" to keep the entrepreneur "warm" in critical situations.

There is strong evidence across a range of studies that, affecting attitude, motivation and intention, the likelihood of becoming an entrepreneur increases with family background [Tidd et al. 2001:354] and parental entrepreneurship [Nicolaou et al. 2007:17]. In particular, family members may serve as role models for entrepreneurship (ch. 1.2.2; ch. 4.3.2).

Focusing more directly on entrepreneurs in technical fields ("founders of businesses in high-growth industries") a recent report from the US [Wadhwa et al. 2009:11] found that more than half of respondents (51.9 percent) were the first in their families to launch a business. For 38.8 percent of respondents, their father was the first to start a business in their family; mother was the first for 6.9 percent and 15.2 percent indicated siblings had previously started businesses. The same study reveals the relative importance that an entrepreneurial family member or friend was a role model: 9.2 percent viewed this as an "extremely important," 12.3 percent as a "very important factor" and 16.2 percent as an "important factor" [Wadhwa et al. 2009:15].

In our model (Figure I.13, Figure I.16) we assume, in line with Smith-Hunter et al. [2003], that there are some *universal*, generic entrepreneurial personality traits, which the "*National Culture*" system does not affect significantly. However, it can shape the development of certain traits and motivate individuals in a society to engage in behaviors that may not be evident in other societies.

A community that accords the highest status to those at the top of hierarchical organizations encourages "pyramid climbing," while awarding high status to professional expertise may encourage premature educational specialization. Both of these are unfavorable to entrepreneurship.

Culture, it appears, may determine potential for entrepreneurship, generating differences across national and regional boundaries (ch. 2.1.2.3). Culture needs supportive features to *cultivate the mind and character of the potential entrepreneur* (Figure I.15). To be motivated to act, potential entrepreneurs must perceive themselves as capable and psychologically equipped to face the challenges of a global, competitive marketplace.

National culture itself, as the underlying system of values peculiar to a specific group or society, is rather stable and changes only very slowly. For instance, although the US has plunged 2007-2010 into its deepest recession since the Great Depression, according to pollsters for The New York Times and CBS News, still 72 percent of Americans in a nationwide survey said they believed it is possible to start out poor in the United States, work hard and become rich – a classic definition of the American Dream ingrained in the US culture [Seelye 2009].

"*The American Dream*" is a code word for entrepreneurship in the US. Similarly, "Americans have always felt that they are masters of their own fate. Decade after decade, Americans stand out from others in their belief that their own individual actions determine how they fare. That conviction has been utterly unshaken by the global crisis." [Brooks 2009a]

1.2.3 Systems, Intelligence, and Learning

Those who do not learn from the past are condemned to repeat it.
George Santayana

For survival and growth open systems, for instance, firms (Figure I.13 - Figure I.17), have to adapt to their environment (or create the environment). In the framework of GST we, therefore, have to look for generalizations regarding the way that systems and subsystems are organized and interrelated and *the means* by which they receive, store, process and recall information, and *the way* they behave, respond and adapt to different "triggers" or "inputs" from their environment.

If information moving backward from a system's performance is able to change the general method and pattern of performance, it is justifiable to speak of *learning*. Hence, GST can refer to related structures and processes for entrepreneurship and innovation focusing on a particular concept of *intelligence*.

The notion "intelligence" is an "umbrella term" with two orientations concerning people. Looking up the Internet one finds definitions as given in Table I.9. Accordingly, intelligence is a theoretically used concept and attribute, but also a construct which is defined and specified so that there can be observation and measurement.

On the other hand, the notion is also used for non-human areas. For instance, a material that provides adaptation or a reaction, a *response*, to *stimuli* from the environment is called an "*intelligent material*" or "*smart material*" [Runge 2006:13-14, 41-42]. For instance, a material on a label on food may change color, if it is exposed to a temperature which exceeds a certain threshold.

Table I.9: People intelligence – defined via property and behavior.

Property (of the mind) or personal trait	**Behavior, action, process**
▪ Cognitive abilities, for instance, memory, creativity, "brainpower," etc., ▪ Understand meanings, ▪ Capacities to reason and learn, aptitude, Acquire knowledge, and apply it to practice.	▪ Solve problems and plan, ▪ Ask the right questions ("Q&A") ▪ Adapt to new situations, Use knowledge to manipulate one's environment.

But rather than emphasizing notions given in Table I.9 for the particular context of innovation and research Runge [2006:520] put forward an *operationally defined* notion of *intelligence* given in the US CIA Factbook on Intelligence. For entrepreneurship we shall also refer to this definition (unless stated otherwise). In particular, this understanding forms the basis of two other important derived concepts for innovation and entrepreneurship, *competitive intelligence* and *technology intelligence* (ch. 1.1.2).

> "**Intelligence** is *knowledge* and *foreknowledge* of *the world around us* – the prelude to Presidential *decision* and *action*" (emphases added).

Both kinds of knowledge include the corporate-internal and the external domains. Knowledge means *actionable knowledge*. In this sense intelligence at a particular point in time is interconnecting a certain static aspect ("current cognitive state") with a dynamic one, action – and thus makes it observable.

(Technology) entrepreneurs should be able to discern and "exploit" their environments and, therefore, a critical competency is the ability "to anticipate, act, and react proportionately in response to internal and external events." Organized as a process technology intelligence requires "*environmental scanning*."

Organizations are marked by the process by which they collect, manage, and use information to create (fore)knowledge which proceeds along the chain

Information – Interpretation – Sensemaking/Knowledge– Coordination – Decisions.

All of these are dependent on communication. In particular, coordination means **communication** of entities (people or things) and actions to work together towards a given goal, purpose, function or effect.

In this chain "sensemaking/knowledge" is of central importance and an issue related to the notion of "knowledge." Starting from description of information as "*data in context*" (Figure I.18) Runge [2006:520] elaborated the issue as follows:

> It is tempting to view knowledge operationally as “information in context.” However, the notion of knowledge has not only this relationship to information, but has additionally a social dimension (Figure I.18).
> Knowledge is *information (in context)* assumed to be *true by social consensus* for a given period of time and shows a historical dimension. The social character also provides meaning to the concept of foreknowledge. Social consensus means also consensus what belongs to a ‘knowledge domain.’ For the temporal perspective knowledge relates to present and past; foreknowledge addresess the future.
> Moreover, in the context of objectives and purposes knowledge has also a *pragmatic aspect*: what is important for decision and action. The pragmatic part, for instance, defines “scientific knowledge” and “technical knowledge” and “business knowledge” of a company as part of its overall “knowledge domain.”

Of course, future is not merely unknown, but unknowable. In so far foreknowledge is often created by various approaches based on social actions. That said, however, one should emphasize here that for entrepreneurship “the future is unknowable, but not unimaginable” [Lachmann].

“Information in context” in the above sense includes data/attributes, facts and states of affairs (is…a, has…a, is…for or serves…as – goal, purpose or function). In contrast to knowledge which is always true in its social context, information may be false (unintentionally; *misinformation*) or intentionally falsified (*disinformation*, for instance, for counter-intelligence).

Counter-intelligence is an organized activity of an intelligence service designed to block an enemy’s sources of information, to deceive the enemy, to prevent sabotage, and to gather political and military information.

In the context of technology entrepreneurship counter-intelligence is disinformation. For instance, if one reads on the Web site of an NTBF concerning its new technology “Patent Pending” this can mean many things: It may be simply a lie – no patent application; it may be a patent application submitted, but not yet published, or an application published and patentability under examination, but patent not yet granted.

The above outline directs immediately to the concept of equivocality in organizational theory. **Equivocality** is the state or quality of being ambiguous in meaning or capable of double interpretation. It is viewed as the existence of multiple and conflicting interpretations about an organizational situation or situations where multiple meanings information or information patterns exist among people (striving for the same objectives).

For decision-making (ch. 4.2.2) there is an important difference between equivocality and uncertainty. While uncertainty requires the acquisition of additional (or timely) information, equivocality necessitates the exchange of subjective views among organizational members to define a problem and resolve disagreements which is knowledge creation. Rather than by new and additional information, equivocality is reduced by means of people coming together to make sense – achieve consensus – of an ambiguous reality.

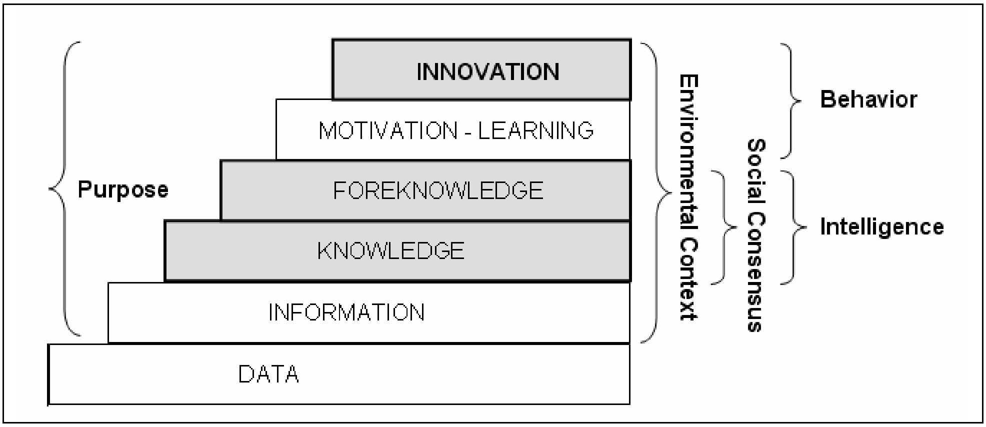


Figure I.18: The knowledge and intelligence hierarchy and its transformation into innovative behavior (adapted from Runge [2006:520]).

Knowledge (what, why, how, when) has a certain position in relation to experience. "**Experience** as a general concept comprises knowledge of or skill in or observation of some thing or some event gained through involvement in or exposure to that thing or event. The history of the word experience aligns it closely with the concept of experiment." [14]

The concept of experience generally refers to *instructional or practical knowledge* (how and when) and skills and a subjective, empirical component. This last component of experience exhibits relations to "tacit knowledge" [Runge 2006:619-620] and to the nature of the events someone or something has undergone.

Experience is what is *happening* to us all the time – as long as we exist. The corresponding German term "Erfahrung," often translated into English as "experience," has that different implication, connoting the coherency of life's experiences. In this regard the motto of ch. 2.1.2.4 relates to the concept of bracketing. A person with considerable experience (and knowledge) in a certain field can gain a reputation as an **expert**.

Communication mechanisms for the organizational system must not only be in place for interpersonal relationships and to share relevant information and understanding between the various organizational sub-units, but also with its environment interconnecting the corporate internal and external worlds. Internal communication barriers and misunderstandings do not only occur between people from various technical disciplines, such as chemistry, physics, biology and engineering, but also between different organizational units, such as R&D, Marketing & Sales and Manufacturing.

The same is true among representatives of different industries or between researchers from universities and public research institutes and researchers from industry. To overcome such barriers and mediate between various internal or internal-external domains interconnections are needed between interrelated systems or subsystems. A common boundary between two systems is called an ***interface***. In case of human-activity systems persons taking the *roles of interfaces* are called **gatekeepers** [Runge 2006:9, 738] or "**boundary spanners**."

The notion "gatekeeper" was introduced as an interface, if "differences" between intervening parts are too large to allow *direct contact and communication between the parts*. In analogy to the "technical gatekeeper" who interconnects various scientific and technical disciplines or corporate-internal and external research the R&D-Marketing interface can be approached through an R&D role of a "*marketing gatekeeper*" [Runge 2006:9,537,783]. Finally, in multi-national organizations there may be also general language barriers which have to be overcome.

Interdisciplinarity for innovation or in NTBFs means often "elevated" experts in one field with some knowledge of other fields who get on with each other, not all-singing all-dancing polymaths. Advances will often occur at the interfaces and require experts with related "gatekeeper" qualities in order to recognize and exploit them efficiently.

The interfaces of the "sciences" often comprise biological principles, chemical properties and physical laws. Here we have linguistic boundaries – special discipline-language and jargon. Gatekepers are related to what is currently called "*T-shaped individuals*." These tend to be professional in one area, but are skilled in many other areas and they work as bridges between disciplines.

So far, learning has been attributed to an individual. But with respect to a system, in particular, a firm, learning of the system in terms of changing its behavior in the environment as a whole becomes important. Such systemic **Organizational Learning** comprises the acquisition, application, and mastery of new information and intelligence, tools and methods that allow more rapid decisions and improvement of those processes which are critical to the success of the organization ("collective behavior").

With regard to the economics discipline, in particular, Peter M. Senge [1999; 2006] and the Society for Organizational Learning (SOL) [15] promote systems thinking for organizational learning (ch. 5.1). Correspondingly, a **Learning Organization** is an organization that is continually expanding its capacity to create its future.

Organizational Learning occurs under two conditions:

1. When design of organizational action matches the intended outcome.
2. When initial mismatch between intentions and outcomes is corrected, resulting in a match.

The first condition covers firm's foundation. And,

> since "what an organization knows at its birth will determine what it searches for, what it experiences, and how it interprets what it encounters" [Huber 1991:91]. An implication is that a new firm's learning and capability accumulation may influence its development markedly.

The key attribute of a Learning Organization is *increased adaptability.* And it should be emphasized that individual learning in technology ventures will include "*learning for the future*": what skills to acquire for future company's needs. But, given that the future is not likely to resemble the past, learning from experience (on-the-job) to prepare the company for the future will not suffice!

The Five Disciplines of Organizational Learning are [Senge 2006]

1. *Personal Mastery*: Organizations learn through individuals. Aspiration involves formulating a coherent picture of the results people most desire to gain as individuals (employee development; Figure I.121); personal mastery is one's drive towards continuous improvement by learning.
2. *Mental Models*: The focus is around developing awareness of the attitudes and perceptions that influence thought and interaction. By continually reflecting upon, talking about, and reconsidering these internal pictures of the world, people can gain more capability in governing their actions and decisions.
3. *Shared Vision*: People have added commitment in a group by sharing images of the future they seek to create through common efforts.
4. *Team Learning*: Through dialogue and skillful discussions teams as a system combine their energies and abilities and provide synergies which are greater than the sum of the individual member's talents.
5. *Systems Thinking*: People learn to better understand interdependency and change, and thereby to deal more effectively with the forces that shape the consequences of their actions. The fundamental building block is the circular "feedback loop" underlying all growing and limiting processes in nature.

Focusing on measurement on a system's output, the **Learning Curve** is an observable related to the whole firm and as such reflects organizational learning (ch. 1.2.3). It is a (graphical or mathematical) representation of the common sense principle that the more one does something the better one gets at it (the more times a task has been performed, the less time will be required on each subsequent iteration).

The learning curve shows the rate of improvement in performing a task as a function of time, or the rate of change in average cost (in hours or €/$) as a function of cumulative output.

For example, an 80 percent learning curve means the per unit average cumulative cost (in hours or dollars) falls to 80 percent of the previous per unit average cumulative cost as the cumulative output doubles. It also illustrates that improvement in time becomes successively smaller until the practically achievable level of methodology improvement is reached. It refers to skill or knowledge gains. An *experience curve* generalizes the labor productivity learning curve to include all the cost necessary to research, develop, produce and market a given product. [16]

The economic learning of efficiency generally follows the same kinds of experience curves. Efficiency and productivity improvement can be considered for individuals as well as whole organization, industry or economy learning processes. The general pattern is of first speeding up and then slowing down.

The "*learning curve advantage*" for technology (associated with lowering costs of operation, for instance, prototype development or production) is a powerful form of accumulated knowledge, experience as well as tacit technologies. In this way firm operations can obtain a competitive advantage over less experienced rivals.

1.2.4 The Technology Entrepreneur in Capitalistic Systems

The socio-economic environment under consideration, for technology entrepreneurship in essentially Germany and the US, is characterized as "capitalistic." There is no consensus on the definition of **capitalism**, nor how it should be used as an analytical category. The views of capitalism have historical (time-dependent), regional (country-specific) and, finally, context and ideological dimensions.

Capitalism became dominant in the Western, the "developed" world. It gradually spread throughout Europe in the 19th and 20th centuries, and it provided the main drivers and means of *industrialization* by technology throughout much of the world. Hence, the question arises which of the particular kinds or views of capitalism (with pro's and con's) are most appropriate to provide a framework to describe and understand technology entrepreneurship. Normative, legal and behavioral notions emerge from common (online) dictionary definitions:

> Capitalism is an economic and social system in which *capital and land*, the non-labor factors of production (also known as the *means of production*), are *privately owned*; labor, goods and resources are *traded in markets*; and *profit*, after taxes, is distributed to the owners or invested in technologies and industries. [17]
>
> Capitalism: An economic system based on *private ownership* of the means of production. Under capitalism, *individuals, companies or corporations* invest in, own, and share in *profits (or losses)* of the entities that produce goods, distribute products or provide services.
>
> Capitalism generally refers to
> a *combination of economic practices* that became institutionalized in Europe between the 16th and 19th centuries, especially involving the formation and

> trade in ownership of corporations (see corporate personhood and companies) for buying and selling goods, especially capital goods (including land and labor), in a *relatively free market* (meaning, free from state control and interference). [18]

These definitions emphasize as defining characteristics of capitalism what is currently called "*tangibles*," such as tangible resources and tangible assets (Table I.8), but disregard key notions of "*intangibles*" of the current "knowledge economy."

The 19th century German social theorist Max Weber's consideration of *market exchange* (and associated exchange value) as the key economic practice rather than production as the defining feature of capitalism can be a start to include aspects of knowledge, information, experience and social interrelations. This can be achieved referring to *sharing* of knowledge, information etc. (and associated *sharing value*) as a key defining economic activity and "*intellectual property*" (IP). For Weber capitalist enterprises, in contrast to their counterparts in prior modes of economic activity, was their rationalization of production, directed toward maximizing efficiency and productivity – a tendency leading to a sociological process of enveloping "rationalization."

Under capitalist economies, a predominant proportion of productive capacity belongs to corporate bodies such as companies and capitalist economies have shown a sustained tendency towards *economic growth*. Many theorists and policymakers in predominantly capitalist nations have emphasized capitalism's ability to promote economic growth.

Capitalistic economies have large numbers of companies and people free to enter into many types of arrangements with each other. The economy reacts to various changes in technologies, discoveries, and other environmental situations, by means of companies and individuals re-assessing their arrangements with each other. Therefore, the control mechanisms of the economy, and the way that information flows through it, evolve over time and lead to competition.

> Defined today, **capitalism** is a practice (decisions, behavior, actions and processes) across the social, economic, legal and political system. Its key defining features is private ownership of property – not only of land, buildings, machines etc. but also of knowledge (know how, know who, know when, know if) and foreknowledge, experience etc. that are used by participants to create profits for themselves – based on exchange and sharing of offerings in markets of sellers and buyers under conditions of relatively free competition.

As described above (ch. 1.1.1.1) Jean-Baptiste Say [1803] commented on a theory of markets to meet *human needs and wants* and how the entrepreneur is involved in the transactions of goods for money. Entrepreneurs are viewed as fundamentally important in the capitalistic society and their role has been a driving force for change (they are the agents of change).

In the last century the Austrian-American economist Schumpeter (see also ch. 1.1.1.1) was one of the first to study entrepreneurs and their impact on society. He equated entrepreneurship with the concept of *innovation* applied to a business context. Accordingly, the entrepreneur is the innovator who implements change within industries and markets by the following five types of innovation ("*creative destruction*") according to activities related to the "systems conversion model" (Figure I.5).

1. The conquest of a new source of supply of new materials or parts (input or resources innovation),
2. The introduction of a new good or quality thereof (new product innovation or the introduction of a new service),
3. The introduction of a new method of production (new process innovation or new methods of production),
4. The carrying out of the new organization of any industry (organizational innovation),
5. The opening of a new market.

Schumpeter believed that innovation and creativeness distinguished entrepreneurs from other business people. He argued that the entrepreneur was at the very center of all business activity including founding new firms. He observed that entrepreneurs create "clusters of innovations" that are the causes of business cycles because their actions create disruptive dislocations and arrive in huge waves (Figure I.90). In fact, Schumpeter believed that entrepreneurs deserve the credit for the industrial revolution.

Examples from the last two centuries include such innovations and transformative products as railroads, automobiles, and airplanes, telegraph, telephones, radio and television as well as the birth of the electrical, chemical and pharmaceutical industries and the various technologies responsible for the IT and Web revolution.

According to Dorf and Byers [2007:22] the processes of new, creative firms forming and old large firm declining and failing represents the disequilibrium of **dynamic capitalism**. This model of renewal and re-vitalization leads to life-cycles of industries associated essentially with formation, growth and decline of firms.

In this regard Schumpeter provided the basis for a concept what is currently called **entrepreneurial capitalism** [Schramm 2006b; Baumol et al. 2007]. Indeed Baumol et al. [2007] put forward that, for instance, the US economy has achieved a remarkable transformation over the last several decades from an economy characterized by large, bureaucratic firms into one increasingly powered by entrepreneurial innovation reflected by development and growth of new firms. And they concluded that the challenge ahead is to cement and strengthen *the entrepreneurial form of capitalism – which also translates into political action and programs* emphasizing economic growth and new jobs. Indeed, a study from the Kauffman Foundation [Pruitt and Kalish 2009b] found that *in 2007, companies less than five years old created two thirds of the new jobs* in the US.

As such, the entrepreneur moves the market to a new equilibrium. Yet, the *managers* of existing businesses are not typically regarded as entrepreneurs. Moreover, over the last fifty years in the US and subsequently to a lesser degree in other capitalistic countries the socio-economic system was transformed to what is called **managerial capitalism** [Bhidé 2000:ix-xii; Heskett 2007; Baumol et al. 2008]. The often very negative perception of this type is currently reflected by headlines reporting of very large payouts to CEOs, regardless of their performance.

The emergence of managerial capitalism was simultaneously associated with a change in the control of capitalist enterprises, corporate governance, from owners (which predominated from roughly 1850-1950) to *control by very well and lately exorbitantly salaried managers (and "outsiders")* striving often for self enrichment. This was perceived as a divorce between the property of the capital and the direction of the enterprise and touched direct oversight of management by owners – an important element of owners' capitalism.

And additionally, the rise of managerial capitalism was associated with a strong rise in *management consulting* activities, growth of management consulting firms and firms "led and directed" by consultants or investment analysts as "virtual CEOs" (Figure I.19).

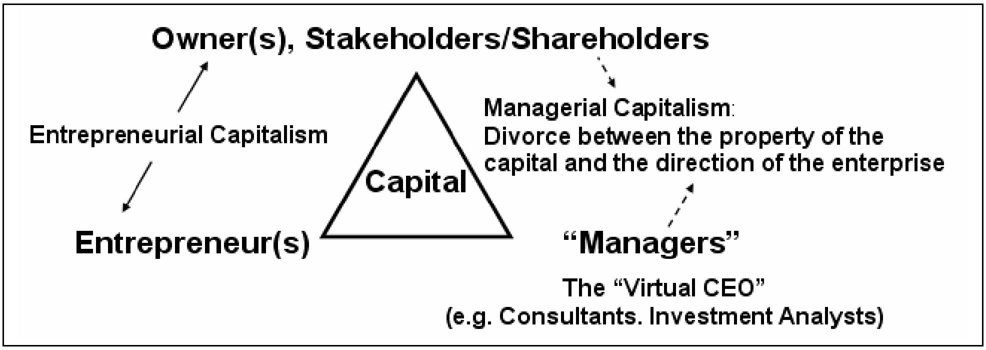


Figure I.19: Entrepreneurial versus managerial capitalism.

With an emphasis on the financial capitalism and related (global) behavior and operations of the Financial System which culminated in "**casino capitalism**" and the Great Recession a peak for managerial capitalism is seen. After realizing that (in the US) "our capitalism has evolved into a financial pyramid scheme and not industry building" the question was raised: what will follow next? The cautious answer was: "The rebirth as always (will) be in the entrepreneurial sector" and a rebirth of Schumpeter and his belief in the power of entrepreneurial behavior in the economic process and entrepreneurial capitalism [Heskitt 2007].

Finance should nurture and mirror the dynamic real economy!

The Great Recession was officially declared in the US to last from December 2007 to June 2009. Additionally, it was assumed that the financial crisis appears to have ended about the same time. However, it has turned out the Great Recession to be quite different from previous recessions in terms of time for economic recovery, for instance, expressed by numbers of unemployment, and also growth of GDP was to slow to reduce unemployment significantly.

Additionally, it is to be noted, and important for entrepreneurship, that "in many ways the venture capital (VC) phenomenon represents a variant of managerial capitalism." "Like the decision-makers in large companies, *venture capitalists* try to use systematic procedures and criteria for making investment and provide capital under well-specified terms." [Bhide 2000:xv] As a variant to venture capitalists venture capital for (technical) startups has been increasingly provided by existing large firms ("*corporate venturing*").

As usually professional managers do not own the large firm they are working for and VCs invest others' funds rather than their own capital.

For the purpose of this book and its systemic approach to technology entrepreneurship it appears useful to divide the capitalist economies into two broad categories, the *Anglo-Saxon* versus the *Nippon-Rhineland* capitalism with the US (the UK, Canada and Australia) providing representatives of the former one and Germany (The Netherlands, Austria, Sweden, Finland and Switzerland as well as Japan) as prototypes for the last one.

Furthermore, the US is associated with a markedly *individualistic society*, whereas Germany exhibits a *consensus-oriented society* (ch. 2.1.2.3). The special kind of partially regulated capitalism in Germany which emerged after World War II is called a "social market economy" (in German "soziale Marktwirtschaft"): Government is to set the parameters, but the real actors are economic actors with the awareness of their social responsibilities.

The rationale for the dissection into two fundamental types of capitalism has been summarized with regard to the national innovation systems by Runge [2006:224-229] in terms of

- Ownership,
- Control, Insiders versus Outsiders
- Corporate governance,
- Management,
- Strengths,
- Weaknesses.

Over the last two decades in the German "social market economy," however, many key actors have taken over a number of attitudes and behaviors from the Anglo-Saxon capitalism. Major areas that changed concern essentially corporate governance and management and the financial subsystem.

Capitalistic nations differ in the, usually imputed, weight of policy, not only as the authority for the legal and regulatory framework and norms of economic activities, but also as a participant in the market with state-owned organizations and as an initiator and supporter of politically wanted economic activities, such as supporting SMEs and entrepreneurship.

With regard to entrepreneurship, Anglo-American, particularly US, capitalism is usually associated with some *myths and ideology*. Contrary to wide-spread believes it is not a “free capitalism” in which for a “free market” essentially only “market forces and laws” and “free competition” are active and the risk of losses are with owners, but one with many policy (including military) induced forces distorting the basic “axiomatic” rules and practice of capitalism.

For instance, markets and entrepreneurship are determined by significant governmental interferences – direct and indirect subsidies, tax incentives and breaks, protectionism, import tariffs and export subsidies, loan guarantees, government/military as a price-insensitive buyer etc., not to speak of influencing and determining legislation by powerful lobbyists of firms and industry and agricultural associations.

Most strikingly, the Great Recession revealed, with regard to capitalism and specifically to the financial industry, that contrary to the ideology of capitalism *losses of subsystems declared as being “system-relevant,” were socialized* at the expense of the nation’s tax payers, but (incredibly huge and ethically highly questionable) gains are privatized.

And related to entrepreneurship there is also a *mythical view* questioned by Peter Drucker, the “godfather of management science” and generally described as “the seminal thinker on 20th-century business organization.” When in an interview with *Inc.* Magazine being asked

Inc.: Do you agree that we in the United States are the best practitioners of entrepreneurship, that we’re way ahead of other countries?

the interview continued [Gendron 1996]:

Drucker: Absolutely not! It’s a delusion, and a dangerous one. We may have the largest number of new-business starts and new-business failures, but that’s all. We’re probably not even number two.

Inc.: Who’s number one?

Drucker: Undoubtedly Korea. Barely 40 years ago, Korea had no industry at all. The Japanese, who had ruled Korea for decades, didn’t allow any. They also didn’t allow any higher education, so there were practically no educated people in Korea. By the end of the Korean War, South Korea had been destroyed. Today Korea is world class in two dozen industries and the world's leader in shipbuilding and other areas.

Inc.: If Korea is number one, and we're not number two, who is?

Drucker: Not too far behind Korea is Taiwan, which like Korea was preindustrial in 1950. Today Taiwan is a world leader in a number of high-tech areas, including microchips. And don't forget the Chinese, who are starting new business after new business on both sides of the Pacific.

Inc.: *Okay, so third is still respectable, no?*

Drucker: The U.S. record is no better than Japan's or Germany's. Japan has a larger proportion of world-class companies that either didn't exist 40 years ago or were mom-and-pop shops: Sony, Honda, Yamaha, Kyocera, Matsushita, for example.

Germany owes its rise from the ashes of World War II to its present position – the world's third-largest economy and number one in per capita exports of manufactured goods – to an explosion of entrepreneurship that turned hundreds of brand-new or obscure little shops into world-class manufacturers and industry leaders.

{Since 2009 Germany with its emphasis on investment (capital) goods is mostly number two in world exports after China which focuses largely on commodities and consumer goods, but still number one in per capita exports. Sometimes the US is number two. Author's addition}

Drucker's assessment is corroborated by recent GEM studies concerning "established business ownership" (defined in Figure I.15 and specified in the Glossary) including technical and non-technical entrepreneurship [Bosma et al. 2009]. Established business ownership indicates the percentage of the population actively involved in running businesses that proved to be sustainable. *The US has an established business ownership rate, which is comparable to those of many European countries and Japan, whereas early-stage entrepreneurial activity is higher in the US.*

The perceived superiority of the US concerning entrepreneurship presumably results from creating successive generations of global businesses from new technology opportunities, such as Microsoft, Oracle, Intel, Cisco, Amgen, eBay, Amazon or Google.

As will be seen in this book, at least concerning technology entrepreneurship and intrapreneurship, the capitalistic systems of the US and Germany currently represent a differently weighted mixture of state-influenced capitalism, managerial capitalism represented by large firms and entrepreneurial capitalism.

In particular, there are situations of two-sided mutually enforcing interactions ("coupling") between NTBFs/startups and larger, established firms which are connected by paths to technical innovation in a "*networked economy of innovation*" (Figure I.20) and interconnections of the Industrial and the Science & Technology System which are interfered to a considerable degree by policy (ch. 1.2.6).

A *"networked economy of innovation*" relies essentially on (startup) entrepreneurship and intrapreneurship. Apart from getting licenses from NTBFs large firms may seek collaborative agreements with NTBFs as an innovation strategy to balance the greater certainty of in-house R&D and organic growth with an earlier but riskier starting position in emerging technologies. The underlying strategy of acquiring technology and building competencies includes the option, probably after having invested in a particular NTBF, to buy it ("cooperate" or "buy"; ch. 2.2.2).

On the other hand, NTBFs address large companies, for instance, to access market channels (via marketing and sales agreements) or access resources of the large company (from consulting to services, such as analytical or information services).

Another aspect of a networked economy occurs if entrepreneurial persons from a large firm, often its intrapreneurs, leave the company and found their own independent firm (Figure I.20). This must not be confused with the situation that for innovation a large firm creates *a non-independent firm*, a spin-off, to execute with the parent company's employees a particular innovation process which requires cutting or weakening the links to the parent to make these intrapreneurs rather free from constraints given by corporate culture and routines, management and decision-making etc.

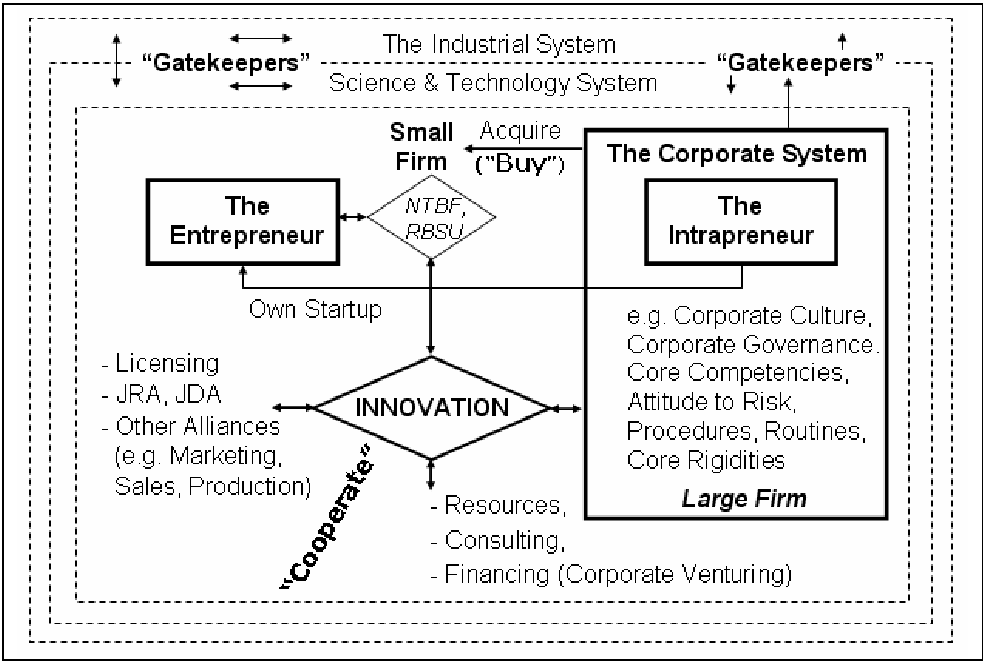


Figure I.20: Coupling of startups/NTBFs and large firms in a "networked economy of innovation."

As a final remark, what is seen to have developed in parallel to managerial capitalism in the US and UK over the last two decades is a shift from the "real economy" of the nation to the Financial System as a major contributor to national "wealth." In particular, it was many so-called "financial innovations" of the US and UK financial systems, characterized as *creating money out of money or out of air*, that contributed to the world-wide disaster of the Great Recession.

All this resembles alchemy with other means which ironically was the basis for the porcelain innovation in 1708 by two Germans, the at the time very famous scientist E. W. von Tschirnhaus and J. F. Böttger [Runge 2006:402-405]. Originally Böttger, an apothecary's boy and alchemist was "hired" by electoral prince Augustus II. of Saxony – in heavy need of money – as he was perceived to know how to make gold out of earth or soil or other worthless stuff.

Fundamentally, the capitalism was re-focused *from profit and cash flow to the "ability to pay"* ("solvency") – and a shift from investing to consumption and *financing debts by more debts*:

> "We've fallen into a trend of diverting and rewarding the best of our collective I.Q. to people doing financial engineering rather than engineering. These rocket scientists and engineers were designing complex financial instruments to make money out of money – rather than designing cars, phones, computers, teaching tools, Internet programs and medical equipment that could improve the lives and productivity of millions." [Friedman 2008]

And this line of describing the situation and effect for technology entrepreneurship in the US is followed by others. "It {the financial industry} has ballooned dramatically in size" and "As a result, most of our top math Ph.D.s were being pulled into nonproductive financial engineering instead of biotech research and fuel technology." [Zakaria 2008].

A letter from the head of the electrical engineering and computer science (EECS) department to the author of an article by Mitra [2009] said "MIT and all other institutions are losing applicants for their EECS programs, and the heads of these departments (one of the largest at MIT) are trying to figure out ways to convince young high school students that EECS is still a great choice for a major. As career prospects, they are offered *finance*, biology and energy. Jobs in these areas, the students agree, are not going offshore to India. Finance as one of the leading options for MIT's computer science graduates is one of the disturbing elements in the message. The other is the complete absence of the word entrepreneurship." "Why should MIT's leaders push their young into this world of unbridled, unadulterated greed, instead of grooming them to become innovators, builders, entrepreneurs, leaders?"

1.2.5 Innovation, Technology, Competition and Growth

The complaint about toughness of competition is often actually only a complaint about the lack of ideas.
Walther Rathenau (1867 - 1922)
President of the AEG Corporation and German Foreign Minister (1922)

Die Klage über die Schärfe des Wettbewerbs ist in Wirklichkeit meist nur eine Klage über den Mangel an Einfällen.

1.2.5.1 Innovation, Its Adoption and Technology Classes

Innovation and Invention

Innovation and entrepreneurship bringing up new firms are intimately related by the concept of *change* and associated with *competition, survival and growth*. Experience and theory tell that in the development and change of industries and their offerings *discontinuous* or *disruptive* changes of categories, such as technology, performance or value, occur repeatedly. In the literature the term discontinuous innovation is often used interchangeably with "disruptive innovation" or "radical innovation."

We shall differentiate types of innovation using a mathematical/physical reference (Figure I.21). In essence we deal with a *discontinuity* of *an otherwise continuous function* if, at a particular point (in time) or during a rather small interval (of width 2ε), a significant jump in an *observable value* occurs. In essence, we visualize *discontinuous innovation* as displacement of a continuously increasing function to a new range of value (Figure I.21). For the range of continuity, the function with increasing values represents an area of "*continuous improvement*" or "*incremental innovation*," respectively.

> In large firms incremental innovations prevail.
> But via "innovation accumulation" over time, many small improvements constitute a significant degree of innovation in a product.

A very simple example for a discontinuous pattern is given by the "Heaviside step function" Θ. The function Θ(x) (for x>0 and x<0) is used in the mathematics of *control theory* and *signal processing* to represent *a signal that switches* on at a specified time and stays switched on indefinitely. In this regard discontinuity can be compared with "phase transition" behavior of material in physics or chemistry where a property under observation changes "suddenly," for instance, for the transition from the solid to liquid phase by melting or the transition of a polymer from one state of order to a different state of order or total disorder (Table I.77, Figure I.137, Figure I.160).

On the other hand, we see *disruption* only in the context of two different value functions, for instance, for novelty and market value of product innovations (Figure I.159). Here, one constellation is totally replaced by another one, probably with a more or less significant overlap for coexistence of both. Our notion of a radical innovation does not allow a degree of radicalness!

We view “*disruptive innovation*” and “*radical innovation*” as interchangeable for something absolutely new (“new-to-the-world” performance features) to permit entire industries and markets to emerge, transform or disappear. A classical example is Hewlett-Packard’s HP35, which represented the world’s first hand-held scientific calculator and was the first product to combine both integrated circuits and “light emitting diodes” (LEDs). This first scientific calculator led to the obsolescence of the slide rule while creating a new industry.

Hence, we shall distinguish three types of innovation according to the type and level of (value) change

- Incremental innovation,
- Discontinuous innovation,
- Disruptive (“radical”) innovation.

Furthermore, we shall characterize innovations quantitatively as “*breakthrough innovations*.” Usually disruptive, but also discontinuous innovations can be associated with breakthrough values. Referring to the market place, for “breakthrough” one generally needs at least *an order of magnitude value added or improvement over current technology* at the systems level. There is no point in developing a technology if improvement will only be twice as good as the existing one, because conventional technology can mostly be tweaked (Figure I.22).

Change is measured on various scales. On the nominal one it represents a qualitative level (different, new; Figure I.21). The ordinal scale is comparative (better, cheaper, more specific). And on a difference scale, for practical quantifications, we characterize innovations as *breakthrough* for value increases according to the following measures:

- 5 – 10x (or >10x) value addition or performance improvement, or
- 30 – 50 percent (or >50%) reduction in cost.

Hence, both, *discontinuous and disruptive,* innovation may turn out as breakthrough innovations.

Disruptive innovation (“new-to-the-world”) means in *market value created*, not in technology! And we shall clearly distinguish “*market value*” from “*technical value*” (ch. 1.2.5.2). Disruptive (“radical”) innovation is expressed in terms of:

- The power to *change customer expectations (and excitement)*
  (new-to-the world performance features, perception of novelty and market adoption)
- Changing the *basis for competition* (“game change”)
- Generating *new industries* (“industry genesis”)
- The power to *change industry economics* (“breakthrough”).

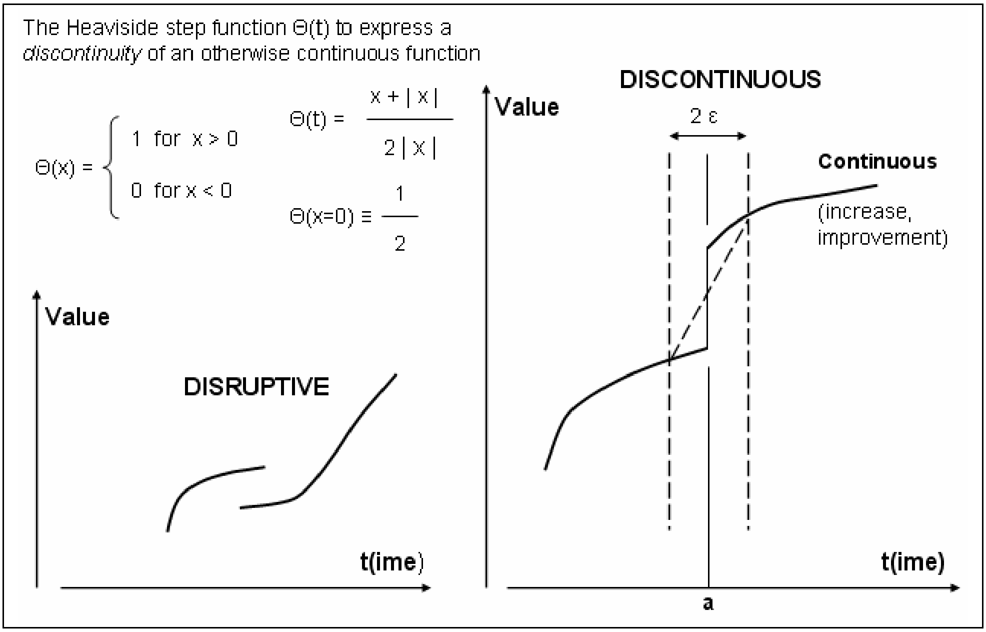
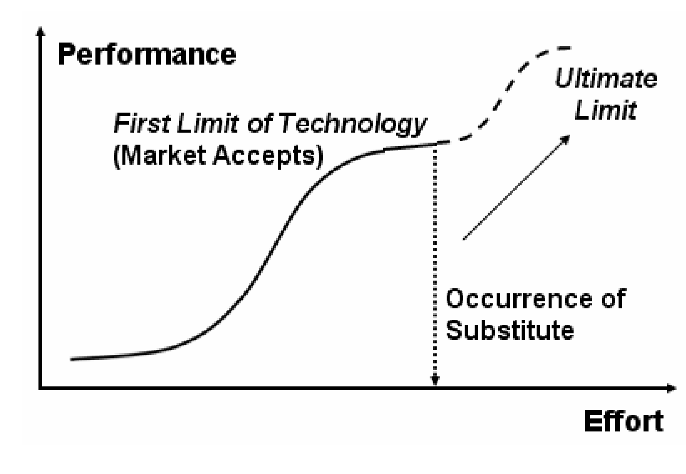


Figure I.21: Disruptive and discontinuous changes (after displacing the continuous change function) [Runge 2006:45].

As with entrepreneurship which means different things to different people, to allow a consistent treatment of “innovation” and “innovativeness” we follow the definitions of Runge [2006:18] as given in Table I.10.



Technology improves slowly at first because it is poorly understood.

Then accelerates as understanding increases.

Then tapers off as approaches reach a first limit in line with market acceptance.

New heavy efforts of incumbents push technology to its ultimate limit

Figure I.22: S-curves in technological improvement.

Table I.10: Operational definitions of innovation and invention and the related “innovativeness” characteristic [Runge 2006:18].

Notion	Generic	Commercial (Marketing)
Innovation	An innovation is an idea, practice or object *perceived* as new by an individual or other unit of *adoption* in a specific (geographical or sociological) domain or category	An innovation is an idea, practice, or object *perceived* as *new with a value* and *acquired* by an individual or other unit of *adoption* in a specific (geographical or sociological) domain
Invention	A new idea, practice, object or entity with the potential to provide value (“*impact value*,” in German Wirkwert; Figure I.31)	To have a new idea, practice or object for providing *anticipated value to customers*
	Innovator	**Adopter/Buyer**
Innovativeness	The power to capture ideas or opportunities or respond to “events” and commercialze value to customers time and again and again continually for years	Innovativeness is the degree to which an individual or other unit of adoption is relatively earlier in adopting novelty than other members of a social system

Hence:

> For entrepreneurship or intrapreneurship innovation and invention are different concepts for which invention may allow interconnections to be established to innovation by getting adopters of the invention who perceive a value to acquire it.

According to Table I.10 there is a path from invention to innovation via adoption and, hence, to entrepreneurship by “inventor-entrepreneurs.” Indeed, many inventors emerge also as entrepreneurs. America’s quintessential inventor-entrepreneur was perhaps Thomas A. Edison (1847-1931). For Germany Manfed von Ardenne (1907-1997; ch. 2.1.2.8) is a prominent example.

Innovativeness is an attribute for the innovator or adopter, respectively (Table I.10). The innovation graph, hence, is a special “*supply-demand relation*” with novelty and value creation attributes for a given constellation. The relation of innovativeness to measurable marketing aspects and monetary value is given by the definition of the American Marketing Association [Runge 2006:50].

Innovativeness (American Marketing Association Dictionary)**:**

Product Development Definition	**Consumer Behavior Definition**
When applied to a buyer, the extent to which that person or firm is willing to accept the risks of early purchase of an innovation.	A personality trait designed to account for the degree to which a consumer accepts and purchases new products and services.

To *measure innovativeness*, GEM asked entrepreneurs and business owners how they evaluate the newness of their product or service, the competition they face, and the novelty of their product or service technology. As this represents individual *entrepreneurs' perceptions* of their own situations, such assessments are inevitably context-specific, and they are likely to vary between countries [Bosma and Harding 2006].

In the above sense innovation is given as a "*result*" of a *binary relation* between innovator and adopter (or a supply-side and a demand-side). Part of this relation is a "*process*." Correspondingly, it embraces all the activities related to develop and commercialize a new product, service, or business system that derives from an idea or is a response to a demand or problem. This includes developing distinct new methods of conceiving, production, distribution or application of existing *offerings* as well as *reorganizing a company*.

Innovation for a new sociological domain may mean "new to a population of a given age range" or transferring something from purely corporate usage to private usage.

> Due to its characteristics of dealing with relations in the context of innovation (or business) one can (or shall) deal with possibly different perspectives of the innovator (supplier) and the adopter (customer) concerning value and novelty.

The aspect of "novelty" for adopters in a particular geographical region may mean that an offering which is well established for a considerable time in one country, say the US, and introduced in another country, say Germany, represents an innovation for the latter country. In a related line of arguments novelty and value may emerge for existing products, if only the design (layout) of an object is changed.

An invention can be protected legally by a (utility) patent. The emphasis can also be on legal protection of the design (layout) of the invention. A design patent protects the ornamental design, configuration, improved decorative appearance, or shape of an invention. This patent is appropriate when the basic product already exists in the marketplace and is not being improved upon in function but only in style.

According to our above definition (the utilization or adoption of change) *innovation is implemented* and accordingly one can look at several classes of innovation.

- *Offering innovation* (specifically product or service innovation): new offering put on sale;
- *Process innovation*: changing the way a given good/service is (technically) produced within the firm or across a value system;
- *Application innovation*: new applications/usages by not necessarily new products or processes;
- *Behavioral or organizational innovation*: changing individual behavior or activities or organizational processes or routines (business processes!) with new ones or changing modes of distributing or accessing an offering (cf. the value chain and value system, Figure I.7).

Product innovations can enable process innovations and vice versa. Process innovation focuses often on efficiency. For instance, in the context of CleanTech (Table I.52) "*energy efficiency*" is typically an incremental innovation. Furthermore, energy efficiency means addressing essentially existing markets and competition with existing products and competitors.

The categories for innovation help clarify how different innovations offer different opportunities (and pose different demands) on producers, customers, users and regulators (policy). Therefore, for technology innovation and entrepreneurship a further class is important.

- *Regulatory innovation*, which is induced by a demand or mandate of a legal or regulatory system imposed on the Economic System by (federal or state) policy and/or industry associations (standards and norms).

Regulatory innovation represents a special expression of what is called *sustainability innovation* in Germany [BMBF 2007]. **Sustainability innovation** by existing or new firms require [BMBF 2007]

new solutions (to environmental issues) which are

- economically successful,
- contribute to environmental protection and
- contribute to societal goals of sustainable development (and CSR – Corporate Social Responsibility).

Sustainability innovation is generally induced by

- Societal push (attitudes of population and policy)
- Regulatory push ("compliance requirements")
- Technology push.

It may be that for the implementation of a *technical innovation* an associated change of behavior, organizational structure or combination of resources is necessary even for the innovator (Figure I.23, firm). Such a circular relationship between innovator and adopter, hence, reflects the innovativeness of both parties.

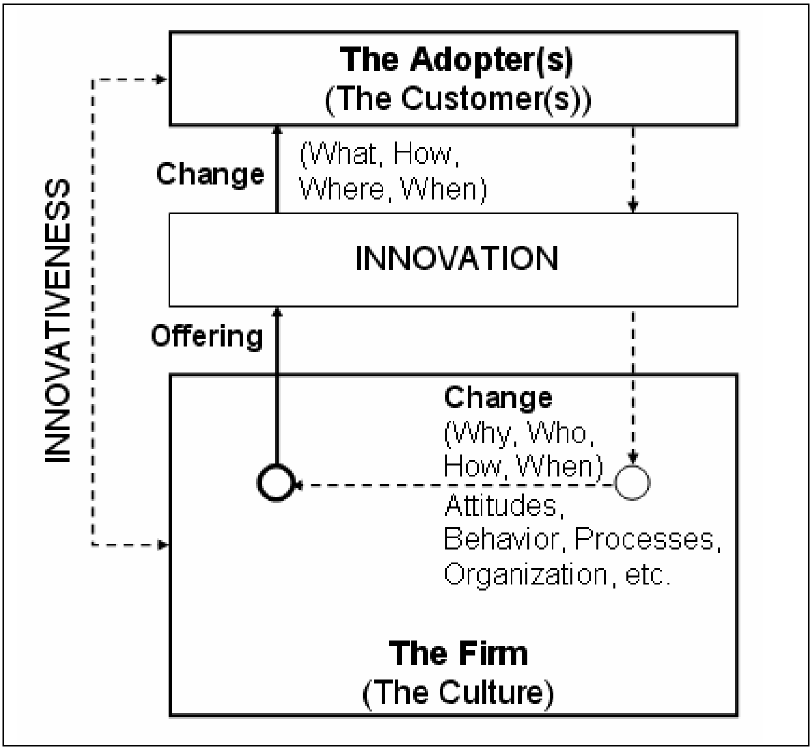


Figure I.23: Interconnections of innovativeness between the supplier of an innovative offering/application and its own innovativeness for behavioral/organizational change.

The association of innovation with a change of a value function is not necessarily confined to value of an offering for the innovator (supplier) and adopter (customer, buyer) of a particular *market with an explicit need*, but for additional domains of adoptions.

Hence, if we refer to the notion of "*market development*," the supplier changing the process to address an existing market by increasing the number of customers of the market responding to *"latent needs"* or initiating adoption of new or other uses of its offering by the customers, may fall under the notions of incremental or discontinuous innovation (shaded areas in Figure I.24, left).

Taking market share from others in a market is not innovation, but a *gain from competition*. It is a "*zero sum game*" – no change of the total value of the market – the sum of market shares of both the players is retained (Figure I.24, right).

As an important remark, in a competitive market having players with various market shares there may be an inherent opportunity. Rather than fighting only to gain market share from the competition a different question should be asked and adequately responded to: Why do not customers buy my product or my customers' products?

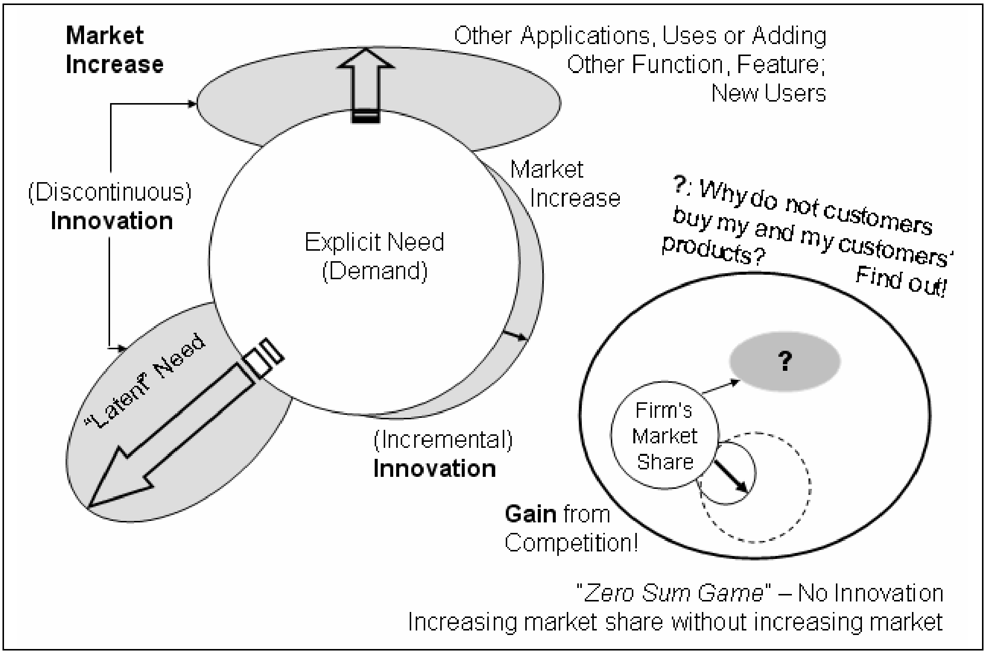


Figure I.24: Illustrating incremental and discontinuous marketing innovation for technology based firms.

According to the OECD [19] changes in organizational processes or customer behavior initiated by a firm is "marketing innovation." Using the OECD definition, for the technical area we regard **marketing innovation** as the implementation of a *new marketing method* involving significant changes in the overall value of the market, for instance, indicated by the number of additional customers. In special cases this may be achieved by offering a changed product design, product placement, promotion or pricing.

Marketing innovations are aimed at better addressing customers' explicit and implicit (latent) needs, or extending markets significantly or opening up new markets. The distinguishing feature of a firm's marketing innovation is the implementation of a marketing method not previously used by the firms in the given market or to create a new market.

But there is another case where marketing plays a key role for technical innovations. This is "*illusionary innovation*" (in German Scheininnovation). Illusionary innovation usually refers to (very high-priced) products pushed into the market for which it cannot be scientifically and reliably proved that they provide better (improved) performance or features with regard to the needs of the adopters (end-user) than products already existing in the market. An example is cholesterol-lowering drugs, for instance, achieving a value of 130 indicator units when there is no scientifically sound prove that this leads to a better cure compared to those products achieving values of 170-190 indicator units [Runge 2006:52-54]. Here, marketing is key to get the product into a “mediatorial market” (Table I.15).

Basically, firms allocate their limited resources between the two fundamental processes: **value creation**, for instance, innovating, producing, and delivering products to the market and **value appropriation**. While both value creation and value appropriation (“a deliberate act of acquisition of something”) are required for sustained competitive advantage, a firm has significant freedom in the extent to which it emphasizes one capability over the other.

The issue is monetizing innovation. Appropriation of value can mean: How are the benefits from innovation (overall value) distributed among different actors of a value system, such as

- Suppliers,
- Innovator (originator),
- Buyers/customers (and ultimately end-users; actors in the value system, Figure I.7, Figure I.11, Figure I.12),
- Imitators and other “followers.”

Value creation versus value appropriation is increasingly complex and fragmented in technological spaces. A technology venture that competes on the basis of value creation constantly moves ahead and innovates as competition erodes the profits from its previous initiatives. A firm that competes on the basis of value appropriation defends its position in the market against competition by erecting barriers to imitation through, “technical value” (ch. 1.2.5.2), for instance, barriers of intellectual property rights by sets of patents.

It is important to have a clear view of what value is created where, and the means to analyze and optimize. Innovators could build a model of the end-user benefit early in the phases of idea generation and revealing opportunity and then the development activities, continually checking out the validity of the model, and use this to optimize the offering as it evolves (Table I.78, Figure I.161).

Innovation must be differentiated from invention (Table I.10). The differentiator between both is “*value creation*.” Innovation refers to a binary relationship between supplier (innovator) and buyer (adopter, customer), whereas invention may be seen as a “unary” relationship (consisting of, or affecting, a single element or component) where “value” is generated primarily for the “inventor.”

An invention can lead to an innovation. It can have the potential to become an innovation under changed technical or market conditions. But, it needs not be utilized immediately to provide value; it has an “impact value” (Figure I.31).

For example, an “invention” legally protected and documented by a patent may not be used by the “inventor” at the time of publication or granting by the patent office. It may be used later directly by the inventor or commercialized later in terms of a transfer to a buyer or a provision as a license. This means *an inventor is different from an entrepreneur* though he/she may become an entrepreneur based on his invention – the "inventor-entrepreneur."

On the other hand, **discovery** describes a novel observation or finding of something already existing, often of a natural phenomenon or effect of a (natural) product. Usually this cannot be patented. For instance, phytochemistry seeks which of the billions of molecules in plants are active and can therefore form the basis for new medical treatments or serve as drug intermediates or candidates. Hence, the primary aim is discovery as a step towards innovation.

As the systemic approach to entrepreneurship focuses on human-activity relationships it is important to deal with and understand the perspectives of both parties' goals and intentions showing up in corresponding relationships, such as the usually different "give and take" perspectives of the

- Innovator (supplier) and adopter (customer) concerning the value of an innovation or product/service,
- Entrepreneur and investor concerning financing (ch. 1.2.7),
- Participants in alliances and cooperative settings, for instance, of a small firm (NTBF) and large firm (ch. 1.2.6.3; Figure I.51).

For instance, Figure I.25 shows the erroneous perspective of a supplier, how he/she perceives the value (immense cost reduction) offered to the customer. But the supplier is (probably) not aware of the customer's overall economics where the supplier's offer does not contribute at all to the customer's cost structure. If the spupplier had been aware of that fact the supplier could infer price elasticity and take advantage by asking for a higher price compared to that which was originally planned.

For technical innovation and technology entrepreneurship important "binding" binary relations are the different perspectives of innovator and adopter concerning *technical value* versus *market value* (ch. 1.2.5.2) and the coupling of technical and commercial competencies in technical entrepreneurs, technical businessmen/-women or the entrepreneurial pair (ch. 1.2.6.1, 2.1.2.5).

This aspect of perspectives is generally fundamental for applied general systems theory. It is the focus on *binary relations between entities*. Correspnding relations are either

- "*directed*" (mono-directional) reflecting, for instance, "teleological relations" (ch. 2.1.2.9, Figure I.78), value chain (Figure I.26) and value system (Figure I.7) or "command (control) – obedience" structures of interpersonal relations in organizations or

- "*binding*" (bi-directional, interactions) expressed in terms of "relative positions" – "distances" or perspectives which may be subjected to change in negotiations – or "binding strengths" in terms of particular means or factors of interactions, such as "social ties of families versus other groups" (social coupling, Figure I.71).

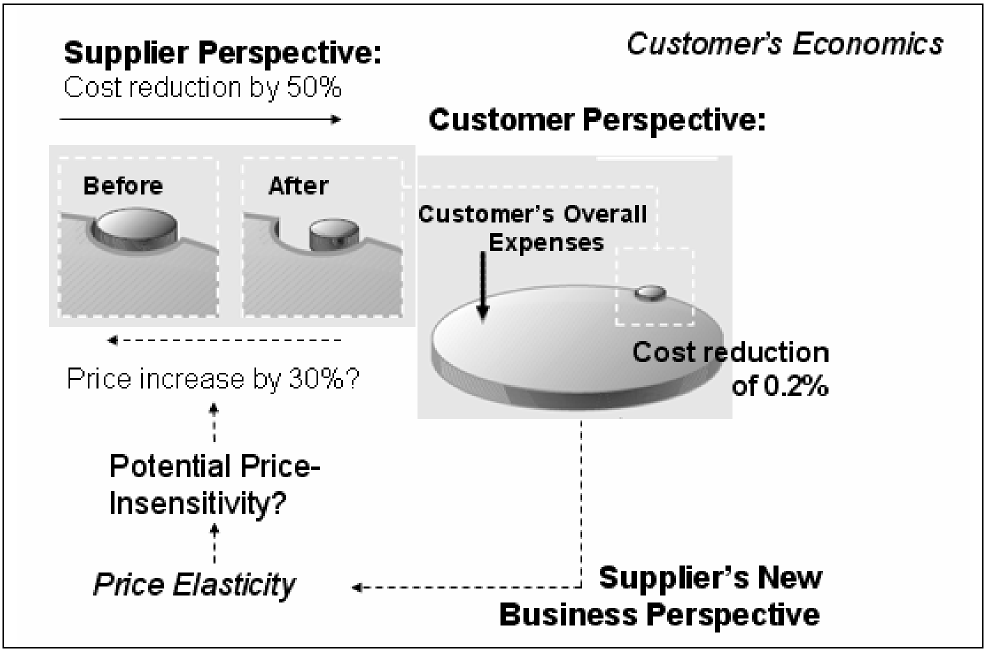


Figure I.25: Illustration of different perspectives of a supplier and a customer for a deal.

Innovation Adoption

Disregarding different activities of the value chain innovation can be represented as a *directed graph* (Figure I.26) interconnecting the innovator and adopter as the nodes (vertices) [Runge 2006:50]. If more actors are involved between innovator and adopter of a particular (innovative) offering, value creation proceeds in steps of a "value system" (Figure I.7). In this case one often also speaks, for instance, of a "supplier-to-customer value chain" which expresses the graph character, but may lead to confusion with the "value chain" concept.

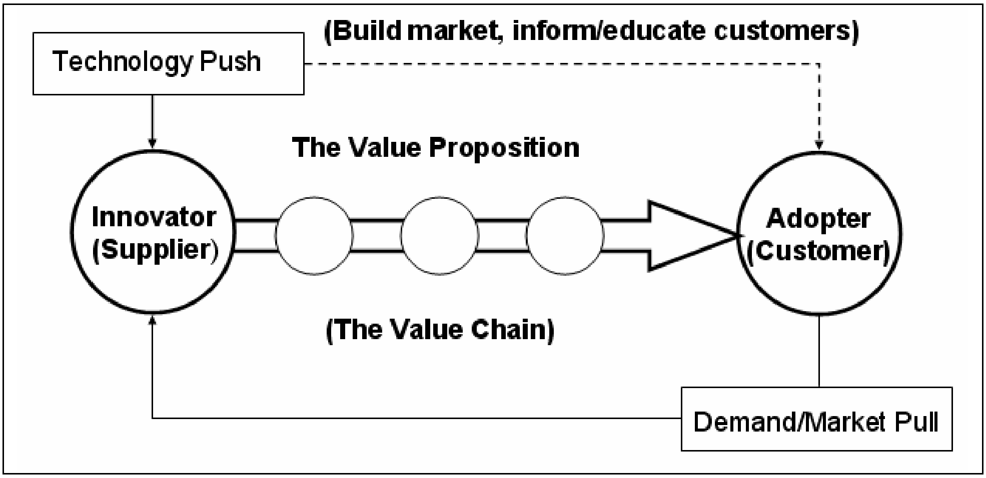


Figure I.26: Innovativeness, actors and the value proposition.

To address support and initiate adoption of the offering the supplier will rely on a **value proposition**, which is a statement how customer value will be created. And remember (Figure I.27), *value attributes belong to offerings* (Table I.3) *not to technology per se*! Technology is usually an input or a resource for conversion and creating an offering (Figure I.5) or a solution. Technology as an offering can occur directly only through an intangible offering (Table I.3), for instance, a license for a patent. The supplier-customer-relationship and value proposition contains implicitly an important aspect discussed above (Figure I.25):

> Suppliers and customers have usually different perspectives of value, which means for entrepreneurship the requirements of presentation and negotiation and having or learning presentation and negotiation skills – and selling.

Figure I.27: Offerings or solutions as the expression of technology to create market value.

For technology the initiation of innovation and revealing or creating opportunity can be expressed in demand or market terms (ch. 1.2.2) and in supply terms, which mean **demand/market pull** versus **technology push** [Runge 2006]. With regard to the innovation-oriented activities of a firm this represents an *outside-in* versus an *inside-out approach*. Usually large firms follow both these approaches.

Many cross-industry studies have shown that innovation stimulated by market needs or technical opportunities (demand pull versus technology push) show a rather constant proportion of about 70:30 [Runge 2006:759]. An expression of market pull will be described for the class of German firms called Hidden Champions (ch. 4.1.1). Currently, innovation and entrepreneurship in bio- and nanotechnology follow largely technology push (they are *science-driven*).

If, for the technology push approach, a “Holy Grail” is achieved there is rarely a need for a value proposition to catch adopters. A **Holy Grail** is a great and unsolved challenge in an industry or a scientific discipline.

For the industry environment researchers having achieved a Holy Grail know from the beginning that they are addressing large markets and do not feel compelled to answer any customer related or market size question by detailed figures. On the other hand, achieving a Holy Grail in science does not necessarily translates into large market demand (as the case of SiGNa Chemistry (B.2) shows).

Except for rather simple technologies adoption of technical offerings is initially slow because the technology is unfamiliar. It accelerates as technology becomes better understood. It may also be that the market is saturated and the rate of new adoptions declines.

Technologies often improve faster than customer requirements demand and technology adoption tends to take far longer than diffusion of related information. This enables low-end technologies to eventually meet the needs of a mass market.

Particular customers will adopt an innovation earlier than others based on various perception and criteria for benefit and utility and risk (Table I.10, innovativeness). The spread through a population of potential adopters is **innovation diffusion** and the *cumulative* percentage of adoption follows essential an S-shaped curve [Tidd et al. 2001:188].

It should be noted that in many cases innovations may require refinement over several years before the offering attains commercial viability and grows. Continuous improvements and refinements of features may be a hallmark of the industry. The developments aim at a dominant design (ch. 3.3).

Dominant Design means that, after a technical innovation and a subsequent era of digestion and progressive developments in an industry, a basic architecture of a product or process becomes the accepted market standard. Dominant designs may not be better than alternatives or be particularly innovative. They have the benchmark features to which subsequent designs are compared (Figure I.100).

For fundamental technical innovation the formation of the corresponding shape of innovation diffusion may take a rather long time as visualized for selected basis innovations in Figure I.28. Radio, telephone and TV come closest to the ideal curve shape.

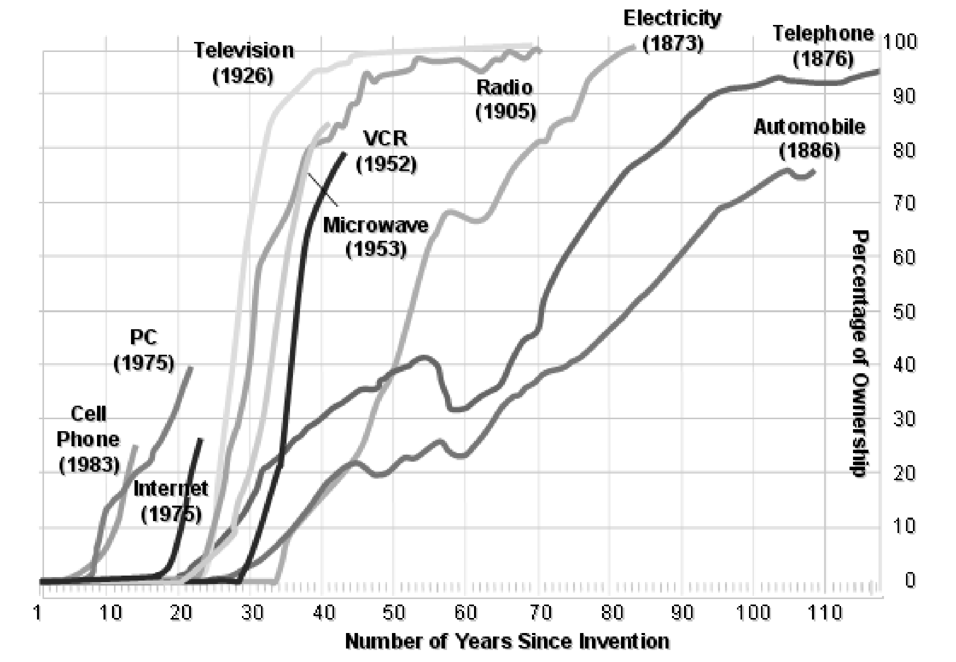


Figure I.28: Adoption curves for selected fundamental technical innovations [Aulet 2006] (VCR – videocassette recorder).

The traditional marketing approach differentiates five adopter categories irrespective of some weaknesses, especially considering that technology entrepreneurship does not only relate to consumers, but in the top/high technology fields largely relate to industrial and professional customers (ch. 1.2.5.3). The classification of the members of a social system on the basis of their innovativeness is as follows [Tidd et al. 2001:185; Dorf and Byers 2007:261-267]:

- Innovators,
- Early adopters,
- Early majority,
- Late majority,
- Laggards.

Innovation adoption ("innovation diffusion") on the individual level with regard to the time dimension usually follows a bell-shape curve with a characteristic distribution of related adopter types (Figure I.29).

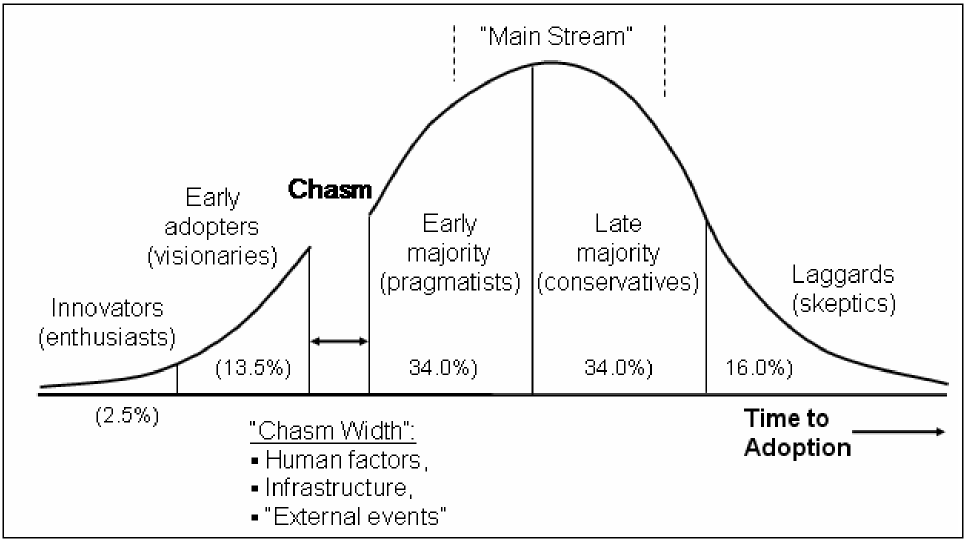


Figure I.29: Innovation adoption with barriers and its macro-description by Geoffrey Moore's Chasm Model.

Often the explanation of the length of the diffusion period of an innovation, say from 10 percent to 90 percent of potential adopters, does not proceed smoothly. To account for this situation Moore suggested a model focusing on a discontinuity for the transition from adoption by early adopters to early majority of adoption and called this the "*chasm*" [Dorf and Byers 2007:263].

The chasm period can be related to "human factors," such as the customers' values or the offering's complexity, unfamiliarity with usage or risk-taking by customers (ch. 4.2.1.1), but also objective factors. It can result from lack of a corresponding infrastructure. For instance, one of the drawbacks of hydrogen based fuel-cell driven cars or trucks is the lack of corresponding hydrogen filling stations or for electric battery-driven electric cars the lack of battery recharging stations providing standardized fast recharging facilities.

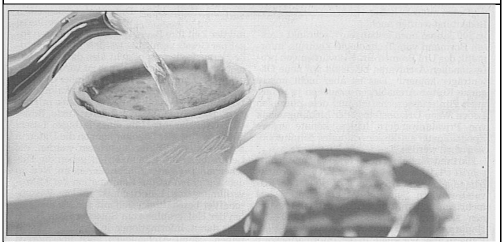
Chasm can also occur through significant external events. For instance, the early rush to Nylon stockings (and other textiles) was interrupted by World War II and the demand of military for Nylon for other uses, such as parachutes [Runge 2006:417]. Furthermore, the dip in the curve retarding adoption may also be induced by an economic crisis. For instance, the Great Depression in the 1930s may have exerted a negative effect on telephone adoption (Figure I.28).

Concerning human factors Dorf & Byers [2007:270] describe, for instance, how the US firm AgraQuest offering biopesticides has to overcome a chasm of pragmatic farmers using chemical pesticides to adopt the new product or tools. If human factors determine the chasm, training and user education may lower acceptance barriers and speed up innovation adoption. For instance, Table I.11 exhibits the fundamental approach used a century ago. In our times, NTBFs use workshops, seminars and in-house training (WITec GmbH, Nanopool GmbH, B.2) or tutorials on the Web (JPK Instruments AG, B.2).

Table I.11: User education and training to cross the chasm of innovation adoption.

<table>
<tr>
<td>German Melitta Group®:
A family firm;
Founded 1908,
Revenue 2010: €1.3 billion</td>
<td rowspan="2">Crossing the Chasm –
User Education and Training:

Melitta shows, how to filter good coffee …


</td>
</tr>
<tr>
<td>
1908 Story:
Problem (opportunity): have coffee free of grounds
Solution: German housewife Melitta Bentz invents the first usable filter for preparing grounds-free coffee (she experimented with blotting-paper and perforated cans)
First usable filter for preparing grounds-free coffee received protection as a registered utility model for “coffee filter with curved and indented bottom and slanting extraction holes,” together with its corresponding “filtration paper”
Melitta Bentz also received a patent for the above-mentioned “coffee filter”</td>
</tr>
</table>

One should be aware, however, that an apparent discontinuity of the adoption pace is not necessarily related to a chasm whose model is based on a given type of customers. We encountered an outburst of demand for PC-printers when developments achieved to bring their uses from professional users (in the office) to the homes of consumers. This represents an overlay of a second, behavioral innovation (the change to a new group of potential customers) sprouting out of the original innovation (Figure I.24).

Shifting applications from one user domain into another one often means (big) opportunities, such as shifting mainframe computers to personal computers, printing and scanning from the professional office environments to the home of consumers or shifting bulk wind turbines from industrial wind parks to professional use by public or commercial organizations and their facilities or ultimately to the homes (Table I.60; Quiet Revolution, Ltd.; B.2).

A chasm situation related to cognitive barriers can be illustrated for the case of automobiles by statements of Carl Benz or Gottlieb Daimler: “Due to the restricted availability of chauffeurs there will never be more than 5,000 automobiles” – “Global demand for motor vehicle will not exceed one million – simply due to the lack of available chauffeurs.” [20]

This reflects retardation of thinking based on extrapolation of past experience concerning mobility and transportation to a new technology: Previous mobility was based on stagecoaches (or carriages) with a (professional) postilion or driver (coachman) of a horse-drawn coach (Figure I.30).

Figure I.30: Chauffeur of an electric car (1904), with the chauffeur on top (from note 53).

A chasm represents a particular challenge for technology push situations. Related to human factors it includes personal and social but also financial (price) aspects. Complexity of technology-based products often requires *educating and training users*, but not always.

> Technology entrepreneurs often tend to spend too much time creating high-tech offerings (products or services) and too little figuring out how to get people to use them.

In particular, for innovation and entrepreneurship on the global level chasm is an issue of *technology adaptation, innovation diffusion* and *appropriateness*. The same technological solution rarely is optimal everywhere. The value of an innovation depends on socio-economic, cultural, regional, and ecological specifics (for instance, climate). Important innovative activities may have to adapt technological solutions to specific conditions.

Export of technologies across regions without adaptation may even lead to negative environmental side effects and waste. A technology may have several versions or extensions to meet needs and capabilities of users in various regions, for instance, the developed Western World versus (developed) Japan versus (developing) China. Typical examples may refer to outdoor paint and coatings in the very humid climate of South East Asia versus the dry climate of Australia with very aggressive UV radiation of the sun or the preferences of colors for automobiles in Germany versus China.

Much effort has been oriented towards identifying which factors influence the rate and extent of adopting an innovation [Tidd et al. 2001:185-194]. Quantifications use statistical or sociological models of the "*diffusion of innovation*." When both technologies and markets are complex, innovation diffusion depends essentially on the nature of the innovation, the characteristics of the potential adopters and processes of communication and learning.

The rate of diffusion of an innovation can be measured, for instance, with respect to the percentage of firms that have adopted the innovation, or with respect to the percentage of total output accounted for by the innovation.

Basically, Tidd et al. [2001:185] present an overview of the characteristics of an innovation affecting diffusion. Classification criteria for adoption include:

- Relative advantage;
- Compatibility;
- Complexity;
- Trialability ("first try, then buy");
- Observability.

A final remark concerning technology or innovation adoption concerns *skepticism* characterizing an innovative offering as "too good to be true" meaning, the view that something so seemingly fine must have something wrong with it, is too positive to be real or believable. German NTBF Nanopool GmbH, for instance, encountered such an assessments for its surface coatings technology based on "liquid glass."

"These treatments have been created in order to satisfy the demand for self cleaning and easy clean surfaces which possess background bacterio-static effects. It may sound as though it is too good to be true but extensive independent testing confirms the exceptional characteristics of the products." (Reference 9 in [Runge 2010]).

Similar problems were encountered by the NTBFs SkySails (B.2, German, Figure I.103) and US Kiteship when promising that their innovative wind propulsion technology to be added to cargo (Diesel engine) vessels would save oil fuel consumption by ca. 15 percent or 10–35 percent depending on wind.

"One of the biggest hurdles in getting major shipping companies to take them seriously is the sheer audacity of the fuel savings they're claiming. Shipping companies said, If you promised us a 2 or 3 percent reduction we'd believe you, but your promise is 10 to 15 percent, and we just don't believe it's that good."

Technology Classes

For technological innovations technologies can be broadly differentiated. An "*object-oriented technology"* is one to produce a fixed object, like steel, an instrument or an automobile. Objects or things to be produced do not change radically by innovation. Essentially their performance characteristics do.

A "function-oriented technology" is to produce something with a fixed or targeted function, like a chemical or material to provide a certain reaction or performance or computer software to provide a certain information processing function. In this last type of technology, innovation may introduce a radically different object or thing to perform the function better.

The products, for instance, of the chemical industry, are usually purchased because they have the required properties which make them suitable for some particular *application*, for instance, a non-stick coating for pans or water-repellency of textiles or a weed-killer. Thus *chemicals are ultimately sold for the effects that they produce*. The function of the material often includes *several dimensions*. For instance, paints or coatings have *protective* (inhibit damages) and *decorative* aspects (colors, feelings and "touches").

A more detailed classification of technology [Runge 2006:621-623] is useful for the developer (entrepreneur) with regard to current or future characteristics of related offerings (Table I.12,), particularly concerning functions, applications and performance characteristics, opportunities or threats (Table I.51), status and finally, whether they can be codified and documented.

For instance, using the classification into base, key and pacing technologies allows a firm to structure its product portfolio and in this way to establish corresponding *resource allocations* to higher value key technology projects ("winner technologies") rather than low value base technology projects.

Concerning technology as a means to an end "generic technologies" provide a substitution potential for existing offerings and represents a "many-to-one" relationship. On the other hand, the notion "*platform technology*" represents the "one-to-many" case (one technology to more than one product or one individual product to several different markets). In so far a platform technology provides a basis for "*economies of scope*" (ch. 4.3.5.2).

Table I.12: Types of technology, their characteristics and some implications.

Technology Type	Explanation and Comments
Base Characteristics: General competency; Price-based competition	A set of technologies, usually associated with a set of standards, that are used by an industry or industry segment and which does not *per se* provides a competitive advantage for a firm; base technology is available externally. Usually company staff job descriptions define basic technology as understanding and use requirements.
Key Characteristics: Specific competency; Competitive advantage	A crucial element in the research and innovation process. It may involve the creation of fundamentally new capabilities (developing, designing, manufacturing and evaluating properties) in areas perceived as value creating currently or in the future, such as nanotechnology. It may lead to competitive advantage and differentiation.
Platform Characteristics: One technology, many applications, products, markets	It is a general-purpose technology that enables a family of options, the basis for "technology exploitation strategies." A "platform technology" allows more than one product to be developed or developing one product for several markets or applications. A "platform" allows achieving customer diversity and product multiplication and being economically at it, with limited marginal investments in comparison to competitors with no such advantages. The assets forming the platform are threefold: technologies, brands and delivery infrastructure.
Generic Characteristics: One function – many technologies	It is defined with regard to an end, a particular product, process or system, and therefore allows implementation through different technologies. For instance, membranes or ion exchange resin technology may be used for *water treatment* or using nails or screws versus adhesives may be used for "*fastening*" parts, batteries or fuel cells for *mobile energy provision*. Generic technologies may also refer to different input to obtain the same product (e.g. biobased versus petrochemical input). They are usually competitive as they are associated with different cost structures and may substitute each other.

Enabling Characteristics: New functions for existing products; A required piece of technology for a specific other one	A subset of technologies which is essential for a specific phase of science, product or process development, or manufacturing. Chemical analysis is a critically important enabling technology. Biotechnology is an enabling technology for the conversion of biomass to bioproducts, biomaterials or bioenergy. Computational fluid dynamics (CFD) is enabling for process modeling, simulation, operations optimization and control.
Enhancing Characteristics: Improving performance for an existing offering	Focusing on only incremental shifts in product performance of existing materials; for instance, chemical nanotechnology may occur as only an “enhancing technology” for coatings or chemical-mechanical planarization (CMP) for the polishing process.
Pacing Characteristics: A piece of technology that determines the function of another technology and/or determines the rate of implementing another technology	A technological area which represents a limiting factor (step) in the progress of a particular program (project or innovation). Pacing technology may currently be not available or applied but can potentially “change the game.” Currently lignocellulose feedstock (LCF) conversion is pacing for a biobased chemical industry (A.1.1) For separation technology filtration and centrifugation are key technologies, membranes/reverse osmosis are pacing technologies. Pacing means technology development-determining or rate-determining; also with regard to scale-up or material processing technology (in German Schrittmachertechnologie)
Emerging Characteristics: An important future technology	A technology anticipated (or proven) to grow and expand and become important and valuable for an industry or industry segment (for instance, fuel cells for vehicles)

Table I.12, continued.

Technology Type	Explanation and Comments
Tacit Characteristics: Bound to people ("in the heads of people")	Practical knowledge, techniques and experience of *people* which is neither documented nor codified; in particular, it is not patent protected. In the absence of strong intellectual property rights tacit technologies provide a more durable source of competitive advantage than those that can be easily codified (e.g. trade secrets)

1.2.5.2 Aspects and Perspectives of Value

Generally, value is viewed as the worth, importance/relevance or usefulness (utility). In business, *value* refers to the worth in *monetary terms* of the *social and economic benefits* a customer pays for an offering (with or without service). With regard to most *technology-based products* value is initially focused on *functionality and/or performance*.

Value is what you get in exchange and can be "objectively" assessed against an equivalent offering and what you get you subjectively attribute value to. In assessing the value of a product the customer perspective of value includes several dimensions given in Table I.13 – and including value perspectives of consumer goods or services.

Table I.13: Value perspectives of customers concerning a product ([Dorf and Byers 2007:64-65] modified).

Product	Performance, quality, features, consistency, safe, self-explanatory, easy to use, selection (version), brand, disposal; references and reviews
Price	Fair, visible/transparent, reasonable, consistent
Access	Convenient, location, nearby/at-hand, easy to find – in a reasonable time
Service	Ordering, delivery, return, warranty, after sales service, technical service, responsiveness
Experience	Intimacy, respect, emotion, excitement, fun (Box I.16); experience with supplier

In economics the concept of utility is usually related to consumers to explain economic behavior in terms of attempts to increase one's utility. And, hence, it is not meaningful to use related concepts generally in an area where professional and industrial customers preponderate.

Utility is an abstract concept. The units to which one assigns an "amount" of utility, therefore, are arbitrary, representing *a relative value. Total utility is the aggregate sum of satisfaction or benefit that an individual gains from consuming a given amount of goods or services in an economy*. The amount of a person's total utility corresponds to the person's level of consumption.

For a to-be entrepreneur another value perspective may emerge. Due to scarcity of resources (ch. 1.2.1; Figure I.7) and allocating resources for entrepreneurship the notion of opportunity cost can play a crucial part in ensuring that scarce resources are used efficiently. **Opportunity cost** is the cost we have when we give up something to get something else. There can be many alternatives that we give up to get something else, but the *opportunity cost of a decision is the most desirable alternative we give up to get what we want*. Consideration of opportunity cost may enter the decision-making of becoming an entrepreneur when "income" as a firm's owner is compared with income as an employee of an existing firm.

For value and valuation in business situations GST emphasizes the character of value to express a relation, the perspective of parties (Figure I.25). Basically, **exchange value** refers to an item or service produced for and sold on a market. Usually, exchange value, is the result of subjective value judgements. Other aspects are use value (utility) and price. [21] If the exchange value is attributed only to money value corresponds to price. In trading processes and markets according to US investor legend Warren Buffet:

> "Price is what you pay, value is what you get."

The customer's perspective of what he or she gets is a "*perceived value*." It is a customer's opinion or assessment of an offering's value to him or her. It depends on the offering's ability to satisfy his or her needs or requirements, helping to solve a problem, providing a solution, giving results or providing excitement. This applies to both tangibles and intangibles.

As we deal with tangibles and intangibles or tangible and intangible assets and mentioned that in-licensing and out-licensing represent important aspects for innovation and technology entrepreneurship (Table I.3, Table I.8) it is worthwhile to inquire further into the value concept (Figure I.31) in the context of GST.

For instance, NTBFs and RBSUs particularly from biotechnology and nanotechnology are often founded on the basis of technology licensed from a university or (public) research institute via corresponding "technology transfer units" (Table I.20) or rely for their business model on out-licensing their technologies (A.1.1; Figure I.183). For large firms making money by out-licensing may become a significant source of revenue [Runge 2006:662, 673-678].

Instead of not losing value over time and keeping value intangible assets may even increase over time. An example is experience related to the *learning curve* (ch. 1.2.3).

In this regard one is led to differentiate two fundamental concepts, exchange value and **sharing value** (in German Mitteilungswert). The expression “sharing value” as contrasted to exchange value denotes a value category rather than the process of sharing value(s). Furthermore, one should note that tangibles usually lose value through usage or over time whereas intangibles do not lose value through usage, they “age” (Figure I.31).

Two primary forms of intangibles can be differentiated in Table I.8 – *legal intangibles* (such as patents, trade secrets, designs, copyrights, trademarks) and *organizational intangibles* (such as various forms of knowledge and intelligence, decision-making, structural activities and systems of activities, including coordination, cooperative activities, leverage activities etc.) or the firm’s relationships with its environment, such as supplier or customer relationships and cooperative activities.

Competitive intangibles impact effectiveness, productivity, and opportunity costs within an organization – and therefore expenses, revenues, customer service or satisfaction, market value, and share price. Human capital is assumed to be the primary source of competitive intangibles for organizations today. [22] Intangible assets usually have an **impact value** (in German “Wirkwert”) and may provide competitive advantage.

Recently, in the context of online games (ch. 3.4), a suggestion has emerged focusing on monetization of “virtual goods” which exhibit a relationship to impact value (Box I.16).

The exchange and sharing value categories differ by several dimensions. The first refers to the character of the business process as a relation including transfer. The exchange value is associated with a *bidirectional transfer* of either assets (or its monetary equivalents) as well as property rights in the sense of law, such as patent swaps. In trading businesses sharing value is essentially related to *content* (knowledge, etc.) or/and *learnables* (behavior, training, change management, “best practice” etc.). In our context sharing value is associated with only a *monodirectional transfer of rights* concerning intangible assets. Actually “transfer” is a misleading notion here.

Sharing means, in reality there is no transfer of “entities” (information, knowledge or practice) from a source (origin) to a target; the “entity” is still with the source. For instance, in a license business the know how for a process is still with the licensor and shared with one or more licensees. The intangible becomes a communality.

Generally, in trading situations sharing value depends on the “sharing ratio” which is the proportion with how many customers a “supplier” shares the offering. The larger the number of customers the “entity” is shared with the less is the sharing value. For instance, if a *license* is only provided to one licensee (1:1 trading) this *exclusivity* will exhibit the highest sharing value (Figure I.31).

Valuation is usually against monetary terms or using monetary terms as an intermediate, a gauge. The last case occurs usually for *cross-licensing* ("patent swaps") between firms. And sharing intangibles may even be reflexive among the partners. An example is "*reciprocal technology sharing*" which is "grant-back" any improvements made to the technology and perhaps also development testing by the licensee to the licensor.

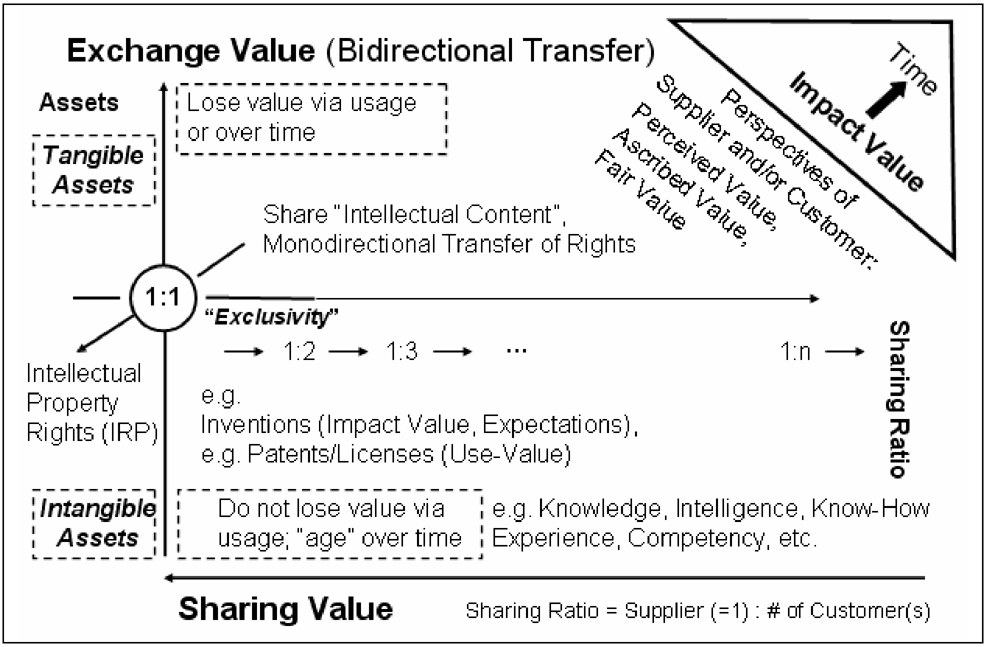


Figure I.31: Special aspects of value.

Sharing value exhibits several aspects of time dependency. Generally, for patents, for instance, referring to legal protection time, early-term patents (and related licenses) are generally more valuable than those that have been in force beyond a few years, and certainly more valuable than those which are beyond their midpoint.

On the other hand, attributing (monetary) value to intangibles, for instance, brand or patent valuations, shows context and time dimensions and is extremely complex. This is particularly true for inventions (patents for licensing). Hence, technology startups relying heavily on an out-license business may have serious problems with income forecasts!

Patent valuation does not reach a broadly accepted practical usefulness. This is, on the one hand, due to innumerable special situations and considerations under which a patent or patents may need to be evaluated. These can range from the need to set value for a licensing arrangement or due diligence for merger and acquisition (M&A) or for an IPO (see below). On the other hand, one needs to assess appropriate qualitative value dimensions of the asset (composite valuation) for the particular time and context of valuation related to the licensing case (Table I.14). There are three popular approaches of patent valuation 1) cost, 2) the market, 3) the income (reward) of the licensor and licensee.

As a complement to the notion “perceived value” which we refer to individuals we introduce the notion “**ascribed value**” as a systemic category which is generated by consensus or common interests and behavior of a social group in attributing value. It refers usally to valuating or perceiving value of a current situation or object and the expectation that it will provide future socio-economic benefit. Value attributes are often using a binary scale (for instance, worth – unworth; in German wert – unwert) or an ordinal (comparative) scale.

But cognitive biases may even provide ascribed value on the ratio measurement scale (ch. 1.2.1). Ascribed value may lead to have strong anomalous effects in the aggregate if there is social contagion of ideas and emotions (causing collective euphoria or fear) leading to phenomena such as *herding* which describes how individuals in a group can act together without planned direction. The term pertains specifically to the human conduct during activities such as setting firm’s stock value, stock market bubbles and crashes, street demonstrations, sporting events, but also everyday decision-making, judgment and opinion-forming. [23]

Ascribed value may become **market capitalization** of a firm, for instance, induced by an Initial Public Offering (IPO) at a stock exchange. According to Wikipedia, market capitalization is *a measurement of the value of the ownership interest* that shareholders hold in a business enterprise. It is equal to the share price times the number of shares outstanding (shares that have been authorized, issued, and purchased by investors) of a publicly traded company.

Under ideal conditions market capitalization represents a public consensus on the value of a company’s equity. But it is possible for stock markets to get caught up in an economic bubble, like the steep rise in valuation of technology stocks leading to the Dot-Com Crash in 2000. Hype can affect any asset class. It rises disproportionately to what many people would consider the fundamental value of the assets in question.

It took the 2011 IPO of LinkedIn (B.2), a professional social networking site, to ignite stock market enthusiasm for the latest generation of US Internet listings (ch. 3.4.2.1).

For instance, in May 2011 shares of US firm LinkedIn (founded in 2003), which operates a professional social network site, opened at $83 on the New York Stock Exchange, up 84 percent from its IPO price of $45. By the market’s 4 p.m. close, the stock had soared 109 percent to $94.25.

At the end of the day, LinkedIn was worth $8.9 billion – despite after years of losses, LinkedIn squeezed out just a modest profit of $15.4 million in 2010. That means, at $8.9 billion its market capitalization was 578 times 2010 profit. In an interview, LinkedIn Chief Executive Jeff Weiner played down the significance of the IPO's surge. "This isn't necessarily indicative of anything," he said. "The market will do what it will do." (ch. 3.4.2.1; LinkedIn Corp., B.2)

And the IPO of US firm Groupon in November 2011 (ch. 3.4) focused the discussion on the Internet as a "*platform for technology speculation*" (ch. 3.4).

Table I.14: Valuation parameters for intangible assets exemplified for patent licensing.

The valuation approach must be in line with the purpose of valuation	
Characteristics of the *invention*, like Type of technology, Type and function of patent and constellation (single or patent family member), Relation to state-of-the art, Development stage in relation to commercialization.	Type of license, like All versus selected patent claims, Exclusivity versus non-exclusivity, Result of licensing – payments (cash) versus transfer of ownership (equity), Cross-licensing, Reciprocal technology sharing.
Characteristics of the *licensor*, like Firm features – industry, size, legal status (public or for-profit), Firm's goal with licensing – strategy and/or income, type of license, market and region, Single patent or part of a "cluster," Cost of getting and keeping the patent.	Commercial situation, like Competitive situation, Market and sales potential, Expected profit of licensee, Expected increase of know-how and further exploitation of licensee, Lost opportunities of licensor.
Characteristics of the *licensee*, like Firm features – industry, size, legal status (public or for-profit), Firm's goal with licensing (strategy and/or income, type of license, market and region, If applicable, role of the licensed patent for the firm's patents, substitution of an "old" one, Options to further develop licensed technology.	Existing industry practice, like Intensity of licensing, Typical cost of licensing a similar patent, Typical contribution of licenses to profit of licensor.

Technical and Market Value

In the context of technical innovation it is important to *differentiate market and technical value* [Runge 2006:613]. **Market value** comprises the degree to which a real customer *perceives the need* for the company's product (offering) and after a cost/benefit assessment pays the product price to purchase it. On the same level the *demand value* expresses a real demand – the total of what everybody in a particular market wants. This may disregard price setting independently from any market influences (price insensitivity), as is often the case for products or services purchased by military or other governmental organizations for political reasons.

Technical value provides *different perspectives* for producer/supplier and customer. To the customer technical value is measured by meeting or exceeding design specifications expressed by the price the customer accepts to pay. The customer simply expects the offering (product, process, system) to work right every time.

To the supplier or producer technical value is measured by how *protectable from the competition* the product is or how *exploitable* the product is as a basis for further offerings, for instance, based on a platform technology. Technical value, for instance, comprises

- Patents,
- Know-how,
- Lower cost of manufacturing,
- Synergy with other products,
- Related service that can be provided,
- Product switching cost (cf. Figure I.94 and below text) with the customer,
- Imitation barriers (for instance, complexity of a product).

Market value and technical value may not match at all. Both have critical time periods and constellations, the W*indow of Opportunity*, which must match to make an innovation or market entry successful.

Technology entrepreneurship is about

- value creation and
- value capture (appropriation)

based on science and technology with three associated questions:

- Concerning value creation, how does the scientific idea or technology create *protectable* technical and market value?
- Concerning value appropriation, can we capture the market value inherent in this idea and/or technology *in the face of competition* and can we increase value by participating in further steps of the value system (ch. 1.2.5.1)?
- How can we create and keep *competitive advantages*?

1.2.5.3 Industry, Markets, Growth and Competition

Technology or innovation diffusion proceeds into various systems (Figure I.13), for instance, into a particular industry or an industry segment or even an overlap between different industries or industry segments. An **industry** is a general term to describe a group of firms or businesses doing similar things. The petroleum industry works mainly with oil and gas, although one could say the fossil fuels industry includes the companies working with petroleum, natural gas, and coal. *Industry legitimacy* has to do with the degree to which the products and services offered by organizations in a given industry are accepted as appropriate and useful by broader publics. *Industry norms* and rules define what kinds of economic behavior are appropriate and socially acceptable.

There are often no clearcut differentiations between industries. Overlap occurs by co-evolutionary developments without giving rise to a particular label identifying the contributing segments by name, such as cosmeceuticals or nutraceuticals originating with cosmetics or nutrition industries combined with pharmaceuticals and health care (Figure I.91). One of the most complex industries in this regard is the chemical industry [Runge 2006].

Rather than focusing on offerings (products, services) one can also refer to another view of an industry focusing on substituting offerings: Generically, an industry describes a group of firms or businesses *doing functionally equivalent things*. Runge [2006:29, 256] describes the example of the "*fastening industry*" which comprises principally mechanical fasting by nails, screws, etc. as well as chemical fastening by adhesives.

He cites the US firm Closure Medical [Runge 2006:39,98-103] as well as the German Hidden Champion Würth GmbH (ch. 4.1.1; Box I.23; [Runge 2006:256-258]) which is a ca. €8.6 billion (in 2010) firm. The core business of the Würth Group is the *worldwide sale* of fixing and assembly materials, including screws, screw accessories, dowels and plugs, chemical products (adhesives), furniture and construction fittings, tools, and stock keeping and picking systems. Closure Medical develops, commercializes and manufactures several medical cohesive products based on its proprietary and patented cyanoacrylate adhesives technology. It emerged as a very serious threat for players in the conventional stitches and suture market as a generic technology to *affect stitches as the primary method of suturing wounds*.

Technology-based industries either rely on creating technology and related offerings (Table I.3), particularly relying on research and development activities, or on utilizing existing technologies to create products and services which are offered in a market.

For entrepreneurs the primary domain entering commercial reality is the market. In mainstream economics, the concept of a **market** is any structure that allows buyers (customers) and sellers (suppliers) to exchange any type of tangible goods or services and share information and knowledge. The exchange of goods or services for money is a *transaction*.

There are two roles in markets, buyers and sellers, *market participants* who influence the price. The market facilitates trade and enables the distribution and allocation of resources in a society. A market allows any tradable item to be evaluated and priced. Hence, it includes also trading of intangibles. Without competition there would be no market.

Markets vary in size, range, geographic scale, location, types and variety of human communities, as well as the types of goods and services and intangibles traded. A business that focuses on a **niche market** is addressing a need for a product or service that is not being addressed by mainstream providers. Targeting a product or service to a small portion of a market is often advantageous for entrepreneurs as it is not being readily served by the mainstream product or service marketers and there is little competition to be expected.

Also customers and consumers exhibit a kind of competition, a competition for social recognition by innovative offerings. There are early users who exemplify a certain type of innovation use that others will imitate (Figure I.29). This changes demand; and in this way niche products even may become mainstream.

In economics, a market in a capitalistic society that runs under *laissez-faire* policies is a free market. It is "free" in the sense that the government makes no attempt to intervene through taxes, subsidies, price ceilings, minimum wages, etc. and thus influences price settings. However, market prices may be distorted by a seller or sellers with monopoly power, or a buyer with monopsony power (a market form in which only one buyer faces many sellers).

However, the *"free market" is mostly an idealistic theoretical concept* as market reality encounters a number of factors that intervene with "market freedom." One, therefore, should differentiate markets based on ideal economic principles, "economic markets," from those which are overlaid by other factors or regulations, such as policy or/and societal attitudes.

A final remark concerns some semantics. According to our definitions, innovation is bound to the adoption of the offering and largely independent from consideration of input/resources and conversion processes (Figure I.5). However, purchasing decisions and adoption are complex according to a spectrum of factors that enter here. Attitude is one such factor, policy is another one. This can be seen from the discussion of "corn ethanol" and ethanol made from food crops (first-generation biofuel) versus "cellulosic ethanol" made from biomass or waste (second-generation biofuel) as a transportation fuel (Box I.1; A.1.1) where input may be essential for adoption.

Technology entrepreneurship, particularly concerning TVT or HVT (Table I.1), can be advantageously be dealt with by several different types of market (which, however, may exhibit partial overlap or effects on each others).

An "economic market" is seen here essentially as that what economists and MBAs tell us a market ideally to be. But the *systems-oriented taxonomy* in Table I.15 which is not taught by economics focuses pragmatically on players, drivers, functions and interferences that distort the model of the "economic market" by affecting (national) technology entrepreneurship and innovation significantly.

An industry may be involved in several kinds of markets. For instance, in the health area the pharmaceutical and partially also the biotechnology industry are in mediatorial markets through prescription drugs which additionally exhibit features of a policy-driven one and of economic markets through over-the-counter (OTC) drugs.

Military-driven markets as part of policy-driven markets are special as they often turn out to be price-insensitive. Furthermore, having military as a customer or financial backer may sometimes raise issues of ethics for entrepreneurs or innovators, respectively (ch. 2.1.2.8).

Table I.15: Types of market relevant for technology entrepreneurship and innovation.

Type of Market	Characteristics, Remarks
Economic markets	Markets where the offering is purchased more or less on the basis of some price/performance/usefulness assessment of the buyer – largely the idealistic model of academic economics ("*free markets*"); however, attitudes may often play an important role for purchasing decisions; These markets develop essentially according to endogenous forces not determined by special supersystems or agents (as given below); Technology entrepreneurship in the areas of software and technology-based services (TBS) address often economic markets.
Policy-driven markets	If policy interferes significantly, there will be "policy-driven markets." It may affect suppliers and customers. Often a response of policy to societal situations, for instance, social or environmental attitudes; policy interference is usually based on political or military programs, setting laws and regulations; acting as a customer; As described below the developments of the IT and biotechnology industries in the US relied essentially on promotion and support by the Defense Department (DOD) and the National Institutes of Health (NIH);

	A similar effect is observed globally for the biofuels market (A.1.1); it is policy- (and military)-driven; Policy intervention is not only through taxes, subsidies, price ceilings, loan guarantees, guarantees of purchasing fixed amounts of goods or services from a particular firm, providing infrastructures, but also bailing for companies' exports, setting tariffs, regulations or industry standards in a way to protect national industries and help financing startups; Policy-driven markets as an overlay to economic markets usually have a temporal existence; its drivers may have a life-time (of a political program or a government) and may disappear to re-establish the situation of an economic market; a political program often appears simultaneously on the supply and the demand side (such as, CleanTech). Customers ("researchers") from public universities and research institutes as part of the S&T System and their purchasing power may be viewed largely as policy-driven. The combination of policy-driven and attitudinal markets becomes particularly powerful as drivers of innovation and entrepreneurship. For health, for instance, in Germany the pharmaceutical industry operates partially in a system of fixed prices for prescription drugs throughout Germany (in German Preisbindung) and fixing of prices for the first year for approved prescription drugs is essentially by the pharmaceutical firms. This is a special "drug market" (in German Arneimittelmarkt)
Attitudinal markets	Markets where potential customers are significantly driven by attitude or ideology or movements in the society, for instance, "green markets" which make their support of renewables strong enough to overcome clear financial disadvantages; Also the "wellness market" belongs to that category; extreme examples are nationalistic movements, such as "Buy American" or "Buy German"; Another example for attitude-related purchasing behavior refers to offerings produced by or containing genetically modified organisms or objects (GMOs) which is an issue for biofuels (A.1.1).

Table I.15, continued.

Type of Market	Characteristics, Remarks
Mediatorial markets	Markets where, at least, partially, "mediators" (agents) determine what end-users should or even can purchase, for instance, that part of the health market in which physicians, by *prescripting* drugs, declare the (medical) needs and determine the associated drug purchase; here we have *decision-making for the end-user/consumer*; hence, here the target of marketing are the mediators rather than the end-users/consumer, supplier is the pharmaceutical and biotechnological industry; These markets are strongly influenced by the type of socio-economic system of a country and the role policy plays here.

The above obviously complex situation for making business is not only a constraint or threat to entrepreneurship. On the contrary, it opens (and initiates) myriad of opportunities or, at least, incentives for technology entrepreneurship and innovation.

For instance, although Germany's geographical position on the world map does not make it an ideal location for solar energy due to it receiving only moderate levels of solar radiation, an outburst of entrepreneurial activities backed by governmental programs in terms of financing options and tax breaks for innovating firms and subsidies for customers of grid connected systems occurred. Germany ranks now first/second place in the photovoltaic (PV) market, generating about one quarter of the total world market having overcome the US and Japan.

A detailed discussion of entrepreneurship and intrapreneurship originating in policy programs is presented for the biofuels field (Box I.1, A.1.1) and photovoltaic and solar cells fields (ch. 4.3.5.2, Box I.22).

A special type of policy-driven markets concerns laws and regulations targeting environmental health and safety (EH&S), for instance, regulations for bringing "dangerous" chemicals into the market or requiring approval of drugs or food processing aids for public use by the Environmental Protection Agency (EPA) in the US or the European Medicines Agency (EMEA). Compliance with corresponding regulations or anticipation of regulations to come represent excellent opportunities for "*regulation-driven*" innovations and technology entrepreneurship.

On the other hand, for policy-driven markets, rather than addressing customers to purchase the offerings of the NTBFs, NTBFs' marketing activities may address political decision-makers, shape the perception of their technologies and streamline their addresses to fit the buzz words of the related programs to obtain backing by policy. This can be seen in case not only for firms engaged in renewable energies (photovoltaic, wind power or professionally managed VC-based biofuels NTBF (A.1.1), but also in case of academic startups (SiGN Chemistry, B.2).

From the technology-based firms' point of view including NTBFs the *basic* types of customers comprise:

- **Industrial customers**:
  Purchasing offerings may be for research or commercialization purpose (development, engineering and production) taking a particular position in the value system; for instance, currently nanotubes are mostly sold to firms for their research on nanotubes; purchasing services refers often to the firm's operations.
- **Professional customers** (in German gewerbliche Kunden):
  Purchasing offerings by non-industrial organizations, for-profit commercial settings (for instance, marts or retailers' facilities), scientists and engineers from academic research units or institutes, respectively, physicians purchasing products to be applied to treat injuries, farmers buying pesticides, but also craftsmen delivering products and services to consumers, such as a repair shops buying paints and adhesives – self-employed like physicians or patent lawyers;
  purchasing by public (governmental and non-governmental organizations, such as municipal infrastructural facilities or services, sport centers, but also universities and research centers)
- **End-users**:
  which may be "professional users" in commercial environments, such as office professionals, but in particular, **consumers** (including do-it-yourself (DIY) users).
- **Military and aerospace customers:**
  A special class of *governmental (public) customers* expressing often their needs in terms of "wish lists" based on political directions and arguments. Combined military and political interferences may be observed, if products of military are also used for civilian purposes by NGOs upon request of policy (such as the UN). An example would be mine clearance machines (MineWolf Systems AG; B.2).

For information & communication technology (I&CT) end-users are often segmented into groups according to level of complex usage of the technology and the level of knowledge and experience with the technology:

- Power users
- "Normal" users and
- "Novices."

The majority of (non-I&CT) technology entrepreneurs is engaged in business-to-business ("B2B") activities which means having industrial and professional customers. In the US, for instance, most *Inc.* startups sold to other businesses; only 14 percent offered consumer goods or services [Bhidé 2000:51]

Business-to-government (B2G) and business-to-public ("B2P") activities include not only military and aerospace, but also universities and public research institutes and, particularly in Germany, also counties, cities and communalities which are engaged often in a semi-public way in utilities provisions, such as water treatment (Puron AG, Figure I.72, Table I.41). Customers in universities and public research institutes have preferentially needs for science, R&D and engineering.

Corresponding NTBFs, therefore, often do not only target these customers, but also the R&D and engineering functions in industry as a further market segment (for instance, German WITec, JPK Instruments or US Cambridge Nanotech; B.2).

In contrast to scientists and engineers of industrial research as part of an economic market *scientists and engineers of academic research units or institutes* as customers may represent a market that is often policy-driven and requires a global perspective to cover the intrinsic internationality of this segment and to exploit the whole market.

It is to be noted that the differentiation of customers has some important consequences for NTBFs, in particular, *differentiating the users from the "buyers."*

- Whereas consumers (as end-users) are the persons who make a purchasing decision, for industrial, but also partially for professional customers the purchasing decision may be made by persons others than the end-users, for instance, through a Purchasing Department in large firms.
- The focus of marketing and its proven methods refer essentially to consumer markets, which are typically little addressed by NTBFs unless they operate in the I&CT area, particularly Internet comsumer services.

The effect a change in price will have on customers is the **price-sensitivity**. Price increases will probably cause a decrease in sales. But, customers will have certain price acceptability, what they perceive to be the *range of price* within which they will buy a particular offering. Price sensitivity reflects the awareness of the buyer to the price of the item he or she wishes to buy in relation to substitutes and expected utility or value.

For entrepreneurship there are some specific situations of *price-insensitivity* in an otherwise largely price-sensitive economy. Most obviously, it has turned out that special demand from military is often price-insensitive as is sometimes demand from the health care area, in particular for prescription drugs.

To a small extent price-insensitivity can be regarded as a matter of delayed reaction, for instance, if curiosity, experimentation, feeling of exclusivity or instinct of play drives innovators and early adopters of an innovation (Figure I.29) before mainstream enters adoption. Another case of price insensitivity can occur, when large industrial customers buy "samples" to be used for experimentation by their R&D or Engineering Departments or want to gain early experiences.

Long-term development (decades or centuries) of an industry is usually associated with fundamental changes in technology. Medium term development (**industry dynamics**) is usually associated with the growth of the industry's firms and the competition among the firms. **Competition,** essentially for market share**,** is a source of internal forces that generate states of non-equilibrium. This results in a change of the landscape of the players, some becoming bigger, some smaller, some split, some new ones ("*entrants*") appearing and some old ones disappearing ("*exits*") as a result of acquisition, re-structuring or bankruptcy.

In an industry "re-inventing" a firm is the norm and, apart from looking for *technical novelties*, companies also have to look for *novel organizational structures and approaches* that might fare better than the traditional ones or provide a better fit to new determinants of the environment. Experience and theory tell that in the development and change of industries and their offerings *discontinuous* or *disruptive* changes of categories, such as technology, performance or value, occur repeatedly.

Competitive advantage is defined as the advantage one business entity has over its rival entities within its competitive industry (or more specifically within the *competitive group* in an industry segment). Competitive advantages give a company the edge over its rivals by an ability to generate greater value for the firm.

Competitive advantage occurs, for instance, when an organization acquires or develops an attribute or combination of attributes that allows it to outperform its competitors (Table I.75).There can be many types of competitive advantages including the firm's cost structure, product offerings, distribution network or customer support.

Understanding your competitive advantage is critical (Table I.75). It is the reason you are in business. It is not enough just to have an advantage over your competitors; you have to keep it over time. It must be *sustainable competitive advantage*.

There is a saying that (in established industries) roughly 70 percent of all new products can be duplicated within one year and 60 to 90 percent of process improvement (learning) eventually diffuses to competitors. The more sustainable the competitive advantage, the more difficult it is for competitors to neutralize the advantage.

Competitive groups identify firm groupings from the demand-side of the market or competition for consumers. **Competitive groups** are groups of firms whose leaders or managers perceive each other as rivals. Competitive groups are seen as distinct from "strategic groups" and are made up of firms that compete in the same market segments and which offer direct substitutes for one another (given in [Runge 2006:33, 221]).

Beginning with commercial activities a startup has to enter an existing market – unless the startup is about to create a new market on the basis of a disruptive innovation. It may also be that even in its early development phase an NTBF identifies an opportunity in a different market which it decides to pursue. Hence, an NTBF will be confronted with entry barriers. In economics an **entry barrier** means obstacles in the path of a firm into a market, that make it difficult to enter a given market, especially a confrontation with existing market participants, the competitors.

Barriers to entry restrict competition in a market. Barriers to entry may be the source of a firm's pricing power – the ability of a firm to raise prices without losing (most of) its customers. Typical barriers to entry for NTBFs include: [24]

- **Control of resources**: a single firm has control of a resource essential for a certain industry, then other firms are unable to compete in the industry;
- **Research and development**: some products, such as microprocessors, require not only a large upfront investment in technology, but also continuously large expenses for R&D including facilities, such as investing in clean room laboratories;
- **Intellectual Property Rights (IRPs)**: particularly patents and trade secrets may hinder to utilize efficient technologies to produce or provide a firm's offerings; there may be requirements for in-licenses from other firms (competitors);
- **Government regulations**: may make entry more difficult or impossible, for instance, regulations with regard to raw material and intermediates for products, environmental, health and safety (EH&S) or industrial hygiene for operation; permits may raise the investment needed to enter a market;
- **Industry standards**: set by government or industry associations;
- **Investment in production (and marketing)**: very large investments are needed to enter the market – not only for production, but probably, except for research and prototype creation, the investments for the remaining scale-up process (Figure I.8, Figure I.9);
- **Sunk costs**: Sunk costs (ch. 5.1) cannot be recovered if a firm decides to leave a market. Sunk costs therefore increase the risk and deter entry (may also be an exit barrier).

However, also leaving a market may turn out to be important, for instance, when changing the direction of commercial activities or giving up the firm after running out of cash. Such an exit does not proceed without barriers.

In economics **exit barriers** are obstacles in the path of a firm which wants to leave a given market or industrial sector. Particularly the cost of the firm to leave the market may prohibit it doing so, financially but also in terms of experiences to run the business. If the barriers of exit are significant a firm may be forced to continue competing in a market, as the costs of leaving may be higher than those incurred if they continue competing in the market.

Typical examples of exit barriers for NTBFs comprise essentially various *types of sunk cost* of high investment in non-transferable fixed assets associated with:

- Heavy investment capital in equipment and instruments for manufacturing or R&D which is specific to one task,
- Investment, implementation and learning of large I&CT systems for a specific task, such as a high-throughput system for R&D;
- Heavy investment in personnel with skills and experiences in just one technology or business area to be lost, such as scientists and engineers;
- A long-term contract with a major customer concerning delivery of a particular product or good.

High barrier to entry and high exit barrier are usually observed for specialized energy markets, such as biofuels (A.1.1).

Industries are often classified according to the number of sellers, presence or absence of entry, mobility, exit, and shrinkage barriers; degree of product differentiation, cost structure and degree of globalization.

The fate of an industry, particularly a technology-based industry, follows the development over time curve observed for living organisms. The **life-cycle curve** follows essentially a bell-shaped development with four phases: emerging, growing, maturing, and declining phases.

A corresponding curve can be observed for a particular technology or product and is shown for an ideal case (a normal distribution curve with standard deviations Sd) in Figure I.32. For the corresponding technology or product life-cycle one speaks of the introduction or launch rather than the emerging phase (cf. Figure I.28).

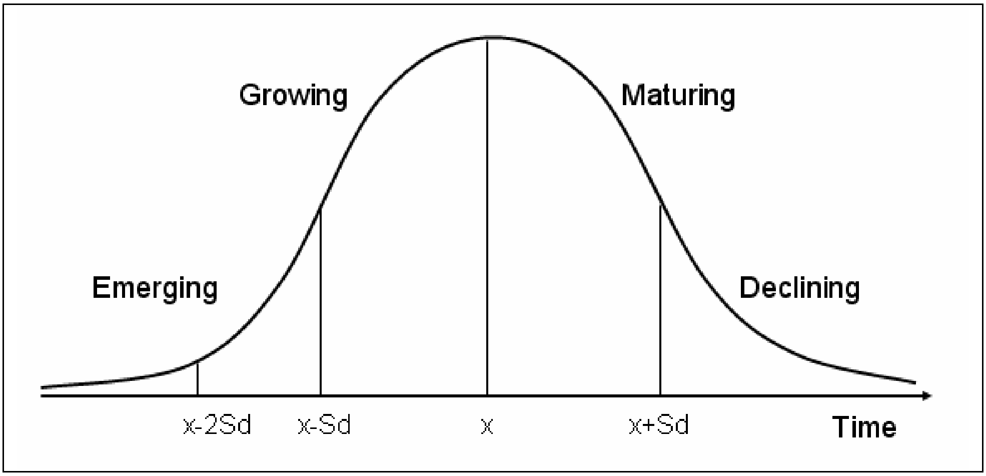


Figure I.32: Ideal life-cycle curves for technology, a product or an industry.

The average life-time of a product plays an important role for the time that can be spent for the development. For instance, for the majority product life-cycles of chemical products are 5 – 10 years with another large set of products having life times exceeding 10 years. Even much more is observed for plastics. But it is estimated that for specialty chemicals “a product will be obsolete in three to five years.”

This is still fundamentally different from the situation of the I&CT and computer industry where the life-times of the majority of products is in the range of 1 – 4 years and only ca. 25 percent of products exists for more than 4 years [Runge 2006:655]. Development and market entry times and cost in relation to the product’s life-time enters as an important factor for a product’s economy.

The question facing any company, in particular a startup or NTBF, is whether to enter or invest in a particular market given its dynamics. An entrepreneurial firm is likely to be a new entrant to the market. Much will depend on the nature and intensity of competition in that market. Michael Porter put forward a *five forces model* that intends to diagnose the principal competitive pressures in a market and assesses how strong and important each one is and, hence, the intrinsic long-run profit attractiveness of a market or market segment is.

Currently a **six forces model** adding “complementors” to the orginal five forces is often used [Dorf and Byers 2007:87-89]. The six forces are industry competitors, potential entrants, substitutes, buyers, and suppliers and complementors (Figure I.33). One goal is then “to find a favorable position in the industry where the company can best defend itself against these competitive forces or can influence them in its favor.”

The complementors added to the five forces of Porter comprise firms that sell products that add value to the products of a focal industry. Complementors may also provide improvements or perfections of another offering. For instance, complementors to the PC industry are firms that produce software applications.

When complementors produce exciting products, such as new games, the demand for PCs grows and *vice versa*. Due to their influence on demand of the original offering complementors’ bargaining power as a special supplier may come into play. When complements are an important determinant of demand in an industry, the health of the industry depends critically on adequate supply of complementary products.

In the sense of GST and for the current context, however, the last model must be extended to an *Encapsulated Six Forces Model* (Figure I.33). It comprises industry-internal (competitive) forces and external driver forces on the industry. The essence of GST is relating a company to its environment (Figure I.13) and in particular to the structure of the industry in which it competes. The environment appears as a set of forces which constrain the structure of organizations and the behavior of organizational participants and to which the organization must adapt.

Following the above classification of markets, essential drivers result from societal attitudes and political programs which both can create *threats, but also opportunities* for the industry’s firms. On the other hand, political regulations usually mean threats unless policy introduces regulations to protect the industry from import competition.

But, there are more factors exerting forces on the Industry System. For instance, there may emerge industry standards by non-governmental organizations (NGOs) or there may be forces through the Financial System (ch. 1.2.7) in terms of reduced risks taking by investors and venture capital firms to support entrepreneurial startups or existing firms for further growth. For Technology Entrepreneurship, in particular, also the national Science & Technology System including Higher Education System will exert important influences (ch. 1.2.6).

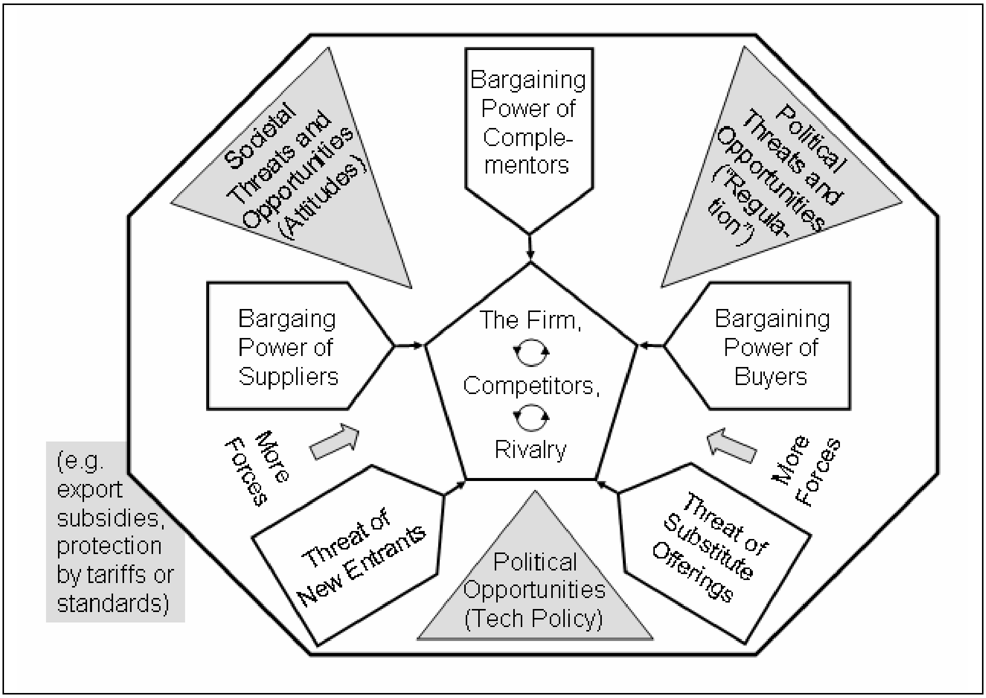


Figure I.33: Outlining the Encapsulated Six Forces Model of intrinsic long-run profit attractiveness of a market.

The emerging biofuels industry (A.1.1) represents an illustration of the various positive and negative as well as mutually enforcing forces which may be active in a policy-driven market.

Emphasizing technology entrepreneurship and firm's foundation we will focus on how the profit attractiveness of a market or market segment may be affected by industry-internal forces. This will help entrepreneurs to decide against unattractive industry segments.

In Table I.16 the unattractiveness referring to Porter's original five forces is outlined. However, it is probably not feasible to evaluate the attractiveness of an industry independently from the resources a firm brings to that industry. It is thus argued that this approach to market forces be coupled with the Resource-Based View (RBV, ch. 4.3.3) of firms in order for the entrepreneur(s) and the company to develop a much more sound assessment.

Another kind of economic or industry, respectively, dynamics with relevance for entrepreneurship is associated with so-called economic cycles or *cyclicality*. **Economic cycles** (business cycles) [25] are a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises. A cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle.

In duration, business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar characteristics with amplitudes approximating their own. These fluctuations occur around a long-term growth trend, and typically involve shifts over time between periods of relatively rapid economic growth (expansion or *boom*), and periods of relative stagnation or decline (contraction, bust or *recession*). Despite being termed cycles, most of these fluctuations in economic activity are recurring, but do not follow a mechanical or predictable periodic pattern.

During recessions many macroeconomic indicators vary in a similar way. Output as measured by Gross Domestic Product (GDP), employment, investment spending, capacity utilization of manufacturing plants, business profits and household incomes all fall during recessions. For NTBFs selling their offerings and profits decrease, payments by customers often occur late or irregular or customers disappear due to bankruptcy.

Table I.16: Impacts of an unattractiveness of industry segments according to Porter's Five Forces Model.

<table>
<tr><th colspan="2">Rivalry Among Existing Competitors</th></tr>
<tr><td colspan="2">An unattractive industry segment: contains already numerous, strong, or aggressive competitors; is even more unattractive if the segment is stable or declining.
Unattractive if fixed costs are high, if exit barriers are high, or if competitors have high stakes in staying in the segment; this will lead to frequent price wars and new product introductions; will make it expensive for the companies to compete.</td></tr>
<tr><th>Threat of New Entrants</th><th>Threat of Substitute Offerings</th></tr>
<tr><td>A segment's attractiveness varies with the height of its entry and exit barriers;
most attractive segment: entry barriers are high and exit barriers are low.
For both low entry and exit barriers firms easily enter and leave the industry, returns</td><td>A segment is unattractive if there are actual or potential substitutes for an offering; substitutes place a limit on prices and on the profits that a segment can earn; price trends in the substitutes have to be closely watched.</td></tr>
</table>

are stable and low. Worst case: entry barriers are low and exit barriers are high; here firms enter during good situations but find it hard to leave during bad situations. Result: overcapacity and depressed earnings for all.	If technology advances, generic technologies (Table I.12) show up or competition increases in these substitute industries, prices and profits in the segment are likely to fall
Bargaining Power of Suppliers	**Bargaining Power of Buyers**
Segment is unattractive if the company's suppliers are able to raise prices or reduce quantity supplied. Suppliers tend to be powerful when ▪ they are concentrated (few suppliers) or organized, ▪ there are few substitutes, ▪ the supplied product is an important input for the buying firm, ▪ the costs of switching suppliers are high, ▪ suppliers can integrate forward. Best defenses: build win-win relations with suppliers or use multiple supply sources.	A segment is unattractive if the buyers possess strong or growing bargaining power. Buyers will try to force prices down, demand more quality or services, and set competitors against one another. Buyers' bargaining power grows when ▪ they become more concentrated or organized, ▪ the product represents a significant fraction of the buyers' costs, ▪ the product is undifferentiated, ▪ the buyers' switching costs are low, ▪ buyers are price sensitive because of low profits, or when buyers can integrate upstream. For protection: ▪ sellers might select buyers who have the least power to negotiate or switch suppliers, ▪ developing superior offers that strong buyers cannot refuse.

There are some industry segments which are assumed to be rather independent from cycles, such as health or food and nutrition. But, particular suppliers to these areas may nonetheless suffer. For instance, suppliers of capital goods (machinery for food and nutrition and packaging) may be affected by limited access to credit for these firms (cf. the so-called "credit crunch" during the Great Recession 2007 – 2009).

An **economic bubble** (sometimes referred to as a financial bubble or a speculative mania) is trade in high volumes at prices that often deviate strongly from intrinsic values (cf. ascribed value; ch. 1.2.5.2). While many explanations have been suggested, it has been recently shown that bubbles appear even without uncertainty, speculation or other effects. As it is often difficult to observe intrinsic values in real-life markets, bubbles are often conclusively identified only in retrospect, when a sudden drop in prices appears. Such a drop is known as a *crash* or a *bubble burst*.

Both the boom and the bust phases of the bubble are *examples of a positive feedback mechanism*, in contrast to the negative feedback mechanism that determines the equilibrium price under normal market circumstances. Prices in an economic bubble can fluctuate erratically, and become impossible to predict from supply and demand alone.

Economic bubbles are generally considered to have a negative impact on the economy because they tend to cause misallocation of resources into non-optimal uses. In addition, the crash which usually follows an economic bubble can destroy a large amount of wealth and cause continuing economic malaise. A protracted period of low risk premiums can simply prolong the downturn in asset price deflation as was the case of the US Great Depression in the 1930s for much of the world and the 1990s for Japan. Not only can the aftermath of a crash devastate the economy of a nation, but its effects can also reverberate beyond its borders.

Another important aspect of economic bubbles is their impact on spending habits. Market participants with overvalued assets tend to spend more because they “feel” richer (the wealth effect). The housing market in the US, United Kingdom (UK), Australia, New Zealand and Spain in recent times is an example of this effect. When the bubble inevitably bursts, those who hold on to these overvalued assets usually experience a feeling of poorness and tend to cut discretionary spending at the same time, hindering economic growth or, worse, exacerbating the economic slowdown.

Generally, it is assumed that *entrepreneurship follow boom-bust cycles* [Metzger et al. 2008]. And also the venture capital system which is relevant for entrepreneurship follows a boom/bust pattern [Bhidé 2000:162]. According to Bhidé [2000:353] “New {technology-based} businesses usually start in markets where they compete against other small companies – or in bubble areas. However, this development is counteracted by another industry force.”

In boom times there are many opportunities for people to find a top job in industry, with top salaries and top working and personal development options. Hence, people will assess perceived security as an employee against uncertainties and perceived risks of becoming an entrepreneur. It is observed that more “potential entrepreneurs” will decide for the industry job. Such a situation is currently found in Germany.

Recently, in Germany, a very severe interference of policy into the economy took place opening many huge opportunities for entrepreneurship and intrapreneurship. After the nuclear Fukushima disaster in Japan in 2011 societal and also political consensus fueled a decision to phase out nuclear power by renewable energy by 2022 by law. This presents huge business opportunities in CleanTech, particularly wind, solar and hydro power, but also opportunities in upgrading Germany’s electric grid and a shift to a “smart grid.” Correspondingly, demand of industry for specialists in these areas has increased dramatically which may reduce corresponding numbers of related startups.

The phenomenon in economics in which too much loose cash finds its way into an area of the market had affected entrepreneurship significantly by way of the *"Internet bubble*" of 2001/2002 (reflected by so-called *dot-com* firms). It resulted from an investment frenzy that led to wildly inflated prices. Economic activity in those areas affected is not sustainable in the long run, so large numbers of new firms and *late investors* eventually go bankrupt.

The most recent bubble in the biofuels area, its context and related entrepreneurial activities emphasizing the particular class of venture capital-based startups (*VC-based startups*) is treated as an "industry case" in the Appendix (A.1.1; The *Biofuels Bubble* and the Related Outburst of Entrepreneurship and Intrapreneurship).

"Biofuels" is actually initiated by governmental initiatives and programs comprising current legislation and future regulation in terms of mandates as well as huge direct and indirect financial support. Overall one observes:

- Financing biofuels related research and development and startups; grants, subsidies and tax breaks or incentives for producers and customers.
- An "explosion" of private investments in a seemingly low risk/high reward opportunity and a learning example how venture capital organizations approach startup investments based on a given portfolio (Figure I.182).
- And finally, a lucid illustration of market and industry realities and innovation strategies by large and giant firms is reflected by c*orporate venturing* (ch. 1.2.7.2) with investment in or acquisition of biofuels startups and other companies, using public funds for company-internal R&D as well as cooperation with universities and public research organizations.

The structural outline of the situation and the sub-optimization issue associated with biofuels-related governmental actions is described in Figure I.34 and Box I.1.

As described in the Appendix (A.1.1) there are globally around 300 large and small firms currently engaged in biodiesel, bioalcohols (bioethanol, biobutanol, biomethanol), biogasoline, biocrude (oil) and biogas and additionally about 200 firms focused on algae as the input. The recent emergence of algae-based biofuel firms and business activities occurred again boom-like.

This means, the to-emerge biofuels industry is a rather large "battle field" with hefty competition for the market and resources (Table I.17). Here the Political and the Science & Technology Systems play an important role as a "catalyst" for industry entry of startups.

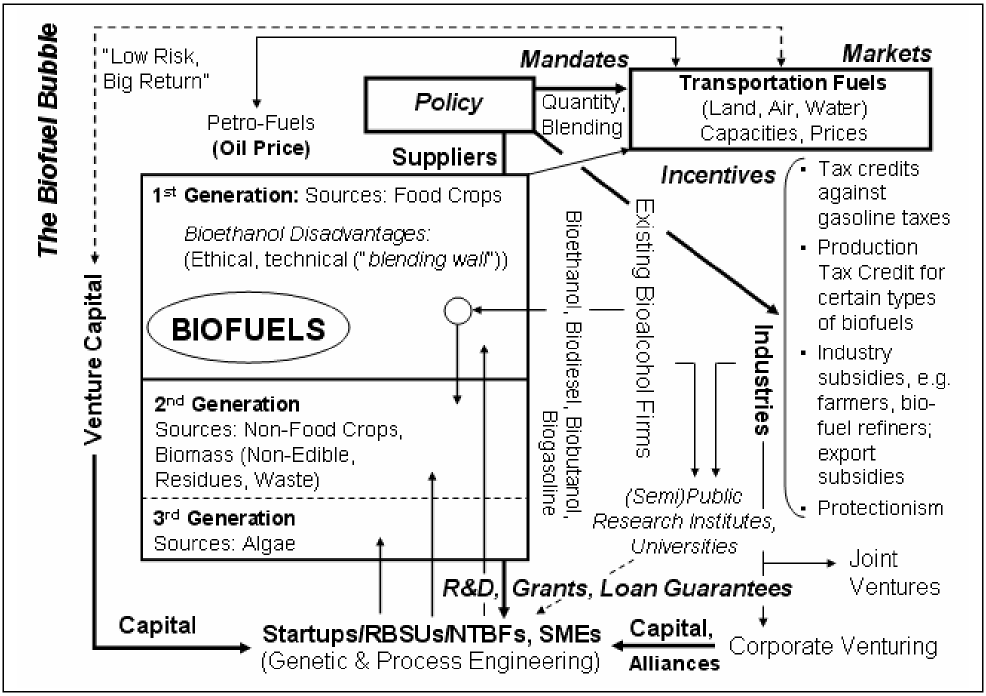


Figure I.34: Structural representation of factors inducing the biofuels bubble.

What we see also is a great variety of financial models for the startups, including those living only on public grants, those capturing public grants and venture capital from VC firms or corporate venturing capital companies (CVCs) as well as JVs or particular forms of joint research or development alliances. Except for corn ethanol there are few biofuel firms or businesses relying on private investments by founders' capital. Overall, *biofuels show up as a policy-driven market* (Table I.15).

Table I.17: Biobased offerings for transportation fuels, product related process technologies and competitive determinants *)

	Competing Product	Petro-Gasoline; Filling Stations	Crude Petro-Oil
Biofuel Products	**Competing Base Process Technology**		
	Thermochemical	**Bioengineering**	**Biothermal ("Hybrid")**
Biodiesel	**Targets**: Diesel engine, Otto combustion engine; jet engine; Flex Fuel Vehicle (FFV)		

Bioethanol	**Input/Raw Material**: e.g. corn ethanol/butanol ("1st Generation"); additionally cellulosic ethanol/butanol, biogasoline, biocrude ("2nd Generation") from non-food crops, non-edible residues, waste
Biobutanol	Algae for biodiesel, jet fuel, biogasoline, bioethanol; biogas ("3rd Generation")
Biomethanol	**Function:**
Biogasoline	Biofuel as a blending component of petro-gasoline
Biocrude	Biofuel as a replacement of petro-gasoline
Biogas	Bioethanol and biobutanol for solvents and chemical raw materials and intermediates

*) Discussed in A.1.1

Detailed product-related forces and related competition in the biofuels market are given in Table I.18. There are myriad technologies and biomass input options to produce biofuels (Figure I.184) and many possible business models (Figure I.183).

Table I.18: Forces impacting the transportation biofuels industry referring to the Encapsulated Six Forces Model.

Rivalry Among Existing Competitors
Tremendous large-scale production cost and price-based competition of hundreds of firms with and without inter-company relationships having the petro-oil price per barrel as the "threshold" and constraint. Competition is based on (A.1.1.5) ▪ end-products as well as application areas, ▪ corresponding production and process technologies and raw materials input as well as availability of co-products for additional revenues (output variety), ▪ access to (public, VC, CVC) financial and human resources, ▪ the market segments, financial and political power of players and ▪ corresponding political interferences in the policy-driven market through legislative, subsidizing and national protection measures which may affect the various types of products and the financial resources allocated to them differently. Entry Barriers: ▪ Huge financial investment for scale-up for new firms with goals of large-scale industrial production ▪ Large corresponding activities of giant oil and chemical firms ▪ IP protections of vast areas of technologies ▪ The "strongest" active and to-be players have large competitive advantages due to very experienced leading teams for technology and management

Threat of New Entrants	Threat of Substitute Offerings
Low entry barriers due to massive financial support by policy and venture capital; "Low" investment barriers: The opportunity with a policy-guaranteed market was perceived by entrepreneurs and investors so large that one does not have to believe in much more than a few percentage points of market penetration for it to be worth the investment. Furthermore, investment decisions could be based on whether startup companies in the biofuels sector have additional government subsidies or not. Continuous foundation and operation of firms largely based on grants, especially RBSUs aiming at licensing-out their technologies	Tremendous threats! Permanent threat of petro-gasoline ("oil price") for biofuels, potential indirect threat through electro-vehicles reducing demand for petro-gasoline and biofuels Bioalcohols compete against each others (Table I.17; biobutanol against bioethanol and biomethanol, specifically (first generation) "corn ethanol" against (second-generation) "cellulosic ethanol" (Figure I.34); Bioalcohols compete against biogasoline; For transportation biofuels biobutanol and biogasoline as direct substitutes of petro-gasoline (not blending component); biobutanol and biogasoline outperforming bioethanol or biomethanol
Bargaining Power of Suppliers	**Bargaining Power of Buyers**
Input suppliers (biomass and waste); Technology (component) suppliers; Microorganism, enzyme firms for bioengineering processes; Engineering, procurement and construction (EPC) firms, plant construction firms in high demand	Giant oil firms owning oil refineries and blending organizations as well as gas filling stations; Independent oil refineries and blending firms
Other Forces	
Policy – State, County, Communality Level	**Biorefinery Complementors**
Competition among entities for "job creation" ; entrepreneurs negotiate favorable conditions where to locate a startup	Firms focused on biobased chemicals and materials (also endowed with "public money")

Analyzing the biofuels area (A.1.1) viewed as an economic market in terms of attractiveness according to Table I.16 reveals that *per se* the area would be largely unattractive: The firms proceeding along the bioengineering process technology may be confronted with an additional threat if they rely on genetically modified objects (GMOs) as there is societal resistance against GMOs in various, especially European, countries.

1.2.6 The Science & Technology System, the Innovation System and New Technology-Based Firms

There is global agreement that entrepreneurship and related foundations of startups and SMEs are essential for national economic wealth and growth, mainly expressed by creating jobs. Correspondingly national governments have installed various programs and initiatives to encourage and support entrepreneurial activities (and SME activities) and are interested in identifying policies that may enhance the level of entrepreneurial activities.

According to the US Small Business Administration (SBA), in 2004 small firms (<500 employees) employed 50.9 percent of the private-sector work force and generated 50.7 percent of the non-farm private gross domestic product. According to that same report, in 2004 firms with fewer than 500 employees had $1.9 trillion in annual payroll, not including benefits.

An extensive report released in November 2008 by the US SBA found that small firms had a higher percentage of patents per employee than larger firms, and that younger firms were more likely to have a higher percentage of patents per employee than older firms [Wadhwa et al. 2009]. Statistics for Germany exhibit a similar situation.

In this regard the *political view* becomes rather focused: Entrepreneurs are the people who arrange novel organizations or solutions to social and/or economic problems. Looking at innovation and entrepreneurship and intrapreneurship from a systems point of view it is important to understand which *directive, supporting and constraining* forces are induced and operative by the S&T and Higher Education Systems (Figure I.13) and how policy and industry interferes with these fields.

For our comparative approach we shall emphasize related *similarities and differences* of the German and US systems. Furthermore, as we differentiated invention from innovation (ch. 1.2.5.1), one must also differentiate the national S&T and Innovation Systems or, at least, be aware of the specifics of the Innovation Systems.

This approach has a built-in restriction: it will deal with the S&T and the Innovation Systems only from the entrepreneurial perspective. Furthermore, it does not discuss how the German Science & Technology System is embedded in or interrelated, respectively, with that of the European Union (EU) though Germany is the main contributor to the EU system with regard to finances and R&D activities.

For entrepreneurship and university-industry cooperation the EU plays an important role for Germany under the heading of “technology transfer” and SME support. For instance, the European Molecular Biology Laboratory (EMBO) in Heidelberg (together with the German Cancer Research Center (Deutsches Krebsforschungszentrum – DKFZ) in Heidelberg), the University of Heidelberg and the Max Planck Institute for Medical Research in Heidelberg is a notable biomedical constellation for the region.

The Innovation Systems of the US or Germany cut essentially across the many national contributing systems. However, there have been and are many interconnections between the S&T and Innovation Systems in the US and Germany. A particular point of interest will be how strong *systemic features* inside and across both these systems will show up.

As a majority of technology entrepreneurs have *higher (academic) education* with university/academic degrees (Table I.2, ch. 1.2.6.1; Figure I.45) and can rely on a broad variety of *relevant experiences* (ch. 2.1.2.3) it is important to understand the Higher Education and S&T Systems of the countries for the entrepreneurship process.

When looking at the S&T and Higher Education Systems we shall concentrate on subsystems, processes and functions, communication and coordination involved in the transfer of technology (broadly defined to include science) from organizations that perform research and development in its widest form, but do not engage in the direct commercialization to organizations that use technology to produce commercial offerings.

Generically, **technology transfer** is defined "as the movement of technological or technology-related organizational know-how among partners (individuals, institutions, and enterprises) in order to enhance at least one partner's knowledge and expertise and strengthen each partner's competitive position." [Abramson et al. 1997] It is the *practice* of *sharing* scientific findings, know how or practical knowledge of one organization with other ones for commercialization. It comprises "ready-to-use" entities, but often requires further developments by the receiver.

The *narrow sense* of the notion is on "*transfer" of technology from non-industrial R&D organizations to the private industry*. Technology transfer in this sense is *transnational* which means, for instance, a large or giant German firm may establish a related interrelationship with a US university and *vice versa*.

> Though the notion of technology (or knowledge of science) transfer with its unidirectional hand-over from one party to another one is semantically not correct as it actually refers concerning its main step to a process of "sharing" between parties (ch. 1.2.5.2), we shall continue to use the well established notion of technology transfer.

In the widest sense technology transfer occurs also between industrial partners, for instance, by selling and purchasing licenses or via license swaps. This may occur directly between the partners or via private, for-profit intermediaries, for instance, Web-based firms, such as yet2.com [Runge 2006:675].

Many large firms have made a business out of this kind of technology transfer and run it through dedicated corporate units. For instance, the US firm 3M has a dedicated Website ("3M Technology Transfer") helping inventors to find the 3M technologies they need to solve research and development challenges. DuPont also posts patents on its own online “Technology Bank” as does the ExxonMobil Chemical Company with its “Technology Licensing” Website [Runge 2006:674-675]. This is found globally for many different industries.

The above described “transfer” of technology from non-industrial R&D organizations to the private industry comprises implicitly the entrepreneurship phenomenon! We introduced new firms originating from universities or public research institutions as “spin-outs” – also called RBSUs – as an important sub-group of NTBFs (ch. 1.1.1.1). Hence, technology transfer will deal specifically with this type of startups. Such a transfer of science out of non-industrial R&D organizations into the industrial system, is often characterized as “*science-to-business*” (Science2Business). This means, focusing on university spin-outs requires to inquire into the S&T systems of the US and Germany in some detail.

Originally, technology transfer for industry and entrepreneurship occurred out of the Higher Education System, specifically the research university, as a source of graduates and applied research. Now, in the established S&T Systems, many universities and governmental/public research organizations have an “Office of Technology Transfer” dedicated to identifying research of the organization which has potential commercial interest and strategies for how to exploit it.

Technology transfer occurs throughout all stages of the innovation process – from initial idea to final offering. The main organizations involved in this type of technology transfer include non-industrial R&D organizations, universities and associated institutions and sub-units, federal and state government-funded research institutes and organizations and a variety of public, private and mixed (public and private) organizations.

The processes of technology transfer, therefore, will emphasize, for instance,

- Source organizations performing different types of science and research
- Direct and indirect modes of transfer which refers to specific technologies, ideas or “projects” via “formal,” visible channels, such as contract research or development alliances, versus sharing of knowledge through “tacit” channels like informal meetings or Communities of Practice” (CoPs)
- Different types of involved firms: new firms, SMEs and large existing firms
- Transfer between only two partners (1:1 transfer) or between more than two partners (1:n or m:n transfer) occurring by linear, parallel, iterative or recurring modes
- The modes of transfer through licensing or marketing agreements, co-development arrangements, training or the exchange of personnel
- Pre-commercial and commercial stages.

As we focus on national differences between Germany and the US we shall look at how these “produce” entrepreneurs. This does not mean that we exclude other nations or regions. In any case,

> Policy is the overwhelming source of funding the origins of technology transfer and initiatives of related political programs and plays a dominant role for the operations of the technology transfer subsystem – and policy has innovation, entrepreneurship, job creation and wealth of society in mind.

In the US the Association of University Technology Managers (AUTM) launched the Better World Project in 2005 to promote public understanding of how academic research and technology transfer have changed the way of life and made the world a better place, for instance, through corresponding reports presenting a large number of corresponding examples from around the world [AUTM 2008] including the startups Verenium (Table I.83, Table I.84) and Mascoma (Table I.99) discussed in more detail in the Appendix (A.1.1).

Abramson et al. [1997:3-4] provide a detailed summary of factors shaping national Technology Transfer subsystems. For the description and assessment of the US system we shall refer strongly to the book by Abramson et al. [1997] covering the US and Germany. Both countries exhibit major similarities concerning institutional categories (individual elements) of R&D and technology transfer units, which is *a structural similarity*. Functionally there are significant differences between the US and German system. The key differences is the much higher formalized organization, communication, coordination and "project" execution in Germany relative to the US.

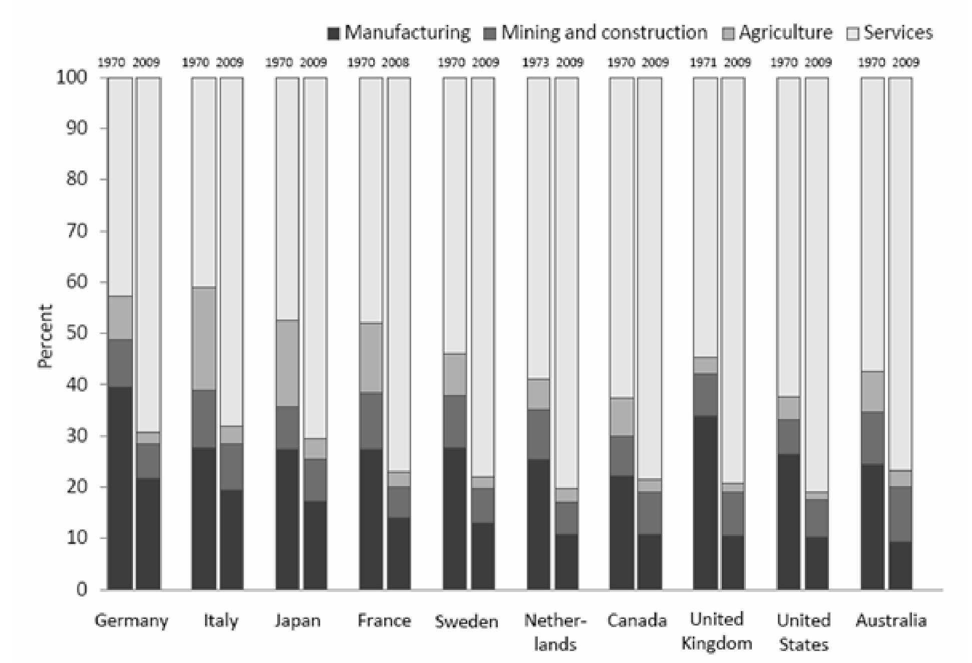
In the US operational responsibility for R&D and technology transfer is more widely distributed among a larger and diverse population of institutions than it is in Germany. Diversity is manifested in terms of size, ownership and management type (private, public, state, federal, for-profit, non-profit etc.).

The German system is more uniform across industrial sectors, scientific fields and regions than its US counterparts. It is also more uniform than the American system in terms of its interactions with the political and industrial systems and also in terms of the patterns of federal, state, and private shared funding practices across these sectors, fields and regions.

Directions of technology entrepreneurship in the two countries will be framed by the respective Economic/Industrial including the Financial Systems. The industrial offerings and R&D portfolios of the US and Germany exhibit differences (Table I.19, Figure I.35) which influence technology entrepreneurship on various levels:

- Directions of technology entrepreneurship,
- Interactions of "public" and industrial R&D,
- Financing startups in terms of corporate venturing and VC (ch. 1.2.7.2).

Over the last forty years developed countries saw a redistribution of employment share away from manufacturing, agriculture, mining and construction areas into services (Figure I.35). The categories "manufacturing" and "mining and construction" sum to "industry." But Germany in comparison to the US has kept a much larger proportion of industry jobs than the US. In relation to the population in 2009 US industrial jobs were only 62 percent compared to those in Germany. Germany's industrial basis is fundamental for its strength and export success.



	Manufacturing		Manufacturing		Industry	
Year	**US**	**DE**	**US**	**DE**	**US**	**DE**
1970	20746	10305	26.4%	39.5%	33.15%	48.70%
2009	113163	26596	10.2%	21.8%	17.65%	28.55%

Figure I.35: Employment in manufacturing and industry (in thousand or percent; DE = Germany) – Source: US Bureau of Labor Statistics [2011].

Apart from I&CT, it can be stated that the US has more emphasis on what is called Top Value Technology (TVT) and Germany in High Value Technology (HVT) as differentiated in Table I.1. However, it must be kept in mind that Germany contributes significantly to many other areas run as European R&D. The different technology portfolios also reflect differences in public R&D funding in both countries (Table I.19).

Table I.19: Differences in industrial offerings and R&D portfolios of Germany and the US.

Germany	US	Remarks
Automotive	Automotive	Automotive in the US declining; premium products from Germany
(Mechanical engineering based) electrical and non-electrical machinery manufacturing	Aerospace	Includes for Germany globally top *environmental technologies*; aeronautics and aerospace activities of Germany are largely run in the European context
Electronic, optical and communication equipment and instruments	Microelectronics; I&CT including software applications	Software (Web) applications and services in the US much more focused on mass markets (consumer services in the broadest sense)
Medical devices and instruments	Medical devices and instruments	
Industrial chemicals and materials including agricultural chemicals	Industrial chemicals and materials including agricultural chemicals	
Pharmaceuticals	Pharmaceuticals	Pharma in Germany compared to other leading nations has declined
Biotechnology	Biotechnology	Biotechnology in Germany much less developed than in the US; Due to societal attitudes in Germany there is much less acceptance of biotechnology involving GMOs than in the US
	Military technologies	In the US various (military and civilian) areas profit from public defense-related R&D

In terms of engineering orientations the US focuses more strongly on computer science and informatics, biomedical engineering and biotechnology, pharmaceuticals and chemistry and chemical engineering. Germany specializes in a broad range of electrical and mechanical engineering and machinery including automotive, civil engineering as well as chemistry and chemical and process engineering.

Furthermore, in the US industrial output is essentially for the *US home market* with consumers contributing ca. 70 percent to GDP (before the Great Recession, but probably decreasing towards 65 percent). On the other hand, since early on German industrial output was heavily *export-oriented*. For instance, German Bayer AG, founded in 1863, acquired an interest in its first coal-tar dyes factory in Albany, New York in 1865, and *by 1913 over 80 percent of revenues came from exports* [Runge 2006:477-479]. Siemens, founded as Siemens & Halske in 1847, turned in 1852 to Russia, and soon after to England.

A rational behind Germany's early export-orientation is the fact that the main competing firms from the UK and France had access to much bigger markets as both countries could rely on a large number of colonies abroad. Hence, to access large markets, since around 1870 the German industry with a comparably small home market must become international. And the particular fierce competition with British firms and their intention to discredit German goods gave rise at about 1900 to the "Made in Germany" trademark – immediately recognized globally as a brand for superior quality products [Runge 2006:284].

Currently, medium-sized firms represent the backbone of the German economy, also with regard to export. Here, in particular, the class of technical and non-technical firms called "Hidden Champions" [Runge 2006:239-241] plays a key role (ch. 4.1.1).

Compared with the US, technology entrepreneurship in Germany is more export-oriented, primarily toward European countries, the US and Japan, but currently considerably also toward China and South East Asia, India and Russia.

> Global and European orientation, therefore, is accepted to be fundamental for most German technology entrepreneurs doing a startup today.

US NTBFs only recently began to search for opportunities abroad [Loten 2011].

A special focus of German public R&D spending is "*industrial development*" which accounts for 15 to 20 percent of public funds, whereas in the US that is around 1 percent [Abramson et al. 1997:8]. This reflects a more direct engagement of German science and technology policy in civilian industrial technology. This is seen, for instance, in the recent efforts and "successes" of industrial developments of environmental industries, such as photovoltaic/solar thermics, wind energy (through wind turbines) and biogas (Box I.22).

But generally, one encounters globally massive political roles and influences on industry and technology developments, for instance, for nanotechnology and CleanTech

(Table I.52), particularly, “renewable energy” for power (PV, solarthermics, wind turbines, fuel cells), mobility (electrovehicles, batteries) and transportation fuels (biofuels) and lighting (LED/OLED).

Industrial development as a common effort of government and private industry has a tradition of two centuries in Germany (Box I.2). In the US industrial development, with some recent notable exceptions due to political rationales (for instance, biofuels for independency from petro-oil), is generally considered to be the province of private organizations.

Box I.2: The foundations of the German industrial development approach [Ohff 1981].

Industry development in Germany or Prussia, respectively, has roots dating back to the early 1800s when Prussia as a still largely agricultural country with a dominating class of civil servants was catching up industrial and technical developments and high-volume production led by the UK. Such a catch-up process is assumed to have shaped simultaneously the financing system in Prussia and later Germany.

The most widely accepted theory, the timing of industrialization (or TOI) thesis, argues that key differences in national financial systems can be traced back to their respective industrialization phases. In countries where this process started early – Great Britain is the key example – firms were able to finance new investment gradually from internally generated funds or from securities issues in relatively developed financial markets [Vitols 2001].

Firms in countries in which industrialization started later, however, faced a double disadvantage relative to their advanced competitors in early industrializing countries. First, internally generated finance was inadequate (or, in the case of newly founded firms, non-existent) relative to the large sums needed for investments in “catch-up” technologies and infrastructure. Second, market finance was difficult to raise because securities markets were underdeveloped and investors were more inclined to invest in safer assets such as government bonds.

Thus only banks could gather the large sums of capital required, take the risks involved in such pioneering ventures, and adequately monitor their investments. Once established, bank-based systems have a strong survival capacity. This interpretation of history provides support for the recommendation that developing countries follow the model of bank-based development [Vitols 2001].

Concerning industry development, for instance, the world renowned Prussian universal man Karl Friedrich Schinkel (1781 – 1841) and Christian Peter Wilhelm Friedrich Beuth (1781 – 1853) played illustrative roles. Schinkel was a Prussian architect with pronounced skills with architectural drafts and technical drawings, a city planner, painter and designer of stage sets. Beuth was a high level executive (State Official) of the Prussian government and member of the Council of State (in German: Staatsrat).

Beuth is assumed to be "the father of Prussian business promotion," for instance, in terms of foundations of tradesmen's clubs, technical schools which formed mechnical and civil engineering and he facilitated Prussian's transformation from human-based productions to industrial production via "technology transfer from abroad." But, in plain language this was often "*industrial espionage*" [Ohff 1981:109-113].

For instance, Schinkel who had already visited England, Scotland and Wales, made an official trip to Britain (in 1826) well equipped with money (by the government) and accompanied by Beuth to officially studying British architecture of museums. However, their focus was more on manufacturing plants and halls including buildings around harbors and inventories and to get information about production and logistics together with technical drawings and real intentions and achievings of the trip are described in detail by Ohff [1981:111].

The basic Prussian approach was to promote industrial development by cooperation of government and the professional public. Prussia sent high-level representatives of the government to the British ally who where accompanied officially by artists but in effect skilled drawers of designs of machines and devices. Furthermore, Prussia had a number of agents in Britain to report on industrial and technical developments and mass production and also to send design drawing, models and samples to Prussia. To be effective bribery was sometimes needed to get relevant information.

Corresponding information was distributed to the public by a non-profit "Gazette of Public Utility" (in German: Gemeinnütziger Anzeiger). Though the owners of the British facilities were informed that someone will come "with the patriot intention to kidnap away what useful knowledge and men he can find in his way" [Ohff 1981:110], the Prussians were very successful.

Beuth, for instance, succeeded through "reverse engineering" to even circumvent the strict British prohibition of exporting industrial goods and information in organizing to put a machine for textile production apart, send the parts to Prussia and let it be put together again to the fully functional machine. The Prussian technology transfer approach was: providing the machine to Prussian industrialists free-of-charge with the condition to demonstrate it to any interested person from Prussia.

Beuth's activities in organizing technology transfer included sending young engineers abroad for learning, organizing distribution of knowledge and networking in Prussia through fairs and exhibitions. And finally, the "Club for the Promotion of Industriousness" (in German: "Verein zur Beförderung des Gewerbefleißes") founded by Beuth in 1821 had an annually awarded Prussia-wide ("innovation") contest based on finding a solution for a particular technical problem or industrial development.

Does this anyone remind of the current approach of China to catch up industrially and technologically? If not, refer, for instance, to Busse [2011].

And for technology entrepreneurship a corresponding rather recent friction between Germany and the US is reported in the context of the German wind turbine firm Enercon GmbH (cf. 2.1.2.7; Box I.7).

To enter discussions of the structure of the Science & Technology System and the Technology Transfer subsystems we shall first consider the situation in Germany. In Figure I.36 the proportion of R&D organizations as the origins of RBSUs (spin-outs) is shown.

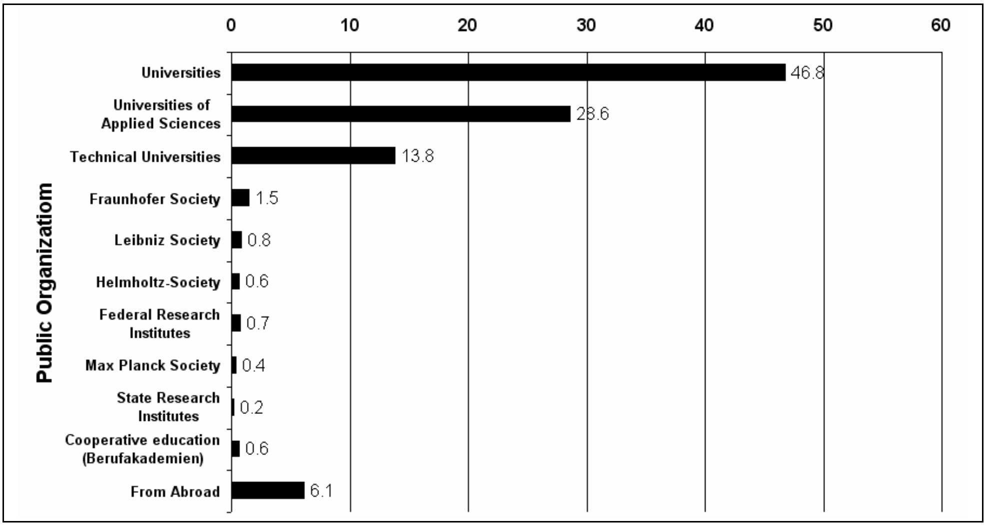


Figure I.36: Origins of spin-outs in Germany in percent (2002) (adapted from Egeln et al. [2002]).

A very personal, but very illustrative description of a spin-out process from a (UK) university and his personal experience of two years in the life of a biotech spin-out is given by L. Milgrom [2003].

With regard to levels of research and development [Runge 2006:614] Table I.20 provides structures as well as manpower and financial endowment of German public research organizations (ch. 1.1.1). All have "technology transfer sub-units." If not stated otherwise estimates are used.

Pre-commercial innovation activities of the German public organizations cover knowledge creation and sharing and technology transfer focusing on the processes 1) – 5), but not on production and sales which is the realm of private enterprises.

1. Basic research, pure science
2. Applied science and research
3. Process development
4. Product development
5. Production development, scale-up and prototyping.

Table I.20: Types of publicly funded research organizations in Germany.

MPG: Max Planck Society (Max Planck Gesellschaft) [MPG 2009] MPG performs basic research (pure science) in the interest of the general public in the natural sciences, life sciences, social sciences, and the humanities. In particular, the MPG takes up new and innovative research areas that German universities are not in a position to accommodate or deal with adequately. Research Institutes: 80 Budget (in bil. €): 1.19 (2009) Employees: > 12,000 Scientists/Researchers: ca. 4,900; ca. 7000 student assistants, postgraduates, post-docs, guest scientists; Startups: 86 (since 1990) (55 are license-based spin-outs; nearly 150 patents are currently licensed to spin-outs of the Max Planck Society) MPI institutes or representatives abroad, for instance, Max Planck Florida Institute (MPFI) Technology Transfer Unit: Max-Planck-Innovation	**HGF-Helmholtz-Society** (Helmholtz-Gemeinschaft deutscher Forschungszentren) Research Centers: 16 Research Institutes: ca. 250 Budget (in bil. €): 3.0 Employees: ca. 30,000 Academics/Researchers: ca.12,100 (incl. postgraduates); Startups: ca. 60 (2002 -2008) Technology Transfer Unit: Helmholtz Enterprise (Spin-outs) One “hybrid”: KIT – Karlsruhe Institute of Technology – Technical University of Karlsruhe plus Karlsruhe Research Center (like a holding)

Table I.20, continued.

WGL: Leibniz Society (Wissenschaftsgemeinschaft Leibniz) Research Institutes: 86 Budget (in bil. €): 1.3 Employees: 16,100 Academics/Researchers: 7,100; Revenues from services and licenses (in mio. €): 81.34 Startups: 74 (1999-2003); after “incubator “ in 2004 “Leibniz X” consulting for ca. 70 projects, of these 18 projects led to firms’ foundation Technology Transfer Unit: Leibniz X	**FhG: Fraunhofer Society** (Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e. V.) The largest and leading organization for institutes of applied research in Europe, undertaking contract research on behalf of industry, the service sector and the government. Research Institutes: 59, 80+ Research Units Budget (in bil. €): 1.6 (research budget); 1.3 (2007) Employees: ca. 17,000; 13,630 (2007) Academics/Researchers: ca. 5,750; Revenues from contract research: €1.3 bil. (2/3 from revenue derived from contracts with industry and from publicly financed research projects) Revenues from licenses: €92 mio. (2006) Startups: 118 (since 1999) Research centers and representative offices in Europe, USA, Asia and in the Middle East Technology Transfer Unit: Fraunhofer Venture Fraunhofer Innovation Clusters Consulting, Prototyping

A comparative description of the activities and functions of public non-university research institutions and how these are funded and endowed is given in Figure I.37 [BMFB 2008].

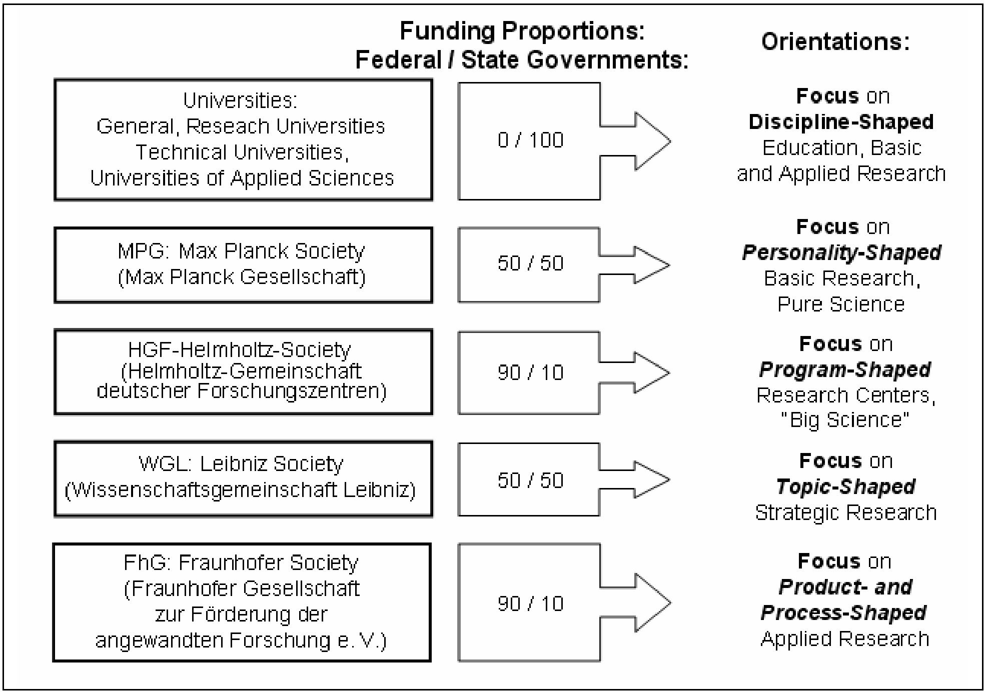


Figure I.37: How public research organizations in Germany are funded as a proportion between federal and state governments and their fundamentally different orientations.

Spin-out intensities as defined by the number of spin-outs per 100 scientists of the organization are given in Figure I.38 [Egeln et al. 2002] differentiated according to *exploitation spin-out* or *competence spin-out*. The former type refers to a startup utilizing research results which are intimately bounded to one of the founders, for the later one special competencies acquired at a research institute are indispensable (definition in ch. 1.2.6.1).

The highest intensity is observed for the universities of applied sciences followed by the technical universities. But also the general (research) universities and the Fraunhofer institutes exhibit high intensity values. The “pure science” Max Planck institutes are notably more pronounced than those of the Leibniz Society and those of the national research centers of the Helmholtz-Society.

For spin-outs universities and public research organizations often run “incubators” aimed at students, graduates, post-graduates, post-docs as well as faculty members to support and accelerate the development of startups and fledgling companies (ch. 1.2.6.2).

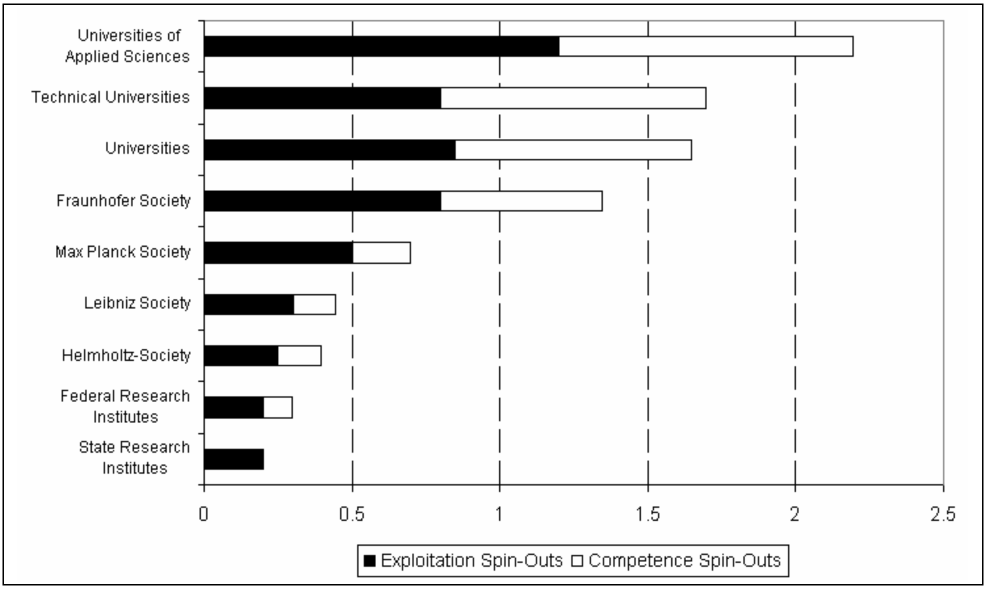


Figure I.38: Spin-out intensities of various German research institutions (for the period 1996-2000) [Egeln et al. 2002].

A comparison of the structures and basic orientations of the US and German Science & Technology Systems are given in Table I.21.

The large German Helmholtz Research Centers and the large US federal (national) laboratories perform basic and applied research in line with areas of public interest and political programs. In alliance with industry partners they also enter development work and even piloting (Figure I.173). The German institutes of the Leibniz society which are subject- and topic-focused are smaller federal and state research institutes and correspond essentially to US smaller federal and state-level institutes.

In both countries government laboratories are in the focus of policy-makers, particularly with regard to the technology transfer subsystem and the division of activities among their national Science & Technology Systems. In this regard, the very recent establishment of the Karlsruhe Institute of Technology (KIT) as a "hybrid" is notable (Table I.20): KIT is a legal and organizational merger of the University of Karlruhe (TH – Technical University) and a Helmholtz national research center ("Forschungszentrum Karlsruhe" – FZK).

UIRCs (University-Industry-Research Centers) are an organizationally diverse set of institutions that facilitate industry access to university research, engage industry in the definition of a research portfolio, and otherwise promote technology transfer to participating firms in exchange for sustained general or targeted funding (primarily grants) from companies. UIRCs vary considerably with respect to their research orientation (such as basic or applied research or even development).

Table I.21: Structural and basic orientations between research organizations in Germany and the US, adapted from Abramson et al. [1997].

Basic Orientation	Germany	United States
Education, Pure Science, Basic Research	Universities (General/Research, Technical Universities, Universities of Applied Sciences)	Universities
Pure Science, Basic Research	Max Planck institutes	University affiliated institutes; selected federal (national) labs and federally funded R&D centers; some independent research institutes
Public Mission, Public Interest, Political Program	Helmholtz (national) research centers and research institutes	Large national laboratories; smaller federal laboratories; state-level institutes
Applied Science, Applied Research	Leibniz research institutes; state research institutes; special institutes at universities	Independent engineering research institutes; University-Industry-Research Centers (UIRCs)
Applied Research & Development	Fraunhofer institutes and clusters; public-private collaborations with diverse partners and ownership; "An-Institutes"	Industrial R&D collaborations (e.g. via industrial consortia)

A German "An-Institute" [26] is an organizationally and legally independent research unit that is affiliated with a German university. Its legal status is private and owners may include various combinations of government, university, association, professors or industry. Management and administration is with one or several professors belonging to the faculty of the university and who are employed sideline at the An-Institute.

According to Abramson et al. [1997:19] industry-sponsored research at the German An-Institutes seems to be more oriented toward short-term applied research and problem solving and is more contract-driven than is true for industry support of American UIRCs.

There are notable differences between the German and US systems. *For the US there are no real equivalents of the Max Planck Society and Fraunhofer Society*. In particular, the personality-shaped Max Planck Society which was founded in 1948 as the successor of the Emperor Wilhelm Society (Kaiser Wilhelm-Gesellschaft) from 1911 is the dream of scientist from around the world. The dream is condensed in a morning phone call you may receive. “Would you like a few million dollars a year in funding, for the rest of your scientific career, to pursue any research you want, with no grant writing, no teaching, and few strings attached?” [Everts 2008]

The public money is given according to the following logic: If you pick out brilliant researchers and give them ample and unrestricted funds to be creative, good things will happen. Directing a Max Planck institute is “the opportunity of a lifetime” and “in fact, you are encouraged to pursue high-risk science,” rule-breaking research.

Since 1948, MPG scientists have won 17 Nobel Prizes [Everts 2008]. Though MPG researchers have no higher-education obligations, many MPG scientists hold university professorships. In the US functionally close to Max Planck institutes (MPIs) are some publicly funded university-affiliated basic research institutes. But there is no corresponding uniformity across the spectrum of research field in the US.

There is no single institutional (public or semi-public) counterpart to the Fraunhofer Society in the US [Abramson et al. 1997:10]. The highly networked German Fraunhofer institutes with research centers and representative offices across the globe conduct primarily applied research, development including scale-up to pilot plants and pursue technology transfer by various means.

Many of the contract R&D and technology transfer functions of the Fraunhofer institutes are done in the US by a large, diverse and dispersed population of public and privately held for-profit and non-profit organizations. Most prominent among these are the large independent engineering research institutes including, for instance, large private R&D and management consulting firms or research units of some US industrial consortia.

Cooperative industrial research, whereby independent industrial enterprises join together to conduct research projects of common interest, is an important vehicle of technology transfer in Germany and the US. R&D consortia have a longer history and a more established role in Germany than they do in the US.

The semi-public German Fraunhofer Society (FhG) receives the by largest share of public funding by the federal government (Table I.20, Figure I.37). FhG’s research and development is heavily demand-driven. However, for the Fraunhofer institutes the exact amount of funding depends on their success in generating sufficient contract work for public and private clients.

Despite the industrial orientation many FhG directors have close relationships with universities by joint appointment as university professors. The competence of the FhG institutes is largely sustained and advanced by R&D projects for public clients that are medium- or long-term in orientation and by public base funding used for self-determined research in new strategic areas.

The organization of the FhG institutes into one society allows for strategic cooperation among different institutes working in the same technological cluster and joint investment in high cost facilities (for instance, demonstration centers). The Fraunhofer institutes have a dense (coupled, networked and coordinated) infrastructure of publicly funded contract R&D institutions that are geared toward serving the R&D and development needs of both traditional and high-tech industries with fields such as industrial engineering, mechanical engineering, material and process engineering or microelectronics, photovoltaic, organic semiconductors, printed electronics and nanotechnology.

The An-Institutes in Germany also perform contract research for firms and often engage in activities similar to those of the FhG institutes. They, however, are not networked.

Figure I.36 shows that for the field of technology entrepreneurship in Germany universities of various types provide the by far largest number of new firms' foundation from largely publicly or mixed private-publicly funded research organizations (which is essentially also the case for the US). German and American research universities have the primary functions of education and research, with the emphasis on basic research. However, the German type of "university of applied sciences" has a dedicated focus on applied research and is the origin of spin-outs to a rather high proportion.

Basically, the US university system (essentially research universities, their schools and colleges) is largely privately organized and financed whereas the German one is publicly organized and almost entirely financed – general, or base institutional, funds – by the federal states (in German Länder). Faculty of German universities, hence, is "civil servants" (in German Beamte) and paid on a monthly 100 percent basis.

In the US the notions "public" and "private" refer to the way a school is funded. Public universities obtain only a part of their support (30-40 percent of operating budget) from the state whereas private universities are supported by student tuition, research contracts, private donations and endowments and investment income – the last one being dramatically reduced during the Great Recession and the time after [Jan 2009; Zezima 2009; Spiewak and Thuswaldner 2009]. In the US there are more than 600 public and 1,700 private universities and four-year colleges, whereas in Germany, compared to the US, there are only few private universities or schools, most of them focusing on economics, business administration and executive management.

This means that, on average, cost to study at a university is much higher in the US than in Germany. Moreover, Americans are going into staggering amounts of debt in order to pay for their educations. In 2010 Americans owed an all-time record of more than $850 billion on *student loans*, which was actually more than the total amount that Americans owed on their credit cards [Snyder 2010].

A “state university system” in the United States is a group of public universities supported by an individual US state. These systems constitute the majority of public-funded universities in the country. Each state supports at least one such system. It normally means a single legal entity and administration, but may consist of several institutions, each with its own identity as a university.

US academic enterprises appear to be much more heterogeneous and decentralized in its administration and management than its German counterparts. There is a “*non-system*” of US research universities and colleges which is a highly autonomous population, each established and developed in response to some unique combination of local, regional (state) and national needs and opportunities.

The institutions vary considerably in the size of their research budgets, general orientation of their research (some are more basic, others are more applied), the reputation (quality and productivity) of their research activities, the scope and intensity of their technology transfer activities, and their administration and accounting practices. German universities are more homogeneous in size, administration and management as well as in the overall breadth of their research portfolios.

Contract and grant funds for German academic R&D come primarily from the German Research Foundation (Deutsche Forschunsgemeinschaft – DFG), the Federal Ministry of Education and Research (BMBF – Bundesministerium für Bildung und Forschung), Federal Ministry of Economics and Technology (BMWi – Bundesministerium für Wirtschaft und Technologie) and also Federal Ministry of Defense (BMVh – Bundesministerium der Verteidigung) … and the European Commission (EC). As a result, the overhead costs related to research supported by these funds must *de facto* be covered essentially by institutional base funds provided by the states. Therefore, in terms of personnel and time, academic research depends heavily on external sources: roughly half of all German academic research relies on contracts and grants if the related overhead funds covered by the states are included.

The issue of overhead cost has marked consequences for university-industry relationships, in particular, when a US or German company sets up a cooperation with a German or a US university. Runge [2006:689] describes the case for cost saving aspects for a private company in a university-industry joint research in Germany.

Cost saving options for an industrial firm may result from “extraordinary services,” such as *utilizing sophisticated, highly expensive equipment or facilities* which are available in a university, but will not be needed on a regular basis in the firm to justify purchase of such equipment or going for a commercial service firm. On the basis of a “rough” model saving key infrastructural and overhead cost would correspond to ca. 60 percent of the cost that would show up if the project would have been done by the firm in-house.

An underlying case was that, in December 1998 the Albert-Ludwig University of Freiburg (Germany) and BASF and private lecturer Dr. Ralf Reski set up a cooperation agreement in the field of *plant biotechnology*. The object of this scientific collaboration was to elucidate the *biological function of plant genes*. The cooperation comprised expenditures of more than DM30 (ca. €15) million over four years.

BASF financed the *salaries* and *operating inputs* for 40 scientists and laboratory technicians. Freiburg University provided the *laboratory building and the infrastructure* required for operating the laboratories. This constellation makes cooperation of firms with German universities "cheap" when compared with the situation in other (Anglo-American) countries. For the US, for instance, for cooperation MIT puts additionnally an "overhead" of ca. 40 percent on top of the cost for personnel.

According to Abramson et al. [1997:15] the share of public base funds in US universities is quite low. Instead, the vast majority of US academic research in science and engineering is sponsored directly by non-academic institutions, via grants or contracts that include money for overhead cost. The main funding sources are the National Science Foundation (NSF, comparable with the German DFG) and federal government. The major sponsors of the US federal government are the Department of Defense (DOD), Department of Energy (DOE), US Department of Agriculture (USDA), the Department of Health and Human Services/National Institutes of Health (NIH), and the National Aeronautics and Space Administration (NASA). NIH is a very large contributor to university research (ca. 50 percent). More than half of the budget of US federal R&D facilities is spent for defense purposes.

Both German and US academic researchers must compete for research funding on a project-by-project basis via peer-reviewed proposals. The competition for research grant proposals requires a great deal of paperwork and grant management which means non-research related efforts by the principal investigator, who may serve as both a grant applicant and a "volunteer" reviewer of the grant proposals of other researchers. Both German and US universities receive also research funding from private industry.

The difference in the establishment of the national university system since the early 19th century as essentially a private endeavor in the US and as an essentially government-driven, public endeavor in Germany induced important consequences for the university-industry relationships in both countries. From early on the German industry had to build up interfaces and closer ties with policy to exert influences on the higher education and the S&T system (Box I.3).

Box I.3: The rise of university-industry relationships in Germany.

In Germany early on a model of "science and technology transfer" and collaboration among corporations, government, and academic laboratories was established – an *industry – science – policy triangle of co-evolution* [Murmann 2003]. The most illustrative example is the exorbitant rise of the German synthetic dye industry (A1.2), then the pharmaceutical industry and simultaneously the tremendous growth of industrial research. And the generics of what is promoted currently as "*open innovation*" has been practiced in various modes regularly in Germany, at least in the chemical industry, since the last third of the 19th century.

The first notable science to industry transfer occurred when in Germany Carl Graebe and Carl Liebermann with Heinrich Caro, then research director of BASF, pooled their discoveries and jointly filed a patent for the alizarin dye in Britain. Working in Prof. Baeyer's laboratory, Carl Graebe and Carl Liebermann achieved the first synthesis of alizarin ("synthetic madder") in 1868. Commercial production began at BASF and elsewhere during 1869-70.

When BASF bought the alizarin patent in 1869 it provided Graebe and Liebermann in exchange 3 percent of the total turnover of the product for the following 15 years. Both had also to support BASF in improving the finishing process [Runge 2006:267, 673].

This kind of university-industry alliance targeting industrial production of key chemicals or materials, respectively proceeded in Germany continuously as shown for the BASF [Jahn 2007, Runge 2006:684].

Chemicals/Material	**University/Industry Alliance**
Indigo (1897)	Adolf von Baeyer, Karl Heumann (University) Heinrich Caro (BASF)
Ammonia (1913)	Fritz Haber (University) Carl Bosch, Alwin Mittasch (BASF)
Polystyrene (1930)	Hermann Staudinger (University) Carl Wolff (BASF – I.G. Farben)
Vitamin A (1963)	Georg Wittig (University) Horst Pommer (BASF)
Strobilurins (1996)	Tim Anke, Wolfgang Steglich (University) Hubert Sauter (BASF)
Vitamin B2 (2000)	José Luis Revuelta (University) Burkhard Kröger (BASF).

Notably, there are five Nobel Prize winners for chemistry in these alliances (Adolf von Baeyer – 1905, Fritz Haber – 1918, Carl Bosch – 1931, Hermann Staudinger – 1953, Georg Wittig – 1979).

Few corresponding examples were found for the US in the first third of the 20th century. This became only significant in the US in the 1980s. Historically, an outstanding industry/academia interaction was the DuPont/University of Notre Dame relationship. Notre Dame's first and most famous effort in technology transfer was Father Julius Nieuwland's groundbreaking work with polymerized 2-chloro-1,3-butadiene, which led to two patents and the development of the synthetic rubber, Neoprene, in 1931 by the E.I. DuPont de Nemours chemical company. That particular bit of "intellectual property" was very good fortune for the Notre Dame University – some $2 million when the royalty payments ceased in 1948 [Runge 2006:692].

Other roles of academia to transfer science to business were also observed very early in Germany. For instance, Justus von Liebig, the world renowned chemist and father of agricultural chemistry, participated in 1857 in the foundation of the stock company "Bayerische AG für chemische und landwirtschaftlich-chemische Fabrikate" to produce chemical products and synthetic fertilizers. Already in 1859 the firm started producing superphosphates. This firm became the German firm Süd-Chemie which was recently acquired by the Swiss specialty chemicals firm Clariant (A.1.1.3).

The more distinct *systemic* directions of the coupled German Higher Education, S&T and Economic Systems compared to the US is also reflected by the associated *interaction, communication and coordination* efforts in terms of *competence networks* (in German "Kompetenznetze"). These networks comprise persons, universities, public research institutes, firms of various sizes (usually mid-sized firms and NTBFs) and associations and are set up with competence-orientation according to a given target.

Functionally, *competence networks act as gateways* (Figure I.20) between the involved system components. Actually they are *often organized across technologies and industries*. Their "Partnering Events" (in German Partnerveranstaltungen) provide a platform for presentations, discussions and personal contacts for people from universities, public research institutes, private (NGO) research institutes and industry (Figure I.39). They allow exchange of research results and sharing information on ongoing projects as well as establishing contacts for potential cooperation [Runge 2006:292].

These *networks often elaborate proposals or roadmaps for future R&D directions* (and coordination) as an input for related political S&T programs. Competence networks provide also an important platform for potential or *nascent technology entrepreneurs* to gain visibility and options for further progress.

The Competence Network Initiative (in German Kompetenznetze Deutschland Initiative) of the Federal Ministry of Economics and Technology (BMWi) brings together the high-performing innovation clusters in Germany. Actually the initiative comprises a total of ca. 116 member networks; these are differentiated according to 9 main topics and furthermore spread in 8 defined geographical regions within Germany.

Topics which reflect directions of German S&T policy include, for instance:

- Biotechnology,
- Energy and Environment,
- Health and Medicine,
- Information and Communication,
- Micro-Nano-Opto,
- New Materials and Chemistry,
- Production and Processes,
- Traffic and Mobility,
- Aeronautics and Space.

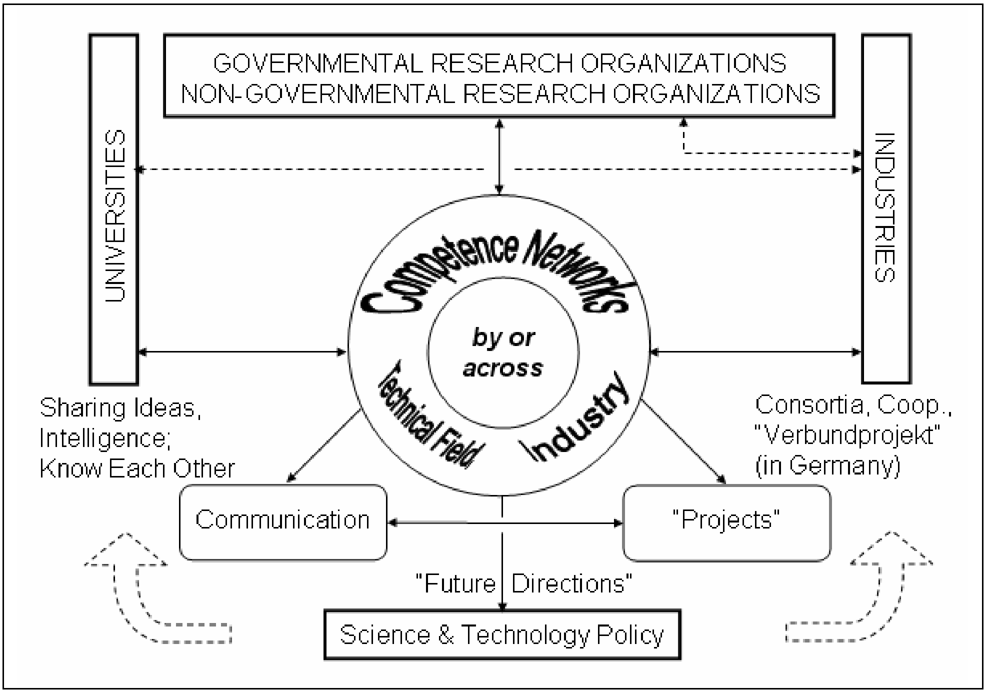


Figure I.39: German competence networks as the gateways for university-industry-policy interactions for innovation.

Over the last years many networks have been set up through public funding and support as well as private activities. The Initiative aims bringing together the most innovative and capable national technical networks of competence which qualify by their high level of activity and cooperation in sharing commonly formulated goals, and excel both in minimizing distance to markets and industry and in their dynamics and flexibility. In the regional technology networks components represent the entire value system of the technology-related markets or industry segments. This facilitates creating innovative products and processes.

There is overall administrative coordination by an "Initiative Office" ("Geschäftsstelle der Initiative Kompetenznetze Deutschland"). Furthermore, there is an independent advisory council assigned by the Federal Ministry of Economics and Technology (BMWi) consisting of well-known representatives of science and economy from the Networks of Competence-community. In close cooperation with the BMWi the advisory council decides on the strategic orientation of the Initiative, evaluates networks of competence willing to join the initiative, and chooses the winners of the annual contest "Network of Competence." [27]

German and US universities are engaged considerably in technology transfer to the private industry and have developed a wide range of mechanisms to execute or facilitate the transfer through various organizational units and channels (Figure I.41), for instance, establishments of patent licensing and technology transfer offices, affiliated institutions and research centers, high-tech incubators, and science (research) parks.

> Out-licensing of patents by universities and public research institutes is an important basis of technology entrepreneurship.

Several universities, particularly in the US, are increasingly proactive, not only in licensing technology but in trying to develop it to the point where it may be more marketable. Their goal is to attract investors by *bridging that valley of death between invention and commercialization*. Some also partner with large corporations to advance research and transfer technologies. And many provide programs and facilities to train and support academic entrepreneurs [Thayer 2008]. Still, most universities do not go this route. Instead, they rely on traditional means of technology transfer. In the worst case, interested outside parties stumble by chance across university IP.

Also consulting by faculty members is an important channel of technology transfer. US and German science and engineering faculty are allowed to spend a proportion of their time for outside activities. Particularly for the German industry it is quite common that people from industry hold teaching positions or professorships at universities around the world. And as cited by Runge [2006:689] a representative of chemical giant Bayer AG emphasized that "this informal intellectual network is the basis for our scientific interactions."

Most German and US universities with substantial research activities have established offices that support the patenting of inventions and the active marketing of these patents. However, there are varieties in both countries in tackling their missions. Some lay claim to all research output generated by their laboratories, others are more flexible in negotiating the disposition of intellectual property resulting from their campuses. This has important consequences for startups that intend to rely on IPR of universities or other research institutes.

In Germany, the dominant form of collaborative research is cooperation of regular university institutes {and/or other public research institutes} with industrial firms of various sizes on projects funded by the BMBF (or BMWi – "Verbundprojekt"). Researchers in *Collaborative Research Centres* funded by the DFG ("Sonderforschungsbereiche" – SFB) are also encouraged to collaborate with industrial partners. Usually, in all these types of cooperation the emphasis is on *pre-commercial (pre-competitive)* activities.

The next higher level of technology transfer concerns innovation, for instance, by "*innovation alliances*" tackling practical applications with coordination of many partners and many sub-projects according to a given high-tech strategy. Coordination may be led by industry representatives. In Germany corresponding policy supported innovation alliances aim to bridge science and industry by tailored incentives to support innovative medium-sized firms. [28]

For instance, as an alliance of around 80 renowned partners from science and industry, the “Inno.CNT Initiative” has the job of driving the development of carbon nanotubes (CNT). CNTs have the potential to open up completely new dimensions in materials technology and to add a unique quality to numerous products and applications. Inno.CNT looks into materials technology of the next generation and the starting point for the alliance was a resolution adopted by the German Federal Government in 2006, formulating a high-tech strategy for Germany as a location for industrial production [BMBF 2011].

In all, Inno.CNT consists of 18 projects. Apart from basic research, the Innovation Alliance CNT is focused on practical applications in the fields of energy and the environment, mobility and lightweight construction. It is precisely here that the major social and economic challenges lie: from climate protection and energy supply through safety, lightweight construction and electronics, health to mobility.

The rationale behind this is: The close networking of all 18 projects enables the entire know-how of the partners to be utilized more effectively and generate valuable synergies. In particular, linking up the crossover technologies with the fields of application provides an optimum framework for combining, within the project cluster, basic research with specific application requirements and market needs. And it provides a framework for developing economically promising solutions.

Around €80 million was needed to implement the Innovation Alliance CNT. 50 percent of this sum was provided by the Federal German Ministry for Education and Research (BMBF) as part of its program “Materials Innovations for Industry and Society.” The other 50 percent were financed from funds provided by the partners in the alliance. In addition, German companies planned to invest around €200 million over the next ten years to establish an efficient CNT industry.

The alliance is represented by medium-sized, large and giant firms, universities and public research institutes including MPG and FhG. NTBFs participating in and taking advantage from this alliance and cited in this book include Novaled AG (Figure I.148, Figure I.149) and Q-Cells AG (Figure I.152, Figure I.153). Coordination of the alliance is with Bayer MaterialScience (of Bayer AG) which is already a large producer of CNTs.

For US federal laboratories the Cooperative Research and Development Agreement (CRADA) is the most heavily used mechanism for engaging in cooperative R&D with industrial partners. In particular, here participating laboratories are authorized to protect from disclosure any intellectual property relevant to the agreement. CRADAs constitute the only mechanism by which the federal government can define in advance the disposition of IPRs in government-industry collaborations not involving a government contract. [29]

Only recently, as part of DOD’s Next Top Energy Innovator challenge, for a bargain price of $1,000, startup companies can get up to three of the thousands of unlicensed patents in the Department of Energy's portfolio. The challenge aims to double the number of startup companies emerging from DOE's 17 national laboratories, which hold more than 15,000 patents. Only 10 percent of federal patents are currently licensed to be commercialized, according to the agency. The Department of Energy will also make it easy for companies to conduct their commercialization R&D at the national laboratories [Mukhopadhyay 2011b].

Constellations for technology transfer from government laboratories, KIT (Germany) or NREL (National Renewable Energy Laboratory, US), are illustrated in the Appendix (A.1.1) for the biofuels area, for instance, for the Bioliq-process in Figure I.173 (KIT) and in the US involving NREL, the startup Algenol Biofuels looking for bioethanol from algae comprosing the giant firm Dow Chemical, Georgia Tech and DOE (Figure I.179, Table I.91).

A typically German approach to technology transfer and technical innovation initiated by policy is the **Verbundprojekt** ("**joint project**", cf. Glossary). It is *a systemic combination* of varies partners including NTBFs tied together by a common explicit goal (and achievable result) through *coordination, control and feedback* and assigning different contributing sub-projects to different partners.

A *value system oriented* "joint project" focuses on *interfaces* between participants. It has the structure of a consortium, but key functions of a project. In particular, it is defined in terms of self-sufficient sub-projects and their interfaces to related sub-projects contributing to the solution of a research, development or piloting task. A Verbundprojekt is usually *opportunity-driven*, such as exploiting a new technology, or *change-driven*, which are new needs, growth or change in the business environment (international competition).

It must be admitted, however, that participants (in reality) often put primary focus on their own interests making interface building a secondary aspect. Hence, success of a Verbund ultimately depends on efficient coordination and authority of the coordinator with regard to interface building.

An illustration of a Verbundprojekt is given in the Appendix (A.1.1.4) for the project "Hydrogen from Microalgae: With Cell and Reactor Design to Economic Production" (HydroMicPro; Table I.92, Box I.25). It involves many types of public research institutes, universities, and several departments of a national research center (KIT; HGF, Table I.20), a Max Planck institute and several SMEs. Others are presented in the IoLiTec GmbH case (B.2).

The overall position of a "joint project" or "joint R&D project", respectively in the German industry development approach is shown in Figure I.40 in relation to a structural value system.

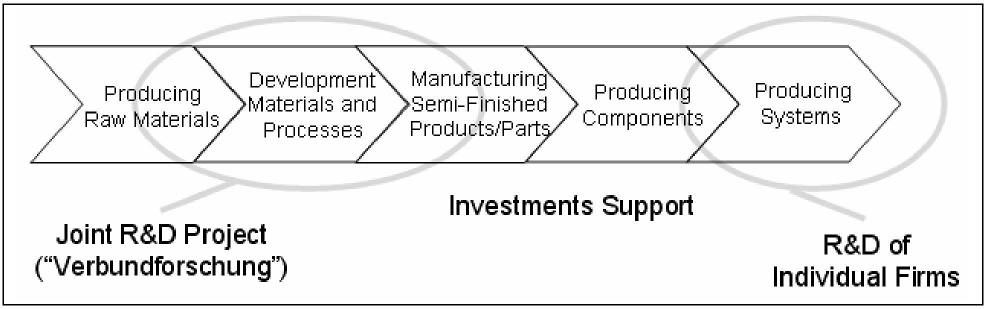


Figure I.40: Exemplary technology transfer funding by the German government and states for materials, components and systems.

On the other hand, a **consortium** is a grouping of two or more legally independent individuals, companies, organizations, public entities or governments (or any combination of these entities) with the objective of participating in a common activity or pooling their resources for achieving a common goal. The grouping submits a tender or an application under a tender procedure or in response to a Call for Proposals. All members of a consortium (that is, a leader and all other partners) are jointly and severally liable to the Contracting Authority. The consortium's approach and shared rights and obligations are to be stipulated in a separate consortium agreement.

A consortium can be active in a pre-commercial ("pre-competitive") manner or, if restricted to only for-profit organizations, in a commercial manner as a "joint endeavor."

> University-industry relationships and related technology transfer does not only play a key role for technology entrepreneurship, but also for research and innovation, respectively, of large and giant companies, and particularly in Germany also heavily for medium-sized companies [Runge 2006:687-692]. This is a basis for a "*networked economy*" of innovation (Figure I.20, Figure I.51).

Due to the many different organizational types of US consortia it is difficult to generalize about the way US consortia define and execute R&D projects and technology transfer.

With the option of establishing or working for a high-tech startup company academic researchers have an important vehicle through which they transfer as well as have a direct hand in commercializing the results of their own research or technologies originating elsewhere. This mode of technology transfer is very important for highly science-based, technically dynamic industries or technology fields, such as software, information technology, biotechnology and nanotechnology.

Technology entrepreneurship using technology transfer from universities or public research institutes may occur either directly or stepwise via an incubation process (ch. 1.2.6.2) of the organization (indicated by NTBF or RBSU spin-out in Figure I.41). These spin-outs may be supported by interested firms through corporate venturing with the alternatives that the new firm can further develop and grow to an SME as an independent entity or may be finally bought (Figure I.20) by the venturing company and integrated as a new unit into that company.

Some examples of very successful technology transfer (via licenses) for technology entrepreneurs and dealt with in this book include

- Cisco Systems (Stanford University; Figure I.145, Figure I.158)
- Google (Stanford University; Figure I.159, Figure I.160, Box I.24)
- US Cambridge NanoTech, Inc. (Harvard University, Table I.80, [Yang and Kiron 2010]) profitable from day one with its ALD (atomic layer disposition) for coatings and appearing due to remarkable growth in the *Inc.* 500 list
- German Novaled AG (Technical University of Dresden, Figure I.148, Figure I.149), multiply awarded for its developments and achievements in the field of OLEDs (organic light emitting diodes), also for its growth rate.

Technology transfer referring to value chain activities has been given in Figure I.20 and comprises joint research or development alliances (JRAs or JDAs), but also contract research of an NTBF for a firm or contract (large-scale) production of a firm for an NTBF.

Big firms usually run organizational units – "University Relationships" – for establishing, financing, managing and coordination of industry-university (public research) relationships. These units are usually closely interacting with other units dealing with innovation, external technologies and new business development (Figure I.41). Basically, technology transfer by university-industry relationships occurs through license-in of technology by the firm or by exchange of personnel or sharing personnel in a dedicated organizational unit, such as a laboratory or a firm.

University-industry relationships are discussed in detail in the Appendix (A.1.3), in particular, those involving exchange of personnel and private-public-partnership (PPP)-firms and laboratories on campus. Participation of academics in such constructs may be a track to gain experiences for technology entrepreneurship (ch. 2.1.2.4, Figure I.64).

Technology transfer via industry-university and inter-industry relationships in terms of contract research or outsourcing research, respectively, is not new at all. In particular, during the transition from the 19th into the 20th century it was common practice [Runge 2006:684].

Outsourcing, originally thought of as contracting or relinquishing responsibility to another organization, has taken on a broader definition for R&D managers of large firms. R&D managers view relationships with universities, national laboratories, contract R&D firms, consortia, and even with other companies often as "outsourcing." But, licensing as described above and also corporate ventures (CV), joint ventures (JV) and acquisitions are also often thrown into the mix.

Currently, for instance, Stanford Research Institute (SRI), headquartered in Palo Alto, CA, and Battelle, both now with laboratories worldwide, are two of the oldest and largest contract R&D providers in the US. In addition to offering specific facilities or expertise, these firms increasingly emphasize their breadth of experience, rapid product development capabilities, and consulting services in their marketing efforts. Battelle is the world's largest, independent research and development organization, working to advance scientific discovery and application.

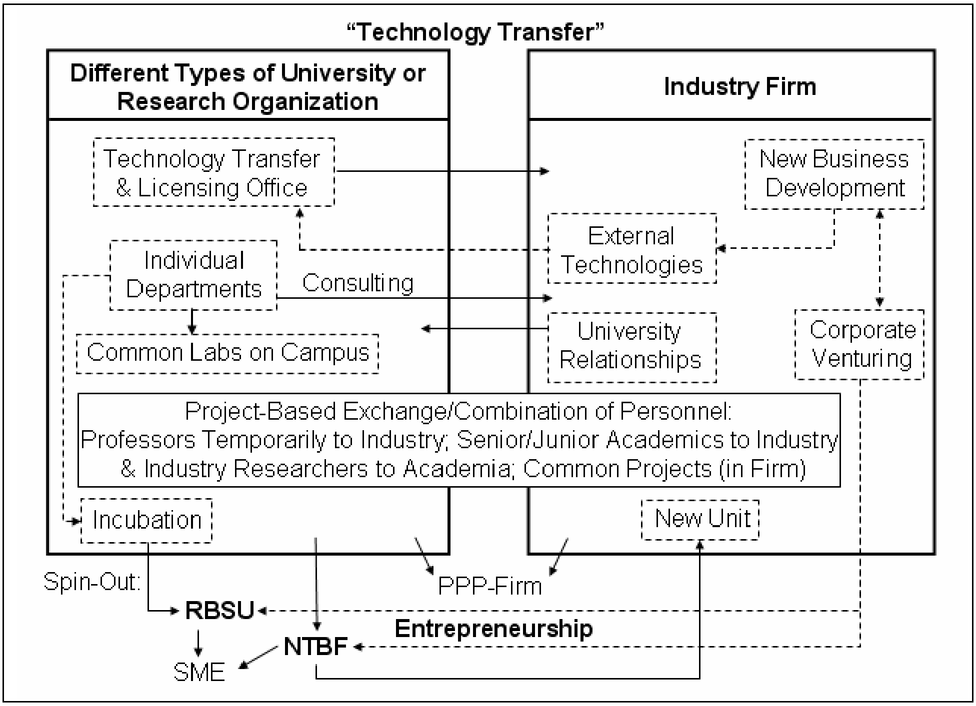


Figure I.41: Key structures involving entrepreneurship and technology transfer to industrial firms.

Today the knowledge sharing process is stratified between academia, public research institutes and industry. All institutions generate knowledge and share certain knowledge, but in most cases the major process barriers are the cultures that impact the ability of both to create new knowledge to satisfy society. There is the research *culture* [Runge 2006:628-632], which is different in universities and public research institutes and the *industrial research culture* (Figure I.42, Figure I.41).

The most significant differences occur between academic research and research in specific business units as there are organizationally different approaches to R&D, executed in a Business Research unit or Corporate (Central) Research unit [Runge 2006:717-720]. Additionally industrial research is also determined by the firm's culture.

However, there are basically some other important differences: time horizons for R&D, confidentiality (speaking about and sharing R&D results) and a business perspective challenging the scientific/technical one. This means first is managing R&D for business growth; then there is integrating technology planning with business strategy and balancing long-term/short-term R&D objectives and finally making innovation happen.

And, as in the case of licensing, there is an additional bottleneck in the transfer mechanism, the tacit knowledge or tacit technology to be codified and documented for a structured knowledge/technology process. This process is preferentially via involved people rather than documents. Knowing each other personally, a lot of informal contacts between academic and industrial researchers and managers via direct and electronic meetings, e-mail, telephone conversations etc., facilitate technology transfer markedly.

The general approach to university/research institute-industry relationships is project-like or establishment of goal- and time-restricted endeavors, whether common laboratories or even firms – private-public partnership (PPP) firms. Examples of the broad varieties of approaches are presented in the Appendix (A.1.3).

Technology transfer may exhibit a route from a university via a spin-out to RBSU or NTBF becoming a new player, an entrant, in a market or industry, respectively. However, technology transfer may go beyond a “one-way street” out of an academic organization to an RBSU or NTBF.

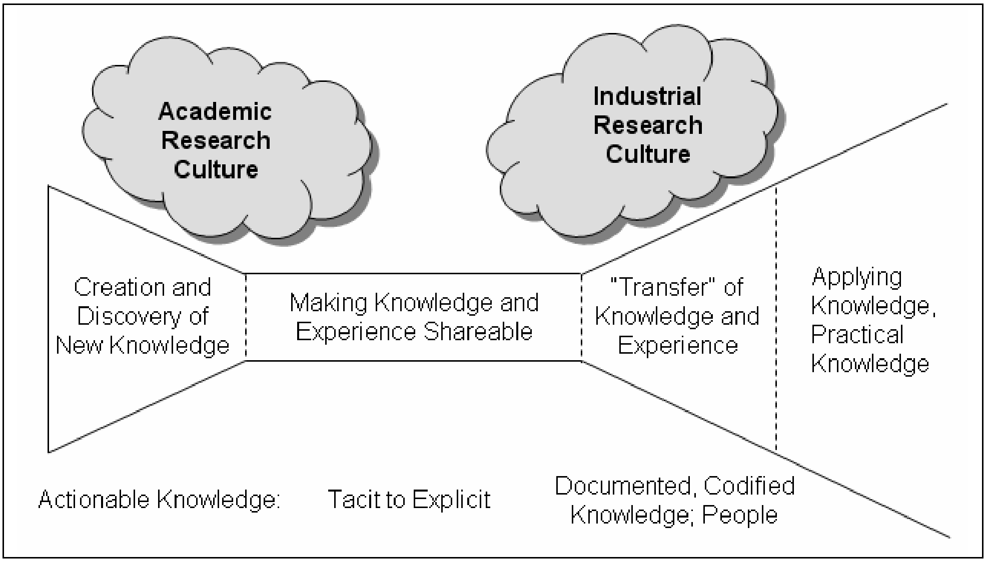


Figure I.42: Issues and bottlenecks for university-industry technology transfer.

Technology transfer may also induce a systemic effect of *reflexivity*; the original cause initiates a reaction onto itself. In this bidirectional relationship both the cause and the effect affect one another via feedback (Figure I.43).

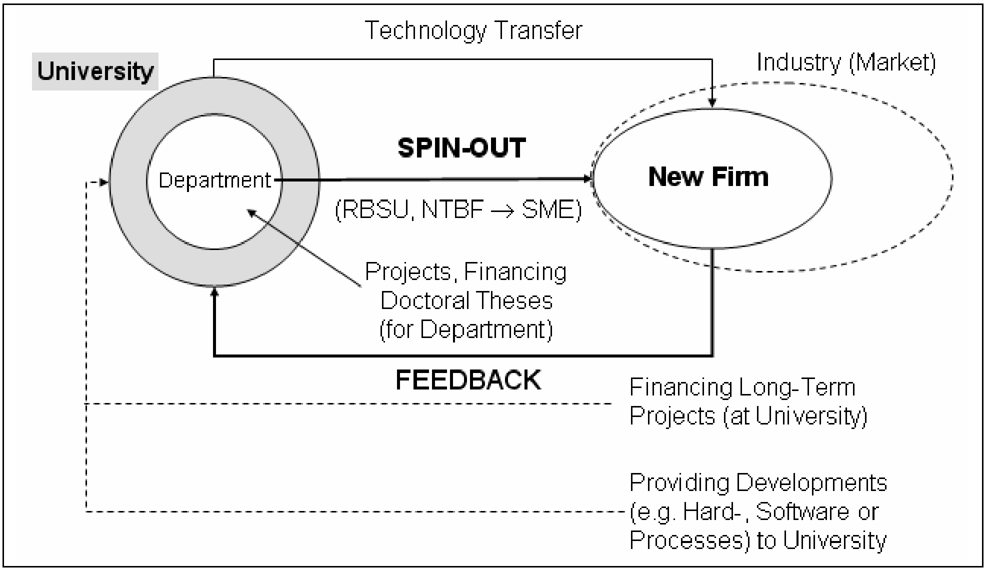


Figure I.43: Potential systemic reflexivity illustrated for technology transfer via a spin-out.

That means a new firm created via spin-out may go back to the university or a respective department to initiate projects of relevance for its own development and growth including financing and providing support for the university. This is done, for instance, by the German NTBF Novaled AG (Figure I.148, Figure I.149, B.2).

With regard to technology transfer startups from research-oriented intellectual properties do not only use licenses for one to five related patents for well-defined direct exploitation purposes, as described for biofuels (Appendix A.1.1), but may be based almost entirely on a wealth of (50-250) licenses from universities as described in Box I.4. Here, the company's vision is different from that of a typical small, venture capital-financed company, which must focus on a particular application or product.

Box I.4: Startup strategies relying heavily on university licenses.

For nanotechnology which is largely science-based a *VC-based startup model* emerged *combining top university research, entrepreneurial spirit and business experience*. Generically, experience here relates to a specification of a "veterans approach" to professional management which is also followed excessively by biofuels startups in the US (A.1.1).

In 2001 a founding team of Lawrence Bock, a successful biotech venture capitalist, Stephen Empedocles, a PhD chemist from MIT who had worked at two nanotech startups and Calvin Chow, founder of two device-oriented technology companies set up Palo Alto, Calif.-based Nanosys, Inc. It eventually brought together ten scientific founders and licensed several hundred patents from the likes of Harvard, MIT, Caltech, Columbia University, and the University of California.

Nanosys' business strategy was to *commercialize its products through partnerships* with leading companies in a variety of industries. According to Nanosys "Nanosys leverages the market expertise and complementary technologies of its strategic partners, while the partners leverage the unique technical and market opportunities enabled by nanotechnology without having to become nanotechnology experts themselves."

Nanosys added experienced product-development people and focused initially on solar cells and biosensors. The company's IP portfolio, which has expanded further over the past years through internal development work, covers everything from compositions of matter and different nanostructures through assembly techniques, specific applications, device integration, and manufacturing methods. "Our goal is to supply our partners with a component that can be integrated easily into their existing manufacturing." These "nanomodules" and the interface with a product will differ to meet each partner's needs [Thayer 2008]. In 2004, the company filed for an initial stock offering but did not proceed when market conditions deteriorated [Runge 2006:552; Thayer 2008].

By 2006 Nanosys had amassed an IP war chest of ca. 200 patents and patent applications in the field of inorganic semiconductor nanomaterials like nanowires, nanorods, and quantum dots [Runge 2006:552]. Currently, its technology, products, and processes are covered by over 700 patents and patent applications and it has around 75 employees. [30] Nanosys does not do any fundamental research, so it still looks to the academic community for research advances [Thayer 2008].

By 2008, Nanosys raised over $100 million in four rounds of venture capital financing. As a private company, Nanosys does not disclose revenues or profits. Currently, heavily VC-backed Nanosys delivers process-ready materials optimized for specific properties for electronic device manufacturers seeking LCD displays with better color gamut and brightness and lithium ion battery makers aiming to deliver higher battery capacity in consumer electronics.

Apart from Nanosys there are several startups following a similar route. For instance, in 2007 Harvard University granted Nano-Terra (founded in 2005) a license to a portfolio of more than 50 issued and pending patents, which cover nano- and microscale molecular fabrication methods for advanced materials and devices. In return, Harvard received equity in the firm and the right to royalties.

Nano-Terra's business plan was to leverage this IP through co-development agreements with large organizations, such as 3M and the Department of Defense or in Germany Merck KGaA or Bayer MaterialScience and the Department of Defense. "We don't see Nano-Terra manufacturing something and selling it." Around 2008 Nano-Terra had a staff of about 30 people and laboratories in Cambridge, Mass. But it also tapped into a global network of academic and industrial collaborators, some of whom are co-inventors of Nano-Terra's IP. Initial capital for Nano-Terra came from the founders, employees, and others in the collaborative network and was quickly augmented by development funding from the first few partnerships [Thayer 2008].

Licenses as a means for revenues of new entrepreneurial firms (Table I.3, Table I.14) or a basis for firm's foundation are usually based on patents.

Patent law is country-specific, and there are *marked differences between the US and German or European, respectively, patent systems*. These differences have implications for RBSUs and NTBFs, but also existing firms, specifically with regard to their R&D processes.

Differences include, for instance, declaring the inventor, disclosure requirements and opposition, but also the interpretation of patent claims. Key differences and implications are summarized in Box I.5.

Box I.5: Key differences of the US and German patent systems and implications for entrepreneurship and the R&D process.

The most notable difference between the patent systems in the two countries refers to the US *first-to-invent* versus the German/European *first-to-file principle*. In Germany and Europe, when two inventors apply for a patent on the same invention, the first person to have filed the application with the patent office will get the patent (assuming the invention is patentable). This holds even if the second person did in fact come up with the invention first. It is the *filing date* that counts.

If in the US two applications for the same invention (a so-called interference) arrive at the patent office, a determination is made who invented it first. This requires a detailed examination for provable evidence and documentation establishing dates of the invention. If the person who filed later is found to have invented earlier, he/she may be awarded the patent. It is the *invention date* that counts according to US law [Runge 2006:885-891].

In the US the first to invent principle has a number of implications for documenting and witnessing the time, activity, findings and conclusions during a research process (in "laboratory journals" or other documents with corresponding authentication and archiving requirements). In the US there is a related higher probability of patent suits associated with inspections of corporate files.

Therefore, it is very important to ensure that in patent evaluations stored in computer files or on paper researchers utilize the proper wording, phrasing, referencing, commenting and explicit inference statements that do not generate future “dangerous” legal implications. Hence, for patent application in the US it is particularly advisable that related inventors’ text is checked by patent attorneys [Runge 2006:885].

A notable and important advantage of the US patent system is the existence of a *grace period for patent application*, a particular advantage for scientists and researchers, who often publish first and decide to patent later. The US has a one-year grace period. This means that the inventor can freely publish his invention without losing patent rights. However, this only applies to the US. The German and European patent system has no grace period and US researchers cannot use their grace period if they intend to file their patent abroad. The absence of a grace period in Germany is viewed often as a barrier to technology transfer from scientific institutions to industry.

Then, according to *best mode requirement*, US patent law requires the inventor to include the best way to practice the invention in the patent application (in the description or examples part of the patent document). In this way, the inventor cannot get a patent and still keep some essential or advantageous aspects a secret which is in favor of the licensing process. In contrast, German or European patent law has no such requirement. It suffices that, at least, one way of practicing the invention is included in the application, but there is nothing that states this way must be the best way, or even a good way. This may raise difficulties in setting up a license process properly by a licensee.

Within nine months after the grant of a German/European patent, anyone can file an *opposition* with the German/European patent office (DPMA, EPO), stating why this patent should not have been granted (with arguments and evidence). *The patent holder and the opponent can then debate with each other*. Finally, the DPMA/EPO will take a decision based on facts and arguments presented by both sides.

While the US has a reexamination procedure, it does not work the same as an opposition. In a reexamination, anyone can present reasons and evidence to the US Patent Office (USPTO) to challenge the validity of a granted patent. However, it is then the patent holder who engages in a discussion with the USPTO examiner to establish the validity of the reasons. The challenger is not a part of these proceedings.

1.2.6.1 Differentiating Groups of Technology Entrepreneurs

In ch. 1.1.1.1 RBSUs were introduced as a special sub-group of NTBFs. The creation of spin-out companies by academic entrepreneurs is an increasingly important entrepreneurial phenomenon with significant interferences by S&T policy. Correspondingly, for technology entrepreneurship technical entrepreneurs and science/academic entrepreneurs have been differentiated essentially according to educational origin and competencies [Runge 2006:438-439]. But Figure I.41 indicates that founders of RBSUs are also special with regard to the options for the founding process and “incubations” of the early phase of the startups as nascent entrepreneurs (Figure I.15).

“**Academic entrepreneurs**” are associated with new ventures originating from (academic) science and research-oriented education and often intellectual properties, usually spin-outs from a university or a public research institute [Tidd et al. 2001:352].

“**Technical entrepreneurs**” or *engineering-type entrepreneurs*, respectively, refer essentially to people with technical backgrounds or educations (and often a business mind or attitude) and tend to have prior business or industry experience. Typically, they stem from various types of technical schools or people with engineering degrees from universities, such as the MIT or Harvard School of Engineering and Applied Sciences in the US or technical universities (of Karlsruhe, Munich, Aachen, Dresden etc.) or universities of applied sciences in Germany (Figure I.36).

A person with practical (technical) knowledge, for instance, through apprenticeship as an electronics or electricity technician, would also qualify as a technical entrepreneur. An example for the last situation is the Opolka twins in Germany who founded the extremely successful firm Zweibrüder Optoelectronics GmbH (B.2).

Concerning sub-classes of NTBFs correspondingly, academic entrepreneurs with a science or engineering higher education could be associated with founding RBSUs or EBSUs. Concerning types of technology entrepreneurs technical entrepreneurs would be associated with academic startups or “other NTBFs”:

<table>
<tr><td colspan="2">Academic Entrepreneurs</td><td>Technical Entrepreneurs</td></tr>
<tr><td>Academic Spin-Outs (Research-Based Startups – RBSUs)</td><td colspan="2">Engineering-Oriented Firms
(Academic Startups – Engineering-Based Startups (EBSUs) plus “Other NTBFs”) (Table I.2)</td></tr>
</table>

Academic entrepreneurs are often involved in “science-based business,” for instance, in nanotechnology or biotechnology. This means, the lag between when scientific principles are discovered or published and the formation of related firms to develop and exploit them may be extremely short. Correspondingly there is often considerable risk associated with commercialization.

Academic entrepreneurs are often shaped fundamentally by the “research culture,” whereas technical entrepreneurs tend to be educated and conditioned by the “engineering culture” (ch. 2.1.2.3) and specifically by the “entrepreneurial climate” of the parent organization (technical universities and colleges). The stronger commercial orientation of technical entrepreneurs is also partially due to the engineering education (ch. 2.1.2.3). Furthermore, for technical entrepreneurs experience of development work appears to be more important than work in research (Figure I.62).

EBSUs are often founded by experienced engineers running an engineering office, such as TimberTower GmbH [Giebel 2013] or many startups in biofuels (A.1.1).

A reflection of these characterizations is given by Minshall and Wicksteed [2005] when describing the roles attributed to academic institutions which have evolved according to two main perspectives on teaching and research:

- The “classical university” (“research university”) generates and transmits knowledge through research conducted for its own sake, and teaching aiming to develop the full potential of students,
- The “technical university” (including in Germany the university of applied sciences) focuses on training students with knowledge and skills that are useful for society and on creating knowledge of direct societal benefit.

Referring, for instance, to preparation and production of biofuels (A.1.1) engineering-oriented startups tend to follow more or less established thermochemical processes whereas academic startups and RBSUs tend to follow new biotechnological routes. The broad spectrum of offerings of an engineering firm specializing in mechanical engineering and plant engineering is described for the German firm CHOREN Industries in the Appendix (A.1.1.3).

As a final remark, the differentiation of technical and academic entrepreneur referring to educational background does not provide a disjoint classification. There is just a fine line in terms of bent toward commercialization. For instance, founders from applied or experimental physics are closer to engineering than to science (as observed for WITec GmbH, JPK Instruments AG, Attocube AG, Nanion Technologies GmbH; B.2). And, finally, academic entrepreneurs seem to be more following an incubation process (ch. 1.2.6.2) than technical entrepreneurs.

Scientific academic entrepreneurs tend to focus on a *technology push* approach, whereas technical entrepreneurs are oriented more toward *demand pull* (ch. 1.2.5.1). There is often a basic misunderstanding of to-be academic entrepreneurs targeting production:

> Scientists/researchers often think that 90 percent of the job is done because they had developed a prototype in their laboratories. But it is quite the opposite – 10 percent of the work is done. The company (mostly) still needs to manufacture real, large-scale products, or materials, market them and resolve customer issues (A.1.1; scale-up – Figure I.8, Figure I.9).

Reversing the focus on strong technical competency and medium or “sufficient” commercial competency or, at least, commercial experience, interest, bent or attitude of technical entrepreneurs let emerge another type of entrepreneur, the **technical businessman/woman** (technical business person) [Runge 2006:445, 777]. This group is characterized by entrepreneurs with strong commercial competency and simultaneously a strong technical bent or additionally a certain technical training.

Here the Opolka twins (Zweibrüder Optoelectronics GmbH; B.2) show up as they started with a successful trading business for knives and cutlery (with production in

China) before they turned to a globally leading light emitting diode (LED) lamps business.

A further recent example is the founder of Nanopool GmbH in Germany who not only has studied psychology and business administration and finished the last one with a university degree, but appears also as an inventor of foundation related technical patents [Runge 2010].

Another example of the rare cases of a founder with a business administration education and related technical competence is Klaas Kersting who developed an online game before founding together with Alexander Rösner the German firm Gameforge AG (B.2) in 2003, engaged in client-based Massively Multiplayer Online Games (MMOGs) and one of the largest global providers of MMOGs (ch. 3.4).

It is, in particular, the software area where MBAs have developed technical skills and thus appear as original founders proportionately more often than in the industrial high-tech areas. But, an MBA is not a typical qualification for software entrepreneurship. Foundations in this area are often by people interested in software and programming with scientific (for instance, physics or mathematics) or various non-technical backgrounds or educations, respectively, such as psychology or arts.

The above outlined grouping of *combining technical and commercial competencies* has been seen as fundamental for technology entrepreneurship, William Henry Perkin (A.1.2) being the historical prototypical example when the two competencies are combined in one person.

However, successful technology entrepreneurship also shows up, if the competencies are associated separately with two different persons. This led to the notion of the "**entrepreneurial pair**" [Runge 2006:439]. Here we have two persons (often "friends") *combining and complementing* their individual technical and commercial entrepreneurial competencies, each one alone missing a required key characteristic or bent to "initiate entrepreneurial action."

Classical examples of entrepreneurial pairs (Figure I.71) covering three centuries of such *co-founding* are Diesbach & Dippel (Berlin/Prussian Blue), Bayer & Weskott (Bayer AG), Röhm & Haas, Eastman & Strong (Kodak) [Runge 2006], Hewlett & Packard (HP, US), Swanson & Boyer (biotechnology giant Genentech, US) as well as Rickert & McClusky (Nanofilm LLC, US), Wrage & Meyer (SkySails GmbH & Co. KG) and Böbel & Ballin (Torqeedo GmbH) (all from the NTBF sample in B.2). Notable is also the pair of the chemist Eugen Lucius and the businessman Wilhelm Meister who founded in 1863 the dyes firm "Meister, Lucius & Co" which became later the chemistry giant Hoechst AG (dissolved in the 1992) [Hoffritz 2013].

One notable advantage of the entrepreneurial pair composed of two friends is that, during a crisis, setbacks or a dangerous situation of the new firm, one may "keep the other warm mentally and emotionally," or both may support each other correspondingly. Finally, Bhidé [2000:303] pointed out that complementing may also occur, if a *detailed-oriented founder* who can take care of operations join with a *founder with the strategic vision*.

Further division and specification of competencies associated with individual persons extends the "pair concept" to the "triple" and, finally, to the **entrepreneurial team**. In his excessive case study of US *Inc.* companies Bhidé [2000:303] found that entrepreneurial partnership "is effective only to the degree that the *entrepreneurs have complementary strengths (rather than overlapping limitations)* and can act as a team."

Differentiated by gender the knowledge and competency focus of the team is on the technical area by almost 60 percent for men and by roughly 75 percent including also natural science as well as technical and commercial competence. On the other hand, technical and commercial knowledge is rather balanced for women at ca. 33 percent each (Figure I.44). This result for Germany can be assumed to be roughly also the case in the US.

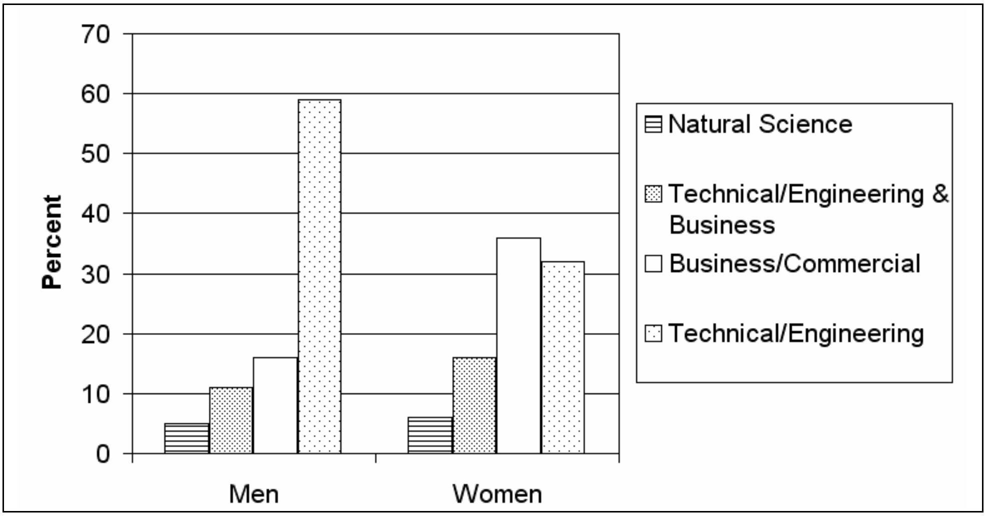


Figure I.44: Focus on knowledge and competencies of male and female NTBF founders in Germany [Gottschalk et al. 2007].

Concerning education of all NTBF founders (in Germany) the highest educational level of one of the founders of a spin-out compared with the overall situation of NTBF foundations is given in Figure I.45 demonstrating that 66 percent (versus 52 percent) have a university degree and 25 percent a doctoral or habilitation degree [31] with only 13 percent in general. Spin-out founders without any degree are usually students.

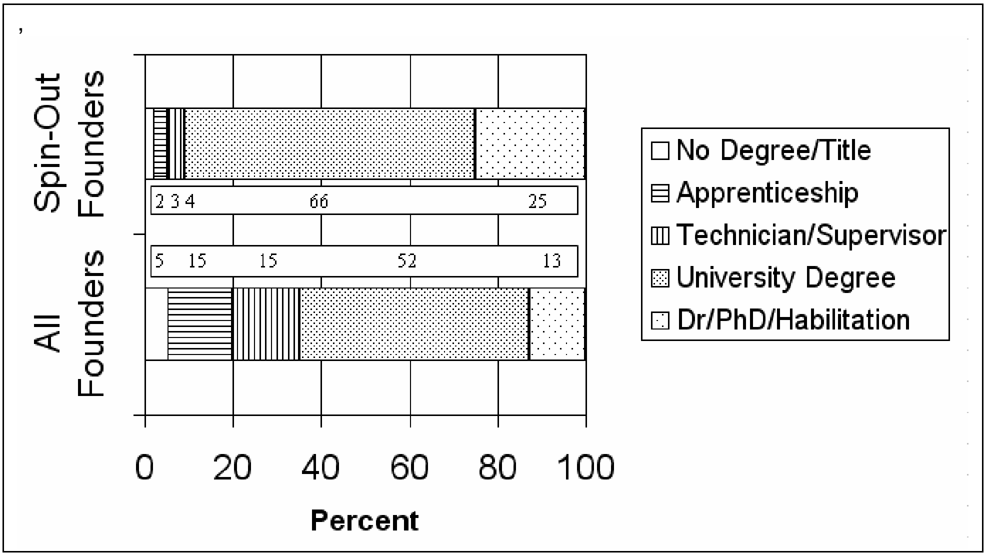


Figure I.45: The highest educational level of one of the founders of a spin-out versus the overall situation of NTBF foundations in Germany [Metzger et al. 2008].

The results concerning education of company (NTBF) founders in Germany cannot be compared with the situation in the US due to the different educational systems and relevance of academic degrees and different data sets for technologies or industries, respectively.

A recent study regarding the highest level of degree of company founders [Wadhwa et al. 2009] revealed that 10.5 percent have a PhD, 19.0 earned a Master and 48.0 percent a Bachelor degree. Specifically, 13.8 percent hold an MBA. The common denominator for Germany and the US is that *company founders tend to be well-educated for technology entrepreneurship*.

Recently Minshall and Wicksteed [2005] argued that "any analysis of spin-outs which implicitly assumes that they are a generic class of new business is inherently flawed." And they also found that at universities there were considerably more startups (companies originating from the university but where the university has no claim on the IP) than spin-outs. Obviously, they connect the notion spin-out on the basis of utilizing a university's IPR. Above we put the focus on differentiating RBSUs and EBSUs.

On the other hand, Egeln et al. [2002] differentiate startups founded by academics positioning RBSUs versus (other) academic startups (Table I.2).

- *Exploitation spin-outs* are based on new research results or scientific processes or methods, for which one of the participating founders was indispensable for the firm's foundation (Science2Business). That is, for the relevant research and science at least one founder has directly contributed or one of the founders has contributed to scientific results by direct collaboration with a public research organization.

- *Competence spin-outs* use indispensable special competencies or/and skills, which one of the founders acquired at a scientific or research institution.

The proportion of exploitation spin-outs versus competence spin-outs in Germany over the time period under investigation (1996-2000) was ca. 1:5 (Table I.2).

Participation of a professor or an employed research leader of a university or other public research institute (example: Nano-X GmbH; B.2) and other people in founding a spin-out is presented in Figure I.46.

Roughly one fifth of all exploitation spin-outs had a professor in the founding team. Furthermore, academic personnel are also more strongly involved in foundations of exploitation spin-outs than in competence spin-outs. On the other hand, professors accounted for just 3 percent of the founders of startups of the research- and knowledge-based industry segments [Egeln et al. 2002].

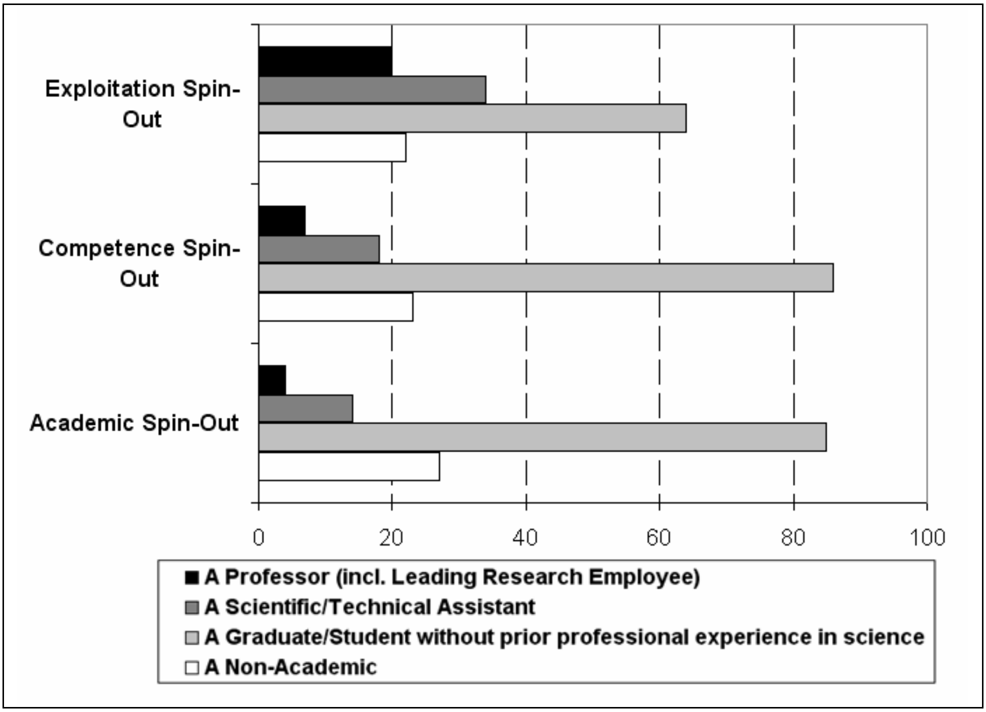


Figure I.46: Participation (in percent) of at least a professor (incl. employed research leader), a scientific (incl. technical) co-worker, a graduate/student without prior professional activities in science or a non-academic person in various types of spin-outs in Germany [Egeln et al. 2002].

Overall, in Germany, for ca. 30 percent of the exploitation spin-outs at least one of the founders was still engaged in science or was still a student. Hence, the transition from science to business was gliding. 22 percent of all founders of exploitation spin-outs were still employed with the parent research institution. This has been interpreted as a strategy to reduce the risk of individual income [Egeln et al. 2002].

For more than 80 percent the incubator unit and parent institution of academic spin-outs are viewed as functionally identical. More than 7 percent of exploitation spin-outs and 5 percent of competence spin-outs have foreign public research institutions as the incubator [Egeln et al. 2002].

From a policy point of view the creation of spin-outs by academic entrepreneurs stimulates economic development – job creation. Correspondingly, policy is interested in revealing barriers for spin-out formation to reduce these obstacles by corresponding initiatives and programs.

Figure I.47 gives an overview of major barriers spin-out founders in Germany are confronted with [Egeln et al. 2002]. Inhibiting factors found in a related UK study [Moustras 2003] emphasized pressure of work in “the day job, lack of experience and lack of an entrepreneurial culture in the department.”

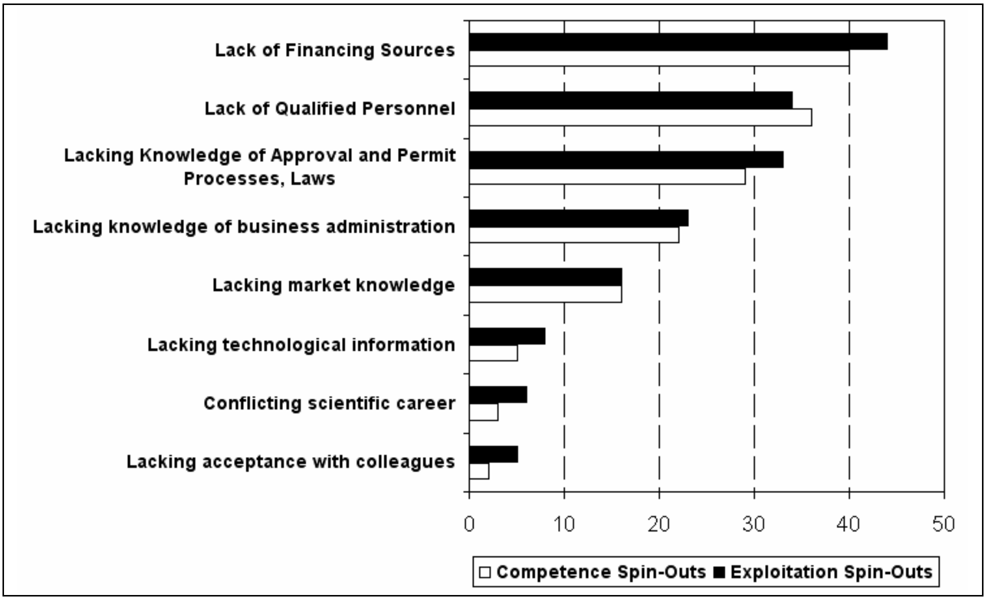


Figure I.47: Barriers for spin-out foundations in percent (multiple selections possible) [Egeln et al. 2002].

What is of *interest from the employment standpoint* is not so much the total number of startups as the number of startups with a high probability of survival and a strong rate of growth (*sustainanble growth*; ch. 4.3.6).

A corresponding characterization of spin-outs as “job machines” often follows the lines of Minshall and Wicksteed [2005].

- Spin-outs with identifiably high growth potential, even if there are considerable risks that the potential will not be realized;
- Spin-outs that are likely to be serious businesses in that they create employment and generate profits, but which may have limited or slower growth potential;
- Spin-outs that are legal vehicles for the commercial development of a technology which, in due course, is likely to be commercialized through the license or sale of the IP.

Through various initiatives and programs targeting factors that influence the probability of building startups policy wants to support and improve spin-out formation [Tamásy and Otten 2000]. And metrics for growth is usually referring to the number of spin-outs and revenues and/or numbers of employees of the startups.

But with regard to metrics Minshall and Wicksteed [2005] made two important points:

1. The number of spin-outs should not be interpreted as a free standing indicator of the relevance of the university’s research to the commercial world.
2. It should not be used uncritically as an indicator of the level of entrepreneurial enthusiasm amongst staff and other researchers.

For instance, Minshall and Wicksteed [2005] cite a study on knowledge transfer in Germany that shows that simply encouraging universities to increase the numbers of spin-out ventures can lead to ideas being prematurely packaged into new ventures that have little chance of attracting funding and hence growing to make a positive contribution to the economy.

That often is a reflection of the situation that some universities or public research institutions tend to set up chairs or entrepreneurship, types of technology offices, entrepreneurship projects funded by governmental programs, and in turn promise to release a number x of spin-outs within y years into the business world (“just get the numbers out”) – thus to legitimate effective use of the funds.

This makes it appropriate to emphasize a corollary for new firm’s foundation:

> Don’t start a company just because you can; have a really good idea and opportunity that are good regardless of the founding and funding situation!

And for policy it is important to remember:

> Generally scientific or technological leadership of a country does not necessarily translate itself into economic leadership of its firms. Leading in science in an area does not imply leading also the market: For instance, the US had the lead in photovoltaic (solar cells) science and research, but first Germany and now China lead the market.

1.2.6.2 Technology Incubation, Science or Technology Parks and Clusters

Technology entrepreneurship, whether academic or technical, requires a *special supportive environment*. A special route of technology transfer, particularly through entrepreneurship in terms of RBSUs or EBSUs, involves "**technology incubation**" (Figure I.) by universities, but also other public research organizations (Table I.20).

> Business incubation is a business support process that accelerates the successful development of startups and fledgling companies by providing entrepreneurs with an array of targeted resources and services through an **incubator** organization. Emphasis is on students, graduates, post-graduates, post-docs as well as faculty members.
>
> The services are usually developed or orchestrated by *incubator management* and offered both *in the business incubator* and *through its network of contacts*, which may include financial resources, such as venture capital organizations or "angel investors" (called "business angels" in Europe) or corporate venture companies and lawyers, accountants, tax and business consultants.

The most complex models of technology incubators integrate technology transfer, incubation, and entrepreneurship education. Technology incubation can be seen as a process to catalyze technology entrepreneurship within a restricted period of time. Therefore, it is often part of technology entrepreneurship education providing potential or individual entrepreneurs with the tools they need for success.

A related entrepreneurship curriculum may include courses on all aspects of the entrepreneurial venture including idea generation and identifying opportunities, commercializing intellectual property, selecting advisors and board members and launching and growing an entrepreneurial firm.

Specifically, technology-oriented incubators shall reduce the barrier from "potential entrepreneur" to "nascent entrepreneur" (Figure I.15) helping with

- Market research and competitor analysis;
- Marketing and sales strategy development;
- Management consulting;
- Technology assessment;
- Patent and trademark applications;
- Location selection of the startup and access to financing sources;
- Business plan development, including financial and marketing analysis;
- Prototype development.

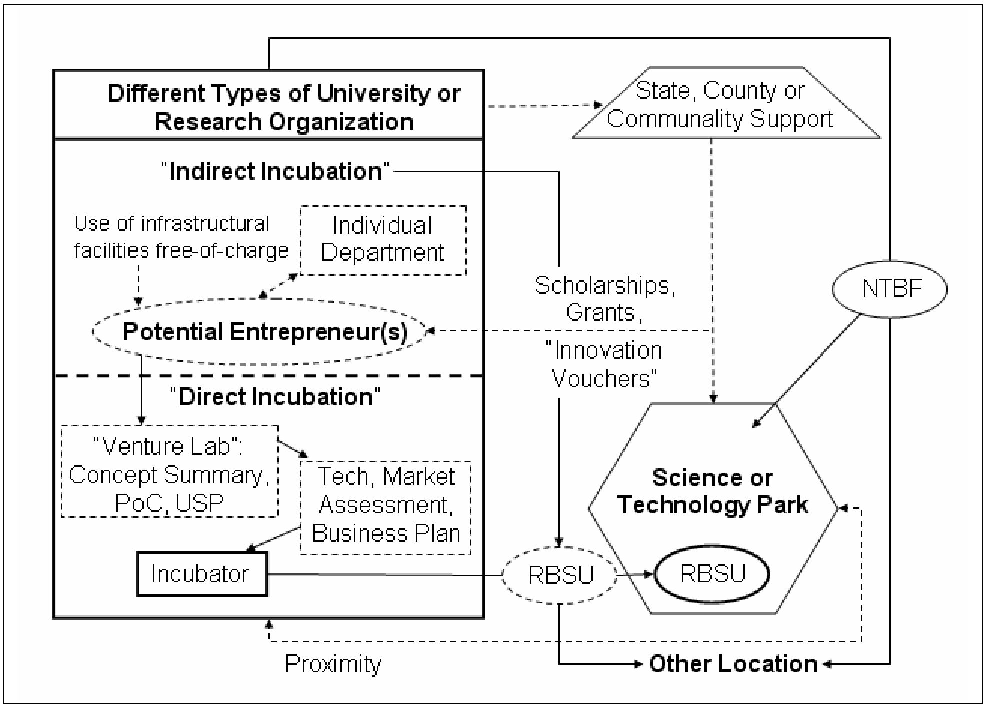


Figure I.48: Incubation for research-based startups and other NTBFs and clusters as means to generate fledgling new ventures.

An issue of public research institutes (and their incubator units) is missing the opportunity to commcercialize their promising developments. The problem is that the incubator acts mostly only reactive upon being addressed rather than also pro-active to initiate commercialization, for instance, through initiating startups or going for potential industrial partners.

With regard to types of science/research it is said that German research policy places a heavy weight on basic research, but simultaneously complains about deficits in development and commercialization of related research results or too slow commercialization (as is also heard from responsible European technology politicians for all European countries).

For instance, in Germany, though the Fraunhofer Society (FhG) invented it and also earned considerable revenues from licensing, an often cited example is the lack of support of FhG to commercialize the MP3 audio compression technology to distribute music tracks in the MP3 format to a major extent by German startups or firms [Bellis]. Moreover, this has become a quasi trauma of German science and economic policy and German industry which “must never happen again.”

Furthermore, global competition for RBSUs and NTBFs is often a hot topic from the beginning, but also concerning trans-national reach, as seen for biofuels (A.1.1). An incubator must take care of the existence of generic technologies and the race to production for the same or substituting offerings and act on that within the range of its mission, competencies and possibilities.

A general "incubation" issue emerges also for intrapreneurship. Sawney and Wolcott, cited by Runge [2006:777], described the related issue which is linked to ideas for innovation in the corporate environment as follows.

"Managers often lament the paucity of innovative ideas in their business. Their logic: ideas are like frog eggs – thousands are laid, but only a few hatch. This logic suggests that businesses need lots of new ideas if a few are to evolve into profitable innovations. However, this logic is seriously flawed: to get more tadpoles, you don't need more eggs – *you need better incubators*. *Most companies have enough ideas* germinating in the minds of their employees but *lack the mechanisms to act on them*. If your employees often don't know where to turn for resources and funding to develop their ideas, eventually their creativity will dry up." (Emphases added)

This translates into fundamental operational guidelines for a technology incubator:

- The worst thing is to push new companies through an incubator and out too soon.
- It is better to start fewer companies and know you have done all you can to stabilize them successfully and put them on a growth track.

There is strong evidence that once the spin-out has taken place, continued support and addition of follow-on IP to the venture from the initiating university (or incubator) is often weak. This diminishes the chances that the spin-out will be successful, either resulting in outright failure or in the spin-out becoming one of the "living dead" with little prospect of success [Fyfe and Townsend 2005].

Incubation may proceed as a one- or a two-step process (Figure I.). There is "*indirect incubation*" in an institute or a department providing for the "to-be entrepreneur" access to its infrastructure (personnel, facilities, devices, advice) complemented by grants and scholarships for entrepreneurship by existing federal or state programs. That may suffice for successfully spin-out of new firm (for instance, the German Attocube Systems AG, Puron AG, ChemCon GmbH, WITec GmbH, Nanion Technologies GmbH, or US Cambridge Nanotech, Inc.; B.2). On the other hand, potential entrepreneurs may prepare spin-out in the incubator unit ("*direct incubation*") which may follow indirect incubation.

In one case, the author observed incubating support when the spin-out had a person doing research for the spin-out, but formally was supervised by a faculty member (an "entrepreneurial professor") and the work being accepted for his diploma thesis.

Direct incubation may cover one or two phases, the first ending with the set up of a Proof-of-Concept (PoC) and USP (Unique Selling Proposition); in the second phase the emphasis will be on technology and market assessments, developing a business concept or business plan and establishing probably customer contacts.

The **Unique Selling Proposition**, basically a marketing and advertising concept, expressed as a statement, emphasizes how a firm's offering differentiates itself from those of competitors, make it a unique offering and specifies value, for instance, by addressing potential customers: "Buy this product, and you will *get this specific benefit (or value)*."

Often technology incubation continues with new firm's foundation in a special, publicly, privately or PPP-supported location, a science or technology park in close vicinity to the university (Figure I.), or an industry park which may be a so-called cluster.

Indeed, a spin-out tends to locate in the vicinity of its parent organization or its incubator. Generally, NTBFs tend to locate in nearby regional networks. Proximity means often keeping *social and family ties* and *keeping regional networks of expertise, advice and technical support* [Tidd et al. 2001:350]. Quantification of this situation in Germany is reflected by Figure I.49.

We shall differentiate the notion cluster from network and view it as a sub-category: A **cluster** is a network with *spatial proximity* of the nodes (organizational components) and *similar or related activities* of the nodes.

Cluster development usually proceeds in a non-controlled bottom-up way by industry initiative. However, it may be developed also in a controlled matter top-down, for instance, through political (state, county or communality) initiative. It is in particular the political aspect that views a cluster as a key contribution to job creation, technology transfer and entrepreneurship.

According to Michael F. Porter "a cluster is a geographically proximate group of companies and associated institutions in a particular field, linked by commonalities and complementarities." Clusters are a common reality in all advanced economies and industries, the most famous one being "Silicon Valley." The clustering concept has worked successfully also for the North Carolina's Research Triangle.

For policy clusters form a layer of national competitiveness (Figure I.50). In this view a *national innovation system* includes the strength of the common *innovation infrastructure*, the specific *conditions supporting locations* with the nation's *innovation clusters*, and the *strength of positive interactions* between common infrastructure and the cluster-specific conditions. And it has been argued that the *strong effect of location* (states, regions) on innovation holds important implications for companies and *creates a new broader agenda for innovation policy* [Runge 2006:273-277].

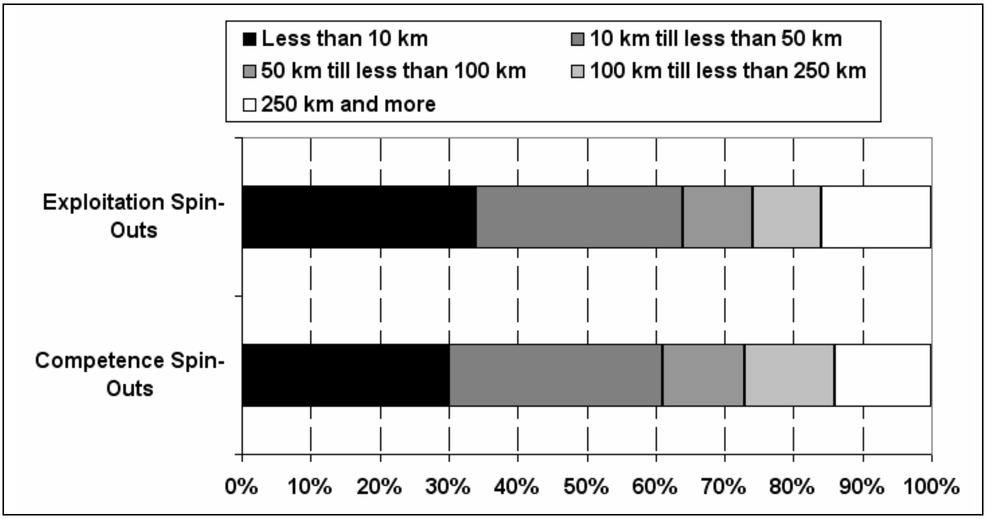


Figure I.49: Distance between the location of spin-outs and location of the incubator units in Germany [Egeln et al. 2002].

"*Clustering*" in the context of economic development *involves grouping companies in the same industry in proximity with each other and with suppliers and other related businesses.* The idea is to create *regional industrial hubs* that drive innovation and economic development.

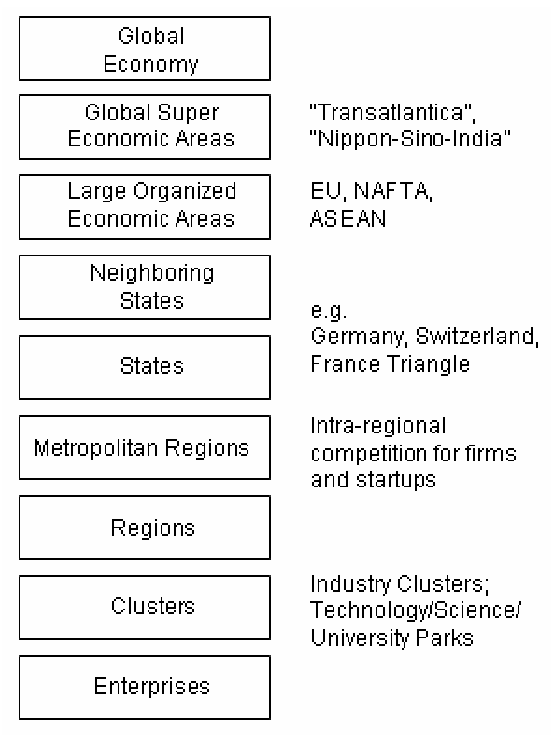
The Research Triangle Park, for instance, was established in 1959 as a planned research park by business, academic and industry leaders. It is a customer-oriented, private sector approach. The Park's development has always been *industry-led with assistance from the state where appropriate*. The purpose of the Park is to provide an economic development incentive to companies doing *world-class research and development in expanding scientific and technology areas*. Besides its ample size and well-prepared infrastructure, the Park was also specifically designed to draw upon the competitive advantage of having North Carolina State University, the University of North Carolina and Duke University within 30 miles of the Park.

As an attempt to emulate such types of clustering for support of founding NTBFs and economic developments in the 1980s and 1990s around the globe "science parks" and "technology parks" were established.

Layers of competitiveness in a global economy with respect to clustering from Germany's point of view are given in Figure I.50. Here, the "Supercontinent Transatlantica" comprises the NAFTA countries and EU and other European regions and "Nippon-Sino-India" covers the Far East, Japan and China, the India region as well as Taiwan, South Korea and South East Asian countries [Runge 2006:298].

Concerning an innovative and entrepreneurial economy within the different countries a result of the drive for clustering by policy is increased *competition of the various national regions* for visibility, attracting promising industries and people as well as national and supra-national funding for technological developments and entrepreneurship. Policy is generally targeting “high tech areas. The regional competency provides opportunities for entrepreneurs concerning financing and locating their startups.

Regions and clusters competing for startups are illustrated for biofuels (A.1.1) and the German NTBFs Q-Cells AG and IoLiTec (A.1.5; B.2).



In Germany, for instance, a “Metropolitan Region” (“Metropolregion”) has been defined as an area of international significance and as an engine for social, societal and economic developments of the region and the country.

Examples (German names):

Berlin/Brandenburg,

Frankfurt/Rhein-Main,

Hamburg,

München (Munich),

Rhein-Neckar/Mannheim-Ludwigshafen,

Sachsendreieck (Saxony Triangle),

Stuttgart.

Figure I.50: Layers of global competitiveness focusing on clusters (German view).

Clusters and competitiveness viewed for several levels are given in Table I.22.

Table I.22: Clusters and competitiveness viewed for several levels.

Clusters improve firms' productivities and efficiencies:

- Access to infrastructure: easy access to specialized suppliers, services and human resources, raw material and intermediates, energy, water, information technology – and waste disposal
- Simplified communication, coordination and cooperation among firms
- Information spillovers
- Rapid diffusion of best practices; and ongoing, visible performance comparisons with local rivals; firms providing role models for other firms
- Compete globally thanks to a better access to information and specialized resources, flexibility and rapid adoption of innovations

Clusters stimulate and enable innovations

- Enhanced ability to perceive innovation opportunities
- Imitation facilitates faster innovation adoption
- Presence of multiple suppliers and institutions to assist in knowledge creation (knowledge and technology transfer)
- Ease of experimentation given locally available resources

Clusters facilitate commercialization of innovation

- Market potentials for new firms and new lines of business are more apparent
- Commercializing new products and starting new companies is easier with the available skills, suppliers, etc.

A Technology Park is an initiative that supports usually the following economic objectives:

- Innovation and entrepreneurship
- Enterprise development
- Job and skill creation
- Investment attraction
- Export and trade
- Diversification of the regional economy
- Sustainable (regional) economy.

Investment attraction requires for entrepreneurship having *interfaces to the financial sub-system*, bankers being able to realistically evaluate risk, and availability of angel investors and/or venture capitalists familiar with the characteristics of small businesses and facilities appropriate for the businesses. A *technology park* may be industry-specific or cover various related or unrelated industries.

Science or university parks usually comprises a region with a large skill base due to proximity of leading edge organizations (universities, public and semi-public research institutes and laboratories, firms with strong R&D activities) at the forefront of research and development.

Value addition of a science park includes park management, infrastructure (may include high-tech instruments for experiments for rent or special R&D facilities like clean rooms to be rented at favorable rates), flexibility of building layouts, non-profit R&D; profit-oriented R&D, education institutions, government and the community – and startups learning by example or imitation and networking. It attracts innovative together with fast-track companies as the ideal catalyst for business startup (new firms, university spin-outs, firms' spin-outs and subsidiaries and joint ventures); often early-stage technology (RBSUs).

If science or technology parks are subsidized by public (state, county, communality) institutions (Figure I.) to provide financially favorable conditions for new firm development they can also be viewed as incubators in the broadest sense.

Technology, science and industry parks in Germany include, for instance,

- Karlsruhe (which is essentially IT-oriented),
- Heidelberg (a science park; covers the biotech cluster of the Rhein-Neckar Metropolitan Region and the BASF-CaRLa; A.1.3),
- Berlin-Adlershof (the largest science and technology park in Germany; covers science institutes of Humboldt-University Berlin, other research institutes and close to 1,000 firms in 2013),
- Chemiepark Leuna (a policy-driven re-foundation of the original "Chemie Dreieck" ("Chemistry Triangle") after the German Re-Unification)

We have differentiated a cluster from a network. **Networking** means lifting physical proximity and a more or less tight interconnection of organizations (or people) with a more or less clear purpose and commitment, including connections across regions, countries or continents (cf. "competence networks" in Figure I.39). For entrepreneurship the term networking will often refer to people networks – meaning communication, strengthening existing or creating new ties or finding common interests and purpose.

To succeed, for startup companies it is advisable to have or build a supportive network, for instance, contacts to people of the incubator or to anywhere in the world, people from other scientific disciplines etc. A startup's "*Advisory Board*" is also a good springboard for networking. Once you have these networks, interesting and unpredictable things for entrepreneurship can happen – for your benefit.

Clustering, industry and technology parks have also appeared in "business models" of firms. For instance, German chemical giant Bayer AG and LANXESS AG (a Bayer spin-off) run Currenta-CHEMPARK (formerly Bayer Industry Services, BIS) at several locations as a partner for on-site chemical and technical services.

This type of park is to a certain degree restricted. It offers effective infrastructure fitting essentially the needs of chemical and processing firms or NTBFs. It offers customized services ranging from technology and production through environmental protection, waste management, utility supply, infrastructure, safety and analytics to vocational training and continuing education courses. Simultaneously, the "Bayer Chemistry Start Up Initiative" supported new company foundations in its own industry park [Runge 2006:278]. The German Polymaterials AG (B.2) is a prominent example of an NTBF for taking advantage from this situation. Similar organizations have been set up by many giant firms from various industries.

Networking of startups and NTBFs can achieve the status of a "*virtual company*" with participants providing complementary as well as customized offerings as well as tangible and intangible resources and sharing resources, information and experiences. Customer facing would be a *one-stop-shop*, including referral to the network member which is appropriate to respond to a request or setting up cooperative activities and efforts to react to customer demand.

For instance, the German NTBF ChemCon GmbH (B.2) is a member of such a virtual company, the "*Drug Discovery Net*." ChemCon is engaged in contract research and custom synthesis and is a market leader in milli- and small scale active pharmaceutical ingredients (APIs) production, usually low-molecular weight organic compounds, but also bio-inorganic APIs ("metals in life processes"). It operates in special niches of "orphan drugs" as well as injectable APIs. *Orphan drugs* are for "rare diseases" that do not receive proper attention. Furthermore, orphan drug status gives a manufacturer or customer financial incentives (in US tax reductions and marketing exclusivity). Big pharmaceutical companies focus usually on diseases "common" for very large populations!

The *Drug Discovery Net* comprises eight small firms, most of them in close proximity in Germany's South West. It sees itself organized like a "virtual pharmaceutical firm" in which the various partners execute particular tasks. On the basis of the experiences of the participants its aim is to cover the whole value system from API research to execution of clinical studies.

Similarly the German NTBF IEP GmbH followed also networking with other small companies, such as CSS from North Ireland and Chiral Quest from the US. IEP offered cost effective customized biocatalytic process development and sales of enzymes to the pharmaceutical industry relying on proprietary technology and intellectual property.

CSS, a small-scale pharmaceutical contract research and synthesis organization and key node of the network, had bilateral deals with two chiral chemistry companies. The agreements enabled CSS – with its strength in synthetic route development – to offer *complementary custom synthesis* of chiral compounds using either the chemical asymmetric hydrogenation technology of Chiral Quest or the biocatalytic asymmetric reduction technology of IEP. Chiral Quest, CSS, and IEP formed a consortium. [Runge 2006:183]. In 2010 the privately held IEP was acquired by the US firm Cambrex Corporation (and was renamed to Cambrex IEP).

As a summary, a "*networked economy*" emerged for a national technical innovation system as expressed by Figure I.34, Figure I.41, Figure I. and finally Figure I.51. It is *a government-university-industry (GUI) "triangle"* relationship involving small firms (NTBFs) and medium and large existing firms and plays a role of growing significance for national innovation efforts and is simultaneously significant for technology entrepreneurship [Carayannis et al.].

An alliance evolves into a community of innovation, if each participant retains the legacy of its origins, but joins a network of researchers that develops its own common values, norms and vocabulary. The knowledge from each participant can then be integrated within the new context of a community of innovation, and applied by each participant toward its own learning goals – and location selection which may be a publicly subsidized cluster. Development and renewal of such a system is based on entrepreneurship and innovation.

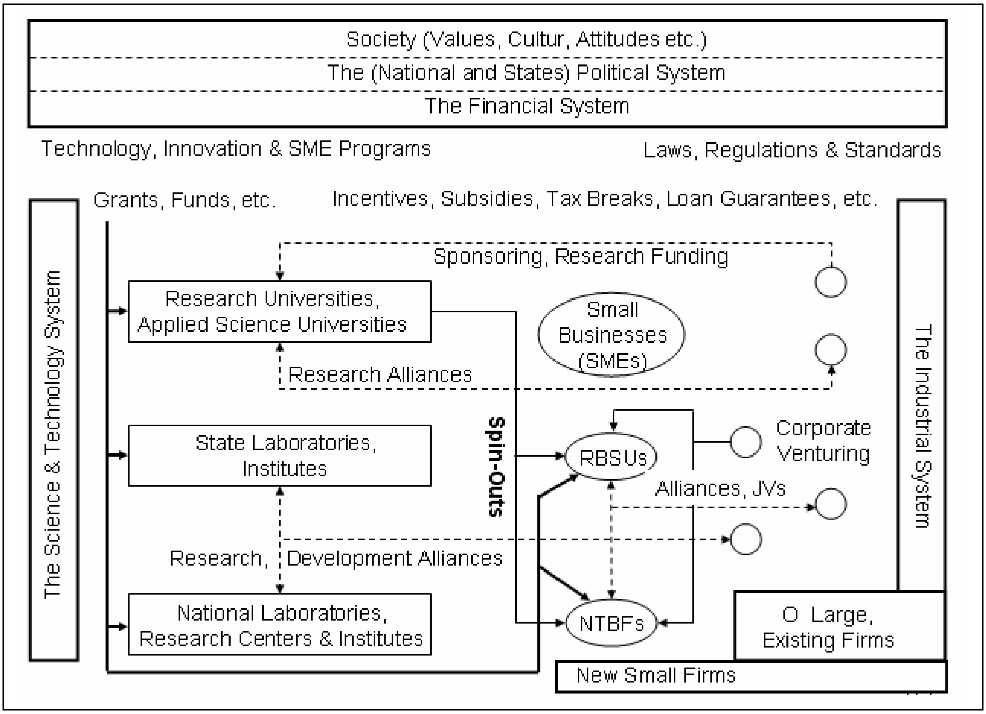


Figure I.51: The "networked economy of innovation" of a national technical innovation system.

Collaboration among networking partners provide many benefits, such as:

- Sharing of risk and cost for long-term research
- Access to complementary capabilities
- Access to specialized skills
- Access to new suppliers and markets
- Access to state-of-the-art facilities
- Creating new opportunities for technological learning.

In the context of dynamic organizational learning cultural gaps among GUI participants can become an advantage. “Organizations involved in successful strategic alliances engaged in learning not only at the level of technical knowledge, but also at the level of organizational structure, with participants adopting some of the organizational routines of their partners leading to greater efficiency in learning.” [Carayannis et al.]

“One indication of the special significance of GUI partnerships is that this new organizational form is emerging in different nations and different economies. This suggests that *there are strong driving forces motivating these partnerships that are common across different national cultures, political structures, and economic systems. While GUI partnerships in different countries have certain unique characteristics shaped by their national environment*, they tend to share processes and structures of membership, governance, and interaction that point to the existence of universal critical success factors which apply to all such partnerships.” [Carayannis et al.]

Carayannis et al. provide some examples for structures of GUI partnerships in the US and Europe/Germany.

GUI partnerships are different from other forms of binary inter-organizational alliances and consortia requiring interfacing values, norms, behavior, the whole culture of participants from three different systems rather than two (Figure I.42). Outlines of GUIs are given in Table I.92 and the Appendix (A.1.3).

1.2.6.3 Technology Transfer to Small and Medium-Sized Enterprises

National governments usually have initiatives and programs for technology transfer (and innovation and additional support) to small and medium-sized enterprises (SMEs), as, for instance, defined for Europe in Table I.4. However, SMEs are defined widely in different countries. The SMEs are defined loosely in the US as any enterprise with fewer than 500 employees. This may lead to different samples of SMEs for studies and correspondingly lead to results which cannot be compared. The targeted SMEs are usually younger than large firms but may include startups. Furthermore, as our definition of an NTBF regarding its life-time to include its twelve’s year of existence, SMEs definitely cover NTBFs.

Policies to promote SMEs and support innovation have a long tradition in Germany, dating back into the 19th-century. In Germany the Federal Ministry of Economics (BMWi) targets SMEs. In the US it is the Small Business Administration (SBA). The

US **Small Business Administration** [34] was created as an independent agency of the federal government to aid, counsel, assist and protect the interests of small business concerns, to preserve free competitive enterprise and to maintain and strengthen the overall economy of the nation.

The SBA provides financial, technical, and management assistance, including access to grants, to help Americans start, run, and grow their businesses and compete in global markets through an extensive network of field offices and partnerships with public and private organizations. It organizes, for instance, a network of training and counseling services via *small-business development centers* and provides export assistance.

The SBA is a large financial backer of small businesses in the US. However, SBA does not grant loans – it guarantees them. Loans are available for many business purposes. The basic loan guarantee program is generally used to fund the varied long-term needs of small businesses. The program is designed to promote small business formation and growth by guaranteeing long-term loans to qualified firms that cannot obtain financing on reasonable terms through normal lending channels [ACS 2011]. The SBA's flagship 7(a) program provides roughly two-thirds of its loans to existing businesses, not startups. This is because it works by guaranteeing loans from commercial banks, which are often reluctant to lend to unproven startups.

SBA acts also through its Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) grants. The Small Business Innovation Research (SBIR) Program is a highly competitive three-phase award system which provides qualified small business concerns with opportunities to propose innovative ideas that meet the specific research and development needs of the Federal Government.

The Small Business Technology Transfer (STTR) is a highly competitive three-phase program that reserves a specific percentage of federal research and development funding for award to small businesses in partnership with non-profit research institutions to move ideas from the laboratory to the marketplace, to foster high-tech economic development and to address the technological needs of the Federal Government. Achieving grants under these programs, however, is challenging [ACS 2011:28]. At the same time, one must recognize that SBIRs initially provide relatively small amounts of capital/cash ($50,000 to $100,000) with a high cost of time for accounting and management and low probabilities for successful award [ACS 2011:35].

Concerning SMEs *in the US the focus tends to be on individual firms and high-tech firms rather than manufacturing* companies. The US R&D and technology transfer infrastructure serving SMEs in these industries is relatively piecemeal, fragmented and weak. "US SMEs in technologically mature manufacturing industries operate on the periphery of the nation's R&D enterprise." [Abramson et al. 1997:30, 31]

On the other hand, the technology transfer and R&D needs of *German SMEs include high-tech and manufacturing industries* and tend to *emphasize cooperation and networking*. In particularly, the more technically stable manufacturing industries are supported by a dense, comprehensive and highly institutionalized network of industry-oriented R&D institutions and non-R&D-performing technical organization (for instance, the Chambers of Industry and Commerce (in German Industrie- und Handelskammer – IHK).

Through participation in robust industrial associations, which have a significant influence on public S&T policy at the state, federal and EU levels, German SME's are considerably involved in the shape and resource allocation of their national innovation system. Moreover, SMEs are considered important pillars of the German innovation system and the overall export industry.

A dense distribution of IHKs over whole Germany for consulting SMEs including start-ups together with a dense distribution of cooperative banks, savings banks and other publicly owned banks (ch. 1.2.7) for financing represent the backbone of the German SMEs.

The BMWi-led Central Innovation Program SME (in German ZIM – Zentrales Innovationsprogramm Mittelstand) is a country-wide support means, open to all technologies and sectors. It is geared to medium-sized enterprises which may cover NTBFs and collaborating research organizations closely aligned with business. Funding through ZIM is intended to:

- encourage companies to dedicate more efforts to market-driven research, development, and innovation,
- reduce the technical and economic risks of technology-based projects involving research and development,
- rapidly implement the R&D results in the form of market-orientated innovations,
- enhance the level of collaboration of companies and research organizations and to expand technology transfer,
- increase the commitment of companies towards R&D cooperation,
- improve innovation, cooperation and network management within the enterprise.

Funding and support modules include:

- Individual projects (ZIM-SOLO):
  Individual R&D projects of SMEs.
- Cooperation projects (ZIM-KOOP):
  Cooperation projects between SMEs and between SMEs and research institutions.
- Network projects (ZIM-NEMO):
  Funding is for external management und organization services for developing market-oriented networks of innovative SMEs.

1.2.7 The Financial Subsystems in the US and Germany

The availability or ability to access the capital necessary to start an entrepreneurial firm is considered one of the factors that facilitate or more frequently constitute an obstacle to the decision of becoming an entrepreneur and building a new company (cf. Figure I.47 for spin-outs). It is therefore important to be aware of the various financing sources for entrepreneurs that exist in the US and in Germany, what role they play and in how far and when the financing systems provide components of the business opportunity for technology entrepreneurship.

A fundamentally important global advantage of the US is that the dollar (still) has the status of the global *reserve currency*, acceptable as a medium of international payments and that is therefore held in reserve by many countries. According to Investopedia it is “a foreign currency held by central banks and other major financial institutions as a means to pay off international debt obligations, or to influence their domestic exchange rate.”

Influencing domestic exchange rate is often *currency manipulation*. For instance, to suppress the value of the Yuan, China takes US dollars and exchanges them for Yuan at a pegged rate. China does this hoping to create jobs and boost exports.

The US calls this currency manipulation and it is. However, it is no more manipulative than that what Ben Bennanke of the US Federal Reserve did. He was flooding the markets and the world with *printing US dollars* hoping to weaken the US dollar and stimulate growth. Hence, in the US this “loose money” enters the US financing system and specifically also entrepreneurship in the US.

1.2.7.1 Financial Sources for Technology Entrepreneurship

To start and develop a new firm (Figure I.15) entrepreneurs need capital – to purchase assets and to operate while building a customer base. They have to find out how much capital will be needed and when, in particular, what is the necessary *initial funding* to start the firm. As a firm grows its needs for finances normally increase.

Working capital is a measure of the amount of cash available in the short-term. It is an indication of the funds needed to operate within a given business size (and time).

In terms of accounting *net working capital* is the difference between a business' current assets and its current liabilities.

Choosing the *right sources of capital* can be as important as choosing team members and the location of the business. The most direct source for equity financing is to access own financial resources and probably additional finances from family and friends, the so-called 3F source ("family, friends or fools").

Having used 3F resources early growth may be financed by the startup's profits and cash flow. Starting a firm this way is often termed a "**bootstrapping**" approach (ch. 4.3.3.1). However, many firms require already more capital for their start and also for their further developments. Furthermore, for their start there are often no own resources and no customers for financing. But accesses to various sources of capital are available for entrepreneurship.

We, therefore, shall look into the various sources of capital to start an NTBF and particularly those parts of the national financial systems that are relevant for technology entrepreneurship. Additionally we shall look into details of financing of the technology area which exceeds common text book knowledge of the topic and tackles also approaches mixing financing sources.

For different countries there are basically similar sources available for financing a new firm. However, they usually differ in the proportion they contribute to technology entrepreneurship and the sources differ also in their ownership structures, modes of operation and (re-)financing themselves etc.

In particular, with regard to their different kinds of capitalistic system (ch. 1.2.4) there are marked differences between the US and Germany with regard to the role government and other public organizations play as financial resources for entrepreneurship. Governmental support includes *direct and indirect* measures (Figure I., Figure I.51).

Focusing on financing NTBFs and taking the perspective of the financial backers one can assume firm development and associated need of capital to proceed in stages. This allows investors their intended total investment to be divided into gates for checking progress against pre-defined milestones.

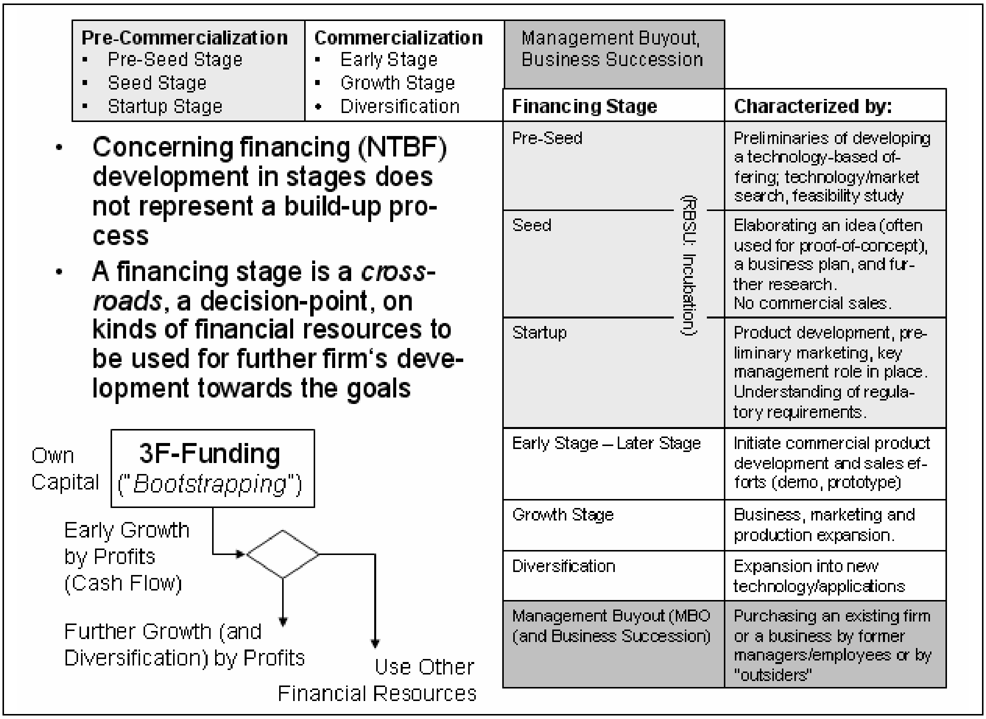
For the entrepreneurs, such gates represent specific "crossroads," decision points, how to finance further developments of their firms. As a framework for financing a new firm we shall use Figure I.52. Here RBSUs as special NTBFs are explicitly considered as they have several additional options for financing through public financing sources, in particular incubation (ch. 1.2.6.2; Figure I., Figure I.51).

Basically, one should differentiate *initial funding* usually comprising the "pre-commercialization period" and "*ongoing financing*." Generally, one must consider that financing is usually different for *NTBFs with intended large-scale production* as these may require very soon capital in the order of several tens of millions. And also *NTBFs from* *specific industries or technologies* will need huge amounts of capital, for instance, many biotechnology startups and biofuels startups (A.1.1).

In Figure I.53 a typical income/loss (expenses) curve for development of a new firm and an association with financing stages is displayed. A key point here is the "break-even." The **breakeven** is the point at which cumulated income (revenues) equals loss (cost, expenses).

It is to be noted that often people relate to breakeven as the point (year) when the company achieves a profit for the first time.

It is of particular interest for entrepreneurs and financial backers in how fast in terms of months or years the new firm's development reaches that point when the company starts to produce profit. For instance, for debts financing after having crossed the breakeven for the entrepreneur(s) *amortization* may begin. This means gradual reduction of term debt by periodic payment sufficient to pay current interest and to eliminate the principal at maturity.



Financing Stage	Characterized by:
Pre-Seed	Preliminaries of developing a technology-based offering; technology/market search, feasibility study
Seed	Elaborating an idea (often used for proof-of-concept), a business plan, and further research. No commercial sales.
Startup	Product development, preliminary marketing, key management role in place. Understanding of regulatory requirements.
Early Stage – Later Stage	Initiate commercial product development and sales efforts (demo, prototype)
Growth Stage	Business, marketing and production expansion.
Diversification	Expansion into new technology/applications
Management Buyout (MBO (and Business Succession)	Purchasing an existing firm or a business by former managers/employees or by "outsiders"

Figure I.52: Financing stages for technology entrepreneurship – for NTBFs, RBSUs as well as management buyout and business succession.

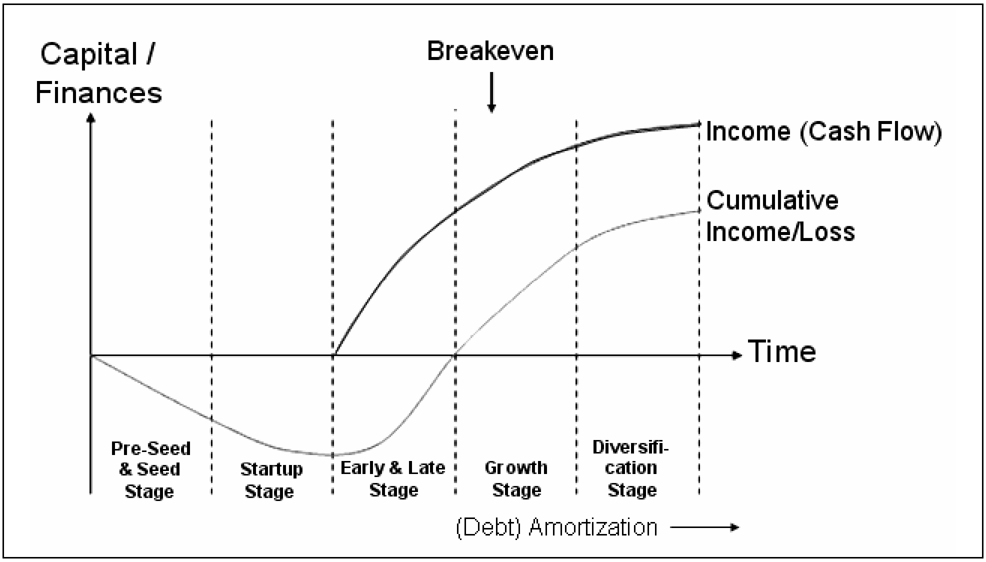


Figure I.53: Typical income/loss (expenses) structure for development of a new firm.

For the US primary sources of capital for founding NTBFs are reported by Bhidé [2000:38] based on an *Inc.* 500 sample from 1996 (mostly firms launched after 1988). They are given in Table I.23. According to the frequency of utilization, personal savings and borrowing are the main sources for *initial* funding of these private companies. Venture capital and private investors play only a small role.

On the other hand, Roberts [1989] analyzed empirical data that come largely from companies founded around 1990 by former employees of MIT laboratories and academic departments. Therefore, they principally may well be unrepresentative of other technology-based new firms. However, his data (Table I.23) match essentially those of Bhidé and thus corroborate the related findings of the roles of personal savings and funding by family and friends versus venture capital and other investors.

Table I.23: Primary sources of initial funding (1996 *Inc.* 500 companies) and 154 firms founded by former MIT employees.

Sources of Startup Capital	**Frequency (Percent)** **[**Bhidé 2000:38]	**Frequency (Percent)** [Roberts 1989]
Personal savings	55	77
Family and friends	13	5
Bank loans	7	0
Personal charge cards	5	-
Venture capital	4	5

Table I.23, continued.

Angel investors	3	-
Private individual investors	-	7
Non-financial corporations	-	6
Public stock issues	-	3

Bhidé and Roberts do not consider explicitly financing of RBSUs. The author is only aware of one study providing some basic information for their situation. Moustras [2003] looked into spin-outs from chemistry departments in the UK. The findings are as follows.

- *Funding in stages is typically*, starting out with founders' funds, business angels and progressing on to venture capital once the company needs to grow.
- A quarter of the studied companies are i*n the very early stages with funding from their founders and/or universities,*
- *A fifth has funding from business angels and over 50 percent are VC funded*.
- Four fifths of the companies in the survey were considering venture capital or had received VC funding. Almost half had their first support from business angels, with only *6 percent citing university funding* and a similar proportion of founders putting their own money in.
- Specifically, *initial funding* provided by the founders was seen as very important to convince other investors that founders and academics are committed to the project, but also their family and friends. *Second round funding* was provided by venture capitalists. Further funding was provided by entering into *joint developments with multinational companies* with interests in the field.
- *Universities typically covered patent costs and legal fees setting up the company, writing the business plan and in many cases provided funding in return for an equity stake.*

It is interesting to note that only 5 percent of the UK chemistry spin-out sample was involved in manufacturing which is anticipated to require huge amounts of capital [Moustras 2003].

Universities in the US and Germany provide similar support. This generally includes some non-monetary forms of investment in the company (Figure I., Figure I.51):

- Micro-funds or grants for professional research in state-of-the-art of technology (patent and technical literature searches) and market research,
- Scholarships and grants for researchers by national research associations (NSF, DFG),
- Providing lab space and time off to focus on getting the company established,
- Providing a university-related incubator,

- Indirect financial support by preferred rates for renting office and laboratory space, use of office services, utilization of highly sophisticated and expensive instruments etc. in science and technology parks.

The German government's microfinance fund (in German Mikrokreditfonds Deutschland) also offers small loans in conjunction with intensive advisory services. You can contact their microfinance team for this purpose. And generally, during firm development there are many options of (US anf German) governments to support technology entrepreneurship, for instance, via loan guarantees, laws, mandates, tax breaks etc. (Figure I.51, CleanTech, biofuels – A.1.1, Figure I.34).

In the US the great majority of initial investing through outside investors has traditionally been undertaken by private wealthy individual investors. Furthermore, being "accountable only to himself for his actions, he/she can afford the inevitable loss and he/she often has motivations for investing which are not strictly economic. (cf. for the US the firm First Solar, Figure I.154, ch. 4.3.5.2; for Germany Box I.23). The private individual seldom seeks out investments. Instead he/she learns of opportunities from contacts within the financial community of which he is often a member [Roberts 1989].

"Familiy investors" often fund an autonomous investing organ (corporation or partnership), managed by a staff of full-time employees who analyze incoming investment proposals, make the investment decisions (usually without family participation in the decision), and work with the investee companies during the post-investment period.

In the US Venrock, founded by the Rockefeller family, and Cascade Investment, an asset management firm owned by Microsoft Founder Bill Gates, are perhaps the best known of these organizations. The family venture capital groups were the models for the formation of specialized closed-end investment companies that focused on venture capital.

A time series reflecting startup development for the various sources used for financing NTBFs in Germany in the early 2000s is given in Table I.24. Accordingly, for instance, 18.74 percent of NTBFs founded in 2001 and 2002 received long-term bank loans between January 2005 and February 2007 (data collection period). This source is rather constant which means bank loans continue to play a significant role for further company development.

Overall and in line with the US data (Table I.23) capital by third parties contributes 5-6 percent – significantly less than family and friends. With increased age of the NTBFs the importance of public grants diminishes considerably. The same is true for the role of own capital.

Table I.24: Sources for financing of young German high-tech companies with different foundation years, in 2005/2006 and before [Gottschalk et al. 2007].

	Foundation Samples; Frequencies in Percent			
Source	**2001/2002**	**2003/2004**	**2005/2006**	**2001-2006**
Cash Flow	73.89	70.59	73.38	72.59
Own Capital	41.26	52.08	80.94	57.56
Family and friends	11.49	14.40	17.63	14.45
Capital by Third Parties	4.67	4.47	5.96	5.01
Long-Term Bank Loans	18.74	16.95	21.38	18.96
Public Grants	9.31	17.07	25.04	17.00
Other Sources	20.94	16.80	13.06	17.00

Notably, the data from 2005/2006 and 2001/2002 show that to a large proportion the German NTBFs can make use of successful operation and revenues early on in terms of cash flow. With time proceeding, from startup into the early/late stage, the significance of own resources, those of the family and friends as well as public grants decrease markedly.

Also US companies in the 1989 *Inc.* 500 list financed their growth primarily through retained earnings (cash flow), fewer than a fifth had raised follow-up equity financing in the five to eight years they had been in business [Bhidé 2000:29].

Identified “cash flow” as a financing source may hide an important source for initial funding. That is a supply agreement (including “customer pre-payments”) with a larger company (Box I.11) and corresponds to startups with having already customers which obviously is not so rare (German ChemCon GmbH, WITec GmbH, Solvent Innovation GmbH, IoLiTec GmbH, Attocube AG; and US Cambridge Nanotech, Inc.; B.2).

The study of only those firms that according to Table I.24 got financing by third parties in Germany provided a detailed view about the different contributors. Data for firms founded in 2005 or later represent sources for initial (start-up) funding.

For instance, for the later stage firms founded in 2001 or 2002 that got financed by third parties between January 2005 and February 2007, 25 percent received money by VC companies. This translates into 1.2 percent overall contribution of VCs in Table I.24. VC contributions increase with further developments of the firms. “Private investors” cover essentially angel investors (called *business angels* in Europe). The tendency for angel contribution is reversed compared with VCs, a decreasing role with proceeding development. They are more usually relevant for early stages of NTBFs.

However, a VC-backed or high investment approach startup model (millions of dollars or euros) dominates in some fields with an emphasis on productions or very high value products, such as biotechnology and biopharmaceuticals and also biofuels (A.1.1) and other CleanTech areas (such as photovoltaic, energy storage by batteries etc.) and computer hardware.

Table I.25: Financing sources of young German high-tech companies by third parties (listed in Table I.24) in 2005/2006 and before [Gottschalk et al. 2007]. *)

	Foundation Samples; Frequencies in Percent			
	2001/2002	**2003/2004**	**2005/2006 *)**	**2001-2006**
Private investors	44.18	55.11	82.04	62.09
Venture-Capital-Firmsn	24.91	16.84	10.80	17.01
Other Firms (Corporate Venturing)	3.73	17.24	18.49	13.58
Public Investments	30.12	21.13	21.52	24.09
Other Investors	14.17	9.26	2.43	8.21

*) Represent initial funding for the startup stage based on the date of investigation.

Beginning in the early 1960s and increasing significantly only in the 1980s, major manufacturing firms have become interested in supplying venture capital to young technological companies. Many of them are seeking to supplement their in-house research and development efforts by backing entrepreneurs in hopes of gaining access both to technology and engineering talent.

Initially US companies, such as DuPont, Ford, Texas Instruments and Union Carbide, experimented with this approach of direct venture capital investment in new or early stage companies [Roberts 1989]. Currently, corporate venturing has become common practice of large and giant firms across industries and the globe. Data in Table I.25

indicate that the significance of corporate venturing versus venture capital as a source of financing development of (German) NTBFs follows opposite trends.

In the US and Germany investment activities of corporations are usually *direct* as part of their innovation strategies which means investing into NTBFs of business interest to them, for instance, seeking to gain access to new or emerging technologies and probably acquire these for future businesses.

In Germany, there is also *indirect investment* via a private-public partnership (PPP) investment organization. For instance, the High-Tech Founder's Fund ("High-Tech Gründerfonds") has been set up by the German giant firms BASF, Siemens, Deutsche Telekom, Daimler, Bosch and Zeiss and the German government (BMWi) and a public bank (KfW Mittelstandsbank; Kreditanstalt für Wiederaufbau – Reconstruction Credit Institute) to provide investment capital based on promising research results, an innovative and technological base, and a high potential market situation for the involvement in new firms. Apart from financing a new technology firm it will provide support, such as coaching, based on a strong network and entrepreneurial knowledge and expertise.

Public investments in Germany (Table I.24) may cover various organizations. The German Mittelständische Beteiligungsgesellschaft GmbH (MBG) is an organization set up individually for each of the German federal states. The MBGs receive support from the federal and the state governments and are non-profit making organizations with similar structures across the states. Basically the MBG acts as a publicly supported capital investment company (for SMEs), working closely together with the state-owned guarantee banks (banks for guaranteeing loans). Shareholders comprise chambers of commerce, chambers of crafts, business associations and leading federal- and state-owned banks (like the above mentioned KfW), sometimes also private commercial banks.

An MBG enters usually into "silent partnerships" with small or medium-sized businesses and businesses which are in the process of being founded – usually getting a share of the firm's annual profit. An MBG acquires also direct stakes in industrial companies. The MBG provides private equity, but it does not intervene in the day-to-day management of its firms. Programs cover the range between seed-capital-financing and financing growth of a company. The investments have to be repaid after 10 years at nominal value. MBG provides equity capital very often in addition to short- and medium-terms loans granted by the company's bank.

The percentage of firms accessing a particular source for financing does not reflect the quantitative significance for its proportion in terms of the total capital provided by that source for a new high-tech firm. Correspondingly, in Table I.26 the financial structure of such firms in terms of the relative volume is shown for groups of firms clustered according to years of foundation [Fryges et al. 2007].

The table reflects the average proportion a particular source contributes to the total volume of capital which the firm has received since January 2005. For instance, for young high-tech firms founded in 2001/2002 own resources correspond to ca. 15 percent of new total capital received since 2005.

> The number of founders in a team can influence the amount of initial capital both directly and indirectly. As the number of founders increases more personal funds are available from which to draw money. This has a direct effect. Indirectly, the more founders there are the greater the possibility that one of them knows a receptive "outside" source.

Independently from the age of the new firm one can see that cash flow and own resources of the founder(s) account for more than three quarters of capital received. However, there is a distinct shift toward cash flow with increasing age of the firms.

An open question is whether the notion "public grants" differentiates grants provided in the context of entrepreneurship and firm's foundation or research and development projects in which NTBFs can participate.

Table I.26: Volume of financing (financial structure) of young German high-tech companies with different foundation years, in 2005/2006 and before [Fryges et al. 2007].

	Foundation Samples; Volume in Percent			
Source	**2001/2002**	**2003/2004**	**2005/2006**	**2001-2006**
Cash Flow	66	57	44	55
Own Capital	15	22	35	24
Family, friends etc.	4	5	6	5
Capital by Third Parties	2	2	1	2
Long-Term Bank Loans	6	6	7	7
Public Grants	2	5	6	4
Other Sources	5	3	1	3

Considering that financing by third parties accounts for just about 2 percent of capital received anew this is not a surprise referring to the fact that ca. 5 percent of all NTBFs mentioned to have received capital from third parties over the 2005/2006 period (Table I.24).

In both the left charts of Figure I.54 average proportions of finances contributed according to the sources given in Table I.26 are shown for only those *firms which received financing by third parties* since the beginning of 2005.

The overall financial structure of those firms exhibits the proportion of capital obtained from third parties to account for 29 percent – close to the percentage (34 percent) cash flow contributes to the overall capital. Of those younger firms of the 2005 and 2006 sample which received financing by third parties the average financial proportion accounted for 22 percent. Out of these private investors provided 74 percent. Hence, private investors accounted for 16 percent of the all the financing sources.

Furthermore, there is a marked change of the financial structure over development time of the German firms putting more emphasis on venture capital and public financing sources at the expense of private investors. Financing is usually by several venture capital firms and also several public or semi-public investment firms. Utilizing public investment firms usually increases the options for financing via third parties of German NTBFs compared to those in the US. Furthermore, there is a dominant role of private investors in Germany.

It remains to be seen what effects the Great Recession (2007–2009) and the following weak recovery will exert on financing sources (cf. Box I.6) and financing strategies for NTBFs.

As an addition to the current discussions Figure I.55 provides another differentiation of the role of the financial sources in terms of frequencies of use and volumes by the sources in Germany. It provides also more details about the role of the public sources [Creditreform - KfW - ZEW 2009]. Foundations in 2007 could rely on own resources by 83 percent which suffices to finance 64 percent of the needed finances for foundation. In 2008 an even higher proportion of own resources (90 percent) was used, however, with a lower amount of volume (52 percent).

Disregarding the founders' own capital Figure I.55 emphasizes that banks contribute most to financing of NTBFs in Germany in the first few years through different means – loans and lines of credit. Furthermore, promotional loans from the national KfW bank and federal state-owned banks show up in the third position. Banks can also help through long-term lease financing of laboratory or manufacturing equipment or providing (mortgage-like) loans for acquisition of instruments taking ownership of these instruments as a security.

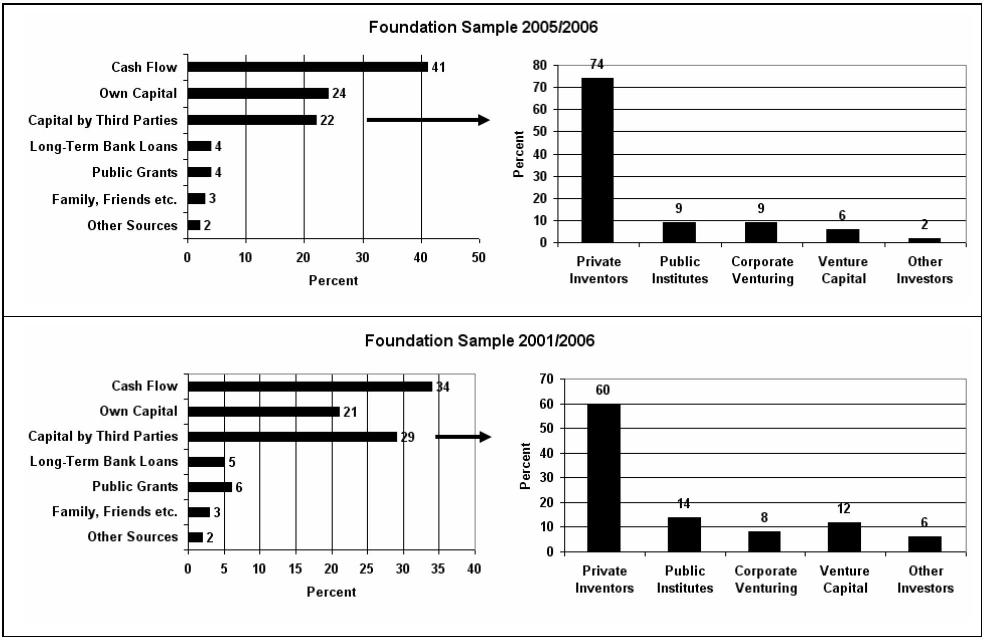


Figure I.54: Financial structure of young German high-tech firms which received financing by third parties since 2005 (sample Jan. 2005 - Feb. 2007) [Fryges et al. 2007].

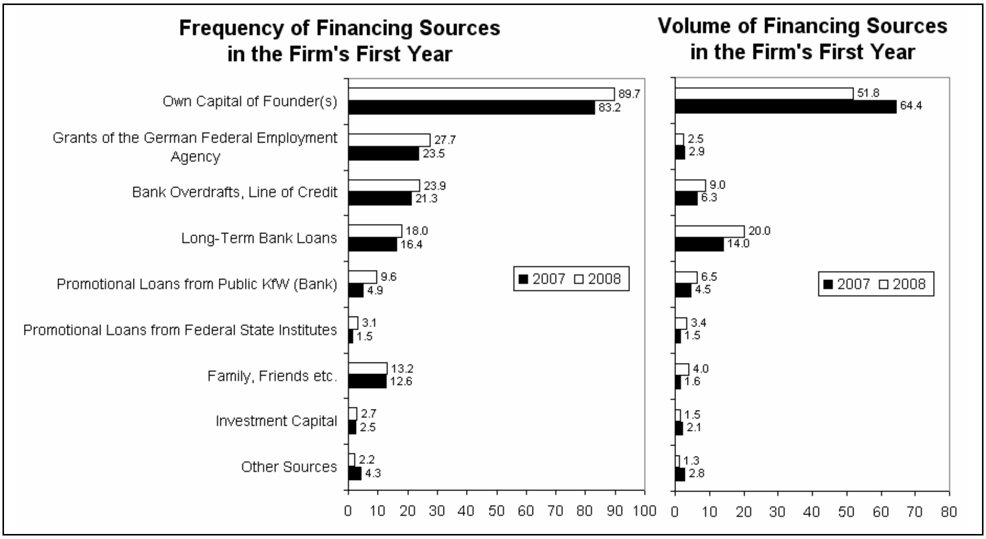


Figure I.55: Frequency and volume of financing sources of German NTBFs (sample 2005-2008, allowing multiple answers) [Creditreform - KfW - ZEW 2009].

Companies having early sales by contract to government (including military) or large industrial organizations may achieve bank loans, as the banks may grant loans to these firms, attaching the contract payments as security [Roberts 1989].

The German government offers promotional loans at affordable terms via the KfW Bankengruppe, while states (in German Länder) offer low-cost loans via funding institutes (for instance, investment banks). These loans usually offer lower interest rates than private bank loans. One generally has an initial phase of several years before repayments are due. Promotional loans must always be applied for through private banks. On the other hand, the current study of NTBF cases (B.2) has revealed that Sparkassen banks (ch. 1.2.7.2) are often involved in providing initial and growth credits to founders.

As a summary,

> Technology entrepreneurship (in Germany) for the pre-seed, seed and early growth phases is facilitated to a considerable extent by federal and state governments and public federal- and state-owned financial institutions and mixed private-public institutions via debt financing modes, but also equity investments.
> Governmental (federal and state) funding may be indirect via universities and public research institutes which are largely financed by the governments (ch. 1.2.6).

Concerning the question of whether NTBFs with a particular firm structure or orientation will get or have to go preferentially for capital by third parties one can say that these are often firms striving *for large-scale production* involving scale-up (Figure I.8, Figure I.9). This is found for many CleanTech areas, such as, biofuels (A.1.1), batteries, fuel cells or lighting (Novaled AG).They may have a need for several dozens of million and will go for financing sources which are in the position to satisfy such needs. The biofuels example show the large emphasis of such new firms on venture capital.

Furthermore, Fryges et al. [2007] found that (in Germany) these “producing NTBFs” have, in general, more emphasis on

- Continuous R&D, a higher proportion of employees in R&D and using own patents
- Have a high R&D intensity (ca. 29 percent)
- Utilize own developed technologies
- Introduce something new-to-the market.

Though *firms which received capital from third parties are representing a small proportion of all high-tech foundations* in Germany, Fryges et al. [2007] have shown that this kind of German firms are larger (by number of employees at firms’ foundation and also ca. five years later), grows faster, is more innovative and tend to be spin-outs from universities or public research institutes [Fryges et al. 2007]. The same applies to the US (ch. 4.3.6).

1.2.7.2 The Components of the Financing Subsystem for Technology Entrepreneurship

Basically, financing technology ventures may be by for-profit organizations or non-profit organizations. In particular, in the US the role of (non-profit) *foundations* for entrepreneurship is more pronounced than in Germany. Many of the similar initiatives in Europe would be financed with public money and therefore are subjected to other constraints. The European model has one striking advantage: Since the European organizations' budget is not fed by the volatile stock market as for most US foundations the budget needs not to be cut so dramatically as if a recession decimates the foundation's assets.

Given the important roles of banks and related debt financing for technology entrepreneurship in the US (Table I.23) and Germany (Table I.24, Figure I.55) it is astonishing how little attention these have attracted in discussions of financing NTBFs (cf. [Dorf and Byers 2007:Chapter 18]). To elevate the differences in the roles of banks for financing NTBFs in the US and Germany the banking systems in the two countries shall be outlined [Vitols 2001].

Banking Systems

One key difference between the US and German bank system is the degree to which financial systems are *bank-based* or *market-based*. In a bank-based system (Germany), the bulk of financial assets and liabilities consists of bank deposits and direct loans. In a market-based system (US), securities that are tradable in financial markets are the dominant form of financial asset.

Bank-based systems appear to have an advantage in terms of providing a long-term stable financial framework for companies. Market-based systems, in contrast, tend to be more volatile but are better able to quickly channel funds to new companies in growth industries.

A second key distinction between financial systems is *the degree to which the state is involved in the allocation of credit*. Government ownership or partial ownership of banks is widespread in Germany, but non-existent in the US. State involvement in credit allocation can turn the financial system into a powerful national resource for overcoming market failure problems and achieving collective economic and social goals. However, financial targeting also runs the danger of resource misallocation due to inadequate reading of market trends or "clientelism."

The banking system in Germany accounts for the majority of financial-system assets (ca. 75 percent, respectively), whereas banks in the US (with about one-quarter of total financial-system assets) are only one of a plurality of financial institutions. US banks still face somewhat more limited power to invest in industrial firms than do banks in Germany, for example. Likewise, industrial firms' investments in banks face more limitations in the US than in the European Union.

In Germany's banking system there are only few large commercial banks. The largest banks, such as Deutsche Bank and Commerzbank, are known primarily because they have large overseas operations. Domestically, the banking system is mainly comprised of regional and private banks, and then there are the standalone savings banks, known as Sparkasse banks.

German *Sparkasse banks* are largely equivalent to *American savings and loans institutions*, except that in Germany they are owned essentially by local governments or/and other public entities rather than private investors. Hence, they are immensely trusted by Germans. Furthermore, there are regionally oriented cooperative banks with an emphasis on private persons and medium-sized firms (Figure I.56).

The "*three columns model*" of the German bank system involves banks differing in their goals and purpose, legal state and ownership structure and are fundamentally differentiated as "universal banks" acting simultaneously as commercial and investment banks and "special banks" (Figure I.56).

Universal banks have long played a leading role in Germany and other Continental European countries. The principal financial institutions in these countries typically are universal banks offering the entire array of banking services. Continental European banks are engaged in deposit taking, real estate and other forms of lending, foreign exchange trading, as well as underwriting, securities trading, and portfolio management. In the Anglo-Saxon countries, by contrast, commercial and investment banking tended to be clearly separated – until the Great Recession.

> The fact that German (federal and state) government owns or part-owns, respectively, banks makes it possible to create more secure long-term investment for startups. And that government owns or is involved in investment companies which just go for "silent partnerships" makes founders get equity *and* retain full control over their ventures.

Similar to *German credit cooperative banks* in the US a "*credit union*" is a cooperative financial institution that is owned and controlled by its members and operated for the purpose of promoting thrift, providing *credit at reasonable rates*, and providing other financial services to its members. Many credit unions exist to further community development or sustainable international development on a local level.

Credit unions are typically smaller than banks. Due to their not-for-profit, cooperative structures, credit unions are exempted from most state and federal taxes. In the credit union context, "not-for-profit" should not be confused with "non-profit" charities or similar organizations. Credit unions are "not-for-profit" because they operate to serve their members rather than to maximize profits.

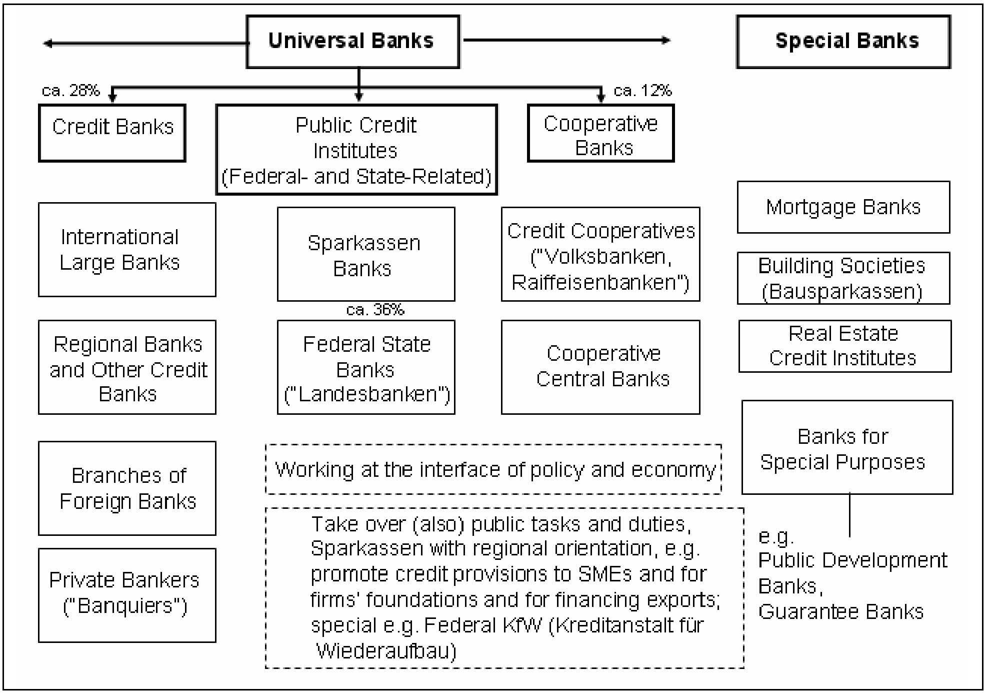


Figure I.56: Outlining the German "three columns" banking system and approximate shares as percentage of the total balance of the German banks.

Special banks play many roles in Germany, especially public development banks like the KfW, and guarantee banks that are privately organized in the US. For instance, US commercial banks are strongly influenced by the Small Business Administration's loan guaranty program (1.2.6.3).

In the US the functional correspondence to German guarantee banks is SBA's Loan Guarantee Program which substantially lessens a bank's risks of lending to a small company. It is designed to help small entrepreneurs start or expand their businesses. The program makes capital available to small businesses through bank and non-bank lending institutions. SBA lenders are, for instance, Bank of America and KeyBank. Its MicroLoan Program is available for up to $35,000 through non-profit, micro-loan intermediaries, to small businesses considered unbankable in the traditional banking industry.

Functionally comparable with the *German MBG* in the US there are *Small Business Investment Companies (SBICs)* established by the "Small Business Investment Act of 1958." SBICs, licensed by the Small Business Administration, are privately owned and managed investment firms. They are participants in a vital partnership between government and the private sector economy. With their own capital and with funds borrowed at favorable rates through the Federal Government, SBICs provide venture capital to small independent businesses, both new and already established. All SBICs are profit-motivated businesses.

A major incentive for SBICs to invest in small businesses is the chance to share in the success of the small business if it grows and prospers. Today there are two types of SBICs – the original, or "regular" SBICs and SSBICs – Specialized Small Business Investment Companies. SSBICs are specifically targeted toward the needs of entrepreneurs who have been denied the opportunity to own and operate a business because of social or economic disadvantage. With few exceptions, the same rules and regulations apply to both "regular" SBICs and SSBICs.

Generally, the US banking industry is less highly concentrated than the banking Industries in many other industrial countries. Historically, US banking laws prohibited interstate banking, and they limited branching activity, restrictions that favored the existence of many small local banks. Even though these restrictions were removed in the 1990s the highly diversified banking sector still exists.

On the other hand, over the last decades in the overall financial system the US banking system has faced stronger competition than those in Europe from fast growing non-bank financial institutions which are particularly relevant for entrepreneurship. For instance, US banks' share of the financial service industry assets has been shrinking for decades and mutual funds and pension plans have been growing much more rapidly than banks.

Investment Organizations – Venture Capital

Apart from banks for technology entrepreneurship a number of other organizations are relevanr which focus on investments. For instance, a **mutual fund** pools money together from thousands of small investors and then its professional management buys stocks, bonds or other securities with it. When you contribute money to a fund, you get a stake in all its investments. A mutual fund will have a fund manager that trades (buys and sells) the fund's investments in accordance with the fund's investment objective (cf. also crowdfunding; end of this sub-chapter).

Investors may make capital investments in opportunities for future cash returns in terms of different targets, for instance, publishers may invest in an author, **venture capitalists** into a (new) firm. Venture capital is an *investment in an unproven business*. In its current form the venture capital phenomenon in the US (and Germany) [35] as a significant factor for entrepreneurship has developed significantly only for the last fifty years. Reference to "historical entrepreneurs," hence, can reveal what technology entrepreneurship is without them.

For NTBFs venture capitalists strive for high reward, based on related uncertainties and many risks. Their investment(s) will be associated totally with high risk (Figure I.6). And as VCs are no adventurers they assess carefully the mean (the entrepreneurs, the firm and the opportunity) with which to exploit the opportunity.

Figure I.57 depicts the basic structure and process when an entrepreneur seeks funding in terms of the cash amount needed at a particular time addressing investors. The elaboration of a final deal requires for the entrepreneur *soft skills*, but usually for the final negotiation of the deal structure the entrepreneurs need (professional) consultants. Soft skills are advantages for addressing any kind of financial backer – and customers!

The process runs essentially in four sequential stages with corresponding decision gates for assessing whether and how to proceed. Usually, venture capitalists look for ventures that can become profitable and attain at least $(€)100 million a year in revenue in the next five to seven years. Venture capital is not provided for the firm's development as a total sum but usually in steps (Figure I.52) defined by milestones (*expected results*) to be achieved by the new firm.

When the entrepreneur has identified what he/she thinks is an appropriate investor (step B in Figure I.57), he/she must be aware of the involved risks (ch. 4.2) to be dealt with – by him/her and the investor:

The process of investigation into the details of a potential investment is ***due diligence***. It is usually undertaken by investors, but also customers. It refers to the process of making sure that people are what they say they are and can do what they claim (for instance, does the product really work, do they really have customers, etc.).

Furthermore, VCs, who invest others' funds rather than their own capital, face additional incentives to institute *systematic procedures and criteria for evaluating and monitoring investments*. That may be one of the roots for the extreme focus on the business plan to be provided by to-be entrepreneurs.

Unfortunately, deep diligence and high conviction is not fully correlated to investment success, as it only analyzes a snapshot, not a movie, about the merit of a startup. Companies often need time to show their worth and truly justify a large commitment.

Financial projection (cash flow forecasts) provide two perspectives:

1. For the founder(s) determining the economic potential of the new venture
2. For an investor demonstrating the potential return.

Key questions regarding the "deal" are:

1. What percentage of the company (*ownership*) do the investors receive for their cash?
2. What special terms and conditions (for instance, control) are necessary to compensate them for the risk?

The basis is *valuation*, assigning a monetary value to the new venture. Valuation and terms of the deal (step C in Figure I.57) are outlined by Dorf and Byers [2007:421-426].

Venture capital partners become actively engaged with a company, typically taking a board seat of a stock company. An early stage venture capitalist sitting on six company boards has a huge workload. With a startup, daily interaction with the management team is common. This limits the number of startups in which any one fund can invest. Few entrepreneurs approaching venture capital firms for money are aware that they essentially are asking for ca. 1/6 of a person [NVCA].

Referring to the example of the US in Figure I.58 fundamentals of the venture capital value chain and VC relationships are displayed. Traditional VCs typically have a General Partner (GP) or Limited Partner (LP) structure (GP is similar to a GbR in Germany) [36].

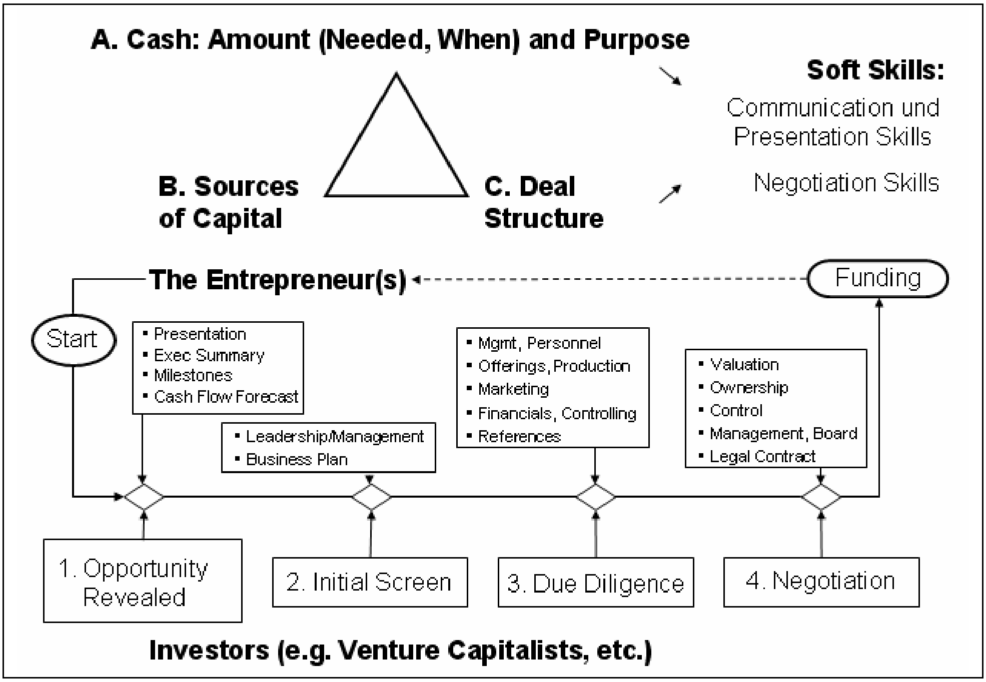


Figure I.57: Structures and processes when entrepreneurs seek investment capital.

Vastly simplified, the GPs are the ones who do the deals and the LPs are the ones who supply the money. Venture capital typically comes from institutional investors and high net worth individuals and is pooled together by dedicated investment firms. Mutual funds and pension funds play here a key role. A *venture capital fund* refers to a pooled investment vehicle, often in terms of a limited partnership (LP) or LLC (in German GmbH) as the legal company form, that primarily invests the financial capital of third-party investors in enterprises that are too risky for the standard capital markets or bank loans.

The (legal) construct of “partners” are also often found with engineering offices.

Things are similar in Germany with the exceptions of the details of capital origins and organizing a VC fund. Generally, venture capital is less organized, less developed and financially much less equipped compared with the US. While in 2009 US venture capitalists invested $18 billion (ca. 1.3 thousandth of GDP) the investment of Germany accounted for only ca. 0.3 thousandth of GDP [Finfacts 2010]. And after the Dot-Com Bubble of 2000, we saw an almost complete collapse of the private German VC industry, and the remaining funds never increased again to the previous level.

Furthermore, in the US a notable number of highly successful technology entrepreneurs became venture capitalists, such as Marc Andreessen (ch. 3.4, Box I.14) and Vinod Khosla (A.1.1.5 – Sun Microsystems). This situation is much less observed in Germany.

“Venture capitalists” are investment professionals; they assess ideas and opportunity according to quality and fit into the portfolio of firms the funds invest in (cf. Khosla, Figure I.182). The “market” or “systemic” risk of the portfolio, rather than the astuteness in the choice of the individual securities, determines the investors’ long-run return.

The reward for VCs is usually obtained in the “**exit**” when selling the successful firm, merging the firm with another one or let it be acquired by another firm (M&A – Mergers & Acquisitions) – or taking it to a stock exchange for public trading through an IPO (Initial Public Offering). The venture firms earn between 2 to 2.5 percent of their capital under management and retain 20 to 30 percent of any profits.

Venture capitalists are looking for two basic things when considering whether to invest in business:

- High return:
  As venture capitalists are willing to take unusual risks by investing in a new business, they require unusual returns as well, perhaps 7-10 times their original investment within 5-7 years.
- Easy exit:
  Venture capital firms will realize a profit by selling their interest in the business at some future point.

The big winners generally have to earn ten times the original investment money in four to five years. A multiple of ten times is equivalent to a 58.5 percent annual return over the five years [Dorf and Byers 2007:418].

Bhidé [2000:145] cites a study that revealed that in the VC area about seven percent of investments accounted for sixty percent of the profits. This indicates that the principle of the” 80/20 Rule” may apply in terms of 20 percent of the funds making 80 percent of the returns.

“In many ways the VC phenomenon represents a variant of managerial capitalism” [Bhidé 2000:xv]. Like the decision-makers in large firms VCs emphasize the use of systematic procedures and criteria for making investments and provide capital under well-specified terms. In essence *VC-based startups* represent an intriguing *combination of individual enterprise and professional management*.

As outlined in Figure I.52, Figure I.57 and Figure I.58 VCs are investing in financing stages and defined intermediate goals, milestones and deadlines. The new information at each state enables the VC to decide whether and how to proceed. *The VC staged process is structurally related to the Stage-Gate® (PhaseGate) process for innovation in large firms (*Figure I.79*,* Figure I.180*) intending to successively reduce uncertainty and risk (*Table I.27).

> It is all about ownership, control and execution, advice and connections – and money.

According to Figure I.53 there is some time before a new firm becomes profitable. For investors that mean in the early phase(s) they can expect a negative cash flow. This is the **burn rate**. The term may also be used to refer to the net negative cash flow of a company with consistent revenue. A typically asked question from an interested investor is, “What’s your monthly burn rate?” which really means, “How much do investors have to cover on a monthly basis before you’re cash positive?”

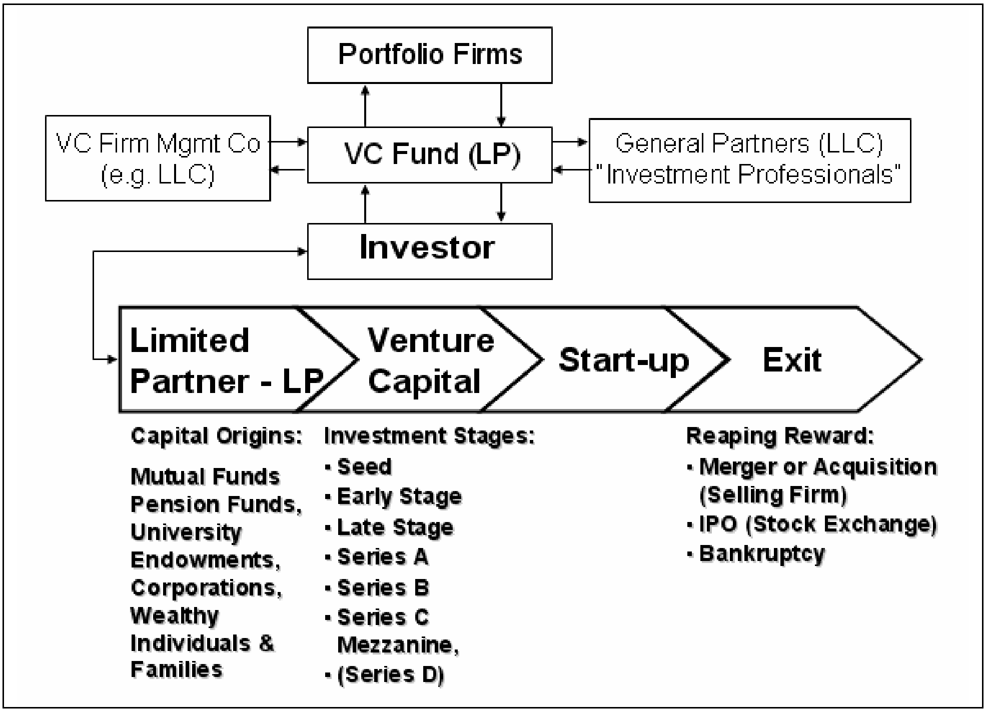


Figure I.58: Venture capital value chain and VC relationships.

Fundamentally, venture capitalists focus on three further differentiated investment stages: seed investing, late stage (development) investing and growth investing. Furthermore, with increasing progress of the new firm more investors may contribute capital giving rise to a “lead investor.”

> The life-cycle stage investment approach (Table I.27) also lent itself to investing more in serial entrepreneurs and avoiding first time entrepreneurs (A.1.1) – meaning to reduce risk.

Typically, also as a means of reducing risk, venture capital firms emphasize deals of financing phases after foundation and early development of a firm which obtained financing by angel investors (seed, startup and early stage; Figure I.52). A further aspect of risk reduction for VCs is when policy steps in as an investor or financial backer of a firm via grants, loan guarantees, tax breaks or tax exemption (Figure I.34).

A **lead investor** is taking a lead position in an investment in a company, usually because he/she is investing the largest portion of a syndicated investment but sometimes because he/she is most knowledgeable about a company, its technology and the market or have made the first commitment to an investment and are leading the due diligence process. Typically a lead investor will have a board seat (cf. Vinod Khosla; A.1.1.5). Such a “first” investor usually increases the credibility of the new firm which means it facilitates getting further investors on board.

For NTBFs corporate venturing companies (CVCs) often take the role of the lead investor.

But especially in biofuels and biobased chemicals (A.1.1), it could be also an opposite situation. When dealing with firms like Amyris and Gevo (Table I.99) as well as Renmatix (A.1.1.6; B.2) the German large/giant chemical firms LANXESS and BASF probably never had invested in Gevo or Renmatix if not the VC firms Khosla Ventures, TPG Biotech or Kleiner Perkins Caufield & Byers (KPCB) had taken the lead in the seed/early stage investments. These “seed” investors are to a large part US based with the ultimate goal to exit their investment via a floating of the shares on the stock market, to establish a (traded) price and later to sell their shares.

In biotech and CleanTech you have to finance heavy in investments upfront in large scale plants and to accept product introduction to take years. Correspondingly, the favorite business model of such VC firms is to get an industrial partner on board prior to the capital intensive investment stage and who eventually will take over the company years later.

Basically, there are two orientations: The so-called *value investors* are not investing in technology *per se*, but on a case-by-case basis in promising companies (in the sense of high-expectation) with unique technologies being applied across a range of industries. In contrast, *momentum investors* look for buzz-worthy sectors and then take a more shotgun approach, hoping to find a winner.

Venture capital funds concentrate on attractive, disruptive and high-growth industries. They *usually have preferred investment fields* which *change over time and follow also boom/bust patterns, waves and hypes*.

That means financing options of an NTBF by VCs may become an important factor in the Window of Opportunity (Figure I.4, Figure I.92). For technology entrepreneurship VC's pet areas included, for instance, information technology, biotechnology, superconductors, Internet (Web firms; ch. 3.4), nanotechnology and particularly now CleanTech (Table I.52), such as biofuels (A.1.1). Consequences for startups after the hype are outlined for new Internet firms (ch. 3.4.1.1).

Table I.27 provides an overview of the financing stages followed by venture capitalists with rough outlines of milestones, time horizons and rough amounts of capital investments. Furthermore, the milestones are specified by requirements and conditions to be met to proceed to the next stage of financing and ending with the VCs' exits associated with sustainable finances' "predictability."

Table I.27: Investment stages, approximate time horizons and related rough investments of capital for VC-based firms.

Stage	Required, Milestones	Amount, Time, Remarks
Seed (Startup)	Concept (Proof-of-Concept), Value Proposition, Few people (R&D team), Business Plan, Founders commit IP to company, Defined & executable milestones & timeline, Managed burn rate	$0.500-1.5 M for 9-12 months of milestones VCs Know lots of people (the right person is over 50% of the answer), Usually have some operational experience Entrepreneurs can expect: Customer contacts, Hiring contacts, Mistakes to avoid, and why, Methods that worked, and why

Table I.27, continued.

Development, Series A	Technology, Product development, Prototype ready for scale-up, Value, Capital Structure, Management team, Board (balanced, investor collaboration), Market definition, Positioning strategy, Market development (beta customers), Business Model	$2-5 M for 12-18 months of milestones
Growth: Series B	Proven business model, Product to market, Customers, Distribution, Revenue start, Step up in value, Product roadmaps, Revenue stream defined, Customer discussions, Executing marketing plan, Market conditions clear Less risk tolerant investor	$10 - 20 M for 12-20 months of operations
Series C, Typically mezzanine capital (if a company has demonstrated a track record in the industry with an established reputation and product, a history of profitability and a viable expansion plan for the business)	Customers, Market expansions, Public profile	$20 – 100 M for 12-24 months, Pre-IPO Investopedia: A hybrid of debt and equity financing for expansion of existing firms; is basically subordinated debt capital that gives the lender the rights to convert to an ownership or equity interest in the company if the loan is not paid back in time and in full (a claim on a company's assets). Mezzanine financing is advantageous because it is treated like equity on a company's balance sheet and may make it easier to obtain standard bank financing.

Series D	Competitive, Mature	> 100 M (new investors and/or backers, e.g. government finances), Prepare IPO
Exit	Sustainable finances predictability	Get money back plus a huge return on investment

The common understanding of the VC situation is that either VC is addressed by startups or NTBFs or venture capitalists are pro-actively searching for promising startups or NTBFs (in the sense of high-expectation). However, a not so rare situation is that venture capitalists, based on a perceived opportunity, are initiating startups by financing and staffing them.

For instance, the approach of Pasadena, Calif.-based Arrowhead Research is: "We identify attractive market opportunities, look for technologies that can serve those, and then build companies." [Thayer 2008] Arrowhead provides an entire management and business development infrastructure in legal, financial, administrative, and regulatory areas. Their view is that the company lives and dies by its ability to combine scientific and business capabilities. Focusing on nanotechnology, this involves bringing in senior scientists as advisers. On the other hand, success hinges on having experienced business people who have created companies in the industries that nanotechnology will impact.

The biofuels field is full of similar approaches of venture capitalists, searching for or "knowing" opportunities, then organizing financing, gathering a management team and board and founding a firm, as observed for the firm Coskata (Table I.99), or specifically by Vinod Khosla with his sponsor approach (Table I.98).

To inquire into the role of VC for the economy a study [NVCA 2009] conducted by Global Insight for the National Venture Capital Association (NVCA) analyzed a database of ca. 27,000 US-based *companies that received venture capital financing* between 1970 and 2008 – not necessarily only venture capital. The study found that venture-backed companies outperformed their non-ventured counterparts between 2006 and 2008 with a 1.6 percent compound annual growth rate (Equation I.10) in jobs and an 5.3 percent compound annual growth rate in revenue versus total private sector growth rates of 0.2 percent and 3.5 percent respectively.

The National Venture Capital Association represents approximately 460 venture capital firms in the US. NVCA's mission is to foster greater understanding of the importance of venture capital to the US economy and support entrepreneurial activity and innovation. According to the 2009 Global Insight study, in the US in 2008 venture-backed companies accounted for 12.1 million jobs (11 percent in private sector employment) and $2.9 trillion in revenue (21 percent of US GDP).

It is, in particular, this kind of assessment and corresponding ones in the past that venture capital (VC)-backed startups have a powerful influence in shaping popular beliefs and perceptions (and formal research) about new ventures. However, Paul Kedrosky, a senior fellow at the Kansas City (Mo.)-based Ewing Marion Kauffman Foundation, a non-profit organization that promotes entrepreneurship, says *VCs' role is overblown*. "Can you say that all the jobs ever created by a company that took venture capital are the result of the initial money put in?" Kedrosky asks, claiming that many venture-backed companies would have found financing elsewhere [Barrett 2009].

Much of the industry's political influence comes from the perception that its role in backing innovative companies makes it crucial to future economic growth of the US. Correspondingly, "Venture Capitalists Head to Washington." For instance, the NVCA has been pushing to allow more venture-backed companies to participate in the Small Business Innovation Research (SBIR) program, which directs federal research and development dollars to small companies with promising technologies that could be commercialized [Barrett 2009].

Looking at the development of the VC industry in terms of numbers of VC deals and VC investments (1980 – 1994 [Bhidé 2000:164] and 1995 – 2005 [Dorf and Byers 2007:418] and including the 2009 trough) it is seen that *the VC industry in the US follows a boom/bust pattern* [Bhidé 2000:162] – which emerges also for the German VC industry. Hence, for entrepreneurship, particularly for the US, it would be important to have an idea what effects the current Great Recession may exert on the VC industry. The 2000 Dot-Com Bubble was so disastrous in part because illiquid startups became liquid public before they were ready. For VCs returns are measured over a multiyear horizon and the impact of the excesses of 1999-2000 was only being played out in 2009/2010.

An overview of analyses and opinions on the current and future state of the US venture capital industry and its relation to entrepreneurship is given in Box I.6, with the quintessence that "venture capital is in dire need of a fix." [Lacy 2009]

The suggested direction setting is to "reinvigorate venture capital by taking it back to its roots, when firms were smaller, more nimble, and more likely to help startups get off the ground." [Ante 2009; Cain-Miller 2009]. Even CleanTech venture dollars suffered more of the blues than other venture investments, with VC's investing 35 percent in American seed and early stage CleanTech companies in 2007, but investing less than 20 percent of their capital in CleanTech in the first six months of 2009, a report concluded [RedHerring 2010].

From a German, probably particularly the author's perspective, (technology) entrepreneurship in the US has become different over the last two decades to a large extent. If someone has a good idea, there is more than enough venture capital and angel funding to go around, and, ingrained largely in public perception and educational approaches, *there is a very set path for how you build that company out*. That has already given rise to myriad poseurs who decide they want to be entrepreneurs first, then think about the actual company they are going to start second (ch. 2.1.2.7).

Moreover, one observes in the US that many VC-based NTBFs without revenues or commercial products continue to shoot for IPOs whether Internet firms (ch. 3.4) or biofuels companies filing for an IPO in the industrial biotech boom (A.1.1).

Box I.6: The US venture capital industry and an anticipated changing role for technology entrepreneurship.

The exponential rise of the venture capital community as a “new form of financial intermediaries” paralleling the emergence of Silicon Valley has been summarized by Bhidé [2000:160-162] under the heading “A Temporary Phase?” And his line of reasoning suggests that “if VCs had more capital they would relax the criteria they use and fund more start-ups” and he outlines the route to “low returns and a temporary ‘bust’.”

Around 2009, particularly in the US, venture capital firms were struggling to raise new cash, hampered by poor investment returns and a difficult economy. There were disastrous returns of the past quarters of the Great Recession following lackluster returns over the past nine years. The venture capital industry was staring at the most vicious shakeout in its history [Buckman 2008; Lacy 2009; Tam 2010].

The concern of lower returns was brought on in part by a dearth of public stock offerings. Five-year returns in the venture capital industry, which reached 48 percent in 2000 at the height of the Dot-Com Bubble, were just 6 percent through 2008, according to the National Venture Capital Association (NVCA). The industry was predicted that a third to a half of the active venture capital firms may disappear before things pick up [Cain Miller 2009].

A survey by PricewaterhouseCoopers and NVCA shows venture capitalists invested $17.7 billion in 2,795 deals in 2009. That marked a 37 percent decline in dollars and a 30 percent decrease in deal volume from 2008. In the US also the green technology sector saw a significant decline in 2009 with $1.9 billion invested in 185 deals, a 52 percent decrease in dollars from 2008 [Reuters 2010].

And also in 2010 VCs’ “darling” CleanTech stayed anemic. After stronger first and second quarters of 2010, capital investment in the third quarter was falling 30 percent. However, the CleanTech industry continued to raise more venture money than the biotechnology and information technology sectors. Within CleanTech technologies related to transportation, biofuels and the electric grid received the most money, but the largest number of deals was at firms focused on energy efficiency. In North America, one of the biggest funding rounds went to Texas-based biofuels firm KioR (Table I.99) [Voith 2010].

The lack of returns for American VC, however, was seen as *a symptom of a larger disease* that needs to be cured.

The *problems in venture capital go beyond the recession*. A shakeout is inevitable as many old-line VC firms have gotten *too big* and unwieldy to build innovative companies the way they used to; funds have grown too large [Ante 2009; Lacey 2009].

It was argued that, instead of figuring out how much startups actually need, too many firms calculate how much they have in their funds, divide it by the number of partners and the number of boards they can sit on, and come up with a sum to invest in each startup. That often meant forcing $3 million into a company that needs $300,000 [Cain-Miller 2009]. Overfinancing results in too many firms backing too many startups that do the same thing (cf. biofuels; A.1.1), some critics said, and it inflates the valuation of companies so that investors get smaller returns when they eventually sell.

Indeed, though special, but nevertheless illustrative, an entrepreneur reported that he learnt how to run a technology company by working for a business that was profligate with cash. "Truck loads of new equipment used to turn up every day. We were spending money as though there was no tomorrow," he said of his four-year spell at Nanosciences, a Connecticut-based startup that went out of business in the early 2000s after attracting about $10 million of investment funding [Marsh 2008].

One of the biggest challenges for venture capital in the US is to *think smaller*. The industry today is largely *structured for big exit deals*, and it is not getting them [Buckman 2008]. But it is not (only) an issue of big deals, the issue is also *quality*. VCs need to do better deals if they want better returns [Lacy 2009]. There is more money going in every year than can be invested properly. The *culture of risk-taking has changed dramatically over the last few decades* as the venture industry has become bigger and more institutional.

Entrepreneurs today in the US and other countries seem to rarely build full companies in garages or starting very small. They no longer have to go into debt, take a second mortgage, or deplete their savings to build a company. If they have a good idea, there is more than enough angel funding and venture capital to go around and there is *a very set path for how you build that company out* – according to a particular line of textbook knowledge and training. That has already given rise to myriad poseurs who decide they want to be entrepreneurs first, then think about the actual company they are going to start second [Lacey 2009]. There seems to be also a tendency to put a lot of money into policy-driven markets, such as biofuels (Figure I.34; A.1.1). Policy-subsidized startups make it also easier for VCs to provide seed capital.

There seems to be also a related issue of the *education, competence and judgment and ambitions of* "*VC personnel*," the MBA's that have invaded the industry and older partners who have lost touch with what is new in technology. The venture industry's struggles are attributed in part to the business school graduates who now populate offices, taking the place of the entrepreneurs who first formed venture firms. At a recent conference: advice for would-be venture capitalists was "Get a real job in an operating company, because what we back is operating companies – until you understand that, you can't be much of a venture capitalist." [Cain-Miller 2009]

But, while fewer venture companies are getting into the *early stages* of the CleanTech game (Table I.53, Table I.54), angel investors were filling the void, with CleanTech accounting for 17 percent of all angel investments in 2009, up 8 percent from 2008 [RedHerring 2010].

In particular, "super-angels" with rather deep pockets, as they are called in the industry, were pushing ahead and financing startups even as big-name venture firms cut back and conserved capital until the economy improves. The firm First Round Capital has quietly become the most active seed-stage investor in the US, outpacing such marquee names as Sequoia Capital and Kleiner Perkins Caufield & Byers [Ante 2009].

According to Dallas Kachan of Kachan & Co., a CleanTech analysis firm, less than 10 percent of global CleanTech venture investment dollars today are going into early-stage deals." And "investors are creating a disproportionate amount of 'walking dead' – companies kept alive, sometimes bolstered by government funding, hoping for an exit." [Voith 2010]

A recent survey found that about 75 percent of venture companies think CleanTech spending is a top priority over the next five years, but they are not putting their money where their mouth is. According to the related report, *seed stage and early stage* CleanTech companies based in the US raised $886 million from venture capitalists in 2007, but only raised less than half that amount, $424 million, in 2009. Some investors were avoiding early stage CleanTech out of concern for messy and complicated exits [RedHerring 2010].

Within CleanTech, technologies related to transportation, biofuels, and the electric grid received the most money, but the largest number of deals was at firms focused on energy efficiency. It is said energy-efficiency deals are attractive because they require small amounts of capital and offer fast payback times [Voith 2010]. But additionally, energy efficiency activities usually refer to known markets and industries, respectively, so that these deals usually are associated with lower risk.

Generally, green energy must ultimately grow its green value to have viable venture capital sources.

Finally, particularly concerning Internet firms, over the last couple of years there was a change in entrepreneur-investor relationships centered in valuations. Investors were rushing investment decisions on hot Internet companies and accepting weaker ownership rights (Table I.74) than in the Dot-Com Bubble based on a class structure for shares as did Google. It is about the investment process involved, the terms and the process. Fast-emerging Internet companies (ch. 3.4) were allowing little time for due diligence, and investors were accepting “unprecedented terms,” taking common equity rather than preferred stock and no (or little) board representation.

Angel Investors (Business Angels)

Much of the US venture-capital industry seems to undergo a shakeout. But a growing breed of startup investors called “*super-angels*” [Tam and Ante 2010] is rapidly raising new money – and ratcheting up competition with established venture capitalists in the process. But super-angels also work with established venture capitalists to bring them new deals.

Super-angels are *micro-cap venture capitalists* raising “super-angel funds” from $20 to $80 million. These players are raising funds with outside money and investing full time. They tend to make dozens of small startup bets and can comfortably make money if just a few of the startups are bought by larger acquirers for less than $100 million. That means super-angels have a different set of exit criteria, specifically tending to exit from startups three months to three years after the initial investment. By contrast, most venture-backed companies now either go public or get sold after a median time of 9.4 years, according to VentureSource.

Investing in super-angel funds can pose risks in that they typically invest in far-less-proven startups than venture capitalists do. And unlike venture capitalists, who have hundreds of millions to invest, super-angels generally do not have enough money to fully fund a company to fruition. What elevates super angels into an unofficial upper class generally is the attracting effect their participation in a deal has on other investors – a main reason entrepreneurs like to do business with them. Some startup entrepreneurs say super-angels have thrown them lifelines they could not secure from venture capitalists.

According to Table I.25 (and subsequent text), at least in Germany, private investors represent a larger part (by frequency of use) than venture capital firms to financing new technology-based firms or have a comparable role for initial funding (Table I.23). Here, in particular, *angel investors* (called *business angels* in Europe) play a role.

As for venture capital-based startups high-tech foundations may comprise more than one angel investor during an investment period [Fryges et al. 2007]. Similar also to venture capital firms investment behavior of business angels follow boom/bust patterns.

Following Colin Mason (cited by Fryges et al. [2007]) a **business angel** is seen as a wealthy person who invests *own money* together with time and special competence in a firm which is not traded on a stock exchange and to which he/she does not exhibit a family relationships hoping for financial profit.

Socio-demographic features of business angels are rather similar in different countries. Usually they are male, wealthy and highly educated (private) persons who have *experience* with firms’ foundation and/or firm management. Experiences in production and R&D are rare [Fryges et al. 2007]. Often angels understand the industry and are attracted by the opportunity as well as the potential return and as they sometimes enjoy working with entrepreneurs they may focus less on early harvesting their return.

A small but increasing number of angel investors usually investing their own funds, unlike venture capitalists, are organizing themselves into angel networks or angel groups to share research and pool their investment capital. This "syndication" of angels is more pronounced in the US than in Germany. It is estimated that in the US 92 percent of angels have established investment partnerships, whereas in Germany the proportion is only 58 percent [Fryges et el. 2007].

Angels as successful, sophisticated business people provide "*smart money*," which is financing in combination with experience and expertise and essential contribution to the non-monetary side to startups/NTBFs via

1. Counseling, advising, consulting and mentoring;
   coaching may cover the whole spectrum of human activities and specifically refining the firm's business model
2. Organization and infrastructure of the firm
3. Initiating contacts (for instance, to customers, technology partners, networks etc.)
4. (Advisory) Board
5. Commercial areas, such as involvement in strategy development.

If angels provide strategic consulting they may exert a significant effect on the firm's orientation and development.

Concerning ("hands-on") engagement in German NTBFs Fryges et al. [2007] report that 46 percent of the firms are supported by angels only one or two days per months. Another 30 percent have support or cooperation for 3 to 5 days per month (15.4 percent 6 to 10 days; 8.7 percent 11 to 31 days).

Angel investors typically invest in the seed, startup and early stage phases of German NTBFs. Fryges et al. [2007] report that business angels focus on financing German startups during their first five years of existence by ca. 85 percent. In particular, the proportion of angel investments for the various financing stages are:

Seed phase (ca. 7 percent), startup (41 percent), early phase (20 percent, 1-2 years) and later phase (15 percent, 3-5 years).

However, sometimes business angels invest even in the pre-seed stage of startups [Fryges et al. 2007].

Angel investors' funding levels typically range from $50,000 to $2 million (€30,000 to €1.5 million). For German startups angels have invested €250,000 and more for the industrial high-tech firms of the categories "top value" and "high value" (Table I.1) – averages being found are ca. €220.000 (TVT) and €300,000 (HVT). For some firms of the manufacturing areas angel investments exceed one million euros [Fryges et al. 2007].

In exchange to their investments angels seek usually minority ownership (< 50 percent) of the firm they invest in. In 2007 the proportion of investments in startups by German angels accounted for 58 percent of external financing, less than 10 percent of capital stock of the related firms. On average a single angel held minority ownership of 26 percent [Fryges et al. 2007].

The most pronounced exit of angel investors is the "buy back," which is buying back the investment stakes of the angels by the founders of the firms they have invested in. It seems, however, that during the period 2005 – 2008 "trade sales" (selling stakes in a firm to a strategic investor) and "secondary purchases" (buying and selling of pre-existing investor commitments to private equity and other alternative investment funds) increasingly showed up.

Corporate Venturing

Among investors there is a special kind, the "*strategic investors*." For them investment opportunities have to meet two criteria: financial and strategic. Financial criteria are not all that different from traditional VCs (or other kinds of equity investors). But there is one important sub-group of "strategists," corporate investment groups that are dedicated venture capital arms of large corporations.

A corresponding *corporate venturing* (CV) unit may either operate externally as a legally separate **Corporate Venturing Company** (CVC) or an internal corporate functional unit. The significance of CV for technology entrepreneurship is their external orientation toward innovation following essentially a "New Business Development" (NBD) process by focusing on *corporate venturing* in startups in line with their corporate and technology strategies.

In the Appendix CV activity is exemplified for the oil and chemical industry regarding biofuels (A.1.1) and particularly for the chemical industry for biobased chemicals (A.1.1.6). NBD does not only cover technology acquisition, but also learning and building new competencies [Runge 2006:554-555, 558, 561, 685-686, 694-697, 722-728].

Corporate venturing is a practice of a large company, taking usually a minority equity position in a smaller company in a related field. CV is a model for corporate innovation and an essential tool for large companies. For an economy corporate venturing plays a dual role acting as a source of financing startups and being a component of the "*networked economy*" of the national innovation system (Figure I.51, Figure I.125).

A marked difference between corporate venturing (by large and giant firms) and conventional investment is its *global reach for entrepreneurial NTBFs* rather than being concentrated on the particular country. Large German firms invest in US startups and *vice versa*.

Generally, one can differentiate two forms:

1. *Internal* corporate venturing means to build a new business through or within the company, but independently outside the given corporate structures and core businesses, for instance, through an “internal startup.” This is always an advantageous solution if the firm has the corresponding capacities and wants intentionally to develop in the particular direction and way modeled by the internal startup.
2. *External* corporate venturing means taking, at least, partial ownership in an independent external investment endeavor mainly through financing and participation in equity. This is a common approach since the 1970s [Gompers 2002].

An *internal* corporate venture attempts to exploit the resources of a large (parent) company, but provides the environment more conducive to discontinuous or even disruptive innovation. Correspondingly, its architectural layout tends to target *intrapreneurship*. Internal CV often run as a spin-off or a subsidiary CVC is designed to be consistent with the needs of new, high-risk and potentially high-growth businesses or entering existing markets, but “new-to-the-firm.”

Corporate venturing is *a management process*. It can be broken down essentially into the following activities: target identification, due diligence, deal generation, portfolio management and exit management. Major aims of external corporate venturing are:

- Tracking the market and learning about the details of the technology the new technology-based firm (NTBF) is working on;
- Access to new markets;
- Acquire skills, capabilities, and technologies outside the company’s current competencies not otherwise easily available;
- Access to entrepreneurs who could impact the firm’s business.

CV occurs across almost all technology-based industries. Corporate venturing also reflects business cycles. It is therefore not surprising that CV currently tends to focus on a few high-technology companies in areas such as CleanTech (like biofuels; A.1.1), biotechnology, medical devices, optoelectronics and to a lesser extent nanotechnology. Of course, the investing firms also hope to make money through investments in new businesses.

Major criteria of firms to attract corporate venturing include the following attributes.

1. A clear value proposition;
2. Large targeted markets and technology with “platform” characteristics (multiple commercialization opportunities);
3. Defensible intellectual property;
4. Demonstration or prototypes (or commercialization units);
5. An energized management team or a visible “outstanding” entrepreneur.

Though being also active in the startup phase CVCs prefer late-stage funding [Runge 2006:560].

Corporate venturing does not necessarily provide equity for exchange of a share of ownership in a company. For instance, rather than using a monetary approach (in 2005) Dow Chemical transferred all its intellectual property (196 patents) in dendrimer technology to the firm Dendritic NanoTechnologies (DNT) in exchange for an ownership stake in the firm.

As a summary, business angels and corporate venturing occur with two "wings." Entrepreneurs can access two channels:

- Financing sources,
  but financial profit for the investing firm may not be the primary goal.
- Access to expertise and resources of the venturing firm
- Access market channels (for instance, marketing and sales)
- Access resources of the large company (like consulting or services, such as analytical, information services or market research)
  - Cooperative settings, such as JRA, JDA, marketing and sales agreements, larger scale production by the investor company
  - Associating the business with a corporate capital source ("lead investor") can add credibility when seeking additional funds elsewhere.

Typical exit options for CV include:

- Acquire the firm, get full ownership and run it as a subsidiary or integrate it into a particular business unit of the investor firm (Closure Medical [Runge 2006:39,98-103], hte AG – B.2)
- "Trade sales" by selling the firm or the stake in the firm, if it is no longer viewed as strategic
- Joint venture – the NTBF and the outside corporation create a partnership, typically one in which the successful NTBF runs the business and the corporation provides further finances and business advice
- Licensing agreement – The entrepreneur with a majority ownership retaining control of the business is giving up the rights to products developed under this agreement.

It is not unusual that more than one company acts as corporate investors of a new firm, if these companies have different strategic, non-competitive orientations [Runge 2006:560]. However, issues may occur if CV and VC investors have stakes in an NTBF. The risks of providing priority treatment to a CV (as opposed to a financial investor) are greater in that there are additional downstream consequences in the event that it is necessary to execute a recapitalization in the future.

The situation can also become complicated if the CV is also an important customer (for instance, in case of the Altana AG – Nanophase Technologies constellation;

Figure I.140). Generally, CVs will take a board observer position in lieu of a Board seat due to potential conflicts of interest. For VCs one concern is whether access to company information by the CVs may be used against the company in customer negotiations.

Finally, for technology startups *stock issues* provide an option of financing, not necessarily for initial financing (Table I.23). Generally, advantages and disadvantages of going for an IPO are presented by Dorf and Byers [2007:428]. Apart from being driven to an IPO by the exit of an investor at a stock exchange like TecDax in Germany or NASDAQ in the US, *stock issues* opens a special route to financing a technology venture – targeting, for instance, "penny stocks" (Pink Sheets). This route is available for US, but not for German startups. [37]

The Pink Sheets is not a stock exchange. In the US there is also stock trading outside one of the major exchanges (NYSE, NASDAQ). To be quoted in the Pink Sheets, companies do not need to fulfill any requirements. A penny stock is a common stock that trades for less than five dollars a share and is traded over the counter (OTC) through quotation services such as the OTC Bulletin Board or the Pink Sheets. Accordingly, the US Securities and Exchange Commission (SEC) warns that penny stocks are high risk investments and new investors should be aware of the risks involved. These risks include limited liquidity, lack of financial reporting, and fraud. Examples using such financings of NTBFs used in this book include Osmonics, founded in 1969 [Runge 2006:91], BlueFire Ethanol (Table I.86) or Industrial Nanotech, Inc., founded in 2004 (B.2).

1.2.7.3 Options for Financing New Technology Ventures

Though initial financing through own funds and those of family and friends and then cash flow seems to be a straightforward and major route for early development (Figure I.52, Figure I.55; Table I.23-Table I.26) financing the foundation and further development of a startup represents an issue for the founder(s). This is indicated by Figure I.54 which shows that NTBFs will soon have developed with a rather complex financial structure for their operations. In particular, spin-outs attribute issues (barriers) with financing sources as the top problem for firms' foundation. (Figure I.47).

For instance, there is a downside of 3F-financing. The entrepreneur, unsure of whether the venture will succeed, properly feels reluctant to "take advantage" of close personal relationships to raise money. The major disadvantage if friends and relatives do invest is that they may feel that the investment gives them the right to advise or actively interfere with direction setting or managing. Therefore, although such "naive" money is relatively easy to obtain, problems may result from its acceptance.

Financing problems may arise for many reasons. Information asymmetry and uncertainty are important, but so are such things as unexpected administrative demands and costs, ignorance of financing options or ignorance about contact persons. Experienced entrepreneurs have more knowledge about these things and are more likely to know whom to turn to for help and advice. Thus, they have advantages over novice entrepreneurs when it comes to financing (ch. 2.1.2.4).

A wide variety of financial sources are potentially available to fund a technology-based company's initial capital requirements and then the successive stages of its growth and development. But, depending on characteristics of the startup and the industry it is active in, what is more important and persistent over time are the relative distributions of which sources are actively involved at the outset of new technical firms, and which ones provide more rather than less amounts of capital (Figure I.54).

The NTBFs' *needs for initial capital* vary enormously by amount and intended use as a function of their industry and type of business being started, with software companies requiring far less than hardware developers and producers, such as startups targeting large-scale production (ch. 3.4).

Especially for RBSUs public resources – research and development grants, micro funds etc. – play important roles for their early phase. Research grants may contribute up to 50 percent of early financing (Nano-X GmbH, B.2). In particular, NTBFs may access funds for projects initiated by political initiatives or programs which formally may appear as a specific stream of revenue of the firm.

> Balancing own financial resources and capital by other parties may provide longer term financial security and relative independence from individual capital providers!

A founder of a technology venture, therefore, must be aware of the *various options of financing sources* (Figure I.59) and assess the sources' characteristics which ultimately will fit the needs of the business at a particular stage in relation to his/her ambitions and success factors as well as *personal attitude* (Box I.20) toward the specifics of the sources.

The ultimate decision in terms of a portfolio of financing sources is also influenced by the Window of Opportunity with regard to financing (Figure I.92). Finally, the legal status of the firm may have an influence on the accessibility of particular sources. For instance, venture capital firms are often reluctant to invest in LLCs (GmbHs in Germany).

> Issues of decision-making concerning financing (ch. 4.2.2) – initial financing and follow-up financing (Figure I.52) – is obviously based not only on monetary criteria (cost and fees), but depends also on motivations why to become an entrepreneur (Table I.39, Table I.40, Figure I.66) and attitudes.

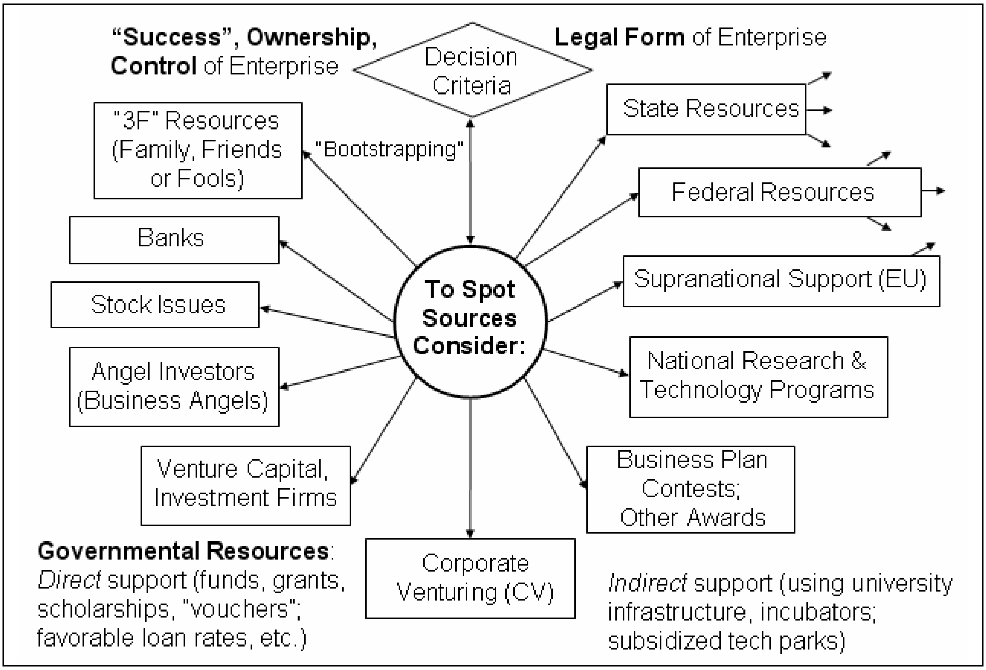


Figure I.59: Sources for financing new technology ventures.

The *number of founders* can influence the amount of available and accessible initial capital both directly and indirectly. As the number of founders increases more personal funds are usually available from which to draw money. Indirectly, the more founders there are, the greater the possibility that one of them knows a receptive "outside" source, if needed. Furthermore, multiple founders are likely to reflect a more substantial intended undertaking, for instance, product development and manufacture rather than just research or consulting. This implied need for greater funds both generates and justifies its supply [Roberts 1989].

A product-oriented company's capital requirements do vary according to the nature of the product, its stage of development, development requirements, the scale of production (small versus large scale, high volume), its production process as well as the demand for the product. For instance, there is a market difference between a chemical startup producing on a kilogram (liter) level (ChemCon GmbH, B.2) versus a biofuel startup intending to produce on a million kilogram (liter) level (A.1.1).

Similarly requirements for producing hundreds of pieces of equipment parts differ from those producing several thousands. A firm dependent upon a product needs capital, whether for product development or production facilities or technical personnel or market launch. Such a firm would have difficulties getting operations underway without substantial capital.

For the scale-up to "mass production" (Figure I.8, Figure I.9) a "*cost ladder*" has been emphasized which positions research at the bottom. Coming next, development costs exceed research cost by multiples and commercialization including production costs exceeds development cost by multiples [Runge 2006:643].

However, the tremendous capital needs of production-oriented startups do not necessarily translate into grasping venture capital. The answer may be a shift of production to a country with very low cost for salary of workers and technicians. For instance, German BlueBioTech GmbH [Runge 2006:577] established a JV in China and Zweibrüder Optoelectronics GmbH (B.2) has a wholly owned production subsidiary in China (Zweibrüder has ca. 60 employees in Germany and 1,300 employees in China; revenues were €3 million in 2000 and ca. €50 million in 2009.

Concerning differentiated financial needs with regard to product development stage information gathered from 110 firms by Roberts [1989] showed that 43 percent of them were based on specific products that had already been developed or which the entrepreneurs planned to develop immediately. The financing situation for a startup still deeply involved in product research is definitely different from the previous one.

Assuming that product-oriented companies have higher requirements for (technical) personal Fryges et al. [2007] hypothesized that (German) startups from top value and high value technology will be characterized by greater investment cost and number of employees than those providing technology-based services and indeed they showed that on average the former ones from industry had larger revenues and more employees.

Finally, raising the question of going for *outside finances*, as reflected by the discussions in this chapter, provides three possible answers apparent to this question and all somewhat applicable:
1) The need did not exist. 2) The desire for outside funds did not exist. 3) The entrepreneurs were unable to obtain outside funds.

The desire for outside sources may reflect a fundamental (affective) *attitude* of the entrepreneur. Some entrepreneurs want little or no equity financing at the outset, whether VC or angel or CV, because they wish to retain a maximum amount of *ownership and control*. They often seek primarily debt from other outside sources.

In a small study of twenty entrepreneurs who were seeking capital, Roberts [1989] compared those who had initially supplied more than 50 percent of their equity from personal funds with those who had obtained that much from outside investors. The *self-funded entrepreneurs were found to have significantly higher evaluations of the importance of independence of action*. In addition five of the seven entrepreneurs in this cluster who indicated that *independence of action was the most important reason for starting a company* (be your own boss) initially engaged primarily in self-financing. Some of our cases also reflect that attitude (Box I.20).

Initial and additional funding depends also on the starting constellation of the new firm as described in Table I.28 for bank loans, but also on credibility and reputation of the founder(s) by risking own funds and assets or having gained a lead investor who may be a corporate venturing company.

Financing a startup in the technology area by *outside sources* is associated with three fundamental approaches associated essentially with private lending organizations (essentially banks and debt financing), investment organizations providing equity financing or public or semi-public sources providing funds, grants, scholarships or acting as lending or investment organizations.

> **Debt financing** means when a firm raises money for working capital or capital expenditures through a loan by a bank (or for an established firm by selling bonds, bills or notes to individual and/or institutional investors). In return for lending the money, the bank (or individuals or institutions) becomes a creditor and receives a contract or promise to repay principal and interest on the debt.

> **Equity financing** is related to ownership interest in a firm. Equity financing is a strategy for obtaining capital that involves selling a partial interest in the company to investors. The equity, or ownership position, that investors receive in exchange for their funds usually takes the form of stock in the company. The firm may issue shares of common or preferred stock to raise money.

There are notable differences between debt and equity financing. Advantages and disadvantages are summarized in Table I.28.

Table I.28: Comparing fundamentals of debt and equity financing of NTBFs.

Debt financing	**Equity financing**
Pro's:	**Pro's:**
You retain control of your company	With the investor you may gain an experienced consultant or mentor vor running your business
Debt is limited to the loan repayment period	With equity financing, you *do not repay* the money invested by others
If having become a bank's client more options for ongoing financing are available, such as bank overdrafts, lines of credit etc. (Figure I.55)	Assessment of your business idea and opportunities. It is in an equity investor's best interest for your business to grow and expand; he/she will be more likely to consider *sound business ideas*

Table I.28, continued.

Debt financing	Equity financing
Con's:	**Con's:**
The difficulty in obtaining them – debts investors look for security of the deal proposed. It may be difficult for a new business to borrow from a bank since lenders usually prefer to lend to established businesses. *However*, three of our cases (the German firms WITec GmbH, IoLiTec GmbH and ChemCon GmbH) demonstrate that having already customers at the start of the firm facilitates the option to obtain bank loans considerably.	Selling a partial interest in your company. You may lose majority or total ownership and control. An equity investor becomes your business partner. Equity investors may not agree with your strategy and plans for the business. They play an active role in the strategic planning phase of your business and seek continuing involvement. They will also expect to be fully informed about operations, problems and whether your joint goals are being met.
A new business is likely to be charged a higher interest rate than a well-established business.	If you give up some control over your business (ownership!), it may be very difficult to retain control in the future.
Monthly payments on a loan. Cash may be scarce and expenses may be higher than estimated during the early years. "Penalties" for late or missed payments may emerge.	Equity investors can resell their interest in your company to other investors.

The various sources for equity financing exhibit rather positive and also negative specifics which are outlined in Table I.29. But there are generally two situations which require financing by investors or venture capital – as tens of millions of dollars/euros are needed:

- NTBFs aiming at large-scale production (A.1.1)
- Fast technical development is required (for instance, German Novaled AG; Figure I.148, Figure I.149).

VCs or CVCs and related investment firms make entrepreneurs operate "under constraint," but in this case, the constraint is built by ownership and control of the firm rather than scarcity of resources (ch. 1.2.1).

Summarizing the above outlines one can say, the particular type of new business and related amount of needed capital as well as growth options and stage of the firm's development determine the appropriateness of corresponding financial sources.

Table I.29: Some particular considerations on sources of equity for startups through private investments.

Financial Source	Special Remarks
Venture Capital Firms	“VCs can be the best thing that happened to your company or your worst nightmare.” Wadhwa [2006a; 2006b] presents a well-structured detailed overview of 10 topics VCs will be looking for that the entrepreneur needs to have in place and “The Good, Bad, and Ugly” that will be associated with accepting venture capital. In particular, after you raise venture capital, your company is not going to be your company anymore. Loss of independence. You may still be the chief executive officer, but you answer to the board. Disagreements about strategy often arise between the entrepreneur and VCs. VCs will want to make sure that you are ready to step aside if they determine you can no longer effectively run the company.
Angel Investors, Personal Investors (Private Investment Partnerships: an arrangement in which one or more individuals agree to provide funding for another individual’s business)	“Incorporating” a business angel may reduce information asymmetry concerning markets during early phases of the NTBF and thus reducing risks (market uncertainties). Choosing the right angel is important, as some may be domineering rather than supportive. Investment Partnerships provide capital and are not responsible for any debts your business incurs and will typically not play a role in managing the day-to-day operations
Corporations, Corporate Venturing	The corporation may have a tendency to interfere more in the day-to-day operations of the young firm than the entrepreneurs find desirable. The corporate investor may oppose the firm “going public,” preferring to merge it eventually into its own operations. A stepwise increase of investment is indicative the investing firm to finally take over the NTBF (hte AG, B.2)
Equity through stock issues	Complicated and time-consuming – you must follow a strict process and comply with a number of legal and reporting requirements for the life of the business. Details of the process as well as advantages and disadvantages of a public issue of stock in the US is described by Dorf and Byers [2007:428]

The desire and acceptance of outside financial sources is essentially governed by attitudes vis-à-vis ownership, control and strategy, reasons why to become an entrepreneur or striving for organic growth by strict management and control of finances (Figure I.52; Table I.39, Table I.40).

With regard to access of individuals to particular financing resources one can hypothesize that

- Individuals looking for independence avoid equity financing by VCs, CV, but probably accept business angels and go for loans.
- Individuals putting themselves behind the vision and related perception of success tend to more readily accept VC.
- Individuals who want intentionally to put themselves under pressure and to make profit for organic growth using cash flow (Box I.20) tend to avoid VCs and CV and prefer loans by commercial and (semi)public banks (WITec, ChemCon, Nano-X etc. – B.2).
- Individuals looking for wealth are indifferent, but more apt to accept VCs and probably also CV.
- Individuals using firm's foundation as a means to provide money for self-realization are more ready to go with VCs or CV.

The challenge for technology entrepreneurs, therefore, is diversification through own financial resources and capital by other parties based on priority criteria and needed amount of capital to provide long term financial security for growth, sustained competitive advantage and longevity of the firm – and, if aimed at, relative independence from individual capital providers. Options for such a balancing process are given in Table I.30.

The complexity of financing technology ventures means that most entrepreneurs require professional advice and support for this subject.

Table I.30: Options for financial sources for various stages of NTBFs related to approximate spans of amount of needed capital ("operations financing structure").

MBO/MBI				**VC, B, PR**	**VC B, PR**	**SI, VC, B**	**SI, VC, B**
Expansion			**CF, B, RG BA, PR**	**VC, CV, SA, PVC, CF, B, RG, BA, PR**	**VC, CV, PI, B, BA, SA PR, CF**	**SI, VC, PI, B, SA, CF**	**SI, VC, PI, B**

Growth (LateStage)			**CF, B, RG BA, PR**	**VC, CV, SA, PVC, CF, B, RG, BA, PR**	**VC, CV, PI, CF, B, BA, SA PR**	**VC, CV, PI, PVC, CF, B, SA**	
EarlyStage (Startup)		**BA, PR**	**CF, B, BA, PR**	**VC, CV SA, PVC CF, B, RG, BA, PR**			
Seed		**SPP, BA, PR**	**RG BA, PR**	**VC, CV SA, PVC, RG, BA, PR**			
Pre-Seed	**BA, PR, SPP**	**BA, PR, SPP**	**BA, PR, SPP**				
	- 10K	**10K - 30K**	**30K - 150K**	**150K - 2M**	**2M - 5M**	**5M - 50M**	**50M - 250M**

B	Commercial (private) banks; public banks (e.g. KfW in Germany)	PVC	Private-public venture capital (e.g. High-Tech Gründerfonds in Germany; SBICs in the US)
BA	Business angel (angel investor)	RG	Public research or project grant
CF	Cash flow	SA	Super-Angel
CV	Corporate venture capital	SI	Stock Issues
PI	Public investment firm (in Germany, e.g. MBG)	SPP	Public micro-funds and special public funds for small business, including public loan guaranties for lenders
PR	Private resources, family, friends or fools (3F)	VC	Venture capital

Since 2005 in Germany the High-Tech Gründerfonds (HTGF) has been financing young technology companies focusing on investing in early stage companies in life science, materials science and information technology (Gründerfonds I). It is a private-public-partnership (PPP) of the German Federal Ministry of Economics and Technology (BMWi) and involves the public banking group KfW (Figure I.56) and strategically limited partners from industry, such as the chemical firms Altana, BASF, Evonik Industries, and LANXESS, but also Bosch and Daimler from automotive and SAP and (German) Telecom from I&CT and others.

Gründerfonds II started in October 2011 with a second close of €301.5 mil. in December 2012. In 2012 HTGF had unconsolidated 1,100 requests for funding a startup, but took a share in only 43 (3.9 percent) of them. However, the probability of funding with HTGF will increase to 30 percent, if the application is associated with a recommendation and a well elaborated business plan [Zbikowski and Brandkamp 2013].

One option of gaining financial support for selected new technology ventures, not listed so far, is getting awards or prizes for achievements, for instance, in business plan contests or for technical achievements. However, such finances only play a minor role for the overall financing mix of NTBFs. But their value is also in adding visibility and credibility which may facilitate access to resources, whether attracting financial resources or people for the firm's Advisory Board.

Overviewing options for (initial) financing does not mean that getting money is straightforward. For instance, the Small Business Administration (SBA), a US government agency, is seen to be not always helpful to startups. SBA usually lends money secured against a firm's collateral. Makers of complex medical devices, electronic devices, and lab instruments often need $1 million or more just to build a prototype, but they often have few assets against which they can secure a loan [Reisch 2011a].

Depending on the industry options to get, for instance, corporate venture capital may not exist. A number of entrepreneurs of corresponding instrumentation startups said they have struggled and made sacrifices as they seek to attract government grants or private capital for their new businesses.

Finding investors to fund a prototype tool in the first place is particularly challenging. Unlike pharmaceutical companies, which often invest in small medical or diagnostic firms, established instrumentation companies typically do not invest in startups. Big companies will buy a startup and its technology when it gets to be a decent size. For instrumentation firms, buying a successful small toolmaker is cheaper than funding research failures [Reisch 2011a].

Striving for have a firm or a business growing means related bodies need to be fed, and particularly a business that grows fast devours cash. One has to make constant investments just to keep even (cf. investment persistence, ch. 4.2.3). Correspondingly, there is a principle when financing (fast) growing young firms:

If things are going well (or excellent) it is the time to provide for the next financing (if own monetary resources do not suffice).
If you have six months' to a year's time to prepare your next financing, you can be reasonably sure you will get it and at favorable terms.

A particular mode of funding is crowdfunding which for the realm of technology entrepreneurship currently at best plays a role for software development, consumer services and leisure. According to Wikipedia it may also address scientific research. **Crowdfunding** comprises "the collective effort of individuals who network and pool their money, usually via the Internet, to support efforts initiated by other people or organizations." Conceptually, the crowdfunding model includes "the people or organizations that propose the ideas and/or projects to be funded, and the crowd of people who support the proposals. Crowdfunding is then supported by an organization (the "platform") which brings together the project initiator(s) and the crowd." (Wikipedia) In so far, it has certain generic similarities with "ideagoras" (ch. 3.2).

2. THE ENTREPRENEUR AND THE ENTREPRENEURIAL TEAM

Potential entrepreneurs are outsiders. They are people who imagine things as they might be, not as they are, and have the drive to change the world around them. Those are skills that business schools do not teach.
Anita Roddick, Founder of The Body Shop

One of the issues of the study of entrepreneurship concerns the question whether entrepreneurs are born or whether they can be created or advanced through learning, education and training [Perman 2006]. In recent years, the field of entrepreneurship has tended to focus less on the role of individuals and more on the role of environmental conditions to explain the tendency of people to become entrepreneurs. In the focused debate on "nature ("genes") versus nurture" the pendulum has swung towards "nurture is out, nature is back"; or, at least, "nature is partially back" [Nicolaou et al. 2008].

Nicolaou and co-authors [2008] delivered recently a unique study. They compared rates of entrepreneurship between and among pairs of identical and fraternal twins in the UK and concluded that nearly half (48 percent) of an individual's propensity to become self-employed is genetic. Emphases of the study were on self-employment, ownership, business (startup) founding, qualification, age, gender and attitudes toward entrepreneurship.

The authors studied self-employment among 609 pairs of identical twins and compared this with self-employment among 657 pairs of same-sex fraternal twins in the UK. Identical twins share 100 percent of their genetic composition, while fraternal twins share about 50 percent, on average. Thus, differences in the rates at which pairs of identical twins both become entrepreneurs and the rates at which both members of fraternal twins both become entrepreneurs are attributed to genetics. Comparing the similarity and difference in entrepreneurship between the two types of twins provides insight into the proportion of variance in entrepreneurship that is explained by genetic factors.

The authors propose several methods by which genetic factors might influence people's tendency to become entrepreneurs. For example, *genes may predispose an individual to develop traits* such as being sociable and extroverted, *which in turn facilitate skills* such as skills in face-to-face selling, which are vital to entrepreneurial success.

In addition, genes have been shown to affect the *level of education* an individual receives, and more highly educated people are likelier to become entrepreneurs because they are better able to recognize new business opportunities when they arise. In relation to their proportion in a general population and their amount of entrepreneurs identical twins show probably also up as entrepreneurs to a similar extent. The roles of identical twins Harald und Rainer Opolka for NTBF will be further discussed for the firms Zweibrüder Optoelectronics GmbH (B.2) from Germany and ConnectU (Box I.9) from the US.

Concerning the same issue, in the foreword to "The Leader of the Future" [Hesselbein et al. 1997], Peter Drucker tackles the topic of *whether leaders are born or made*: "...there may be 'born leaders,' but there surely are far too few to depend on them. Leadership must be learned and can be learned – and this, of course, is what this book was written for and should be used for."

Hence, dealing with the Entrepreneurial Personality will also emphasize what can be taught by entrepreneurship programs and in how far entrepreneurial attitudes and intentions of (essentially science and engineering) students can be influenced.

2.1 The Entrepreneurial Personality

It is not sufficient to know, you have to apply as well;
it is not sufficient to intend to do,
you have to do it.
Johann Wolfgang von Goethe

Es reicht nicht zu wissen,
man muss auch anwenden.
Es reicht nicht zu wollen, man muss auch tun.

Dealing with "The Entrepreneur" we shall refer to aspects of personality psychology. Personality psychology is the scientific discipline that studies *the personality system*. The discipline seeks to understand a person's major *psychological patterns* and *how those patterns are expressed.*

2.1.1 Personality and Systems Theory

For our GST framework of entrepreneurship the question emerges how GST is related to personality psychology of an entrepreneur. In "The Systems Approach to Personality Psychology" Mayer [1993-1994] explains:

"There is the "Systems Framework for Personality Psychology." The Systems Framework for Personality Psychology is not a part of GST. It considers personality to be a largely unique system. To study it, one must develop a language tailored and suited to the topic. It draws on aspects of GST. In other words, General Systems Theory is a legitimate member of the theories that help inform personality psychology, but it has no special status within the Systems Framework" (Figure I.13, Figure I.16, Figure I.17).

On the other hand, entrepreneurship by more than one founder will refer to the common aspects and principles of GST in terms of interactions of and by social groups.

2.1.2 Personality and Behavior

First, have a definite, clear practical ideal;
a goal, an objective.
Second, have the necessary means to
achieve your ends; wisdom, money,
materials, and methods.
Third, adjust all your means to that end.
Aristotle (BC 384-322)

Difficulties increase the nearer we approach the goal.
(Die Schwierigkeiten wachsen,
je näher man dem Ziele kommt.)
Johann Wolfgang von Goethe

The study of entrepreneurs concentrates on *the person in the process* of entrepreneurship. There is a vast amount of research results linking *personality dimensions and attitudes* to entrepreneurship. As summarized by Nicolaou et al. [2008:3] a variety of *factors* have been associated with the *tendency* of people to engage in entrepreneurial activities, including psychological attributes, such as *need for achievemen*t, overconfidence, *locus of control* , optimism, and *risk taking propensity*, and *demographic factors*, such as *education*, age, employment status, marital status, income, *career experience*, social ties, and *social skills* .

Dorf & Byers [2007:5,36] add more to the above list, such as resilience (in the face of setbacks), having flexibility to adapt to changing conditions and well developed talent for problem-solving, able to learn and acquire skills needed for the task at hand; "entrepreneurs are often dreamers, visionaries, or just good thinkers."

However, it is important to establish links between traits to the distinctive *nature of the businesses* entrepreneurs start *and the tasks* they face.

Attitude is a *hypothetical construct* that represents an individual's degree of like or dislike for an item. Attitudes are generally positive or negative views of a person, place, thing, activity or event – this is often referred to as the attitude object or entity. Attitude is a complex mental state involving beliefs and feelings and values and dispositions to act in certain ways. *Each and every person has a different attitude at different conditions.* People can also be conflicted or ambivalent toward an object, meaning that they simultaneously possess both positive and negative attitudes toward the entity in question.

Attitudes show up judgments. According to the "ABC model" they develop with three components. These are:

- Affective;
  the affective response is an *emotional* response that expresses an individual's degree of preference for an entity.
- Behavioral;
  the behavioral intention is a *verbal indication or typical behavioral tendency* of an individual.

- Cognitive;
  the cognitive response is a cognitive evaluation of the entity that constitutes *an individual's beliefs about the object*.

A habitual or characteristic mental attitude that determines how you will interpret and respond to situations is called a "*mind-set*."

> According to P. Drucker "one characteristic of entrepreneurs is the *attitude that it is important to interact with customers to ascertain their needs, because customers produce results for a firm."* [Olson 1986]

Basically, one should differentiate between *intrinsic psychological attributes* (such as traits) and *skills* which can be learned. Concerning social ("soft") skills presentation, negotiation/selling, conflict management skills and leadership stick out. Leadership competencies are attained from experiences, learning and talent. Although the prevailing view in the literature is that the environment may influence traits, traits are generally considered stable over time. Attitudes, in contrast, can be adopted and may vary in the same situation for the same individual.

Psychology can be distinguished from other behavioral sciences by its emphasis on the *behavior* of the individual person. Behavior, in turn, is influenced by the way in which the external world is represented in the mind, and by the individual's exercise of *choice*.

There are two distinct schools in the field of entrepreneurial psychology [Smith-Hunter et al. 2003]. The one focuses on the *personal characteristics of the individual* ("*traits'*), such as locus of control, risk taking, achievement motivation, problem-solving style and innovativeness, perception, and work values. One's "locus" can either be *internal* (meaning the person believes that he/she controls his/her life) or *external* (meaning persons believe that their environment, some higher power, or other people control their decisions and their lives).

The second group has taken a social cognitive approach (social psychology), looking at the *relationship between an individual and his or her environment*. An individual's behavior is affected by the interaction between the internal factors (personality, motivation, self-concept etc.) and external factors (culture, work situation, support and role models, etc.). This is reflected by the systemic views of entrepreneurship (Figure I.16) and intrapreneurship (Figure I.17).

We are interested in the *impact of entrepreneurial attitudes and behavior* on the broad topic of (technology) entrepreneurship. Behavior appears as the *activities and processes* in relation to what an entrepreneur in a particular environment *intends* or what he/she *hopes or expects* to accomplish ("entrepreneurial success," ch. 4.1).

In relation to our model (Figure I.16, Figure I.17) we follow Smith-Hunter et al. [2003] to discuss personality and behavior focusing on personality characteristics and particularly on psychological characteristics for entrepreneurship processes, such as problem-solving style and following innovativeness, role models, work experience and education – in the context of a given environment.

Furthermore, we accept that "*there are some universal entrepreneurial traits, which culture does not affect – or affect only little*. Culture tends to affect the propensity to act, thus, the actual number of entrepreneurs in relation to the overall population of a nation that will attempt to start a business." [Smith-Hunter et al. 2003] Features of such an approach are also found with Dorf and Byers [2007:4-6, 37-39].

Similar to the list given by Bhidé [2000:92] in Table I.31 antecedents of entrepreneurial behavior are summarized. Corresponding macro-studies often actually just provide empirical support for the idea that in a sample for the group of entrepreneurs *a related trait emerges as a factor which is larger than that compared to non-entrepreneurs*. That means, the listed traits are not a prerequisite to be or become an entrepreneur, they just represent a spectrum of facilitating traits which may enter in different composition to build the entrepreneurial personality. Admittedly, there seem to be traits that are more important than others.

The vast majority of corresponding studies originates in the US [Tidd et al. 2001:353-358] and, hence, does not take cultural differences (ch. 2.1.2.3) into account. For instance, an EU Green Paper noted that, compared to the EU average of 45 percent, as many as 67 percent of US *citizens* would prefer to be self-employed (cited in [Brandon 2003:6]).

The problem in Europe is that entrepreneurship is not seen as an appropriate career choice. However, the author is not aware of any study narrowed to samples of relevance for technology entrepreneurship, for instance, firm founding engineers and scientists. Most studies are based on samples covering entrepreneurship in non-technical and technical areas.

Particularly, an "Entry Questionnaires" after the first hours of the first three courses of the author on Technology Entrepreneurship showed that around 53 percent of the attendees had already considered founding their own firms. On the other hand, across students of all disciplines, in Germany the proportion of students wanting to be self-employed through an RBSU is 49 percent (contrary to the US with 63 percent) [Tamásy and Otten 2000].

Specifically, we assume a dependency of the relative importance of particular personality traits on the nature of the business. This means in our context also an association with different types of technology entrepreneurs (ch. 1.2.6.1).

The features listed in Table I.31 will not initiate a new venture. For that, an individual is needed, one in whose mind the relevant situational factors come together, and who has the motivation to pursue opportunities in an entrepreneurial manner.

Hence, we hesitate to consider these traits as necessary or sufficient for entrepreneurship, but view them as *facultative enablers*. This view relates entrepreneurship emergence to an *entrepreneurial orientation or an entrepreneurial disposition*. Finally, personality is one factor in the decision to become an entrepreneur, but is not necessarily a factor for the success of an entrepreneur.

Formalized and rather metaphoric, entrepreneurial personality P(Personality) may be described in terms of a linear combination (Equation I.3) of the "major enabling characteristics" (Table I.31) and "personal orientations" (Table I.32) as the independent variables x_i.

Equation I.3:

$$P(\text{Personality}) = a_1x_1 \oplus a_2x_2 \oplus \ldots \oplus a_nx_n \text{ and } \sum\nolimits^{\oplus} a_n = 1 \text{ and } 0 \leq a_n < 1$$

The symbol $\oplus$ denotes a "combinatorial" (more than the common additive/subtractive) relation. It is a "systemic addition" including interactions and reinforcements which affect the various components x_n. In the sense of General Systems Theory for an "entrepreneurial personality" comprising, say four significant components x_i, the formal representation with component parts ($a_1x_1 \oplus a_2x_2 \oplus a_3x_3 \oplus a_4x_4$) is to be interpreted as a *distinct pattern* including how the four variables interact and thus result in a "*whole entrepreneurial personality*" (Figure I.60, Figure I.61).

The variables in Table I.31 contain features, traits, and other determinants, which actually result from environmental influences on the personality, in particular, factors resulting from conditioning and means external influences over a rather long time in a particular direction.

If, on the other hand, a personality is exposed to external factors for a comparatively short time span, we are led to the notion of *personality disposition*, personality in a specifically defined, relevant situation that induces replicable, relevant behavior.

In the sense of GST "every personality disposition incorporates, whether explicitly or implicitly, a situational context that literally helps to define the disposition." [Johnson 2001] For GST, while isolated trait words, such as risk taking propensity or locus of control, contain no explicit reference to the relevant context, the context is tacitly built into the socially shared meaning of the trait word; it contains an implicit *standard reference* for a measuring process.

In terms of GST, Equation I.3 and its interpretation as a pattern and Johnson's [2001] arguments, personality and situation cannot be separated. Furthermore, at the outset situations and personality dispositions invoke forces whose magnitudes can be compared. Figure I.60 illustrates the case that "a personality disposition is responsive to a particular type of situation rather than a causal force whose magnitude could be compared to the strength of a separate, situational force."

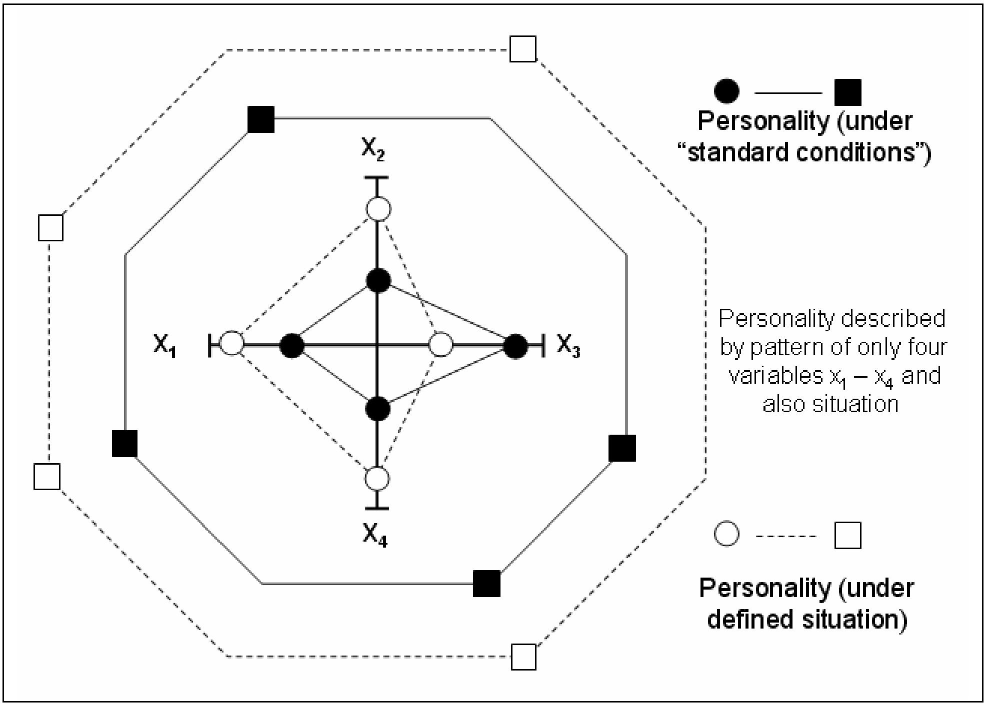


Figure I.60: Illustrating personality disposition and its measurement referring to a standard.

And "in the case of human beings, the ability of a situation to elicit behavior depends wholly on the person possessing the requisite personality disposition." [Johnson 2001] This is illustrated referring to corporate entrepreneurship in Figure I.17. Boiled down to entrepreneurship the question arises how can we tackle the dynamics of traits that guide people into entering or even creating particular situations?

Table I.31: Favorable personality characteristics and trait shaping factors for technology entrepreneurs.

Major Enabling Characteristics	Remarks and Minor Enablers
Values	Refers to an individual's idea about persons and things, understanding and appreciation of one's place in the society; reflects need for achievement, and independence and effectiveness of leadership

Table I.31, continued.

Major Enabling Characteristics	Remarks and Minor Enablers
Need for achievement	Achievement motivation exists as a stable characteristic; overcoming obstacles; ability to cope with setbacks and rejection; associated with perseverance and persistence (**Persistence:** viewed as sticking to a *course of action*; **perseverance:** viewed as *sticking to a belief or idea*; that is being steadfast or loyal)
Locus of control	Need for achievement seems to be related to the belief of *internal locus of control* (relate to individuals who also believe themselves to be in control of their destiny); self-confidence
Tolerance for ambiguity (ch. 4.2)	"Entrepreneurs who undertake uncertain initiatives face a wide spread between desirable and undesirable outcomes, but they cannot quantify the odds they face or even anticipate the possible results." [Bhidé 2000:26]
Risk taking	"Educated" risk taking (moderate and "calculated" risks *), judgment, decision-making (ch. 4.2.2) and technology intelligence (ch. 1.1.2)
Innovativeness and problem-solving	A central value of (technology) entrepreneurial behavior; expected to be the core of the entrepreneurial capability; two fundamental problem-solving styles (ch. 2.1.2.1 and below text); creativity, imagination, inspiration, mavericity(ch. 2.1.2.2); (cf. 3.2 The Idea and the Opportunity)

Perception	Perception of positive result of entrepreneurial action; perceived self-efficacy is the perceived personal ability to execute a target behavior; entrepreneurs' perception of the situation around them; listening skills; pattern recognition
External Shaping Factors:	
Role models and family backgrounds	Self-employed parents or one of the parents may affect motivation and/or attitude
Culture	Cf. ch. 2.1.2.3
Education	Entrepreneurs appear to benefit from both appropriate experience and education; education should also be on developing curiosity, motivation and self-efficacy (ch. 2.1.2.4)
Knowledge of and/or interest in (bent for) technology/science, applied sciences and research	Application of science; interest in commercial aspects
Work Experience	Cf. ch. 2.1.2.4

*) "Calculated" in the sense of qualitative, information-based assessment rather than quantitative on the basis of a more or less sound mathematical model.

Entrepreneurs seem to have a high *need for achievement* rather than a general desire to succeed. This transforms into the following characteristics.

- Likes situations where it is possible to take personal responsibility for finding solutions to problems
- Has a tendency to set challenging, but realistic personal goals and to take calculated risks.

A need for achievement is a generic entrepreneurial trait as it shows no or little dependence on the environment, for instance, the corporate environment. The "bootlegging" phenomenon (ch. 2.2.3) is a related expression of this fact.

Locus of control refers to the extent to which individuals believe that they can control events that affect them. Individuals with a high internal locus of control believe that events result primarily from their own behavior and actions. Those with a high external locus of control believe that powerful others, fate, or chance primarily determine events.

People with a *high internal locus of control* have better control of their behavior, tend to exhibit more political behaviors, and are more likely to attempt to influence other people than those with a high external locus of control; they are more likely to assume that their efforts will be successful. They are more active in seeking information and knowledge concerning their situation. [38]

Particularly with regard to intrapreneurship we follow Utsch et al. [1999] to conceptualize personality orientations to mean propensities to use certain behaviors for the work task, given that the environment allows the expression of these orientations.

The relationship between personality traits and behavior is stronger in situations that do not constrain the person – so-called *weak* situations (weak systemic couplings). Intrapreneurship represents a special situation with strong systemic couplings (Figure I.17), whereas entrepreneurship will correspond to small to medium couplings (Figure I.16). In the last case behavior relates to the orientation of the (founded) firm and not the orientation of an individual, and as such it describes the necessities that the job of an entrepreneur entails and how he/she executes the tasks in the startup environment.

According to Utsch et al. [1999] need for achievement and innovativeness represent *personality orientations*. Table I.32 lists three further orientations of relevance for the context of entrepreneurship.

Table I.32: Additional orientations for entrepreneurship.

Personal orientation	**Remarks**
Autonomy	Self-actualization, self-efficacy, control rejection
Pro-activeness	Means a high degree of initiative; taking quick action to implement one's goals; stay active in spite of setbacks (action orientation after failure); related to need for achievement
Competitive antagonism *)	Related to a special group of technology entrepreneurs, often with extraordinary ambitions to found and develop fast growing firms, and finally large global firms

*) Originally termed "competitive aggressiveness."

Three psychological constructs related to *autonomy* are viewed as important in the study of Utsch et al. [1999]:

1. Higher order need strength (HONS), which generally deals with the relationship between job performance and job satisfaction, implies the wish to *self-actualize*. This can be done in an area in which one is not constrained by other people's values and commands.
2. *Self-efficacy*, defined as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances," the belief in one's ability to succeed.
3. *Control rejection* implies that one does not want to exercise control because one is afraid of negative consequences and the responsibility that goes along with control. Whereas autonomy implies that one wants to be in control, control rejection should be low in small-scale entrepreneurs.

Competitive antagonism shows up in various forms and purposes. For instance, when the leading engineer August Horch and founder of the German automobile company "August Horch & Cie" ("Horch" means literally "hark" in English) left the firm to start a new one in 1910, he gave it the name Audi – "Audi Automobilwerke GmbH" (which means "hark" in Latin). [39] He was forced by law (related to trademark infringement) not to use his name as part of the firm name.

Similarly, when in Germany the two identical twins Harald und Rainer Opolka started their own business in competition to the firm "Zwilling" ("twin" in English) they gave it the name "Zweibrüder" (which is "two brothers" in one word), and they even won a legal suit about the naming (B.2). In the same line Viktor Dulger, founder of the pump and water treatment firm ProMinent® in 1960 [Runge 2006:74] was led by a verbal cynical devaluation of his innovative pump by an established large competitor "to strike back to all those established and *prominent competitors*" and, therefore, he flagged his firm by the name Prominent.

On the other hand, in the US the founder of Osmonics Corp. in 1969 Dean Spatz [Runge 2006:89, 92] made "competitive antagonism" part of his strategy. Counter-intuitively, Spatz believed that competition from very large industrial companies, such as Dow Chemical, Eastman Kodak and DuPont, also helped his firm's prospects. "It turns out that if you're a startup company and you have big name competitors, that gives you a lot of credibility."

When Sun Microsystems, Inc. started in 1982 (and purchased in 2009 by Oracle) its goal was building a general-purpose workstation to take on IBM and DEC in their mainstream business [Bhidé 2000: 270]. And Scott Rickert of Nanofilm LLC (founded in 1985), which leverages recipes, formulas for ultra-thin films (coatings) called nanofilms, for surface treatment addressed the emerging competitor Nano-Tex LLC, founded in 1998, as follows:

"If NanoTex [of stain-resistant textile fame] were to adopt the motto of 'coating all the textiles of the world,' ours would be to coat all the surfaces of the world.'" [Teresco 2005].

And recently US Sapphire Energy (Table I.93) which is engaged in using algae for biofuels positioned itself as an energy company stating “really, who we are competing with is big oil and gas.”

The suggested expression “competitive aggressiveness” by Utsch et al. [1999] seems to have emerged from the writings that as “far as Bill Gates is concerned, business is war” (cited in Bhidé [2000:314]) or the former DuPont CEO “Chad” Holliday who commented on business in the chemical industry: “It’s a war where environmental performance, market knowledge, intimate customer knowledge, pace and innovation are the ‘fronts’.” [Runge 2006:44].

Competitive antagonism is a basic orientation for all kinds of entrepreneurship and innovation which originates from “improvement.” This is a comparative and, hence, contextual approach which refers to deviating from a “standard” set by competitors. In this situation entrepreneurs will have to be very aware of the existing and emerging competition. Competitive antagonism is also found with combating a monopoly. The classical example based on science and technology is the case of lifting the Chinese monopoly for porcelain in 1708 by two Germans, the at the time very famous scientist E. W. von Tschirnhaus and J. F. Böttger [Runge 2006:402-405].

Challenging the competition in the sense of competitive antagonism originates with questions like

What can I do …	**Process category**
Better (including cheaper)	Improvement; Incremental Innovation
More special	Customization, Segmentation, Positioning
Different	Replacement/Substitution; Discontinuous Innovation
Totally new	Disruptive (Radical) Innovation

Thomas Edison encouraged *innovation and entrepreneurship as a search for change of the existing*: “There’s a better way to do it, find it!” (cf. Ernst Werner von Siemens [46])

It was exactly the related statement “I can do that better” which was the origin of founding the German firm Torqeedo GmbH by two friends in Germany in 2005 (B.2). Torqeedo develops and manufactures electric outboard motors for the marine market. The same is observed for one of the founders of Gameforge AG (B.2).

But Herbert H. Dow, the founder of the Dow Chemical Company, added an important check: “If you can’t do it better, why do it?” [Runge 2006:467]

For a GST context the key question for the above traits or orientations, respectively, is their relation to behavior, in particular, *volitional control concerning targeted behavior*.

That is, *actions and behavior done by conscious, personal choice*; done by an act of will, not based on external principles; done not by accident. [40]

Following Bird [1992], “since much of human behavior appears to be under volitional control . . . the best single predictor of an individual’s behavior will be a measure of his **intention** to perform that behavior.” Intention is a state of mind directing a person’s attention, experience, and behavior toward a specific object or method of behaving.

New organizations are the direct outcome of individuals’ intentions and consequent actions, moderated or influenced by environmental conditions. Entrepreneurship and starting and developing a new firm through initial stages are *largely* based on the vision, mission and values (Figure I.16; ch. 2.1.2.7) and motivations of individuals. Intention operates to structure attention and action through time and is a necessary *precursor to organizing*.

Founders’ intentions represent an important means by which they influence their organizations. Extant entrepreneurship literature provides evidence that contextual factors may influence entrepreneurial intentions. For instance, the university setting or that of a public research institute is one of the contextual factors. For spin-out formation related to the university setting factors are the (entrepreneurial) cultural environment of the institution and the presence of entrepreneurial role models among faculty [Villanueva et al. 2005], the “entrepreneurial professor” (ch. 4.3.5.2).

Intention forms also a precursor to strategy and directs critical strategic decisions (in contrast to day-to-day decisions in the firm). In the early stages, rather than following a formalized or even routinized approach, strategy and strategic planning shows up as “*strategy logics*,” which is the subjective logics representing the thinking of key person(s) in the firm, often the founder(s), dealing with the “*what and why, where and who, when and how.”* It is more a creative than a deductive exercise.

Strategy logics require factors, such as the goals and values of the decision-maker(s), the firm’s resources and opportunities – and threats. This means, strategy logics should focus on “fits” among goals, resources and opportunities and a related set of “rules” (“how”) or activities derived thereof.

“Where” covers two aspects. One refers to where to found the startup, which means location selection (Figure I.16). On the other hand, there is another dimension of “where and how.” Strategy logics define where and how the firm will seek to add value and the opportunities it will pursue. It asks whether the firm’s offering is new or not, is an *innovation*, “new-to-the-world,” “new-to-a region” or new to a particular group of buyers, or only an imitation or replication of an existing offering and what are the implications thereof. “Where” includes also questions of internationalization.

The “timing factor” (“when”) comprises also two different aspects:

- The right time to introduce the new firm’s offerings (Window of Opportunity, economic cycle), “ahead of the times” or late to market and

- Timing of behavior – the sequencing, coordination, synchronizing and pacing of actions, experiences and events.

In Table I.33 overt (observable, not hidden) strategy logics as a part of the very early stage of firm's foundation is given.

The period until strategy logics has turned into an explicit and formalized approach may be rather long. For instance, "it was more than two decades that after Walton {Samual, founder of Wal-Mart} had opened his first store that a critical element of Wal-Mart's strategy was put in place." [Bhidé 2000:273]

Technology entrepreneurs have goals for their organization and they desire to enact values (Figure I.16). As they enter into a very broad range of industries and markets the selected domain with its specific characteristics will partially determine their behavior.

In particular with an entrepreneurial aspect of founding or building a large firm associated with longevity Bhidé [2000:208] emphasized the significance of *ambition* and especially *audacious ambition* as the drivers of entrepreneurs.

Psychology is varied in its approach to different human traits and like every other attribute humans ambition can be approached with different psychological theories.

Table I.33: Overt strategy logics: from self-assessment to a lift-off.

What? (Strategic)	How? (Planning)
Assess and control the task situation	List the things you can do to get to where you want to go (my goals); Streamline the task so it is easier and takes less work; Assess for which areas you need support and look for advice and cooperation; Lift "noise" and "distractions"; Gather "materials" and finances and people (team) to get the job started
Involve and control others in the task setting	Ask for help/advice from friends and/or others; Ask for alternatives and recommendations for choices; Tell the advisors if he/she is not being clear when explaining things

Basically **ambition** is positive and is geared towards a person's overall development. Ambition is a basic life force and viewed as a complex process and trait in humans. It is assumed to be triggered by, and usually a combination of, negative and positive factors, such as,

- Fear of failure in professional or social life,
- Feelings of inferiority (superiority),
- Lack of or increased confidence,
- Social and financial needs,
- Creative urges,
- Competitiveness.

Ambition will be about using your energies, feelings, needs and positive or negative factors in life in a way that would be most beneficial for attainment of life goals.

See ambition as a part of your value system that you must give equal attention to along with other priorities you hold valuable or dear. There are many expressions of ambition – an ardent desire, strong drive to attain success in life, a desire to achieve personal or professional advancement, a desire to achieve money, power, fame, rank, position, or a desire to achieve any particular end or complete an activity or attain the fruits of an activity.

In the context of entrepreneurship [Locke et al. 2006] ambition can target a firm as a means to an end, such as getting wealth, power, fame or an end providing a firm's longevity, delivering a legacy or feeling a "breeze of immortality." And for entrepreneurs Ghaemi [2008] hints at two further aspects of ambition. He refers to a trade-off and cites a little-known psychiatrist Elvin Semrad, who once said: "You can achieve whatever you want, as long as you are willing to pay the price." Hence, what will you need to give up reaching your dream? Furthermore, at some point, all ambition has its price. When the price paid exceeds the merits of the prize, then ambition becomes hubris, and the seeker becomes lost.

Furthermore, related to entrepreneurial firms with exceptional growth or success Ghaemi [2008] made a link from "not trying to do more with ones potential" to the American essayist, philosopher and poet Ralph Waldo Emerson and his aphorism "*we aim above the mark to hit the mark*." Today we would say "reach for the gold, do not settle for bronze." And, indeed, concerning his firm and stores Sam (Samuel Moore) Walton, the founder of the world's largest retailer Wal-Mart [41], was "somebody who wants to make things work well, then better, then the best they possibly can be" and, furthermore, he wanted to "leave a legacy" (cited by Bhidé [2000:292]).

In the same direction, there is a success configuration of European, particularly German, *medium-sized companies* to come up with a class of firms that share basically *comparable structures and strategies*. The *class of excellence* by virtue of their superior growth, sustained superior profits over very long periods of time, financial strength, global reach and continuous and consistent innovation was named "*Hidden*

Champions," a term that entered European business lingo. The characteristics of Hidden Champions are how they are structured, staffed, and managed (ch. 4.1.1). A typical representative of the Hidden Champions, with a legacy and business succession through the founder's sons, is Prominent Group (Box I.18).

Organizationally, often they appear to be managed by hands-on CEOs whose knowledge of the key technologies is equal to their knowledge of the customers that they personally work with. Being highly focused, their survival depends on doing one thing extremely well. These companies always aim to be No. 1; they do not mean No. 1 in home markets, but globally. Many of these Hidden Champions were truly global long before the term "globalization" was coined.

Finally, there is a special class of entrepreneurs full of ambitions and aspirations, the serial entrepreneur. **Serial entrepreneurs** have already started a company or were self-employed before starting another one. Serial entrepreneurs have sold (usually with big reward) or closed down a business in the past which they at least partly ran and owned and who currently run another, possibly new business which they at least partly own.

But it is not just ambition that drives serial entrepreneurs, it is essentially attitude. To start a business endeavor time and time again, whether their last one failed or succeeded, is in their blood to create and form businesses. And there is the *thrill of challenge* – the thrill involved with creating a successful business. When the success or failure of a business hangs on a single individual's decisions and actions, there is much more of an adrenaline rush.

Since serial entrepreneurs are clearly doing something right, it behooves us to understand them. Attitudes tell us why entrepreneurs are motivated to do what they do, behavior is how they are doing it and professional skills and learning-by-doing reveal what they do well – they may be "role models."

Serial entrepreneurs emerge from other entrepreneurs due to the following reasons.

- It is an entrepreneur who continuously comes up with *new ideas* and starts anew. Some serial entrepreneurs have continuously good ideas matching opportunities. They are curious and are often asking the question, "what if..." or "why not …" (ch. 3.3).
- They have *experience* (ch. 2.1.2.4) with success and failure, too. And they tend to *learn* from both developing the professional skills vital for success [Bonstetter et al. 2010]. Serial entrepreneurs are always open to the risk of failure. They have a lot of energy and *confidence* that sets them apart from the "normal" entrepreneurial types.
- They may follow "negative thinking" ("effectuation"; A.1.7).
- Entrepreneurial experience is part of human capital and should enable entrepreneurs to make superior *decisions*.

- They often have a network including other entrepreneurs and investors and they often occur as a kind of "investor-entrepreneurs" (A.1.7; ch. 3.4.1, LinkedIn Corp., Gameforge AG, Zynga, Inc. – B.2).
- They have personal *funds* from previous ventures or have the ability to raise funds based on past successes [Bonstetter et al. 2010]. In particular, they often provide the essential of initial financing for a startup (Gameforge AG, LinkedIn Corp., Zynga, Inc. – B.2).
- Their track record makes them more likely to create "*entrepreneurial growth companies*" (EGCs) which tend to grow faster and bigger and thus employ more than a typical startup. In particular, they have shown their ability to sustain a business past the first year [Bonstetter et al. 2010]. This makes financial backers perceive their involvement in a new firm their risks to be reduced.
- Serial entrepreneurs often have *high risk-to-reward tolerances*, as they do not mind taking risks that come with high stakes.
- Many serial entrepreneurs are out to prove themselves. They go for *achievement*, they want to succeed on their own terms and make an impact with the results of their endeavors. It may be seeing their ideas come to life or simply showing others that they have the ability to succeed.

Apart from personality characteristics Bonstetter et al. [2010] list a number of professional competencies that form a basis of experience and lift serial entrepreneurs above average and novice entrepreneurs. These cover a number of "soft" skills, such as presentation, interpersonal relationship, negotiation and conflict management skills.

It should be noted that a considerable number of the very successful entrepreneurs turn to become investors, venture capitalists or supporters of science, such as Vinod Khosla (A.1.1.5 – Sun Microsystems) in the US or in Germany Hasso Plattner (SAP AG – A.1.4) and recently Lars Hinrichs (Xing AG – ch. 3.4.2).

When looking at the multidimensional perspectives for analyzing entrepreneurs' personalities it is important to consider the key factors which influence entrepreneurial behavior. They help explain why some will become entrepreneurs *intentionally* (by an "*internal drive*", by conviction) and others do not.

Entrepreneurial orientation can help explain why certain people become attracted by or selected to entrepreneurship. And they will also helpful to assess chances when persons are driven by *external factors*, such as a layoff, to become a "successful" entrepreneur (necessity entrepreneurs). This would also include persons, who become entrepreneurs by suggestion of or persuasion by other people (Nanosolutions GmbH, B.2)

2.1.2.1 Psychometric Approaches to Entrepreneurial Personality and Problem-Solving

There are several approaches to quantification of the personality of entrepreneurs or innovators. The Myers-Briggs Type Indicator, or MBTI®, is the most famous personality test of experimental psychology which, among other applications, is currently widely used for hiring personnel – despite criticism. However, it is also often used for building teams. The second important psychometric approach is the Kirton Adaptive-Innovative (KAI) Inventory.

The Myers-Briggs Type Indicator (MBTI) assessment is a psychometric questionnaire designed to measure psychological preferences in how people perceive the world and make decisions. MBTI and its extension, the MBTI-*Creativity Index*, measures one's social interactive style. KAI provides an instrument to measure problem-solving, teamwork and creativity. As far as the author is aware of there are no studies using MBTI or KAI dealing only with technical entrepreneurs. [42]

Presenting the MBTI approach in some detail shall demonstrate the complexity of human personality in contrast to any discussion of personality in terms of a list of traits given in Table I.31 and Table I.32.

The MBTI Indicators are based on the theories of the Swiss psychiatrist, influential thinker and founder of analytical psychology Carl Jung (1875 – 1961), which he developed attempting to explain the differences between normal healthy people. Based on observations, Jung came to the view that differences in behavior are the result of innate tendencies of people to use their minds in different ways, to look at and differentiate personalities based on preferences in how people perceive information from their environment and make decisions. It uses a psychometric questionnaire to categorize the taker's personality into one of sixteen basic types.

MBTI uses a basic set of personality dimensions which are related to each other as four interrelated, but non-overlapping and opposed pairs (dichotomies). The split represents opposing forces ("drivers") of a personality. The four dichotomies including typical scales (in italics) for measurement are as follows:

Extraversion	*Energy – Making Contact*	Introversion
Sensing	*Gathering Information – Exploration*	INtuition
Thinking	*Making Decisions – Commitment*	Feeling
Judgment	*Life Orientation – Setting Goals/Change*	Perception

A person's preference in each choice is recorded with a letter to form a *four-letter personality type*. For example, someone described as ESFJ exhibits extraversion, sensing, feeling and judgment.

The four MBTI type letters are too often misconstrued as the component parts of an (additive) sum as in INTJ = I+N+T+J. Whereas in reality INTJ is the *code designation for a distinct pattern* of how the eight functions interact and result in a "*whole type*," as expressed, for instance, by Equation I.3. Furthermore, as described below, there is an order in the four-letter code describing the weights of the component parts and a hierarchy. The first dichotomy records a person's approach to the world.

Most entrepreneurs show an extraverted (E) tendency, since this is the type most associated with *action and activity*. Introverts (I) typically think before participating and ask questions before completing tasks. Typical keywords describing E are active, outward, people, expressive and breadth, those describing I are reflective, inward, privacy, quiet, depth.

The terms sensing (S) and intuition (N) describe how the *subject prefers to see the world*. The first type of persons prefer to gather information from the world around them by looking and listening; the second type is more at home with more nebulous information, acting on instinct and gut feelings based on experiences. Typical keywords describing S are details, present, practical, facts, direction, repetition, those of N are patterns, future, imaginative, innovations, instinct, variety. A preference for intuition may provide more benefit to entrepreneurs.

Thinking (T) and feeling (F) describe how someone prefers to *come to decisions*, by considering the logic or by empathizing with all parties or coming to a decision by consensus. At the head of a business, people who favor thinking over feeling are more likely to be successful. Typical keywords describing T are head, objective, cool, nonpersonal, recognize, those of F are heart, subjective, caring, personal, appreciate.

Finally, there is judgment (J) and perception (P). This is a *lifestyle choice* relating to how a person chooses to *present him-/herself to the outside world*, and for an extraverted type reveals their dominant function.

Judging types are characterized more by their TF preference than their SN preference; for perceiving types, the reverse is true. Typical keywords describing J are organized, structure, control, decisive, closure, plan, those of P are flexible, flow, experience, curious, openness, evolve.

Given that curiosity and the reaction to changes in the environment is so important to success as an entrepreneur, a preference for perception over judgment would seem to be a slight benefit.

> According to Dorf and Byers [2007:38] entrepreneurs are most often profiled as ENTP.

To account for preference that affects a person's choice Myers-Brigg introduced a specification of the basis set of components and pairs in terms of weights for the personality with E-I and J-P standing out as the first or last letter in the code. S-N and T-F are viewed as "mental functions" represented by the middle two letters of the code (Table I.34). Although the four letter type code only shows two of these functions, everyone has and uses all four of them.

Table I.34 gives more specifications concerning the MBTI code collected from various sources; further details can be found in the special literature.

Table I.34: Specification of the Myers-Brigg Type Index code.

Extraversion and Introversion refer to the two polar opposite directions of psychic attention and energy. Whatever is a person's *dominant* mental function was directed to either the external world (E) or the internal world (I). The preference in attitude of E versus I is a *major distinguishing feature in personality type patterns*.	
E-I Extraversion or Introversion: To focus the dominant (favorite) process on the outer world or on the (internal) world of ideas	This energy preference for the dominant function is denoted by the first letter in the MBTI code.
S-N Sensing or Intuition: To use one kind of perception instead of the other when either could be used	(S) and (N) considered *Perceiving functions*; two contrasting ways of *taking in information*
T-F Thinking or Feeling: To use one kind of judgment instead of the other when either could be used	(T) and (F) considered *Judging functions*; two contrasting ways of *making decisions*
J-P Judgment or Perceptive: To use the judging or the perceptive attitude for dealing with the outer world	One of these two most favored *processes of cognition* takes the lead
Perceiving and Judging are essential components to all *cognitive activity*. There can be no Judging without prior Perception; and no Perception without some form of Judging inevitably following. Whatever is a person's most favored Perceiving process combined with whatever is his/her most favored Judging process is at the core of personality and is a major influence in the overall constellation of personality development.	

Each of the 16 personality types has a characteristic pattern in the alignment of the four mental functions. This pattern is referred to as a "hierarchy" because they typically differ in the degree of influence on the personality and the degree they are consciously experienced.

As indicated above, the most important or influential function is termed the "Dominant" function (#1) and the second most important is termed the "Auxiliary" (#2). The third in the hierarchy is called the "Tertiary" (#3) and is the polar opposite of whatever function is the Auxiliary. The Fourth in order Jung termed the “Inferior” function (#4). It is the mental process with the least conscious awareness and typically the least developed of the four functions (Figure I.61)

The rationale for the opposite relationship of the Dominant and the Inferior has to do with energy and the natural polarity of the mental functions. For example, a person with dominant Intuition will direct his/her primary energy to this function – which happens to be in the exact opposite direction of Sensing.

It is like trying to go North and South at the same time. It is much easier to couple that Dominant with either the Auxiliary or Tertiary because these are not polar opposites to the main direction. They are like East and West on the compass. So navigating NW or NE is a natural direction of movement – but North-South is not [Reinhold].

Similar to a radar chart, Figure I.61 provides also how a systemic “whole type” of personality can be represented as a characteristic pattern. Furthermore, combining (N) and (T) – the path from N to T – can be interpreted as if the direct mixing of N (patterns, future, imaginative, innovations, instinct, variety) and T (head, objective, cool, non-personal, recognize) requires “catalysts” which make the mixing easier.

A description of some selected types is given in Table I.35 where in the upper row personalities are given matching entrepreneurial characters. One of the rarest of types of the general population are INTPs. They have been selected to present types having the NT versus the ST combination which are relevant for entrepreneurial versus managerial characters (see below).

Another psychometric approach to measure people’s characteristic preferred style of problem-solving, a style of creativity, is the Kirton Adaptive-Innovative (KAI) instrument developed by Dr. Michael J. Kirton. It has thirty-three questions.

The tool attempts to measure the approach and *methodology an individual uses to bring about change*. The KAI item inventory has a range of scores of thirty two to one hundred sixty (32-160). The observable range is from forty five to one hundred forty five (45-145). The results have a midpoint of ninety-six (96) with a mean of ninety-five (95). Two-thirds of responses range from seventy eight to one hundred fourteen (78-114).

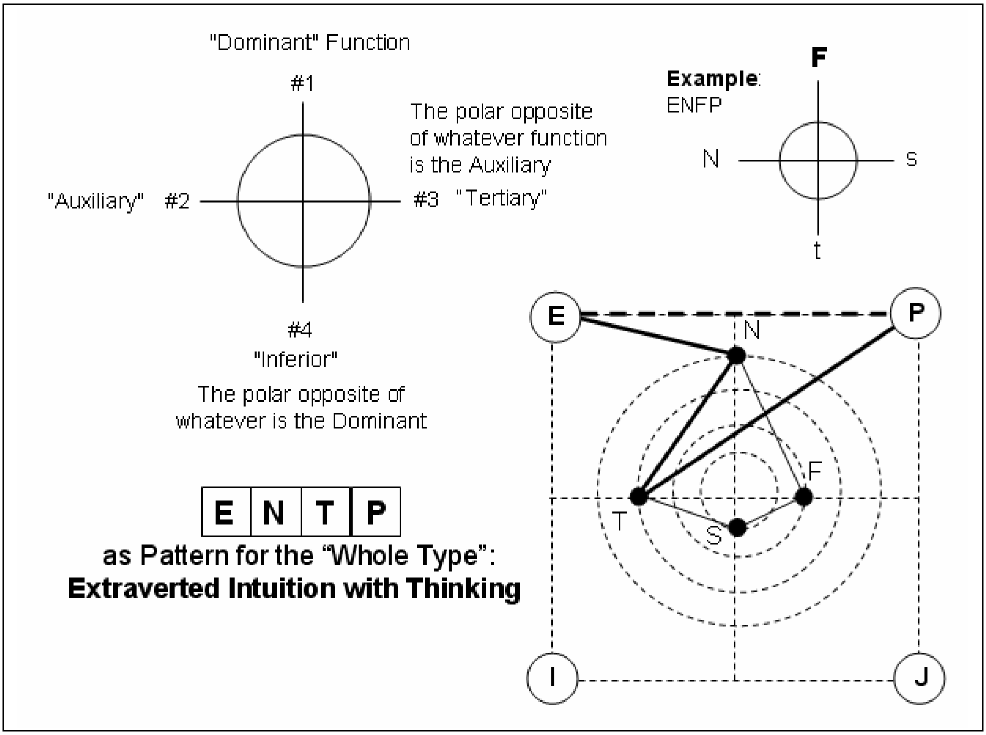


Figure I.61: Specification of hierarchies in MBTI functions and illustrating a systemic "whole type."

Table I.35: Description of selected MBTI personality types [The Myers & Brigg Foundation; note 42].

ENTP:	**INTP**
Quick, ingenious, stimulating, alert, and outspoken. Resourceful in solving new and challenging problems. Adept at generating conceptual possibilities and then analyzing them strategically. Good at reading other people. Bored by routine, will seldom do the same thing the same way, apt to turn to one new interest after another.	Seek to develop logical explanations for everything that interests them. Theoretical and abstract, interested more in ideas than in social interaction. Quiet, contained, flexible, and adaptable. Have unusual ability to focus in depth to solve problems in their area of interest. Skeptical, sometimes critical, always analytical.

ESTJ:	ISTJ:
Practical, realistic, matter-of-fact. Decisive, quickly move to implement decisions. Organize projects and people to get things done, focus on getting results in the most efficient way possible. Take care of routine details. Have a clear set of logical standards, systematically follow them and want others to also. Forceful in implementing their plans.	Quiet, serious, earn success by thoroughness and dependability. Practical, matter-of-fact, realistic, and responsible. Decide logically what should be done and work toward it steadily, regardless of distractions. Take pleasure in making everything orderly and organized – their work, their home, their life. Value traditions and loyalty.

The KAI indicates whether one has a preference as an *adaptor* or *innovator*. With the mid point of the scale being 96, those with scores higher are considered innovators. Lower scores indicate one is an adaptor. These styles form a continuum from adaptive through to more innovative.

People with KAI scores of more than ten points apart are assumed to notice a difference in problem solving methodology. Kirton is careful to point out that this scale does not mean adaptors are not creative. They can be equally so with innovators, but the way they solve problems is different.

The more adaptive style shows a preference for solving problems through incremental improvement within a system, whereas those who work in a more innovative way have a preference for restructuring the system in order to solve the problem or capitalize on opportunities. The characteristics of persons approaching problems according to the two KAI styles are given in Table I.36.

The Kirton Adaption-Innovation inventory [42] as an instrument that measures the preferred way of thinking, solving problems and creating change is a *measure of cognitive style*. Furthermore, it is generally accepted that the Adaptive-Innovative (A-I) cognitive style represents a stable cognitive process within the individual which is *largely uninfluenced by national culture*. Evidence that A-I cognitive style varies has to be attributed more to occupation and by work function than by nation [Tullet 1997]. And it can be assumed that this is also true for corporate culture.

Table I.36: Characteristics of adaptors and innovators according to KAI [Hipple et al. 2001; Note 42].

Adaptor	**Innovator**
Efficient, thorough, adaptable, methodical, organized, precise, reliable, dependable	Ingenious, original, independent, unconventional
Accepts problem definition	Challenges problem definition
Does things better	Does things differently
Concerned with resolving problems rather than finding them	Discovers problems and avenues for their solutions
Seeks solutions to problems in tried and understood ways	Manipulates problems by questioning existing assumptions
Reduces problems by improvement and greater efficiency, while aiming at continuity and stability	Is catalyst to unsettled groups, irreverent of their consensual views
Seems impervious to boredom; able to maintain high accuracy in long spells of detailed work	Capable of routine work (system maintenance) for only short bursts; quick to delegate routine tasks
Is an authority within established structures	Tends to take control in unstructured situations

In the previous text the difference between entrepreneurship and management or entrepreneurs and managers, respectively, has been emphasized several times (ch. 1.1.2, 1.2.1, 1.2.4) and also qualitatively described. But most research on this topic suffers from the fact of incompatibility or non-comparability (Figure I.2 and text below it). Most studies tackling the difference compare real, “independent” entrepreneurs with managers in medium to large firms.

A proper study targeting differences in personalities has to investigate managers versus corporate entrepreneurs (intrapreneurs). Then, both managers and intrapreneurs are conditioned by the same corporate culture and personal experiences (Figure I.60) while climbing the career ladder in the firm or gaining experiences in several firms. In particular, risk taking or risk aversion or being a technology leader or a follower due to corporate culture will enter decisively and subject both to the same influences and thus make them comparable. Such an approach is reported by Hipple et al. [2001].

The study by Hipple et al. [2001] looked into former corporate innovation champions (intrapreneurs) to gain valuable insights and knowledge that can be used to plan and execute innovation programs. All of the participants had either corporate or major divisional responsibility for innovation, “new-to-the-firm” business activities, or both.

They could also use the results of the study to tackle differences between managers and intrapreneurs, as the questionnaire concerning the fifteen intrapreneurs' innovation experiences was also asking the individuals for information about their Myers–Briggs Type Indicators (MTBIs) and Kirton Adaption–Innovation (KAI) profiles.Their companies were spread across the chemical (8), pharmaceutical (2), consumer products (2), food (1), and pulp and paper (1) industries and the military (1).

The MBTI profiles of the fifteen innovators varied greatly. Six of the individuals were INTP or ENTP (Table I.35). In all, thirteen were intuitives and twelve were extroverts. The NT combination was present in ten of the individuals, the largest two-attribute combination. The split between judging and perceptive was approximately 50:50. On the other hand, previous studies have shown that up to 95 percent of senior corporate managers are STJs (Table I.35).

> The difference between the innovation champions and managers sets up potential conflicts. Intuitives and sensers view the world very differently. A change will always seem greater to an ST than an NT because STs are typically comfortable only with continuous change and very uncomfortable with discontinuous change. An NT, however, may actually enjoy discontinuous or disruptive change. As an intrapreneur is trying to initiate change, differences about acceptable and desirable degrees of change can have significant effects on perceived performance.
>
> Entrepreneurs and managers have different life-anchors. Whereas the life-anchors for entrepreneurs is to create and build something, for most professional executives it is more a matter of power, status and money. The whole issue of life-anchors is very important. Different people have different drivers.

The KAI profiles revealed something even more dramatic. The average KAI score, within industry and the general population, is between 90 and 95, with business and engineering managers typically scoring 95–105. The scores for the innovation champions ranged from ~95 to 155; one-third of the group scored ~135, and the average score was ~125.

This result, along with the MBTI findings heavily weighted toward intuitives and especially NTs, paints a picture of a typical innovation champion in this group as someone who is very comfortable with substantive change, operates to a significant degree on intuition, and is not likely to check with authority before taking action (cf. bootlegging in ch. 2.2.3) that he or she believes is right. It reinforces several potential major conflict areas for people with these profiles in certain corporate innovation situations.

KAI style refers to an adaptive, building or analogical problem-solving style versus an innovative or pioneering style. Both skills are needed for organizational problem solving, but the differences are often not recognized or measured. The builder versus innovator dichotomy in particular becomes relevant for the various types of innovation. For instance, for incremental (and probably also discontinuous) innovation as well as technology exploitation the focus will be on the "builder/adaptor," but disruptive (radical) innovations require the "innovator/pioneer."

This essential dichotomy plays an important role for R&D management or innovation in large firms. The fundamental is to *match research and innovation tasks against personality* features and establish the *right mix* for research and innovation *project teams* which means *team building*.

The fundamental issue of the typical innovation process in industry (Figure I.79) is that some persons do development better than others. According to a Research Director in Dow Chemical, "The biggest obstacle to launching great new products was *not having the right people in the right jobs*. Job assignment is everything – and that was my biggest job, to shift people around to the right place." Correspondingly, he reassigned his employees, distinguishing "pure inventors" from those who added value in later phases of innovation based on the Myers-Briggs Type Indicator personality test [Runge 2006: 446-448, 629].

2.1.2.2 Creativity, Imagination and Inspiration for Entrepreneurship

Imagination is more important than knowledge. For while knowledge defines all we currently know and understand imagination points to all we might yet discover and create.
Albert Einstein

Microsoft's only factory asset is the human imagination.
Bill Gates

In Table I.31 creativity, imagination, inspiration and mavericity have been noted as favorable personality characteristics for technology entrepreneurs in the context of innovativeness and problem-solving. Mavericity is a quality to generate uncommon interconnections between ideas or to do the unexpected. For instance, this quality could show up in a word-association test if the answer to "black" is not "white," but rather "caviar" [Runge 2006:431].

(Technology) Entrepreneurship is associated with *creative activities of people* and requires imagination, inspiration and intuition as well as sensitivity towards social and societal interconnections. In our context, it is an essential part of innovation and invention and is important in science and engineering, business, industrial design, graphic design, and teaching.

There is no single, authoritative perspective or definition of creativity which is a subject of psychology and cognitive science. Many view it is a gift. For instance, the Dutch serial technical inventor and innovator Ron Kok [Morais 2004] sees it as a gift of God. Others promote it can be taught with the application of simple techniques and make a good business out of that. Some essentials of creativity in science and technology were summarized by Runge [2006:750-757].

Concerning creativity there are two major theoretical directions, a static "attribute" or a systemic dynamic process orientation:

- The *attribute theory* emphasizes the individual (here the entrepreneur) and holds that specific characteristics and traits of biological origin predispose a person to creativity and that creative people share common observable attributes.
- The *systemic process theory* emphasizes the systems approach and looks at creativity as a highly complex, multifaceted phenomenon based on individual characteristics, skills, aptitudes, but also experiences, actions and social (organizational) conditions and interactions.

In order to put **creativity** into the context of innovation and entrepreneurship (rather than the entrepreneur) we shall emphasize the systemic view. Accordingly one can say creativity is a *mental and social process* involving the *generation of new ideas or concepts* (ch. 3.3). It is fueled by either conscious or unconscious insight. The notion creativity is typically used to refer to the act of producing new ideas, approaches or actions.

From a scientific point of view, the results of creative thought of an individual (and often his/her social interactions) are usually considered to *have both originality and appropriateness*. It covers the ability to recognize that which is not obvious!

Important elements of creativity include or can be characterized by

- the ability to *identify new connections* between seemingly unrelated objects or events – connections between (scientific and technical) disciplines or domains of knowledge,
- the *unification of seemingly unrelated data, information, facts or ideas and concepts*,
- *seeing the world differently*, from an ability to think across *conventional lines of thought* and *breaking the mold of how things are normally done.*

Outstanding drivers of creativity are "*to make things differently*." A creative person inclines to a choice which differs from the majority. The internal barrier for creativity is the tendency of mankind to seek to confirm one's one prejudices or as Francis Bacon described it: "The human understanding when it has once adopted an opinion … draws all things else to support and agree with it."

In case of disruptive innovation outcome of creativity stems usually from an "*assumptions-breaking process.*" Creative ideas are often generated when one discards preconceived assumptions ("out-of-the-box thinking") and attempts a new approach or method that might seem to others unthinkable. In science this means change of a paradigm and has been characterized as "mavericity" by De Solla Price [Runge 2006:431].

Creativity is a process and a "product" (outcome), as is intelligence (ch. 1.2.3).

Creativity is supported by *associative and metaphorical thinking* and *analogy identification*. It is also supported by *complex pattern recognition*, in particular, by completing pattern or gap identification and analysis.

Many issues of creativity revolve around "measurement" and what actually has been measured. The author's position is that creative ability is not truly measurable on an absolute scale. But there are measures providing a style of creativity when measurement refers to how we relate to problems (ch. 2.1.2.1, ch. 3.1). An example is the Kirton KAI (Kirton Adaptive Innovative) instrument. KAI measures whether one is an adaptive or innovative problem-solver.

Another important contribution to creativity and progress is **imagination** [Runge 2006:758]. Imagination refers to the power or process of producing *mental images and representations of ideas*. It is the process of forming mentally something not present to the senses or never before wholly perceived in reality, but *what can be* (in the future).

Imagination belongs primarily to a private sphere when it creates partial or complete personal realms within the mind. Imagination provides an experimental partition of the mind (for instance, in physics a "Gedanken experiment") [43] used to create theories, ideas or future states based on functions. Taking objects from real perceptions, the imagination can use complex WHAT-IF-questions to create new or revised objects or processes (ch. 3.3).

Imagination exhibits interconnections with vision. **Vision** refers to the category of intentions that are broad, all-inclusive and forward-thinking. For an entrepreneur or a firm it is the image that a business must have of its purposes/goals before it sets out to reach them. It describes aspirations for the future, without specifying how (means and processes) to achieve those desired ends. It is a mental image of the desirable and future state of the organization and comprises the pursuit of an image of success (ch. 2.1.2.7).

Contrary to ideas visions are normative (or even ideological) and focused (or biased) towards a clear aspiration of how the world should be. They strongly reflect the personal culture, convictions, ambitions and intentions of the thinker [Verganti 2010]. (Cf. also the Five Disciplines of Organizational Learning; ch. 1.2.3)

Visions as the source of ideas or related problem-solving can originate with individuals to initiate their activities, but visions of individuals or for political programs can also initiate activities of others. A classical example in the nineteenth century was the vision of the German chemist Liebig [Runge 2006:293] which resulted in the dyes (A.1.2) and pharmaceutical industries:

> We "believe that tomorrow or the day after tomorrow someone will discover a process ... to make the wonderful dye of *madder* or helpful *quinine* or morphine from coal tar."

A more recent example is the EU Biofuels Vision from 2006 focusing on biofuels.

> VISION: By 2030, the European Union covers as much as one fourth of its road transport fuel needs by clean and CO_2-efficient biofuels [EU 2006].

In science and innovation activities creativity and **inspiration** can manifest themselves through “eureka” moments (albeit with an underpinning in extensive research and experimentation). Normally *inspiration is both sudden and unexpected*.

For illustration, Runge [2006:752] presents a case when “a bulb went on the head” of 3M researcher S. Cobb attending a scientific conference. There he came across light pipe technology and was struck by the idea *how 3M technology could be used to commercialize the basic scientific phenomena* (outside 3M’s businesses at that time). The related microreplicated prismatic materials and their applications are now “big business” of 3M [Runge 2006:378, 752].

Hence, we see inspiration as an influence on the mind or an event influencing the mind initiating activity, a stimulation of the mind (“response”) to special unusual activity or creativity.

Inspiration has got a striking description by Goethe which maps the goal-directed situation of entrepreneurs:

> As soon as the mind targets a goal a lot will come to meet him.
> (in German: Sobald der Geist auf ein Ziel gerichtet ist, kommt ihm vieles entgegen – ch. 3).

If we refer to creativity as an iterative process involving reflection and action and social interactions seeking feedback and discussing new ways of doing things we are led to the notion of “**organizational creativity”** which is a relatively new and emerging research area within the field of organizational behavior.

Current models of organizational creativity focus on conceptual frameworks that give importance to social and contextual influences on creativity of people in social systems, such as employees in firms or members of entrepreneurial teams [Zhou and Shalley 2008]. Due to the close connection between creativity, ideas and social contexts we shall discuss that when discussing idea generation and ideation for entrepreneurship and innovation (ch. 3.3).

2.1.2.3 The Culture Factor

A whole stream of research has emphasized the deep-rooted and mostly unconscious cultural characteristics of a society as being important factors influencing entrepreneurship. We in Germany learned over the last twenty years after the fall of the Wall, when re-unification of Germany took place, how persistent and of longevity the different cultures of the two parts, free and capitalistic versus non-free and socialistic, are. Many corresponding German entrepreneurship studies looked specifically into this constellation.

Culture means patterns of values and orientation for thinking, feeling acting and, therefore, is a key for behavior and perception [Böhm 2005]. Culture finds expressions on various sociological, interpersonal, behavioral and educational levels, such as levels of obedience, power distance, duty, and communication [Runge 2006:392-394], which all affect entrepreneurship.

Basically, rather than attributing cultural traits or "properties" to a nation what we actually are dealing with is *statistical prevalence of certain features*, a tendency to behave in line with such features. For instance, focusing on the extremes Runge [2006:393] labeled Germans and Americans as "complexifiers" versus "simplifiers."

On the other hand, "power distance" (Table I.37) can be defined as "the extent to which people in a hierarchical situation feel they can and should control the behavior of others, and the extent to which those others are conditioned by reflexes of obedience" [Runge 2006:461].

Geert Hofstede's extensive culture study from 1980 (as cited by Mueller and Thomas [2001]) provides a clear articulation of differences between countries in values, beliefs, and work roles. Hofstede's originally four cultural dimensions as extended to the five Geert Hofstede™ Cultural Dimensions ("5D Model") [Itim International] are by far the most frequently used cultural explanatory variables for entrepreneurial activity and behavior (Table I.37). Although Hofstede did not specify the relationship between culture and entrepreneurial activity *per se*, his culture dimensions are useful in *identifying key aspects of culture* related to the potential for entrepreneurial behavior.

Table I.37: Geert Hofstede™ Cultural Dimensions ("5D Model") [Itim International].

Cultural Dimensions	**Comment**
Power Distance (PDI – Power Distance Index)	Refers to a society's tolerance for human inequality; the extent to which the less powerful members of organizations and institutions (like the family) accept and expect that power is distributed unequally; Represents inequality (more versus less), but defined from below, not from above. It suggests that a society's level of inequality is endorsed by the followers as much as by the leaders

Individualism-Collectivism (IDV – Individualism)	The cultural value a given society puts on the individual or, alternatively, on the group; the degree to which individuals are integrated into groups; on the individualist side there are societies in which the ties between individuals are loose: everyone is expected to look after him/herself and his/her immediate family; on the collectivist side, we find societies in which people from birth onwards are integrated into strong, cohesive in-groups, often extended families
Long-Term Orientation – LTO	Values associated with Long Term Orientation are thrift and have perseverance (Table I.31); values associated with Short Term Orientation are respect for tradition, fulfilling social obligations, and protecting one's "face" (not to be confused with "long/short-termism" in business of capitalistic societies; ch. 1.2.4)
Masculinity-Femininity (MAS – Masculinity)	Refers to the distribution of roles between the genders which is another fundamental issue for any society to which a range of solutions are found; a society's emphasis on values which are considered masculine (male), or alternatively feminine (female). For instance, competitiveness and ambition have traditionally been attributed to men, and interpersonal relations and caring have traditionally been attributed to women; men's values from one country to another contain a dimension from very assertive and competitive and maximally different from women's values on the one side, to modest and caring and similar to women's values on the other.

Table I.37, continued.

Cultural Dimensions	Comment
Uncertainty Avoidance (UAI – Uncertainty Avoidance Index)	A society's tolerance for an unknown future, its tolerance for uncertainty and ambiguity; indicates to what extent a culture conditions its members to feel either uncomfortable or comfortable in unstructured situations (unstructured situations: novel, unknown, surprising, different from usual); uncertainty avoiding cultures try to minimize the possibility of such situations by strict laws and rules, safety and security measures; uncertainty accepting cultures, are more tolerant of opinions different from what they are used to; they try to have as few rules as possible Uncertainty avoidance is related to risk-aversion.

Table I.38 lists Geert Hofstede™ Cultural Dimensions ("5D Model") of selected countries differentiated economically according to type of capitalism followed in the countries (ch. 1.2.4) with the emphasis of this book being on Germany as a representative of the "Nippon-Rhineland Capitalism" and the US being the most prominent representative of the Anglo-Saxon Capitalism.

Most remarkably, Japan shows up with extreme values for all the five indexes supporting common prejudices that Japan is a strongly hierarchical, command and control, consensus-oriented society with long-term views and strong masculinity orientation. In Table I.38 notable data points for the corresponding indexes of the other countries are emphasized by bold face.

Table I.38: Selected countries characterized by Geert Hofstede™ Cultural Dimensions [Itim International].

Country	PDI	IDV	MAS	UAI	LTO
Nippon-Rhineland Capitalism					
Austria	**11**	55	**79**	**70**	
Finland	33	63	26	59	
Germany	35	67	66	65	31
Japan	**54**	**46**	**95**	**92**	**80**
Netherlands	38	**80**	**14**	53	44
Sweden	31	**71**	**5**	29	33
Switzerland	34	68	70	58	
Average-All	34	64	51	61	47
Average-Europe	**30**	**67**	**43**	**56**	**36**
Anglo-Saxon Capitalism					
Australia	36	90	61	51	31
Canada	39	80	52	48	23
United Kingdom	35	89	66	35	25
United States	40	91	62	46	29
Average	**38**	**88**	**60**	**45**	**27**

European countries exhibit broad varieties in their cultural characteristics. Masculinity (MAS) is strongest in German speaking countries (Austria, Germany, and Switzerand). The Netherlands and Sweden exhibit the lowest values in MAS and highest values in individuality (IDV).

Uncertainty avoidance (UAI) is significant for Germany and Austria. Germany and Sweden show the least long-term orientations.

There is more coherence within the group of English-speaking countries which all have roots in the culture of the United Kingdom. There is a certain closeness between the US and the UK – except for uncertainty avoidance. The most remarkable differences of these countries compared with the European countries (disregarding the UK) refer to individuality and masculinity. Comparing specifically the US and Germany individuality and uncertainty avoidance appear as the most significant differentiators.

The emphasis on individuality in the US has a distinct effect on entrepreneurship. For instance, Stephan Haubold, the founder of the German firm Nanosolutions GmbH (B.2) and grown up in very diverse international environments, commented on cultural differences that the whole concept underlying *the birth of a business* is different in the US from that in Europe and particularly Germany. He stressed “not better or worse, just different.”

“If an interested market is the condition for success in Europe, money and the idea are of greater importance in the United States. In the United States there is so much money in motion that you can get start-up capital just for having a vision, if you have a strong personality.”

Uncertainty about the future seems to be induced by the terrible and devastating wars in Europe over the last four hundred years. This contrasts with the “eschatological faith in the future” as described by Brooks [2009b], concerned with what are believed to be the final events in history or, at least, the current age. He provides the following rationale for that accepted also by Europeans:

> “When European settlers first came to North America, they saw flocks of geese so big that it took them 30 minutes to all take flight and forests that seemed to stretch to infinity. They came to two conclusions: that God’s plans for humanity could be completed here, and that they could *get really rich* in the process. This *moral materialism* formented a certain sort of manic energy. (Author’s note: “formented” in the text probably should be “formed”)
>
> It may seem like an ephemeral thing, but *this eschatological faith in the future* has motivated generations of Americans, just as religious faith motivates a missionary. Pioneers and immigrants *endured hardship* in the present because of their *confidence in future plenty*. Entrepreneurs start up companies with an exaggerated sense of their chances of success. *The faith is the molten core of the country’s dynamism*.” (Emphases added)

However, New York Times columnist David Brooks [2011] recently seemed to restrict this view pointing to narcissism and overconfidence as the source of many of the US society’s current social and political problems. With his “Modesty Manifesto” his current view is that over the past half century, particularly, the last two decades, America has moved from a culture of self-effacement – I’m no better than anybody else, but nobody is better than me – to a culture of self-expression, a “me, me, me society.” If this reflects reality, it would affect entrepreneurship in the US.

Concerning communication Runge [2006:394] presents comparisons between Americans and Europeans on the basis of selected American and European behavior and how they perceive each other which reveal drastic differences in behavior and perceptions. For working together on a global basis and for trans-national firms communication *and cultural behavior of team members have key influences for the success* *of cooperation*. This is not only of relevance for intrapreneurship, but also for entrepreneurship.

"*Intercultural competence*" is more than speaking other languages. It is also more than following customs, the usual way of behaving and acting. Intercultural subject competency comprises knowledge and awareness of the own cultural values and attitudes and how one's own personality is influenced by cultural values and attitudes. Social competency in this context means proper handling of conflicts and contradictions in interaction with other cultures [Runge 2006: 393-394].

Relating culture and entrepreneurial traits (Table I.31, Table I.32), for instance, Mueller and Thomas [2001] put forward that an internal *locus of control* orientation is more prevalent in individualistic cultures, such as the US, than in collectivistic or consensus-oriented cultures like Germany or Japan.

Likewise, they expect that an innovative orientation (*innovativeness*) is more prevalent in low uncertainty avoidance cultures than in high uncertainty avoidance cultures. However, since neither internal locus of control nor innovativeness alone is sufficient to explain entrepreneurial motivation, they also proposed that individuals with both an internal locus of control and innovative orientation should appear more frequently in highly individualistic and low uncertainty cultures.

Recently, Tajeddini and Mueller [2009] provided an inter-cultural study focusing on technology entrepreneurs. Their comparative analysis of high-tech entrepreneurs in Switzerland and the UK was undertaken to determine the extent to which they differ in terms of entrepreneurial characteristics. They revealed that some entrepreneurial characteristics such as *autonomy, propensity for risk, and locus of control* are higher among UK techno-entrepreneurs while other characteristics such as *achievement need, tolerance for ambiguity, innovativeness, and confidence* are higher among Swiss techno-*entrepreneurs* (cf. Table I.38).

Management and leadership in different cultures is also an area to deal with. Here a key indicator is power distance. The author's experience of working for eighteen years in a large US company is corroborated by Gorlick [2009]. Some aspects refer to *open disagreement* and what is called "*open constructive critique*" as a habit in Germany. In the US no-one would simply stand up and contradict openly a superior or senior one.

There is a stronger awareness for hierarchies in the US than in Germany. In the US, if the most senior person makes a statement, there is no further discussion about it; it is just accepted.

For instance, at the Kodak company there is (still is?) a hierarchical culture that believes in the omnipotence of leadership. It is so powerful a habit that when Antonio M. Perez came to Kodak from HP in 2003 as chief operating officer, he could not get people to openly disagree with him. "If I said it was raining, nobody would argue with me, even if it was sunny outside," he lamented [Business Week 2006]. Furthermore, in the US supervisors and colleagues sense a lack of leadership if it takes too long to achieve agreement and if negotiations take too long.

Basically, for entrepreneurship and intrapreneurship in the US versus Germany one should stress two important differences.

- Action-oriented attitude:
  For Germans a plan must be totally complete (100 percent), for Americans 80 percent will suffice to start.
- Science- and research culture and market-oriented attitude:
  Preference of perfecting technology or technical offerings (Germany) over customer contacts (US – but cf. overshooting, Figure I.88).

There are particular views about the way people from other nations do research or engineering. For instance, an American view of Germans was, for instance, expressed in the context of the SAP enterprise resource planning (ERP) system (A.1.4) as follows: "SAP is like everything German. It's over-engineered, with more options and flexibility than ever seen before." [Runge 2006:393]

In some cultures, *failure* is seen as a positive learning experience, while in others it has a certain negative stigma attached. Fear of failure is often considered an important cultural component that is detrimental to new firm activity. The US culture tends to reflect the first situation while the German culture the last one. All this plays important roles for entrepreneurship and intrapreneuship.

Fear of failure is above average in Germany compared to other countries. But this above-average fear of failure seems to be a matter of risk awareness. According to a survey, when asked for reasons for abandoning a startup project, would-be entrepreneurs mentioned extensive financial risk more often than fear of dropping in social status [Metzger 2007]. Fear of failure is usually higher during economic recessions as the implications of failure are larger: There are fewer alternatives available on the job market for those who will not be able to make their startup venture sustainable.

In this regard, risk-taking as an expression of national culture American entrepreneurs have a higher level of risk-taking than the German ones. And also angel investors (business angels) in Germany concerning investing in startups are more risk-averse than their counterparts in other countries [Fryges et al. 2007]. Tellingly, venture capital is also called "Risikokapital ("risk capital'") in Germany."

Finally and particularly relevant for technology entrepreneurship with its high level of highly educated persons (ch. 2.1.2.4) learning and speaking/understanding foreign languages is more prevalent with the German culture with its long-standing global business and export orientation than with the US culture.

Culture and societal attitudes also affect financial behavior of entrepreneurship. For instance, it was not unusual in the US before the Great Recession and credit crunch to found a firm based on personal charge (credit) cards (Table I.23), for instance, founding an IT-firm with a financing requirement of ca. $50,000 making use of ten credit cards [Newton 2001; Fergerson 2007; Rosenfeld 2007; Cramer 2008]. This is unthinkable in Germany – referring to cultural attitudes and habits irrespective of the fact that in Germany debts on credit cards must be repaid fully after one month.

Cited by Runge [2006:393], over 170 years ago Alexis de Tocqueville commented on the broader issue of the role of science and the attitudes toward science in the young US republic that he visited in the 1830s which still governs European views on America's approach to science and innovation to a large extent.

> "In America the purely *practical part of science* is admirably understood and *careful attention is paid to the theoretical portion, which is immediately requisite to application*. On this head, the Americans always display a clear, free, original, and inventive power of mind. But hardly any one in the United States devotes himself to the essentially theoretical and abstract portion of human knowledge ... *every new method which leads by a shorter road to wealth, every machine which spares labor, every instrument which diminishes the cost of production, every discovery which facilitates pleasure or augments them, seems [to such people] to be the grandest effort of the human intellect*. It is chiefly from these motives that a democratic people addicts itself to scientific pursuits. ... In a community thus organized, it may easily be conceived that the human mind may be led insensibly to the neglect of theory; and that it is urged, on the contrary, with unparalleled energy, to the applications of science, or at least to that portion of theoretical science which is necessary to those who make such applications." (Emphases added)

Particularly with regard to technology entrepreneurship *societal attitude toward the scope of scientific inquiry and applications*, such as genetically modified objects (bacteria, microbes, plants, etc.) or stem cells, and technical novelty can play a key role. And there are also differences in attitudes and readiness to use new software products or software systems and privacy of social data on the Internet between Americans and Germans (ch. 3.4).

Notably professional *social networks* will be affected by national cultural differences and particularly by the "*business culture*" (ch. 3.4.2). In the context of entrepreneurship "*business culture*" is important which does not only concerns general cultural differences of social interactions, but focuses specifically on customer contacts, meetings, communication style, negotiating, selling, bargaining and team work.

An important aspect for technology-based firms with business implications observed across the countries is the discipline- and epistemology-related *cultural difference between functional units of a firm*, such as Research & Development versus Marketing & Sales or Manufacturing.

In particular, the culture of science or research personnel emerges with some very special features [Runge 2006:626-630]. Some fundamental epistemological differences of physics, chemistry and biology (ch. 1.1.2, Figure I.2) which form also communication barriers for interdisciplinary research or startup foundation, respectively, are discussed by Runge [2006:212-216].

Considering all these findings it must be reconsidered, however, that many studies emphasizing cultural effects for entrepreneurship disregard special emphasis on the part of the population of interest for technology entrepreneurship and simultaneous influences from other subsystems (Figure I.13), such as national political programs for entrepreneurship and the roles of the financial subsystem and the "Science & Technology" subsystem.

Here, usually combined effects of the national culture, economic and financial system (Nippon-Rhineland, Anglo-American style) and political (including military) effects are operative and separable only for some cases. This is seen in particular with regard to the eminence of the US in IT and biotechnology which emerged during the 1980s and 1990s.

For instance, "… some observers have concluded that the strong US performance in innovation cannot be satisfactorily explained simply by the combination of entrepreneurial management, a flexible labor force, and a well-developed stock exchange. The US experience has not been repeated in the other Anglo-Saxon country with apparently similar characteristics – the UK." [Tidd et al. 2001:93]

"Many argue that the groundwork for US corporate success in exploiting IT and biotechnology was laid initially be the US Federal Government, with the large scale investments by the Defense Department in California in electronics or the National Institutes of Health (NIH) in the scientific fields underlying biotechnology." [Tidd et al. 2001:93] (cf. also [Lécuyer 2001]). Policy plays a role through legislation and regulations, financial sources or as a customer.

As a study by the Breakthrough Institute notes, after the microchip was invented in 1958 by an engineer at Texas Instruments, "the federal government bought virtually every microchip firms could produce." This was particularly true of the Air Force, which needed chips to guide the new Minuteman II missiles, and NASA, which required advanced chips for the on-board guidance computers on its Saturn rockets. "NASA bought so many [microchips] that manufacturers were able to achieve huge improvements in the production process – so much so, in fact, that the price of the Apollo microchip fell from $1,000 per unit to between $20 and $30 per unit in the span of a couple years." [Zakaria 2009]

In a similar way, with regard to efficiency, the important role of policy/military for the national innovation system has been observed for Germany between the two world wars and described for the chemical industry by Runge for synthetic fuel and rubber [2006:270-272,424-425] and the same occurs now globally for CleanTech like photovoltaic and solar cells and specifically for the biofuels area in the US (Figure I.34; A.1.1).

For technology entrepreneurship not only the above “mega-systems” are relevant but also “micro-systems” of the national S&T System. For instance, in Figure I.36 it is shown that the numbers of origins of spin-outs in Germany are very low for the federal research centers of the Helmholtz Society and other federal research institutes. This is attributed to a large degree to the fact that (science and engineering) employees usually have the status of “civil servants” with very high job security and they are very risk averse. Furthermore, employees are conditioned by the significant bureaucracy of these large organizations.

A similar situation seems to apply to the US. For instance, as part of a congressionally mandated review of science and management performance at Lawrence Livermore and the other two big national security labs, Los Alamos and Sandia, one can read:

“Lawrence Livermore National Laboratory has made good on its major defense and science commitments. However, continuing bureaucratic challenges and increased costs associated with a 2008 contract change have reduced its efficiency, lowered morale among employees and made it much harder to work with federal agencies outside its traditional sponsor, according to Lab director George Miller.” [Garberson 2011] And more drastically, for the Los Alamos National Laboratory (LANL), the perception is:

“The bureaucracy here is horrible. LANL has an enormous support staff, creating enormous overhead, but many of these people are not very productive. It seems that a major part of the LANL mission is to provide jobs for northern New Mexico.” [glassdoor 2010]

Culture Conditioned by Higher Education

A final remark for technology entrepreneurship and intrapreneurship shall concern “professional culture” and “functional culture,” for instance, expressed in large firms by behavior and attitudes of people from R&D/science versus engineering or marketing people [Runge 2006:242].

For technology entrepreneurship the differences between scientists and engineers are particularly striking and are one essential basis for the differentiation between academic and technical entrepreneurs (ch. 1.2.6.1). The effect shows up markedly even between research chemists and chemical engineers. Chemical researchers’ perception of chemical engineers is often one of hard-hat wearing plant operators [Van Noorden 2009]. How much chemists and chemical engineers rely on one another’s support is seen for the biofuels fields (A.1.1), where today’s innovative chemistry requires a good appreciation of the interplay between molecular behavior and process engineering.

The educational and cultural differences between scientists and engineers, specifically chemistry scientists and chemical engineers, are a topic of considerable interest and debate in (technical) universities. Obstacles to bridge the divide between chemistry and chemical engineering were summarized by Poliakoff et al. [2009]. Such educational and cultural differences form a basis for differentiating RBSUs and EBSUs.

Research culture is discussed by Runge [2006:242,627-629] and also differences between scientists and engineers [Runge 2006:626]. An *engineer* is a *problem-solver*, looking for a solution that may not be labeled by a particular name. He/she starts with the function of what he needs. He/she searches for the right device by looking for the attributes it must have. Engineers collect much of their advanced technical information in discussions with vendors, salesmen, consultants and other engineers. They are more likely to engage in "interpersonal communications" rather than writing structured memos, reports, project proposals and papers.

In the traditional view "engineers" are basically "realists." The "realist" is the planner who takes a practical approach to design. He/she is a "doer," willing to put partial plans and solutions into effect. Imperfect action is better than no action at all. To the realist there is no need to prove the premises of a plan as long as the plan works and accomplishes one's objectives.

On the other hand, the "scientist" is more of an "idealist." The "idealist" does not accept a theory unless the premises on which the theory is built can be proven correct or acceptable. To the idealist there is an absolute good and perfect. Differences between scientists and engineers are viewed as smallest for the field of applied physics [Blochwitz-Nimoth 2008:52]. A structural comparison (a "more realistic view") between a scientist and an engineer is provided by Campbell [2007] in Figure I.62.

Mission-oriented work attracts a greater percentage of engineers. Characteristics of engineers are also often found with "process researchers," "technical sales" and "technical service" (TS) personnel. In particular, "TS folks" have bents towards verbal communication, personal contacts, "fire fighting," and they often like traveling.

Scientists…	**Engineers…**
▪ create knowledge	▪ create knowledge
▪ are problem driven	▪ are "real world problem" driven
▪ seek to understand and explain, get insight	▪ seek to understand and explain
▪ design ***experiments*** to test theories	▪ design ***devices*** to test theories
▪ prefer ***abstract*** knowledge	▪ prefer ***contingent*** knowledge
▪ … but rely on tacit knowledge	▪ … but rely on tacit knowledge
	▪ put plans together for projects to be implemented in the "real world" starting with a "project proposal"; link projects with costs

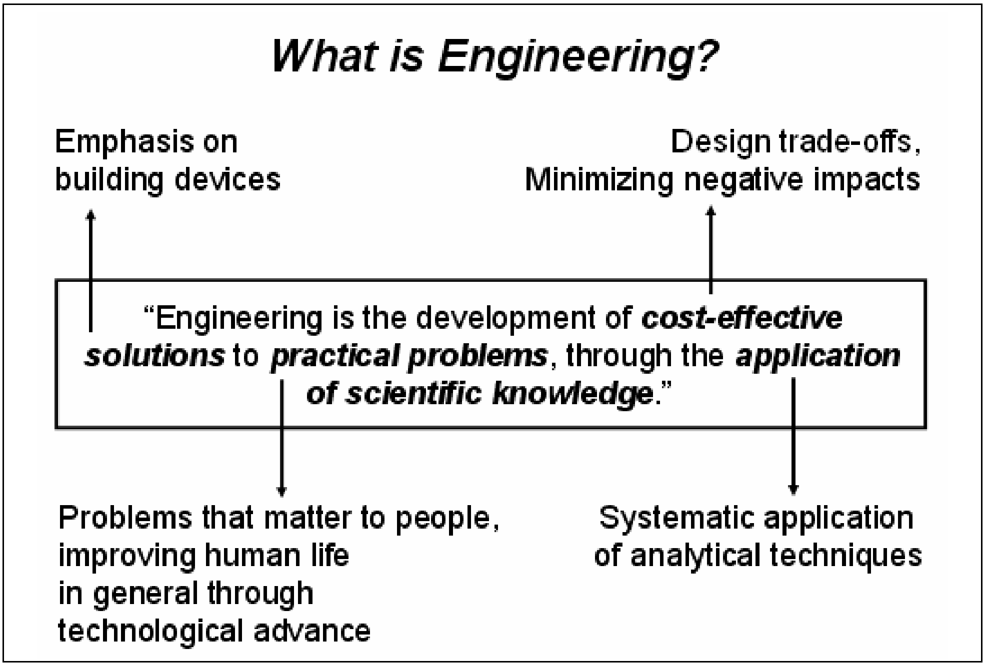


Figure I.62: Differences between scientists and engineers. Courtesys of Jennifer Campbell and Steve Easterbrook, University of Toronto [Campbell 2007].

Generally, communication between disciplines and corporate functions is hindered by the various "special languages" and jargon, but there are other important obstacles. A systematic overview of the tremendous cultural differences between R&D and Marketing personnel in large firms with regard to work environment and professional orientation is presented by Tidd et al. [2001:295].

For instance, the "cultural mismatch" between R&D and Marketing may affect input into new product development. Most market research and marketing on new products is done in the first third of the innovation process. As a rule of thumb, the selling chance of a product is determined to 70 percent by the definition of the requirements. Gathering product specifications and product performance requirements is often established by Marketing or even seen as one primary responsibility of Marketing.

The Marketing culture, however, has usually a large "tolerance" for numerical data and, therefore, technical specification data collected by Marketing/Sales personnel often lack precision that is needed for product development by researchers and developers. Ill-defined, incomplete or imprecise product specifications or misconceptions of specifications and related product performance problems in particular are one major reason for project cost overruns and delays or even project failure. Problems also arise from late reporting of specification's changes by Marketing.

Though being rather stable time developments of culture are often assumed to be reflected by certain “periods” which may be related to the German concept of “Zeitgeist.” This concept relates to the idea that society consists of a collective consciousness which moves in a distinct direction, dictating the actions of its members (cf. Goethe’s definition in the Glossary).

One can say that national culture represents the fundamental background for attitudes and behaviors, but its expression may be overlaid by particular time-specific events affecting the surface of the cultural background. This has been told us by William Hewlett, one of the founders of HP (Hewlett – Packard, founded in 1939):

> “As I talk about the start of the company, it is important to remember that both Dave {Packard} and I {William Hewlett} were products of the Great Depression.” [Hewlett].

Additionally, the development of HP was perturbed and shaped by World War II.

And Dietmar Hopp, one of the founders of Europe’s largest software firm SAP AG (founded 1972; A.1.4) tells us [Nonast 2006].

> “What is often forgotten today is that we had time for develop ourselves. We had our diligence, our capacity to work hard and our will. And that sufficed in the 1970s. Today this does not suffice anymore. Young entrepreneurs in the software industry are chased from the beginning and have to deal with venture capital funds and must deliver numbers and reports instead of taking care of the business.”

One can expect that the late Great Recession (2007-2009) will have a profound influence now and on entrepreneurial expectations, operational fields and behavior in the following period. The US is an interesting example since the crisis started there and its impact on the country seems to be substantial.

The Global Entrepreneurship Monitor (GEM) provides the evolution of overall (technical and non-technical) entrepreneurial attitudes, activities and aspirations in the US working age population from 2001 through 2009. Consistent with general findings, the American population appears to have acted from around 2006 as if it anticipated trouble ahead. From 2006 through 2009, fear of failure rose, as did the share of necessity-driven entrepreneurship, while nascent entrepreneurial activity dropped from a high of 8 percent in 2005 to 5 percent in 2009. While new entrepreneurial activity is a smoothed measure, it too showed a decline. The discontinuation rate showed no deviance from the long term trend in 2009. Four different measures of entrepreneurial aspiration also declined during this period [Bosma and Levie 2010].

For Germany consequences of the recession for technology-based firms are available [Creditreform - KfW - ZEW 2009]. Accordingly almost half of the young firms (48 percent) investigated for a study (by summer 2009) reported negative effects. Only a minority (9 percent) said to be able to utilize the recession positively. Major reported drawbacks concerning orders and the revenue and profit situation. 41 percent of the new firms suffered from decrease of orders, just 8 percent exhibited an increase of orders. Similar proportions were reported for revenues and profits (43 to 7 percent; 40 to 7 percent).

A final remark concerning the role of society and culture and comparing their relevance for entrepreneurship in different countries shall be kept in mind. Each society and culture has its own stories, legends and myths for the various situations of life and history – and this is also true for entrepreneurship: First who invented or discovered something or a technology, second who and how technology was applied etc. This enters often as a bias in the related popular literature and other media and even in the scientific literature.

For instance, Drucker referred to the myth of the US being the best in practicing entrepreneurship way ahead of other countries (ch. 1.2.4). Furthermore, there is a cultural tendency extending to firms to assume that superiority of the US in science as expressed by the number of Nobel Prize winners translates directly into superiority in innovation which are unrelated categories.

A very typical phenomenon on the firm level resulting from related attitudes has translated into the "*not invented here*" (NIH) syndrome [Runge 2006:374, 686] which means good ideas or suggestions from outside are resisted or rejected.

2.1.2.4 Education, Age and Work Experience of Technology Entrepreneurs

Experience is not what happens to a man; it is what a man does with what happens to him.
Aldous Huxley

Erfahrung ist nicht das, was einem zustößt; Erfahrung ist, was du aus dem machst, was dir zustößt.

American technology entrepreneurs are young college dropouts – often from prestigious universities – who start companies often out of their garages; so goes the stereotype, reinforced by tales and examples, such as Bill Gates (Microsoft) Steve Jobs (Apple), Larry Page and Sergey Brin (Google) and Mark Zuckerberg (Facebook).

However, startup hotshots are older and more educated than generally thought. Twice as many technology entrepreneurs start ventures in their 50s as do those in their early 20s. For instance, a technical entrepreneur will have around 13 years of work experience before establishing an NTBF. There is no ideal pattern for previous work experience. However, experience in development work appears to be more important than work in basic research (for instance, to found an RBSU). Due to the formal education and the enabling experience a typical technical entrepreneur will be aged between 30 and 40 years when establishing his/her first NTBF [Tidd et al. 2001:355].

> Overall, one finds an importance of the classic human resource factors – schooling/education, age, and experience.

According to a recent study in the US based on a sample highly concentrated in technology sectors (Figure I.63), with the emphasis on computer hard- and software and engineering consulting, the following findings emerged [Wadhwa et al. 2009].

- The average and median age of company founders when they started their current companies was 40 (median age of technology company founders were 39).
- 95.1 percent of respondents themselves had earned bachelor's degrees, and 47 percent had more advanced degrees (a doctorate being superfluous).
- The majority of respondents (75.4 percent) had worked as employees at other companies for more than six years before launching their own companies.
- The majority of the entrepreneurs in the sample were *serial entrepreneurs*. The average number of businesses launched by respondents was approximately 2.3; this means early interest and propensity to start companies.
- But 41.4 percent of the sample was running the first business they had started.

The US study is meant to be illustrative of the backgrounds of entrepreneurs in industries that are expected to show higher growth.

Results of a German study based on a sample of NTBF foundations in 2005-2008 correspond largely to the above findings [Creditreform - KfW - ZEW 2009]. Founders were on average ca. 40 years old. And in the sample 35 percent of the firms' foundation had at least one *serial entrepreneur* (in Germany called "restarter") as a founder. Founders had 13.2 years experience in the industry or particular segment, respectively, in which their firm operates. The US study did not focus on average time working as an employer (instead, it states that 75.4 percent had worked as employees at other companies *for more than six years* before launching their own companies).

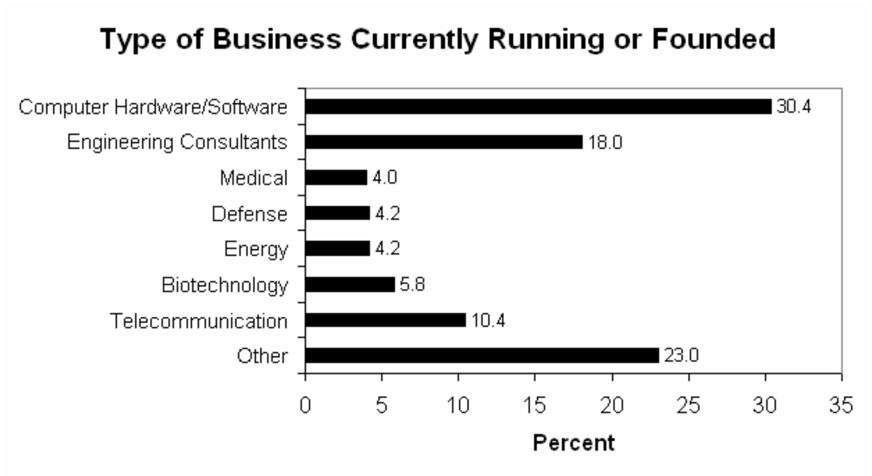
A specific reflection of this situation is seen in the biofuels fields where the notion of "veteran technology entrepreneur" can be introduced to characterize entrepreneurs or a "veteran management team" having members with 45+ years of age and with 15+ years of experience in the oil/petroleum industry or biobased chemical/bioplastics industry or a closely related industry (A.1.1).

Disregarding the many founders from I&CT in their mid twenties or, at least fewer than 30 years (Google, Facebook, Xing, and Gameforge), also academic founders from science and technology show up who will be under 30 or even under 25 years. But often they appear as co-founders with senior co-founders (SiGNa Chemistry, Inc. (B.2), Cyano Biotech GmbH and Cyano Biofuels GmbH (Box I.25).

Founders of RBSUs in Germany are ca, 30 years old.

Concerning the high-tech area and the highest level educational degree of one the firm founders the US findings (Figure I.63) reflect qualitatively those in Germany (Figure I.45).

Survey of 549 Company Founders:



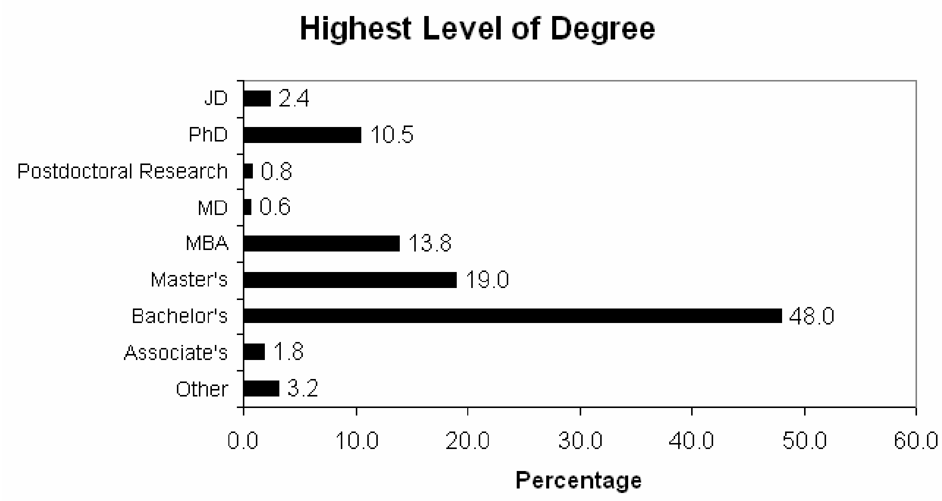


Figure I.63: Highest level educational degree of one the firm founders in the US for types of business investigated [Wadhwa et al. 2009]; courtesy of Vivek Wadhwa.

More than 95 percent hold bachelor's degrees or higher. A higher percentage of respondents had just bachelor's degrees (48 percent) rather than advanced degrees (47 percent). The majority comes from middle-class or upper-lower-class families. Respondents from a "lower-upper-class" background" are more likely to be driven by wealth or wanting own a company and are interested in entrepreneurship during college. Serial entrepreneurs are extremely interested in starting business in college and motivated by wanting to own a company. The majority of the entrepreneurs (ca. 60 percent) in the sample were serial entrepreneurs.

Most technology entrepreneurs had *significant industry experience when starting their companies* [Wadhwa et al. 2009:16]. An entrepreneur may even seek intentionally to gain industry experience before launching his/her startup (Magnetfeldtechnik Resonanz GmbH [13]). A very prominent representative of the intentional approach to gain industry experience before becoming an entrepreneur is LinkedIn's co-founder Reid Hoffman (ch. 3.4.2.1; LinkedIn Corp. – B.2).

Experience plays a key role when people are confronted with options that will shape behavior and, hence, will be a key for entrepreneurship. And success stabilizes routines in decision-making and behavior (ch. 4.3.5.2).

Entrepreneurial ventures by ex-employees of an incumbent firm are widespread in industries. Founded by former employees of an incumbent firm, these independent *initially new ventures*, not owned or controlled by an established organization, compete often in the same industry as the parent. They have no equity relationships with any incumbent. This contrasts with an intrapreneurial *corporate spin-off* which is controlled by the parent, usually by equity relationships, and often focused on the identification and exploitation of previously unexplored opportunities and products for the parent – "new-to-the-firm" or even "new-to-the-world."

The incumbent firm may be a large to giant existing firm or even an NTBF. For instance German Q-Cells (Figure I.152, Figure I.153) active in photovoltaic was formed by ex-employees of Solon AG when two of the Q-Cells founders already participated in the foundation of the photovoltaic firm Solon. The German startup IoLiTec GmbH focused on ionic liquids was formed by a former employee of the ionic liquids NTBF Solvent Innovation GmbH (A.1.5; B.2).

Entrepreneurial NTBF spin-outs may be created voluntarily and intentionally by ex-employees of an industry firm as a result of having revealed an opportunity ("*opportunity entrepreneurs*") or by enforcement, for instance, through a lay-off ("*necessity entrepreneurs*").

They may work in an area of their former employers or in a different field. The first ones may pose a special threat to incumbents since the founders can capitalize on knowledge gained from discoveries made during the course of their employment in incumbent firms and, intending to operate mostly in the same market, may even capitalize on contacts to customers. Knowledge possessed within an existing organization is typically viewed through the lens of competitive advantage.

Furthermore, affiliation benefits may make it easier for employees of leading firms to raise the financial and other resources needed to start their own new ventures. Recent examples of necessity entrepreneurs, their activities and opinions, resulting from lay-offs in the US pharmaceutical industry are described by Ainsworth [2010].

A very different situation of becoming a necessity entrepreneur was observed after the German Reunification in 1991. Then many necessity entrepreneurs emerged in the former socialistic Eastern part of Germany out of science when their research institutes were closed and they had to enter a capitalistic commercial or industrial environment (cf. as IGV GmbH (A.1.1.4) or ASCA GmbH, B.2).

However, employees leaving a large firm to found their own firm in the same industry are not necessarily viewed as a potential competitor. On the contrary, if the entrepreneurial NTBF spin-out will occupy a niche, the parent company (or even the whole industry) may welcome the offerings of the entrant as a complement, and the parent may even become a customer of the NTBF. An example is provided by the German firm Polymaterial AG (B.2) which emphasizes contract R&D and medium-scale production.

As a consequence of being laid-off, capitalizing on the vast knowledge and experience obtained in industry, necessity entrepreneurs in technology often start as self-employed consultants with options to work for competitors of their former employers. On the other hand, starting as a consultant, gaining here knowledge and experience and then change over from corresponding services to other “hard” offerings, such as products, is a not so rare route of technology entrepreneurship to NTBFs (Quiet Revolution, Ltd. (Table I.60; B.2), ChemCon GmbH (B.2), PURPLAN (Box I.21).

Though limited by the focus on a single industry an investigation by Agarwal et al. [2004] on entrepreneurial NTBF spin-outs in the disk drive industry provides some fundamental evidence to describe the situation of entrepreneurial NTBF spin-outs which operate in the same or a closely related area of the former employer and which can refer to a knowledge and behavior legacy that links incumbent parents to spin-outs.

- As employees internalize an organization’s culture (Figure I.17, Figure I.20), they imbibe procedural and declarative knowledge related to functional capabilities, such as R&D and Marketing. And it is suggested that prior employment affiliations may influence not only new venture formation, but also product-market strategies and firm survival.
- Organizations with abundant, but underexploited knowledge are especially fertile grounds for entrepreneurial NTBF spin-out. An imbalance in an organization’s focus on value creation and value appropriation increases its likelihood of generating spin-outs.
- Evidence supports the idea that it is not abundance of knowledge *per se*, but its utilization that determines spin-out generation.
- Further, direct links to industry knowledge through founders seem to better facilitate the integration of this knowledge than grafting knowledge through hiring employees with industry experience. (cf. also the biofuels situation; A.1.1).

- In terms of a key performance dimension, it was found that spin-outs survived at a higher rate than any other form for entrant into the industry, thus supporting the notion that their entrepreneurial form and origin from incumbents endow spin-outs with greater motivation and capabilities.

Fundamental and special experience can be gained from work in industry, particularly working in leading positions for “New Product Development” (NPD), for “New Business Development” (NBD) units, working in or for a firm’s intrapreneurial corporate spin-offs – or having worked in the R&D *and* Marketing functions.

Working in NPD or NBD means essentially experience in R&D or innovation project work (ch. 2.2.1, ch. 2.1). Industrial experience is also the most important factor to develop new product innovation and solving technical problems in existing firms (ch. 3.1). New knowledge that results from technological breakthroughs or customer insights is the fountainhead of new firm entry.

> An important experience gained through working in industry is working in and with teams.

Prior industrial experience usually comprises an additional type of experience, having encountered an economic recession and having observed how the firm overcame the situation or having actively participated in a firm’s “survival” during such a crisis.

> In particular, required management skills to deal with a recession are quite different from working in economic good times and for a firm’s growth.

A different situation for “entrepreneurs with prior industry experience” or prior entrepreneurial experience is represented by the special category of *serial entrepreneurs.* Serial entrepreneurs have already started a company or were self-employed before starting another one. Serial entrepreneurs have sold or closed down a business in the past which they at least partly ran and owned and who currently run another, possibly new business which they at least partly own (ch. 2.1.2).

Extremely successful serial entrepreneurs who have created considerable wealth often act simultaneously as angel investors or venture capitalists, such as Reid Hoffmann (ch. 3.4) and Vinod Khosla (A.1.1.5) in the US. Similarly, in Germany one of the founders of SAP AG runs a venture capital organization, Hasso Plattner Ventures, for companies in the IT and CleanTech fields throughout Europe and Israel.

Serial entrepreneurs can either rely on generic pieces of entrepreneurial experiences if they start a further firm of quite different characteristics, such as a startup in an industry different from that of the previous firm or a startup with a different type of offering or starting in the same industry (“*activity-related experiences*” versus “*activity- and subject-related experiences*”).

A striking example of activity-related experiences as the basis for a new business is the German Opolka twins who started with a successful trading business of knives and cutlery (with production in China) before they turned to a globally leading light emitting diode (LED) lamps business relying on a large production facility in China (Zweibrüder Optoelectronics GmbH; B.2).

Serial entrepreneurs often have the important experiences of *financing* a startup. And additionally, if having been successful in the past, they will have gained *reputation* and *credibility* with investors or lenders and *contacts* in the business community. Hence, serial entrepreneurs have a huge advantage over novice entrepreneurs.

Special serial entrepreneurs shall be termed "*start-over entrepreneurs*" if they start a new business in the same or closely related area as the previous one. Examples from the author's sample include the sequence from AgraQuest to Marrone Bio Innovations (MBI) (founder P. Marrone) in biopesticides or from Solon to Q-Cells (ch. 4.3.5.2) in photovoltaic. AgraQuest is Pam Marrone's entrepreneurial NTBF spin-out after having worked on biopesticides in industry [Dorf & Byers 2007].

Serial entrepreneurs have gained experience in

- Financing a startup,
- Execution of entrepreneurial activities including often managing through an economic recession, managing "survival mode,"
- Keeping goal or mission persistence (ch. 4.3.2),
- Following opportunistic adaptability.

Opportunistic adaptability [Bhidé 2000:18] means to "adapt to unexpected circumstances in an 'opportunistic' fashion."

A further important aspect of gaining experience for a serial entrepreneur is if his/her startup did not succeed which means *learning-by-failure* (Table I.7) and if he/she tries again and launches another startup.

> "Failure is the opportunity to begin again, more intelligently." (Henry Ford)

For serial entrepreneurs failure is always a reality, but it is never a deterrent. A serial entrepreneur is always open to the risk of failure. They have a lot of energy and confidence that sets them apart from the "tire-kicker" entrepreneur types. Since serial entrepreneurs are clearly doing something right, it behooves us to understand them.

The scale of serial entrepreneurship is significant. In Germany they contribute ca. 35 percent to technology entrepreneurship (Figure I.65 and related text), the proportion in the US sample was much higher, ca. 60 percent. Serial entrepreneurs show up widely in the biofuels field (A.1.1).

There is an analysis comparing novice and experienced entrepreneurs concerning financing issues. Financing problems may arise for many reasons. Information asymmetry and uncertainty are important, but so are such things as ignorance.

Though not representative for technology entrepreneurs, Metzger [2007] found some general insights into significance of experience to deal with issues of financing startups. The relevant survey from 2003 referred to 40,155 individuals of the German population and 1,125 individuals answered in the affirmative when asked if they had become self-employed during the last twelve months.

Founders of the Metzger [2007] study often had big problems with firm financing issues. According to the study experienced entrepreneurs have more knowledge about financing issues and are more likely to know whom to turn to for help and advice. Thus, they have advantages over novice entrepreneurs when it comes to financing. Experience has some effect on the probability of utilizing different financing sources and the relative extent to which each is used (Figure I.59. Table I.30).

Experience can also be gained by education in business or by practicing business. For instance, in the US we hear from Chad Hurley, a co-founder of YouTube, with a degree in art from Indiana University of Pennsylvania after having studied design how he remembers his days with the Internet company PayPal (A.1.7) as an *education in business* [O'Brien 2007]:

> "You may not have a business degree, but you see how to put the process into effect. The experience helped me realize the payoff of being involved in a startup."

In Germany Lars Hinrichs, the founder of Xing (ch. 3.4.2.1, B.2) added:

> "I have studied {at a university} exactly one day and then founded my first company. Almost everything what I know I have learned from other entrepreneurs." [Helterhoff 2007]

There is another level of gaining experience, not from personal employment in industry, but through contacts to, cooperation with or common projects with industry while still being affiliated with a university or public research institution. Though usually not a coherent set of experiences, a whole spectrum of enabling and facilitating pieces of experience can be gained. As described in detail in Appendix (A.1.3) under the heading of academia-industry technology transfer various valuable constellations are possible, not only for academic entrepreneurship, but all kinds of entrepreneurs.

- Working in a joint organization of a university or other public research institute and industry firm, usually led and managed by industry, such as a public-private-partnership (PPP)-firm,
- Working in a joint research or development alliance (project) of academia and industry
- Working in academia on an industry project, for instance, for a doctoral thesis
- Working in academia-industry arrangements of sharing personnel, for instance, in a "lab on campus" or industry "project house" or working as a "guest researcher" for a period of time in an industry laboratory.

Rather than gaining experience role models provide learning options for potential technology entrepreneurs. The basis is the "psychological identification" with the model – by which an individual unconsciously endeavors to pattern him-/herself after another and a person's behavior for comparable situations. Such role models are provided, for instance, by the presence of *entrepreneurial role models among faculty*, the "entrepreneurial professor" who builds and influences the entrepreneurial climate of the department, the culture, and who may also act as a mentor (Figure I.120).

A typical constellation for founding a new firm may comprise a post-doc or even a graduate student and the "entrepreneurial professor" as an entrepreneurial pair or part of a team. In the course of development of the startup the professor may continue to stay in the startup's management team or change over to the advisory board. Examples among the cases of this book include US SiGNa Chemistry and mNemoScience (B.2) in Germany, the last one comprising the famous MIT professor Robert Langer and a German post-doc (Andreas Lendlein).

With regard to the impact of *role models,* such as *family members or entrepreneur's friends*, for the US Wadhwa et al. [2009:15] found that 37.8 percent of respondents indicated these played an important, very important, or extremely important role in the decision to start a company. Also in Germany a significant part of technology entrepreneurs have entrepreneurial parents (or relatives) or self-employed parents.

A notable example is female entrepreneur Katja Heppe (Germany; now Katja Richter, born Heppe) who co-founded Heppe Medical Chitosan GmbH (B.2). Chitosan is one of the most common polymers found in nature. Her parents are not only highly educated (a professor and an engineer), but they also founded "BioLog GmbH" (with a subsidiary Heppe Biomaterial GmbH, Europe's largest producer of natural product chitosan). She gained (enabling) experiences in her parent's firm and filled a niche in the chitosan field, by offering high pure chitosan of consistent composition or nano-chitosan with application in cosmetics and pharma and contract production of customized chitosan specialties.

There are also types of role models which do not relate to the social environment of a to-be entrepreneur. It could be other entrepreneurs. For instance, Scott Rickert, the founder of US Nanofilm LLC (B.2) referred explicitly to Herbert H. Dow, the founder of The Dow Chemical Company. In this case *biography* acts as a driver for entrepreneurship. Examples of contemporary entrepreneurs may also serve as role models which affect intention. For instance, J. Koenen, a co-founder of WITec GmbH, emphasized the significance of an entrepreneurial example through strengthening self-confidence and self-motivation: "If he/she can do it, I can do it too." [Koenen 2010]

Figure I.64 lists a number of possibilities to get "*enabling experiences*." Particularly striking in Germany is the fact that incubation processes (ch. 1.2.6.2) via Fraunhofer institutes and universities of applied sciences (Vitracom AG, Novaled AG; B.2) with their stronger orientation towards application and commercialization are obviously particular successful (Figure I.36, Figure I.38, Table I.20, Table I.21).

Figure I.64 provides a summary of the key constellations for technology entrepreneurs to gain experience. The types of experiences given in Figure I.64 are non-exclusive. For instance, Pamela Marrone founded AgraQuest as an "entrepreneurial NTBF spin-out" and then Marrone Bio Innovations as a "start-over entrepreneur."

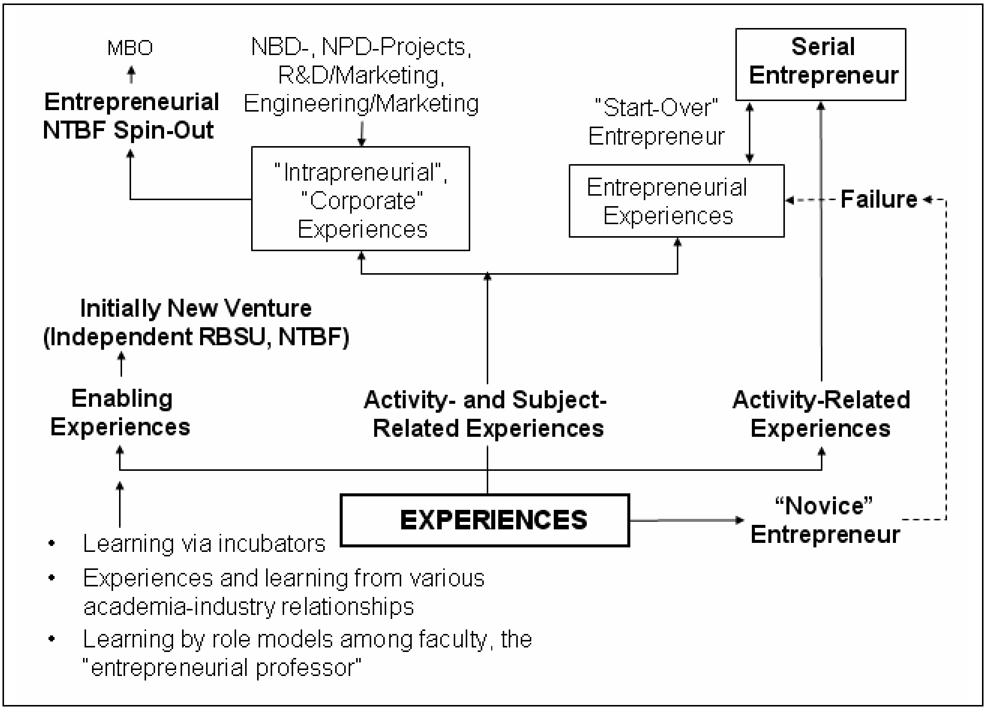


Figure I.64: Options to gain experiences for technology entrepreneurs.

The notion "*novice entrepreneur*" in Figure I.64 means an entrepreneur without any own personal experience or experience from close role models like parents. However, there are several possibilities to take advantage from technical and commercial experiences of other people, for instance,

- Help and advice from the social environment or
- Establishing a proper selection of persons to form an Advisory Board for the founded firm.

With regard to novice characteristics it seems that by education engineers are closer to entrepreneurship than scientists (Figure I.62). In particular, they often may have been in (real or simulated) projects to learn about "project proposals" which by approach come close to business plans (ch. 2.1.2.3).

Nascent entrepreneurs are typically advised to develop business plans of their projected ventures. While planning will allow entrepreneurs to generate new knowledge (through the gathering and analysis of information), it is unlikely that planning will be able to compensate for low prior knowledge of the business activity. This is because prior knowledge is needed to identify and address the most knowledgeable information sources, to ask insightful questions, to guide planning activities, to build on and challenge information that has been gathered, and to apply new information appropriately.

Experience and preexisting knowledge, particularly from technology and its applications through education, are critical to NTBF survival.

Dencker et al. [2007] emphasized that *knowledge acquisition activities* are generally critical as they enable the augmentation of existing knowledge and the exploration and pursuit of new strategic directions. Foundation and development of German WITec GmbH (Table I.41 and close-by text) and Cyano Biotech GmbH (Box I.25) represent typical cases for this situation focusing on learning-by-doing.

Referring to two important kinds of knowledge acquisition activities, knowledge acquired through *learning-by-doing* and knowledge acquired *through planning*, Dencker et al. [2007] examined the direct impact of these activities on the survival of new firms on the basis of a sample of a 2001 cohort of entrepreneurs in the Munich, Germany, region who received government assistance to support their transition from unemployment to self-employment. Their business activities were divided into three broad areas: trade and commerce (31.5 percent of respondents), freelance business activities such as consulting or Internet services (58.5 percent) and craft activities (10.0 percent). They examined the extent to which planning and learning-by-doing can compensate for low prior knowledge and/or management experience.

Dencker et al. [2007] have presented indications that planning be more useful for founders who have high levels of prior knowledge than for those who have low levels of prior knowledge, and that planning will be unable to substitute for prior knowledge. In particular, they argued that

- Learning-by-doing compensate for low levels of prior knowledge and management experience to increase firm survival rates. Learning-by-doing compensated for low levels of management experience – in the case where the founder had high levels of prior knowledge – and compensated perhaps to an even greater extent for low levels of prior knowledge when founders had high levels of management experience.
- High planning does not compensate for low levels of prior knowledge or management experience. That is, for founders with high levels of prior knowledge, high levels of planning did not compensate for low management experience, and for founders with high levels of management experience, high levels of planning did not compensate for or low levels of prior knowledge.
- High levels of planning generally lead to higher failure rates, particularly for founders who had low levels of prior knowledge and management experience.

As a consequence, for entrepreneurs lacking experience opportunistic adaptability and learning on the job (or training on demand) are indispensable.

For instance, J. Koenen of WITec GmbH (Table I.41), which had already a product buyer before the team decided to found the firm (B.2), achieved his broad spectrum of competencies only after startup by training on the job, actually training on demand ([Koenen 2010:14] and personal communication).

And also N. Fertig, co-founder of Nanion Technologies GmbH, followed learning and training on the job focusing on "need to know" (B.2). Similarly, the founders of HP, William Hewlett and Dave Packard, [Bhidé 2000:235] and SAP (A.1.4) did that, learning on the job in the early phase of the firm.

"In the early days, Dave and I tackled almost every job from sweeping the floors, to keeping the books, to inventing products, and to taking care of the general management of the company. We were very small and insignificant, and we had to employ whomever we could. We had to train them and then hope that they would work out." [Hewlett]

Similarly, Scott Rickert, founder of Nanofilm LLC (B.2), had no business experience, just ideas. But he met Donald McClusky, a retired vice chairman of the board at B.F. Goodrich. McClusky taught him business practices and invested money in the company for foundation.

Also female chemist and necessity entrepreneur Christine Welder (ASCA GmbH; B.2) learned on the job. After the German Reunification the scientific institute she was working for was closed in 1996 and she together with chemistry professor Hans Schick survived for several years with a small crew on the basis of EU grants. But in 2001 both founded their own firm, ASCA GmbH, starting with 14 employees. Schick kept the science side, but Christine Welder dived into law, marketing strategies and other aspects of business administration. Now she represents general management including human resources and finances. The firm has currently ca. 30 employees (and ca. €3.5 million sales).

Finally, also the author's experience when he became R&D Operations Manager is in line with the above observations: He grasped the needed level and needed subjects of accounting, budgeting and controlling targeted and fast by learning on the job.

This indicates that *important human resource attributes and capabilities (at the time of firm's foundation) are not always given, but are created through entrepreneurial actions in the context of the firm* (Figure I.16; cf. also ch. 4.3.3). This fits the proposition of Foss et al. [2006] based on *subjectivist theory* of team entrepreneurship.

A subjectivist theory focuses generally on individuals (subjects), on their knowledge, capabilities, and resources, and on the processes of creativity and discovery that constitute the heart of entrepreneurship. In the proposed subjectivist theory of team entrepreneurship, human resources and resource learning are key contributors to a firm's evolving bundle of productive resource services (cf. ch. 4.3.3, RBV).

Generally, by subjectivism the Austrian economist Hayek (1955) meant first, that individuals hold different preferences, knowledge, and expectations, and second, that *explanations of individual and social action* must begin with the mental states of the relevant individuals and must take into account the relevant differences in mental states. While ultimately only individuals think, act and choose, entrepreneurial judgment and discovery is influenced by context – as is viewed by GST.

Subjectivism holds that for individuals one cannot understand an individual's behavior without reference to that individual's subjective beliefs and values. "In the subjectivist approach to entrepreneurship developed here, the product of team entrepreneurship is a cognitive and creative *team* output that is *unique*" (cf. Figure I.68).

Two special paths of becoming an entrepreneur relying on experience are to buy an already operating business from its present owner – through a management buy-out or business succession.

Entrepreneurship by knowledgeable, skilled and experienced employers of a firm may take the form of a **management buyout** (MBO), a form of acquisition where a *company's existing managers* acquire an existing product line or business or the company. MBO often refers to a large firm and the management team buys out the business it manages.

Management will take a business or the company private because it sees the opportunity and it has the expertise to grow the business better if it controls the ownership. Management establishes the new firm often by the purchase of the shares in that company, often with the assistance of a private equity investor.

For MBO the management team of the new firm does not only have technical and commercial experiences as well as management experiences in the particular business, but often also keep the employees and existing customers.

MBOs represent the broader aspect of entrepreneurship concerning *changing management and/or ownership*. MBO means changing ownership but keeping management of an organization. And, if the acquisition is backed, for instance, by bank loans keeping control with the management team, there is the ability and freedom to further develop the existing business areas and to offer additional products and services to its client base. There is significant evidence of entrepreneurial effects also in the form of capital investment that would not otherwise have occurred [Ucbasaran et al. 2004].

Allowing the involved organization to be a public research organization leads directly to MBOs observed after the German Reunification associated with state-owned research organizations of the former German Democratic Republic, such as IGV GmbH (A.1.1.4).

The transfer of ownership in an existing firm is typically accompanied by entrepreneurial actions that reconfigure the way in which the firm operates. As cited by Ucbasaran et al. [2004] it was found that over a period of ten years following management buyouts, new markets and product development were reported to be the most important influences on sales and profitability growth. Examples are the cases of the German firm AluPlast GmbH (now managed by the two sons of the "founder": business succession; B.2) or the Dutch BioMCN (Table I.87; a quasi management buyout).

On the other hand, **management buy-ins** (MBIs) means *outside managers* purchase an existing organization, often with institutional finance (equity) or loans. MBI, changing ownership and management can be considered as a form of entrepreneurship.

An example is the German Hidden Champion (ch. 4.1.1) OHB Technology GmbH with a number of subsidiaries and renamed in 2011 into OHB (Orbitale Hochtechnologie Bremen) AG, the Group being restructured from five to two business units. Within the "Space Systems" corporate division the focus is on the development and implementation of space projects. The "Aerospace + Industrial Products" corporate division places emphasis on the manufacturing of products for aviation and space travel, as well as electronic data transmission. Total consolidated revenues came to €453 million in 2010 on sales of €425 million (ca. 1,600 employees). OHB addresses entirely the military/aerospace segment of a policy-driven market (Table I.15) – as does the German firm "von Hoerner & Sulger GmbH" (vH&S) which was founded by Hanna von Hoerner [Runge 2006; 482-484; Von Hoerner 2008].

In 1981/1982 the small firm Otto Hydraulik Bremen GmbH (OHB) was bought by Christa Fuchs. When her husband Manfred Fuchs, a former director of aerospace with MBB Erno, a precursor of EADS (European Aeronautic Defense and Space Company, Boeing's competitor), joined OHB in 1985 they totally transformed OHB into a firm active in the space segment. Correspondingly the firm was renamed keeping the OHB acronym as" Orbital- und Hydrotechnologie Bremen–System GmbH." OHB is still owned by the Fuchs family by 70 percent. Father Manfred is the visionary and CTO, mother Christa is the cool and critically calculating Chairwomen of the Supervisory Board and son Marco is responsible for overall operations as chairman of the Board of Executive Directors [Bläske and Kiani-Kreß 2010].

Studies have shown that the most significant contribution to organizational performance improvements emanate from managerial equity stakes rather than the commitment to servicing the debt used to finance the purchase of a business. This suggests that entrepreneurial activities are taking place in these new organizational forms [Ucbasaran et al. 2004]. Management buy-in occurs specifically for situations when for family-owned or family-controlled firms there is no member of the family who is able or willing to succeed the original founder/owner. That is the case of "*business succession*" through outsiders exemplified for the German firm KWO Kunststoffteile GmbH (B.2).

Similar to OHB, when an executive manager with broad experience became entrepreneurial also the NTBF ATMvision AG was founded by a person out of an executive management position (B.2).

The broad spectrum of levels of prior experiences of potential and actual entrepreneurs in technology entrepreneurship suggests that there is no "one fits all" or ideal pattern of previous work experience to be recommended for starting a new firm. Theory cannot be generally normative!

Actually, one can expect a rather differentiated attitude, knowledge base and behavior for the start and early development of the NTBFs, in particular with regard to team formation (ch. 2.1.2.5), other human resources and networks and the pursuit of financial resources.

2.1.2.5 Foundation Motivations – Technology Entrepreneurs and Entrepreneurial Teams as Systems

There are many (personal and socio-cultural) factors and conditions for a person (or a team) why to become a technology entrepreneur:

Why Become an Entrepreneur?

GST suggests to separate the origins into motivations by an *internal drive* versus those initiated by *external factors* which is foundation triggered by an event or by a person that inspired company creation.

Usually several factors, for instance, attitude and vision in addition to external factors, will be operative in affecting the decision to found a firm. For instance, Tidd et al. [2001:358] report indications that a high proportion of "technical entrepreneurs claim to have been frustrated in their previous job."

True motivation stems from within the individual who wants to satisfy his/her needs, wants and desires. The motivational level of a person is the product of internal motivational factors (based on needs and self-worth perceptions) as well as external motivational factors in the surroundings. An overview of these factors together with examples from firms' foundation in Table I.39 presents a non-weighted listing of reasons to become a technology entrepreneur.

Table I.39: Reasons to become a technology entrepreneur (derived from cases and descriptions).

Reason	Company Examples, Remarks
Internal Drive	
Personal Life Circumstances:	
Wealth generation, become rich (as such or for self-realization or social benefits)	By large income via the firm's profits or selling the firm to another firm or other persons Many very successful technology entrepreneurs became philanthropic.
Independence, self-employment, be your own boss	ch. 1.1.1.1
Attracted by activities in a startup or small firm culture	
Personal Motivation and Behavioral Patterns	
Determine own destiny	
Vision, dream; sometimes an obsession	ch. 2.1.2.7; ch. 2.1.2.8
Creating something new out of nothing, shaping one's development; often associated with basic attitudes	Tinkering (von Hoerner & Sulger, GmbH, vH&S [Runge 2006:482-484; von Hoerner 2008]); create something "green"
Opportunity; market opportunity, business idea	ch. 3; business idea → further specifying thoughts → opportunity
Problem-solving; improving something, referring to existing	Comparative: better (Torqeedo GmbH, Gameforge AG, B.2), different, more specific etc., results often from a "what if" question; solve societal problem; ch. 3
Like the challenge	Lift a monopoly (for porcelain, HAFB case – Box I.11 and associated text); lift customers' dependency on just one supplier; respond to a bet (Gevo, Inc.; Professor Frances Arnold of the California Institute of Technology, A.1.1.5, Table I.99)

Transfer science or technology to application	The wish to sisseminate and commercialize a technology, e.g. for the benefit of society
Business initiated by or related to a hobby	SkySails GmbH & Co. KG (B.2); GameForge AG (B.2)
External Factors	
Direct request for offering (product, service)	A considerable number of NTBFs cited in the text started with a product buyer or request to provide a particular product or service
Attracted by a "boom" or "bubble"	The German dye industry 1860-1914 (BASF, Bayer), the current German photovoltaic industry (Q-Cells, Solon, Solarworld); the Internet ("dot-com") boom/bubble, the pack of biofuels startups (A.1.1) where many entrepreneurs worked previously with other firms in this or a related area
Blocked ambition or projects in large firm	"Blocked" may mean the career ladder being hindered or blocked in a firm for any reason or rejection of an idea or proposal for a project or business in a firm and materializing this as an independent entrepreneur; German SAP founders wanted to develop "their" product within the IBM Corporations as employers, but internal infights within IBM raised frustration of the founders who then decided to do it with their own firm (A.1.4) [44]; cf. also PURPLAN (Box I.21)
Necessity	Layoff; getting out off or avoiding unemployment (ASCA GmbH, B.2)
Externally driven, internally internalized	
Role models, precedents of success	
Convinced or persuaded by others	Accepting the challenge, internalizing the "job," for instance, follow a professor's suggestion (Nanosolutions GmbH; B.2) or those of VCs (A.1.1.5)
Cultural environment	"The American Dream"

Self-realization through wealth creation and independence as reasons for entrepreneurship may be interconnected. For instance, firm's foundation can be viewed as a means to achieve self-realization. A successful founder may sell the firm to achieve independence and the financial basis for subsequent self-realization in other areas of life, William Perkin being a prototypical example of this path (A.1.2).

Precedents of success may build a *dream* which is different from a vision. A dream is sometimes all a little like people who think for software of the next Microsoft. But, there was not a next Microsoft, but Google.

If one asks the question "*why not to become an entrepreneur*," there is usually reference to one alternative – work as an employee with advantages like good salary and career options, little risk and better plannable future. However, currently students will face a corporate landscape which is different from that the generations before them encountered.

- Climate is volatile in industry associated with layoffs, mergers and acquisitions of firms, joint ventures (JVs) etc. and continuous re-organizations of firms,
- More graduates will have to look for employment by small and medium-sized enterprises rather than large companies,
- Rather few students will start and succeed in a scientific career at a university or (non-profit) research institute.

Ainsworth [2010] provides a citation of a necessity entrepreneur who characterizes the situation as follows. This is not only true for the time of the Great Recession, but will also be true for the time ahead of us.

> "We can no longer depend on large companies to support us throughout our careers." "Going through school, we were told to get good grades so we could land a job with a good company and make the best possible salary. I'm not sure we can tell our kids that anymore, because we don't know if a particular job or company will even exist in six months."

Hence, more graduates should think of founding their own firm.

To understand the motivations that underlie founders' intention to start a business via a spin-out, Villanueva et al. [2005] suggested examination of the relationship between motivations to file an invention disclosure (patent) and intention to launch a spin-out.

Indeed, this relationship has been found to be an appropriate predictor for (academic) entrepreneurial behavior. Also the desire to disseminate and commercialize the technology had a relationship with intentions to start a spin-out. And, finally, they revealed that the social good was a motivation that exhibited the strongest relationship with entrepreneurial intentions (Table I.39). This motivation can have some connection to the goal of bringing the technology to market; as the commercial and the social duty factors were significantly correlated.

Other academic research revealed further reasons for spin-out including enhancing academic reputation, enhancing prospects for future research funding, and advancing future research prospects. Commercial reasons included turning the discovery into a finished product, making it broadly available, and simply commercializing the invention. Here it is important to note that "make it available to other people" reflects that one of the reasons behind spin-out formation is the will of the inventor to make his or her invention available regardless of the financial implications. [Villanueva et al. [2005].

A recent study by Minshall and Wicksteed [2005] on spin-outs in the UK gave also a response to the question: “How do you decide when to form a spin-out?” The following points emerged:

- For platform technologies,
- For a generic technology with many different applications,
- The inventors are very keen to commercialize the technology themselves,
- When the idea needs to attract substantial investment to develop IP relating to the technology for subsequent licensing,
- When the technology is not readily licensable.

As motivations for becoming entrepreneurs in the US building wealth, owning a company, startup culture and capitalizing on a business idea emerge strongly (Table I.40). The first two reasons reflect the American Dream to start your own business and become your own boss, control your own destiny. This locus of control: makes it also likely that, if the goal is highly personal (financial), one is probably more inclined to pass ownership and control of the new firm to others (VCs).

Table I.40: Motivations listed for becoming a technology entrepreneur in the US [Wadhwa et al. 2009].

<table>
<tr><th>Motivation</th><th>Weight</th><th>Remarks</th></tr>
<tr><td colspan="3">Important</td></tr>
<tr><td>Desire to build wealth</td><td>74.8%</td><td rowspan="5">Motivations of academic entrepreneurs (from chemistry) in the UK (see also above text):

Mainly to take a good idea through to market, often in the form of a product that would be beneficial to society and the economy; also it would be a change from academic research and even fun.
Only a minority of 25% mentioned making money.</td></tr>
<tr><td>Capitalizing on a business idea</td><td>68.1%</td></tr>
<tr><td>Appeal of a startup culture</td><td>66.2%</td></tr>
<tr><td>Have always wanted to own a company</td><td>64.2%</td></tr>
<tr><td>Working for others not appealing</td><td>60.3%</td></tr>
</table>

Table I.40, continued.

Not important or less-important factors		
Inability to find traditional employment	80.3%	Only 4.5 percent said this was an important factor.
Role played by an entrepreneurial friend or family member	37.8%	For 27.9% a co-founder's encouragement was important
Developed a technology they wanted to commercialize	18.1%	

It is interesting to note that, in the US, for all high-tech foundations only 18 percent of respondents said that *taking a technology* they already had developed in the lab and trying to see if it could make an impact was an important, very important, or extremely important motivator toward their business launch [Wadhwa et al. 2009:13,15].

In the context of roles played by family members it is worthwhile to note that within the current sample of NTBFs firms were actually founded by two very close family members, such as

- A married couple, such as Avery Dennison [Runge 2006:474], Osmonics [Runge 2006:91], Cisco Systems (Figure I.145), ATMvision AG (B.2), Xing AG (B.2), OHB AG (ch. 2.1.2.4; Table I.92), CeGaT GmbH [CeGaT 2012] (B.2)
- Son and mother: Nanopool GmbH [Runge 2010],
- Brothers, particularly identical twins: ConnectU (Box I.9), Zweibrüder Optoelectronics GmbH (B.2); in biofuels Robert E. “Bud” Klepper and Kenneth L. Klepper (A.1.1.3), whose firm Kergy, Inc. was transformed into Range Fuels (Table I.99).

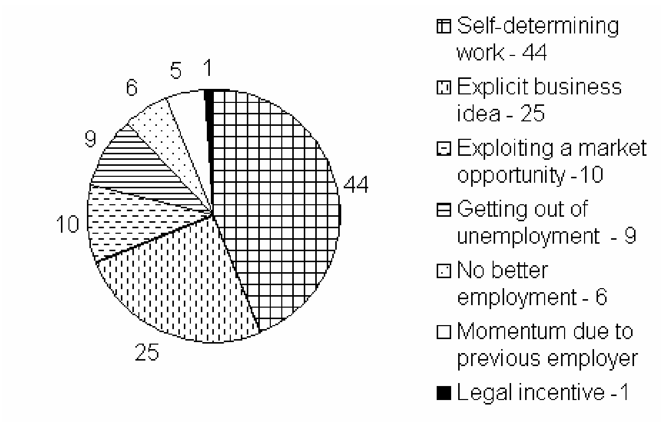
Founding motivations in research-intense industries in Germany are given in Figure I.65. Specifications for academic entrepreneurs or spin-outs, respectively, are shown in Figure I.66.

As for the US self-determined work, be your own boss and control your own destiny weigh heavily. Also the importance of motivation of the “Capitalizing on a business idea” in the US has a correspondence in Germany (Explicit business idea). However, becoming rich is no significant motivation or motivation not spelled out across all German NTBF founders.

For the 2005-2008 sample it was found that for 35 percent of firms' foundation at least one serial entrepreneur participated. But restricted to only foundations by teams the proportion increases even to 61 percent.

On the other hand, income aspects show up highly for founders of spin-outs in Germany (Figure I.66) comparable with those in the UK (ca. 25 percent, Table I.40). Roughly a third of the respondents were driven by higher personal income expectations. Furthermore, this group also mentioned better career options than in the science area. One can hypothesize the emergence of the income aspect by spin-out founders in Germany to be related to the rather rigid and constraint salary structure for academics who are mostly civil servants.

It should be noted in the context of national cultures that the related motivations were “desire to build wealth” in the US versus “increase personal income” in Germany.



Technology-based services (telecommunication services, data processing & databases, contract research and engineering offices, labs) exhibit a similar distribution; the key difference concerns “Explicit business idea” with 39%

Figure I.65: Founding motivations in research-intense industries in Germany in percent for foundations in 2005-2007 [Heger et al. 2009].

Furthermore, the “direct request for offerings” in Figure I.66 is a notable motivation for spin-outs as it reflects a relatively large number of spin-outs to be founded by market demand. Indeed, the current sample of NTBFs contains some (German) examples of firms’ foundation as a response to a direct request (and purchase) of a product by customers (ChemCon GmbH, WITec GmbH, Solvent Innovation GmbH and IoLiTec GmbH (A.1.5), PURPLAN GmbH (Box I.21) and Attocube AG). A similar situation is observed in the US for Cambridge Nanotech (B.2, Table I.80).

As a summary, concerning firm’s foundation there seems to be differences between motivations of academic and technical entrepreneurs, at least, in Germany (cf. also ch. 1.2.6.1).

Complementary to the above findings are those of Moustras [2003] and Fyfe and Townsend [2005] who report on investigations of spin out-companies from chemistry departments of UK universities (firm sample from 1991-2004, about two thirds from 1998-2004).

In the context of the Anglo-American capitalistic system, inquiring personal motivation for starting a spin-out-company provided the following key results:

> There was almost unanimous agreement that the motivation was mainly to *take a good idea through to market*, often in the form of a product that would be beneficial to society and the economy. Many respondents also thought it would be a *change from academic research* and *even fun*. Only a minority (25 percent) mentioned making money.

The UK results indicate that attributing high importance to financial reward through firm's foundation in the US has essentially a socio-cultural origin rather than one of the Anglo-American capitalistic systems.

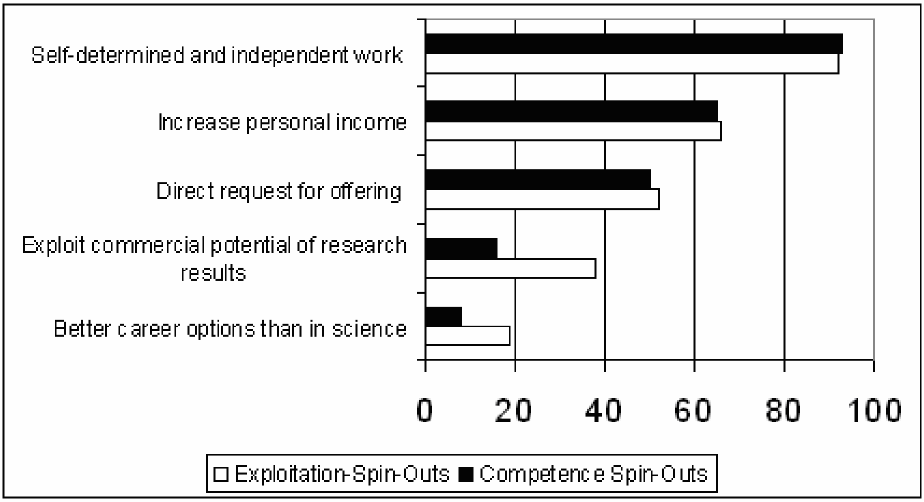


Figure I.66: Motivation for spin-out foundations in Germany in percent based on a sample from Egeln et al. [2002].

Assessing motivations for new firms' foundation, in particular, the relative proportions of the spectrum of reasons, has to be separated from the decision to found a new firm (ch. 4.2.2). The motivation will depend on spatial (and related national culture) and temporal factors.

For instance, the ratio between opportunity and necessity entrepreneurs will be affected by the national economic situation, such as the economic cycle (boom or bust) or specifically bubble situations like the Internet Dot-Com Bubble or currently the biofuels bubble (A.1.1). For instance, Egeln et al. [2002] focusing on a 1996-2000 sample studied just an economic boom phase. For Germany the result was that there was proportionately more emphasis on going for employment than entrepreneurship.

But there may be also other special events, such as the German Reunification and associated reorganizations which led to a higher proportion of necessity entrepreneurs when in the former German Democratic Republic (GDR) university institutes and other research institutes were closed (cf. ASCA – B.2 or IGV – A.1.1.4). But also the industry segment and its current situation and future prospects may enter entrepreneurial motivation. A fundamental temporal determinant for successful firm's foundation will be the Window of Opportunity (Figure I.4, Figure I.92).

Potential entrepreneurs who want to implement a definite business idea tend to "weather" unfavorable economic developments to found a firm. It has turned out that, during their first phase of life (the "startup thrust phase," ch. 4.2), foundations during bad times suffer much longer from additional burdens and obstacles of the crisis they have to deal with than firms created during "normal" times [Heger et al. 2009].

Entrepreneurship by Teams

According to the basic entrepreneurship process model (Figure I.1) teams are assumed to play an important role. In ch. 1.2.6.1 for the context of firms' formation different groups of entrepreneurs have been characterized, in particular, for firm's foundation by a single (sole) entrepreneur or by a group of founders – the entrepreneurial pair or triple or, generally, team.

The notion of a "team" for entrepreneurship is associated with various conceptions. For instance, one can look at an *ideal foundation team* as a small number of people with *complementary skills* who are committed to a

- common purpose,
- performance goals, and
- approach,

for which they *hold themselves mutually accountable* [Dorf and Byers [2007:274]. And one can attach the following as key success factors to team operation.

- Motivation,
- Leadership,
- Achievement.

With his definition in quotes we follow Cooney [2005] and regard an **entrepreneurial team** as consisting of "'two or more individuals who have a significant *financial interest* and participate actively in the development of the enterprise" and *share the purpose and the risks* of the new venture founded *simultaneously* by these individuals.

On the other hand, we shall speak of a **founder team**, if for the new venture one or more members do not have significant financial interest in the new venture – or if it is unknown whether all team members have a financial stake in the startup.

These two types of teams differ from the "*new venture team*" for technology-based firms introduced by Dorf and Byers [2007:274] which has been defined prescriptively in terms of management and leadership skills and skills and knowledge in finance, marketing, product development, production and human resource management – as personal operational competencies (Figure I.72, Table I.41).

The definitions mean, in particular:

- The team members need not have equal financial interests.
- It eliminates sleeping or silent partners (who invest capital but do not involve themselves beyond seeking a return on their investment).
- Referring to "the development of the enterprise" acknowledges the dynamic nature of the enterprise and allows team members to join (or leave) at any stage of the firm.
- Team formation may occur before foundation or during formation or even in the very early firm phase.
- The team has control over the startup, either by a majority of ownership or by contract.

Our definitions concentrate on new venture creation rather than on team development before firm's foundation or within the established organization. It further differentiates the entrepreneurial or founder team from a "*management or leadership team*" in a "rather new" firm, for instance, when one to three entrepreneurs are pro-actively seeking other people with needed competencies to fill functions or provide resources. These people may share entrepreneurial features, follow corresponding behavior and may be fully integrated into the team without changing the fundamental spirit of the team. Entrepreneurial, founder, management or leadership teams may only partially overlap.

For instance, rather shortly after foundation of the German JPK Instruments AG the founder team added an additional person to the leadership team (Table I.41, note b).

In another situation personnel may be *hired* later by the entrepreneurial team to fill a leadership or management position provided with execution power just by contract and status. These individuals may be given direct influence on strategic choice, often without having any ownership Such constellations are often observed if serial entrepreneurs found a firm.

If, for a nascent enterprise, a team is set up by an entrepreneur or entrepreneurs by adding members for a (leadership/management) team we shall speak of the "*entrepreneur and his/her team*"; or short the "**entrepreneur plus team**" (Figure I.68). For this constellation very fundamental and far-reaching decisions have to be made. Such a situation is often observed for RBSUs when professors as co-founders leave or change to the startup's Advisory Board and the remaining founder building his team.

Decision and action initiation in VC-based firms is often by a management team installed by VC firms with members providing "science, technology and policy competencies and connections" and set up as a "veteran technology entrepreneurs" approach (ch. 2.1.2.4). This is often based on "*old boys networks*" (cf. the biofuels NTBFs; A.1.1). An old boys network is an exclusive informal network linking members of a social class or profession or organization in order to provide connections and information and favors (especially in business or politics), often indicated by current or past affiliations to the same organization.

For these cases one usually has a leadership or management team with a technical entrepreneur taking the role and the job of a Chief Science Officer (CSO) or Chief Technology Officer (CTO), as observed in many cases of the startup scene of the biofuels area (A.1.1.).

With regard to team formation and stability one should be aware that venture capitalists or personnel from corporate venturing having sufficient ownership and control over a startup (ch. 1.2.7; Figure I.126, Figure I.128) may add rather fast a professional manager and equip him/her with power. Such investors may even replace (“fire”) members of an original entrepreneurial team.

There are few examples when VCs are actually the driving force of entrepreneurship and firm’s foundation and setting up a management or leadership team (Table I.99; Gevo and Coskata; A.1.1.5).

We associate the “entrepreneurial veterans team” with the notion “*new venture team*” as both relate considerably to the type of top management team in large firms. Specifically, management teams within the context of corporate entrepreneurship and particularly “New Business Development” (NBD) can be considered as “new venture teams.” Hence, we shall differentiate the “founder team” which may comprise the “entrepreneurial team,” the “entrepreneur plus team” and the “new venture team.”

For technology-based large firms and corporate entrepreneurial or management teams there is a myriad of *literature available in the context of innovation for “new product development (NPD) teams,” but less for “new business development (NBD) teams.”* Whether we look at NPD, NBD, task forces, etc. in large firms related activities with corresponding teams actually run projects or act as project controllers which are quite different from activities to found a firm.

Insights from behavior and actions of “intrapreneurial teams” can contribute only little to the understanding of formation and behavior of teams to found new firms.

The incompatibility of NPD, NBD or innovation teams and founder teams does not only result from the exogenous factors members of such a team are subjected to, such as corporate culture or politics (Figure I.17). It is also due to the important fact that the goal and the way of executing a business idea to grasp an opportunity may be modified or even totally changed by a special “force,” a “project assessment committee” (Figure I.79).

Furthermore, team compositions in large firms are often determined by available manpower in the firm’s business unit rather than through a selection by the project initiator(s) or intrapreneurs, respectively. And also the decision on continuation or finalization of the project is not controlled by the project team. A project is usually limited to a (predetermined) time period and the goals and purpose and change of project direction are often extrinsic to the project team.

Sometimes startups and team formations – for instance, foundations of new technology-based firms in biofuels (A.1.1) – proceed in a project style (ButylFuel, A.1.1.5), some of them having their origins in engineering firms or offices, such as Kergy-Range Fuels (Table I.99) or Bluefire (Table I.86).

After having classified teams founding new technology ventures it is important to have quantitative insights into the magnitudes of those teams – the numbers of team members. In Figure I.67 the proportions of magnitudes of founding teams for different kinds of startups (Table I.2; ch. 1.2.6.1, Figure I.46) derived from a questionnaire in 2001 are quantified for Germany [Metzger et al. 2008; Gottschalk et al. 2007; Egeln et al. 2002]. It is not clear, however, whether the design of the underlying study differentiates explicitly or implicitly the entrepreneurial team from "the entrepreneur and his/her team."

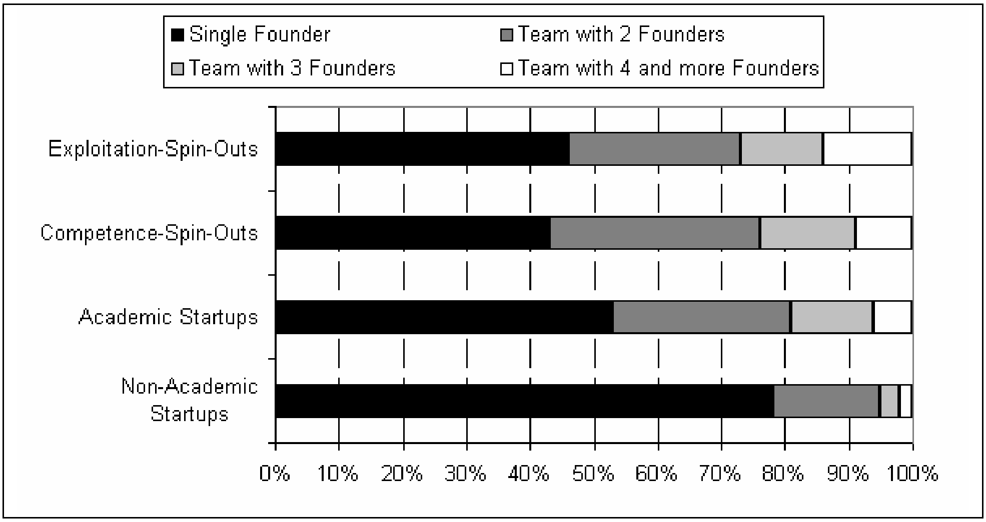


Figure I.67: Magnitudes of foundation teams for spin-outs and other academics-based startups in research- and knowledge-intense industries [Egeln et al. 2002].

According to the study, in Germany around one half of the foundations of high-tech firms (Table I.1 plus I&CT) are executed by a single person. Considering spin-outs and academics-based foundations 40-50 percent of them are founded by teams. Foundations by two persons account for 30 percent. On average a foundation team consists of three persons. Non-academic NTBFs (Table I.2) are founded overwhelmingly by a single person (ca. 80 percent) and teams correspond almost entirely to two persons (ca. 15 percent). Specifically founders of software firms are reported to group into teams more often than founders in other branches (by 54 percent).

The line of arguments for foundation by teams put forward in the study is that in the R&D-intense high-tech area offering of products or services requires *different competencies* that can be found seldom in one or two persons.

Furthermore, an enlarged number of founders may mean *a strategy of risk sharing* and thus more decision security in a rather uncertain environment of offerings' acceptance by the market as expected or hoped according to the foundation idea. However, to ensure this proposal it would be necessary, for instance, to assess whether all team members have a financial stake in the startup or whether one or more do not engage financially.

Based on his excessive case study of the US *Inc.* 500 list covering the fastest growing private firms in America (which represents a special sample) Bhidé [2000:303] observed that in his *Inc.* sample two thirds of the ventures started as a partnership had just two founders and none more than four and he suggests that *coordination problems limit the number of partners a team can have*. This would mean a notable difference between the situations in Germany and the US.

Inquiring further into the German situation, with regard to the proportion of team formation Pleschak and Werner [1998], having studied a sample of 340 promising East German (former GDR) high-tech ventures which obtained substantial support from the Federal Government, found that 68 percent of these firms were founded by two or more persons indicating a much higher proportion of team formations in the technology area than presented by Egeln et al. [2002] (Figure I.67).

Zolin et al. [2008] complemented this last finding. They drew a (special) representative random sample of German incubator firms (presumably in science and technology parks according to their below characteristics). Out of 178 randomly selected firms 53 responses were collected. Out of these 33 firms (59 percent) were founded by teams. 42.4 percent of the teams' firms are offering products and services in the information technology industry while the remaining 57.6 percent originate from various industries such as engineering, consulting or biotechnology. Accordingly, the average founder team in that sample consisted of 2.96 members; their respective firms were established 6.91 years ago.

Considering all, the bias of the samples toward software for information and communication technology and data processing, the unclear differentiation of research designs concerning the "*entrepreneurial team*" and "*the entrepreneur and his/her team*" entities and the, admittedly unsystematic, findings of the author on NTBFs for this and the previous book [Runge 2006], one can *estimate* that in Germany only around 30 percent of new research- or technology-based firms are founded by solo entrepreneurs – in line with Bhidé's finding [2000:303]. This means, *the vast majority of NTBFs (and RBSUs) is founded by a team* (probably "the entrepreneur and his/her team" ca. 30 percent and an entrepreneurial team ca. 40 percent).

But there is still a widely shared feeling about the important role of the individual for entrepreneurship as expressed by General George Doriot, considered to be the founder of venture capital funding in the US:

> "I prefer a 'Grade A' entrepreneur and team with a 'Grade B' idea over a 'Grade B' team with a 'Grade A' idea."

For further discussions referring to the underlying framework of General Systems Theory (GST) in this book

> the "founder team" or "new venture team" is *a system of its own* with the purpose to successfully found a firm or develop a new business; it is more than a collection of individuals (cf. also "Variations on a Theme" in A.1.6).

As people in a group interact and influence each other, groups develop a number of dynamic processes that separate them from a random collection of individuals. These processes include norms, roles, relations, development, need to belong, social influence and effects on behavior.

"*Human (group) dynamics*" determines the outcomes of the team and it comprises the actions and interactions of personnel, interpersonal, and social/contextual factors and their effects on behavior. Correspondingly, discussing teams of NTBFs will focus on structure (team members) and their links, team formation, coordination, decisions and actions.

Entrepreneurship often occurs as *a creative team act*, in which heterogeneous mental models interact and produce a *collective entrepreneurial judgment* and "*teamwork*." On the individual level there are differences in personal developments, values, preferences, knowledge, skills and expectations as sources of creativity and resources; and entrepreneurial interactions and behavior is embedded in a social context.

Hence, (technology) entrepreneurship as a process requires for the majority of cases a differentiation of emphasis, a *shift from the individual entrepreneur (*Figure I.15*) towards considering teams or groups (co-founders;* Figure I.16*) as the primary unit of analysis* and correspondingly, for instance, a shift from individual learning to organizational learning (ch. 1.2.3) and focusing on communication and coordination. Coordination and communication (and network formation) is facilitated by sharing and internalization of common goals.

Most of the literature on group and organizational learning has addressed concepts associated with cognition. As a generic term, cognition can be seen as the mechanism of information processing or data processing and storing in the human nervous system. With diversity in cognitive models and experience, the team is more likely to consider a wider range of strategic options in decision-making. On the other hand, high levels of conflict can potentially even block the emergence of a synergistic cognitive synthesis and a vital "dominant logic" within the entrepreneurial team [Prahalad and Bettis 1986].

Team formation is based upon agreement about a common purpose and goal and a win-win agreement or compromise, if the team members have different individual reasons to become entrepreneurs (Table I.39, Table I.40). Conflicts in teams may arise, for instance, if the goal is agreed upon, but not the way to the end or if a team is confronted with the offer by another firm to purchase the NTBF.

Most small businesses select team members based on common interests (and knowing each other) and not on the unique functional diversity added by each team member. Functional diversity is either developed by existing team members or there is agreement about functional roles the team members will take (Table I.41) or it is acquired by hiring from outside. But selecting team members may be associated with serious pitfalls (ch. 4.2.3).

Additionally, there may be a structural effect built into the team. The founding team and its firm often have an Advisory Board, whose members may keep different relationships to the members of the team. This particular network may create "information asymmetry."

Not in line with economic definitions which refer to transactions, **information asymmetry** is viewed here as a state of social group interactions where one or several individuals of the group has more or better information than the other ones; or, at least, one party has information relevant for a subject under consideration whereas the other(s) does not. This could lead to *imbalance for decision-making or power* which may become counter-productive for the group. Moreover, team members may also generate their own networks. Furthermore, other links external to the team can be envisioned, ties to banks, VCs, consultants, industry researchers etc.

In Figure I.68 a systemic view of the entrepreneurial team (illustrated for a triple) based on entrepreneurial personalities is given as a process involving a pre-formation phase focusing on the intention of firm's foundation and then the actual decision and action of team formation. Additionally, key characteristics for the dynamics of entrepreneurship by a team are given (cf. the above mentioned subjectivistic view).

Lechler [2001] has shown that the quality of social interactions within entrepreneurial teams is crucial for the new venture success. Though social interactions in entrepreneurial teams can be seen as an important factor, they are not the only factor of business success. And as depicted in Figure I.1 the founder team's social interactions may be important for revealing opportunity and resources to start its business.

Team entrepreneurship for the technology area will specifically have to deal with

- The personalities of team members – the system components
- Systemic structure (components and kinds of interactions; team composition) – structure-functions-model
- Team formation and dynamics (including changes in the team; team interpersonal process) – process-behavior-model.
- Endogenous and exogenous factors of team formations and dynamics, for instance, for RBSUs versus other NTBFs, financing modes like own capital versus external capital by VCs etc. – cf. also the system-environment-model.

In the GST view the "*entrepreneurial team*" (with a leader in terms of "primus inter pares" or a joint leadership process with distributed responsibilities) and *the single entrepreneur and his/her team* (the founder, the "*lead entrepreneur*," building his/her team before or during firm's foundation and early development; cf. Figure I.15) would show up as different entities, as depicted for entrepreneur ③ in Figure I.68. Such a differentiation, however, may become vague if, for instance, there is an "entrepreneurial pair and their team."

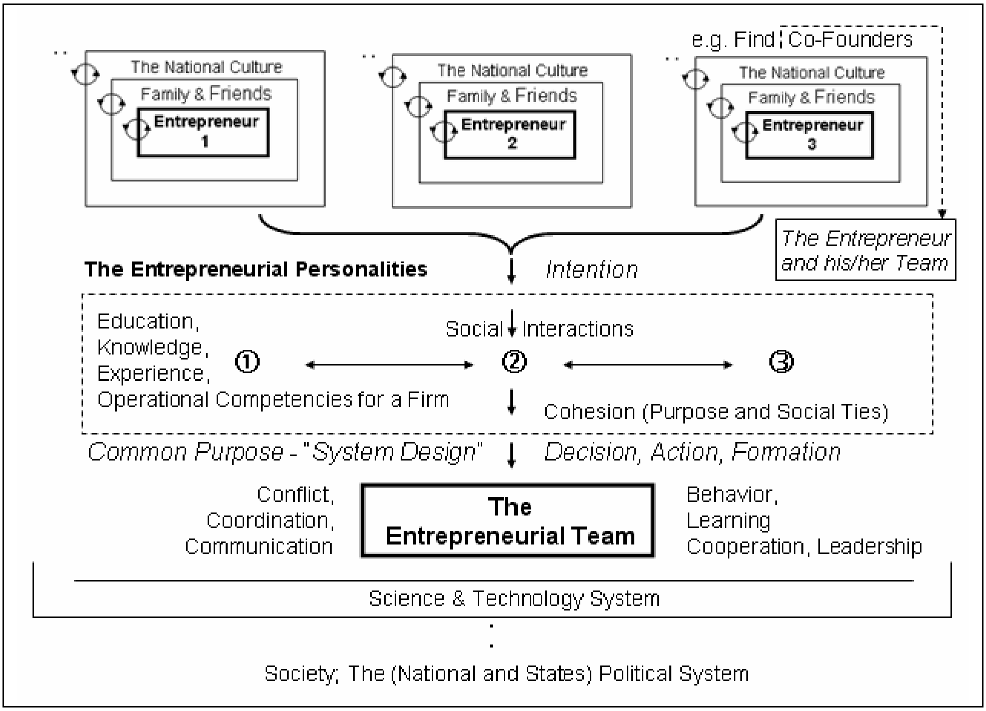


Figure I.68: A systemic view of the entrepreneurial team and key characteristics for the dynamics of team entrepreneurship.

When a team, with two or many members, has agreed to start a new firm an important aspect of "Systems Design" (Figure I.68; ch. 5.1) is setting up the firm's culture which defines how the entrepreneurial team interrelates to the other people of the firm (Figure I.120). Early decisions and implementation of *corporate culture* may have longevity.

For many successful large firms corporate culture did not change significantly from that established forty, seventy or one hundred years ago by their founders. This can be observed, for instance, with 3M or HP in the US or SAP in Germany.

For instance, William Hewlett of HP [Hewlett] said, "the recipe was simple."

- Have no hire-and-fire operation,
- operate, as much as objectives;
- be close to our employees (“open door policy”),
- explain and teach them;
- gain agreement, with modification if necessary;
- have everyone share in the success of achievement; and
- be egalitarian to assure that communications are open,
- listen to concerns of the employees; and to respond to these concerns,
- employees should be able to share to some extent in the progress of the company (a “bonus plan”); possible, on a pay-as-you-go basis, that growth be financed by earnings and not by debt.

And furthermore,

> “The type of close relationship that existed in the company encouraged a form of participatory management that has carried on to this day. We were all working on the same problems. We solicited and used ideas from wherever we could get them. The net result was that all felt they were members of the team.” [Hewlett]

Such normative recommendations, however, do not explain team behavior, how teams work. Currently there is no real understanding of the dynamics. Dynamics of team behavior is generally described as a joint function of *interactions* among team members, *flexibility* of team members to *handle changes*, unity of team members to maintain *group solidarity*, and involvement of the *team leader* in the day-to-day activities of the team.

Several measures for quantifications of team dynamics include *task complexity, team flexibility, and team culture*. In a founder team flexibility is likely to be evidenced by the ability to modify the task agreements with the team members and the ability to exit the relationship if required. The ability to modify the agreements within the founder team, without creating dissatisfaction, means that the firm can be more dynamic and agile.

On the other hand, a *dynamic team behavior model* should capture the team formation and development processes. First efforts have started to deal with dynamic models, for instance, by combining systems approaches and empirical team research. Here a team is formally represented as a system of mathematical relationships and variables (*interdependence, goals, cooperation, conflict, coordination, communication, cohesion*) determining its behavior, complexity and dynamics to be quantitatively explored. Then, simulation models are constructed and simulations performed.

A particular simulation study focused on assessing stability, equilibrium, equifinality and controllability [Patrashkova-Vozdolska 2005]. The mentioned team parameters correspond to a large extent with the factors of the social interactions of a team given by Dorf and Byers [2007:282, 283]. However, simulation models are usually found to be tested via behavior of student teams or other non-technical groups rather than highly educated scientists or engineers with often a dozen years of experience. Hence, such approaches currently contribute only little to team dynamics in technology entrepreneurship.

For all these reasons we shall concentrate the further discussion essentially only on the significance of teams as well as competencies, knowledge structures, functions and social interactions of entrepreneurial groups on an empirical, analytical and descriptive level. This is looking into roles and responsibilities with the constraint that a learning team has to maintain a level of trust and responsibility to one another that must exist in order for the team to remain successful.

In the *knowledge work* performed by entrepreneurial groups in technical areas some important components of behavior include information sharing, problem solving and creativity. *Team creativity* is expressed, for instance, by divergent thinking in groups as reflected in ideational fluency [Chen et al. 2004].

We shall refer to *static models* that offer a *snapshot* of team behavior, as is given, for instance, by Dorf and Byers [2007:38, 282]. But also some non-systematic aspects of how a group of people came together prior to establishing an enterprise based on investigated cases (B.2) are added.

A number of common assumptions and believes about *advantages of founder teams* when compared to single entrepreneurs exists.

- Founder teams tend to outperform solo entrepreneurs when performance is measured in terms of financial indicators, such as return on investment (ROI), sales growth rates for last year and an average sales growth rate over the past five years or the growth rate in the number of employees or profitability [Dorf and Byers 2007:282].
- It is suggested that firms founded by founder teams were more likely to achieve fast growth than firms founded by lone entrepreneurs [Ensley 1998; Cooney 2005].
- Apart from financial burdens also the capability-related burdens of the generally very intense foundation process may be distributed among more people.
- Team foundation tends to become successful if the comparative strengths of the team members can be combined complementary for the foundation project.

It has been proposed [Chen et al. 2004] that

> an entrepreneurial group compromised by engineering, marketing and field sales to new product development will reduce the risk in *new product ventures,* particularly in a dynamic environment.

However, foundation teams also have *disadvantages*. Decision processes to achieve agreement among several people may delay decision-making. There is a threat that, due to different intentions, opinions and power structure in the team, the foundation may be at enhanced risk [Creditreform - KfW - ZEW 2009]. Sometimes key players of a team are lured by the prospects of “making the difference” in the team.

Rather complicated situations are observed in the biofuels sector (A.1.1) where often founders or founder groups are complemented by VCs almost from the start by a management team of veterans with 20+ years experience in the related fields.

Though not entirely focused on NTBFs Egeln et al. [2010] have shown that for young firms led by teams almost one half of those firms gave up due to disagreement in the leadership team though the firms did not encounter economic problems (ch. 4.2.3).

Various theories of group development exist. Aspects of group processes include: [45]

- Patterns of influence (authority)
- Patterns of dominance (for instance, who leads, who defers)
- Roles/relationship
- Patterns of communication and coordination
- How conflict is handled
- Balance of task focus versus social focus
- Level of group effectiveness
- Emotional state of the group as a whole, what is called basic assumptions.

For their study Watson et al. [1995] introduced four dimensions for the team interpersonal process: *leadership, interpersonal flexibility, team commitment, and helpfulness*. Leadership involved partners who contributed to the leadership functions of problem-solving, setting quality standards, continually improving, and setting goals. Interpersonal flexibility described partner exchange with the other partner. Team commitment meant having enthusiasm for team performance and focusing on common team goals

Generally, entrepreneurial group performance has close relationships to organizational goals which have three levels: behavior, results and organizational effectiveness. *Organizational effectiveness* is the aggregation of results to reflect the organization’s success in achieving its goals.

An inquiry into completed team foundations [Creditreform - KfW - ZEW 2009] regarding cooperation of and communication across the team, which is an aspect of the *entrepreneurial group process performance (behavior)*, has focused on several aspects of social interactions. It assessed the aspects on a scale from 1 (is not at all true) to 5 (is fully true). Behavior refers to observation of *operational behavior*, such as the performance of work processes. Furthermore, it is differentiated between teams of men only and mixed teams with men and women. Teams of women only could not be assessed statistically. The results are presented in Figure I.69.

Accordingly, in general, for new German firms the leadership/management team is very satisfied with the team interactions. “Discussion and further developments suggestion” of the leaders are highly appreciated. On the other hand, though still being appreciated, the aspects “sufficient extent of information sharing,” “easy agreements on different opinions" and "handling of tasks is closely coordinated" range lowest here indicating certain critical areas of social interactions.

Furthermore, the differentiation of team composition according to gender indicates "female leadership style" to focus more on communication and information sharing and responsiveness to suggestions of others (ch. 2.1.2.6, Table I.42).

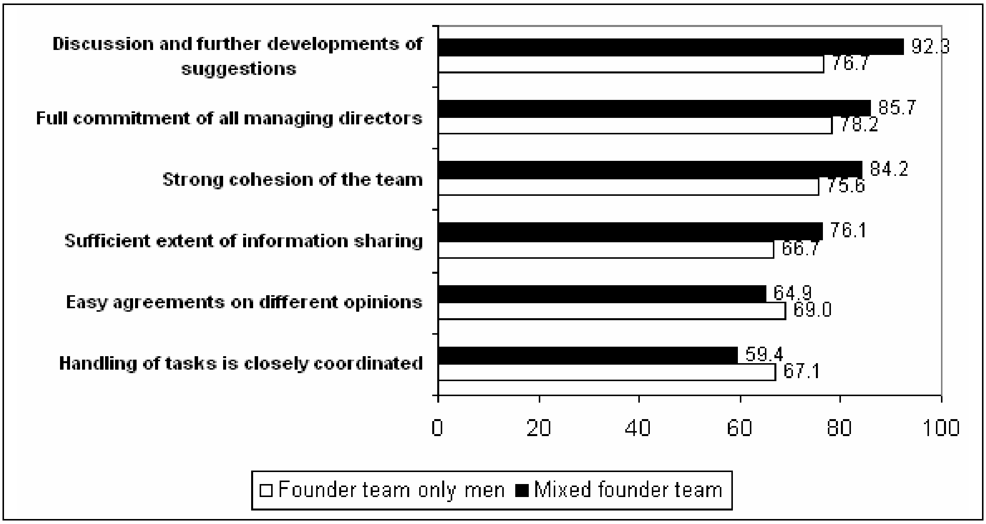


Figure I.69: Kinds of cooperation and communication in the leadership/management team of team foundations in Germany (in percent) [Creditreform - KfW - ZEW 2009].

In general, team members can be expected to possess different knowledge and skills, personally aim for different work or career goals or prefer to use different decision-making strategies. Hence, there is informational diversity, work style diversity and work goal *diversity for decision making*.

Entrepreneurship by an entrepreneurial group has *diversity* at the heart of initiation and development of a creative team act, as it exposes individuals to different and sometimes even contrasting stimuli – and various levels of conflict to resolve by communication (as a sequence of messages).

Watzlawick et al. [1967] observed that every message in a sequence narrows down the number of possible next moves. Messages as part of the interpersonal context exert an observable constraining effect on conversation and discussion, resulting in communication patterns. Hence, according to the GST view, once a first message is stated, it is likely that the subsequent behaviors are not purely random.

Research on joint or dyadic decision making has received attention from behavioral scientists. *Information giving, agreement, and reason giving* are the most frequent task criteria and match categories for the interactions. This means, a *process of the formation of opinion* is a process which involves a continuous change in the data and information and whose significance must therefore be completely missed by any theory which treats these data as constant [Lenk Krueger 1983].

Another aspect of diversity of entrepreneurial groups to be noted concerns education and related *multi-disciplinarity of scientific and engineering fields* which is important as a large part of current technology entrepreneurship occurs in cross-industry areas. A corresponding reflection of this aspect may refer to the composition of spin-outs from chemistry departments of UK universities [Moustras 2003; Fyfe and Townsend 2005].

Concerning technology area 45 percent of the companies under investigation were in the area of biosciences and pharmaceuticals, 21 percent were in functional materials, optoelectronics and polymers, whilst only 6 percent were in the conventional (fine) chemicals sector. Of the remaining spin-outs 8 percent were in analytical services and micro-technologies and 20 percent were split evenly between food, contract services, water, process & engineering, energy, sustainable development, medical devices, environmental and other.

Concerning discipline it was found that, apart from chemists, sixty-nine percent of these “chemistry spin-outs” employ bioscientists, 38 percent engineers (the majority in electronics and device engineering), with 15 percent employing materials scientists and IT specialists. Hence, the communication issues may arise on the one hand between the scientific disciplines (chemistry, physics, biology/biotechnology) (ch. 1.1.2) and on the other hand between scientists and engineers, as noted above (ch. 2.1.2.3).

According to current thinking groups of individuals gathered to achieve a goal, either as a team, committee or some other grouping go through several phases before useful work can be done. Formation of teams is described by models in terms of time-variable periods characterized as “stages” with predefined characteristics and rather clearly separated from other periods, with a corresponding “staged model” being also used for modeling firm development (ch. 4.3.1; Table I.68).

Such groups may be characterized either by appointed or emergent leadership. Any individual in a leadership position whose responsibilities involve getting groups of individuals to work together should both be conversant with the phases of the group process and possess the skills necessary to capitalize on these stages to accomplish the objective of forming a productive, cohesive team.

A notable “staged model” of small group development has been proposed as a conceptualization of changes in group behavior [Tuckman 2001]. The stages are separated into those descriptive of social or interpersonal group activities and those descriptive of group-task activities. It covers the “natural-group setting” on the basis that the group exists to perform some social or professional function over which the researcher has no control, whereas most studies refer to psychological therapy groups, human relations training-groups or “laboratory groups.” Tuckman’s model emphasizes four stages.

- *Forming*:
  Includes the setting in which the group is founded and the size, group subject or problem area, group composition; task activity orientation serves to define the boundaries of the task (what is to be done) and the approach that is to be used in dealing with the task (how it is to be accomplished).
- *Storming:*
  Group structure establishment, effects of negative independence featuring rebellion, opposition and conflict; the group deals with problems of control and responsibilities; entails a leadership struggle in which individual members compete to establish their place in the organization culminating in resolution.
- *Norming:*
  Development of group cohesion, getting used to each other and developing trust and productivity; the formation of the concept of the group as a functioning unit and the emergence of a team "dialect;" the establishment of group norms; *seeding company culture*.
- *Performing:*
  Structure is internalized with associated functional roles; emphasis on task achievement which is superordinate to social structure (what the business needs); working in a unified group to a common goal on a highly efficient and cooperative basis.

Previous research suggests that the *initial choices and actions of the entrepreneur or the team have a lasting impact on the way the company evolves*. This has important implications how a new firm develops. In particular, it represents a **self-reinforcing** mechanism (ch. 1.2.1), a positive feedback mechanism by which a system's output or state is enhanced or brought into a more favorable situation. Particularly group formation is likely to be associated with processes of system's development by self-reinforcement and self-enforcement.

Self-enforcement refers to internal codes of conduct and socially sanctioned norms. It reflects the situation that it is in the interest and agreement of all actors to adhere to the constitutional rules. Examples of *self-reinforcement* include, for instance,

- Decision-making self-reinforcement (that is, past acceptances make future acceptances more likely)
- Adaptive expectations (further belief in prevalence; Box I.17)
- Learning effects – for instance, the "learning curve" (improved products, lower costs; ch. 1.2.3).

A learning curve phenomenon is generally fitted analytically to a hyperbolic function for quantitative predictive purposes. The basic assumptions are 1) the time required to complete a specified task or unit of a product or item will be less each time the task is performed, 2) the unit time will reduce at a decreasing rate and 3) the decrease in time will follow a certain pattern, such as a negative exponential distribution shape. The concept of the learning curve for the production area proposes that as the total quantity of units produced doubles the time per unit declines at some constant rate. Its essence is essentially numerical "curve fitting" which does not allow understanding the phenomenon as a stepwise self-reinforcing process.

For instance, one can take $H_j = H_0 \cdot j^C$ (H_j hours to produce unit or complete task; H_0 hours to produce the first unit or complete the task for the first time, j is the sequential number (j = 1, 2, …) of the last unit for which the hours to produce the unit is of interest or hours to complete the task for the jth time is of interest, C is the learning curve slope obtained from two measurement points).

Understanding or insights into systems' phenomena is mostly by verbal descriptions in terms of entities, interactions, activities or processes and results. And the above examples of self-reinforcement follow that line. However, GST makes also use of another approach to description and partial understanding or even quantification. It describes a phenomenon in terms of algorithms for staged processes (ch. 4.3.4), specifically by a related equation that undergoes iteration, a form of feedback based on recursion that provides insights rather than curve fitting.

Though the presented approach in Figure I.70 creates the "stage impression" we shall lift the strict separation of stages in Tuckman's team formation model of sequential stages with given characteristics. Rather than concentrating opposition and conflict into just a "storming" phase of a seemingly sequentially proceeding process we propose Tuckman's "forming, storming and norming" stages to be interwoven with fundamental tensions due to existing and upcoming situations across the whole process which will be lifted to finally provide the ultimate stable and "performing" state.

Intention to found a firm (Figure I.68) requires the individual's ability and willingness to sustain temporal tension, to stretch between a vision of what could be and current conditions. This is also true for teams. Temporal tension bridges the interval between the idea for a new business and the existence of some approximation of that business. Temporal tension also encompasses the unfolding or duration of specific events, such as the often formidable task of writing a business plan, securing resources, finding an appropriate location for the startup, making a first sale or attaining a milestone or breakthrough [Bird 1992].

Tension becomes particularly important if there is no foreseeable release, as is probably true in the ambiguous and chaotic initial stages of a venture. New venture temporal tension heightens motivation when it is associated with personal, financial and psychological investments, the need for control, temporal forms of cognitive complexity, and speed. Thus temporal tension may be associated with the intervals of the venture creation process and venture's very early development state [Bird 1992].

We shall *simulate* the situation when a group is formed to achieve a given goal – which may be a team to found a firm – emphasizing self-*reinforcement*. For instance, before reaching a performing state, due to "mild" disagreements (D), "serious" conflicts (C) and even 'fierce" infights (I) there may exist a related group-internal "tension energy" T_1 exceeding the "normal" energy level E_S. E_S would be the value of a rather stable, *quasi-equilibrium state* with only small fluctuations and perturbations which allow an efficient mode of operation of the group (Equation I.4). The energy E_S of a "normal" state may be very approximately viewed as characterized in Figure I.69.

The initial tension T_1 in the group depends on the number n of team members and it requires some time t to bring down this tension, at best to the E_S level when T_1 disappears ($T \to 0$). As mentioned above there is evidence that such tension will increase with the size of the group, Hence, T is assumed to increase monotonically with n.

Equation I.4:

$$T = T(D, C, I, n, t) \text{ and } T(D, C, I, n, t) \leq T(D, C, I, n+1, t)$$

The group's state with tension T_1 may exist for a certain period of time after which, presumably working on a particular issue, by initiation of a leader lifting destructive tension will (must!) begin and then proceed supported via self-reinforcement. For a related model we assume the process to proceed through (group-specific) time intervals with various durations and separated by key tension releasing events, meetings, discussion or group activities.

For simplicity and illustration to describe the algorithm of this self-reinforcement phenomenon of releasing tension we use the well-known "*logistic difference equation*" (Equation I.5) which is a recursive function (the function being defined is applied within its own definition).

Here $f_S(n)$ is a driver for the process, an empirically determined "stabilization factor." We assume $f_S(n)$ to remain invariant for a particular size of the group, but for group formation to be dependent on the strengths of social links, if exist, between the members (Figure I.68 - Figure I.71) and also dependent on the external environment.

The reduction of tension during team formation is exemplified in Figure I.70. In this illustration, to mimic Tuckman's four stages of team formation, it is assumed that the tension is four units of "internal energy" higher than the quasi-equilibrium, the constellation being stable over time. The states of reducing tension start with T_1 characterized as "high tension" (= 4) and proceed via states having characteristics of medium, low and very low tension reaching ultimately a stable state.

Equation I.5:

$$T_{j+1} = f_S(n) \cdot T_j \,(1 - T_j)$$

The algorithm of Equation I.5 is used in the following manner. Start with the initial value of T_1 (= 4) and fix the value of the driving factor, $f_S(n)$ ($f_S(n) \neq T_{j+1} / T_j\,(1 - T_j)$) to achieve $T \to 0$ in four steps – discernable by their numerical values T_2, T_3, … T_i. For low values of $f_S(n)$, as j goes to infinity, T eventually converges to a single number – or oscillates between two values.

Non-linear dynamics here shows that *self-organizing systems* are irreducible and hence unpredictable because effective factors (for instance, states, function or context) unaccounted for in the system's initial measure of "energy" are later generated by the dynamics. By a mapping to Tuckman's model the norming stage would end up (T_4) with very little tensions, whereas the forming state has much tension. This is not astonishing considering how much trouble may emerge on how a task is to be accomplished.

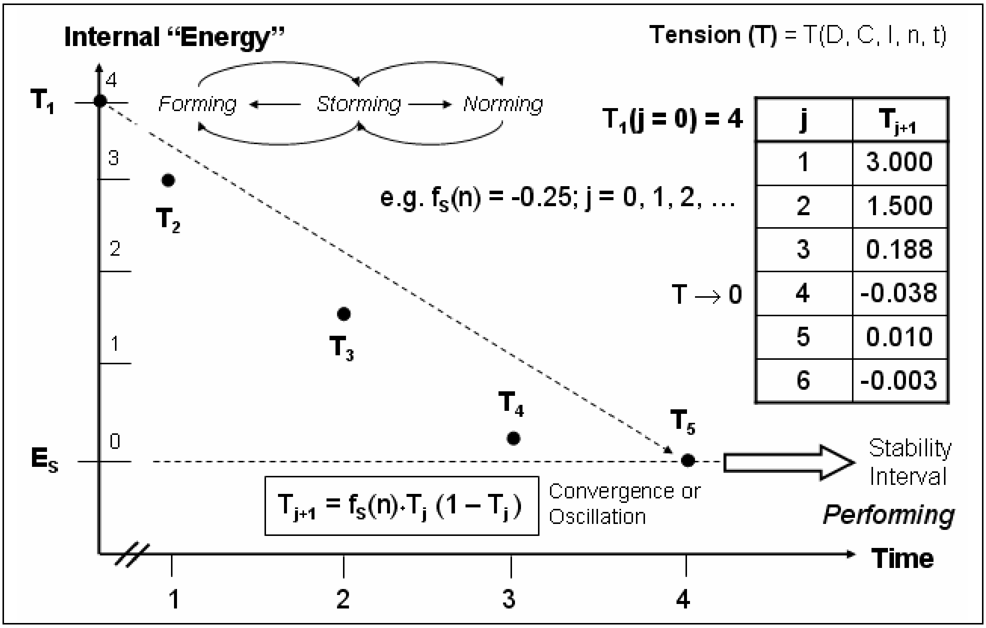


Figure I.70: Illustrating reduction of group tension by self-reinforcement in terms of the "logistic difference equation."

There is one effect to be noted when using Equation I.4 and Equation I.5. Assuming decrease of tension to be reduced, among other things, by agreement and decision it seems easier to reach decisions in teams with the number of members being an odd interger which may bring up a majority for a decision.

A very illustrative description of the formation of a four-member founder team is presented for the German startup Suncoal Industries GmbH (founded 2007, motto: Reinventing the carbon industry, B.2) by the detailed "founder's diary" (Oct. 2006 – Jun. 2009) of co-founder and managing director Hans-Joachim von Massow. The company develops, builds, and operates plants (Biomass-to-Coal plants) that process biomass to a carbon-rich, dry solid. SunCoal can be efficiently burned or further refined to diesel. Its patented process is based on the process developed in 1912/1913 by Friedrich Bergius (Nobel Prize awardee for chemistry 1931) whose work also plays a key role for the biofuels field (A.1.1.3).

Apart from overcoming obstacles and special issues the team formation obviously did not encounter “storming” features – the four founders were friends.

Two examples of serious problems or dissolution of the founder team are described for the US startup Cambridge Nanotech (B.2) and German IoLiTec (A.1.1.5; B.2).

Team Constellations of Technology Entrepreneurship

Team formation means the integration of different personalities, *characters*, to work toward a common goal. In the context of psychometric approaches to entrepreneurial personalities it was mentioned that the MBTI approach was used in industry to identify and integrate the “right” persons in a team for research or innovation processes referring to a fit of the corresponding MBTI personality descriptions of the envisioned team members (ch. 2.1.2.1, at the end).

Similarly, two German founders of RBSUs (Novaled AG and Nanion Technologies GmbH, both cases in B.2 and B.3; also [Fertig 2012:18]) address also the issue of having functionally the right characters in a team for firm’s foundation and early development.

Often technology entrepreneurship is characterized by the existence of *social groups* entering firm’s foundation. In the case the founder team as a system shows already interactions of its members, in particular, social ties of various strengths in the group as a basis for further interactions.

The **entrepreneurial pair,** occurring by ca. 30 percent of all kinds of NTBF foundations or by an even higher proportion, emerges as the smallest team and *the simplest system* (ch. 1.2.2). It is *special* as defined by the theoretical number of interactions among team members – there is just one (dyadic) channel for communication, coordination, cooperation and finding common agreements on how to tackle issues.

There may be special ties in the entrepreneurial pair, but also in the triple or team: The members may be friends knowing each others’ characters and having a high level of trust. Furthermore, one finds a number of entrepreneurial pairs connected by family relationships, such as spouses, son and mother or brothers (ch. 1.2.2).

Entrepreneurial pairs with complementary technical and commercial competencies were already discussed (ch. 1.2.6.1). Further widespread pairs comprise scientists or engineers (or university drop-outs), where both are involved in all kinds of activities or one of them continuously on the technical track whereas the other one, often through dedicated learning, takes care of the commercial track.

Prominent examples include Siemens & Halske (who founded Siemens AG in 1847, Europe’s largest engineering conglomerate) [46], the friends, university classmates and electrical engineers Hewlett & Packard (HP founded in 1939; Dave Packard worked four years for General Electric), childhood friends Bill Gates and Paul Allan (Microsoft; founded in 1975; then marketing a BASIC programming language interpreter), Larry

Page and Sergey Brin, having met working on their doctorates in computer science at Stanford University and having dropped out of Stanford (Google, Box I.24). And in the current NTBF sample (B.2) one finds, for instance, ChemCon GmbH (two chemists), Nano-X GmbH (a chemist and an engineer), Polymaterials AG (two polymer chemists; one with industry experience including controlling and strategic planning). Finally, ties may be looser in entrepreneurial pairs that were colleagues in the same firm, such as PURPLAN GmbH (Box I.21).

The last constellation, founding out of the same organization (company or university), is also seen for three-membered to five-membered founder teams (Table I.41; SAP AG, A.1.4). Similarly, friendship correlations are observed for SunCoal Industries GmbH (B.2). Colleagues and co-workers from different firms showed up for Q-Cells AG (Figure I.152. Figure I.153). And there are many examples of establishing a startup's management team in the biofuels area (A.1.1).

But it may well be that the cohesion of the team with three or more members with a certain level of social strength is weakened if it exhibits strong and weak ties simultaneously, as, for instance, observed for the founding triple of the firm ConnectU with two identical twins as co-founders (Box I.9).

Pair dynamics has been investigated theoretically for the software area, which means programming. This can be viewed as a metaphor for *combined problem-solving*. The very nature of pair programming implies a psychological and social interaction between the participating programmers and thus brings into play systemic synergy that is not seen with the conventional individual programming model.

From a field survey with a group of professional pair programmers, it was revealed that the programmers perceive a partner's *personality* (characterized via the MBTI type; ch. 2.1.2.1), *cognitive style* and *communication skills* as the top three factors that lead to prudent pair programming. It was also found that the *sub-group of subjects who were diverse in MBTI type personality exhibited higher productivity than both alike and opposite groups* [Choia et al. 2009; Choia et al. 2008].

As a summary, for entrepreneurship by entrepreneurial pairs (time- and location independent) *generic structural components of the team systems* emerge which can be differentiated by the strength of interactions due to the social relationships of the partners and the mixing of competencies, *a priori* technical and commercial competencies, or generating corresponding competencies by various activities required for the founded startup (Figure I.71). Social coupling often reflects the extent of group cohesion.

What is termed "loose coupling" in Figure I.71 can be operationalized by statements which were used for a questionnaire to assess ties. According to Zolin et al. [2008] these are:

- I knew this person (before s/he joined the enterprise team)
- We had common acquaintances (before s/he joined the enterprise team)
- We were in contact (before s/he joined the enterprise team).

In terms of observation it must be admitted that there is a fine line between intermediate and loose coupling. Friendship may evolve during the entrepreneurial process.

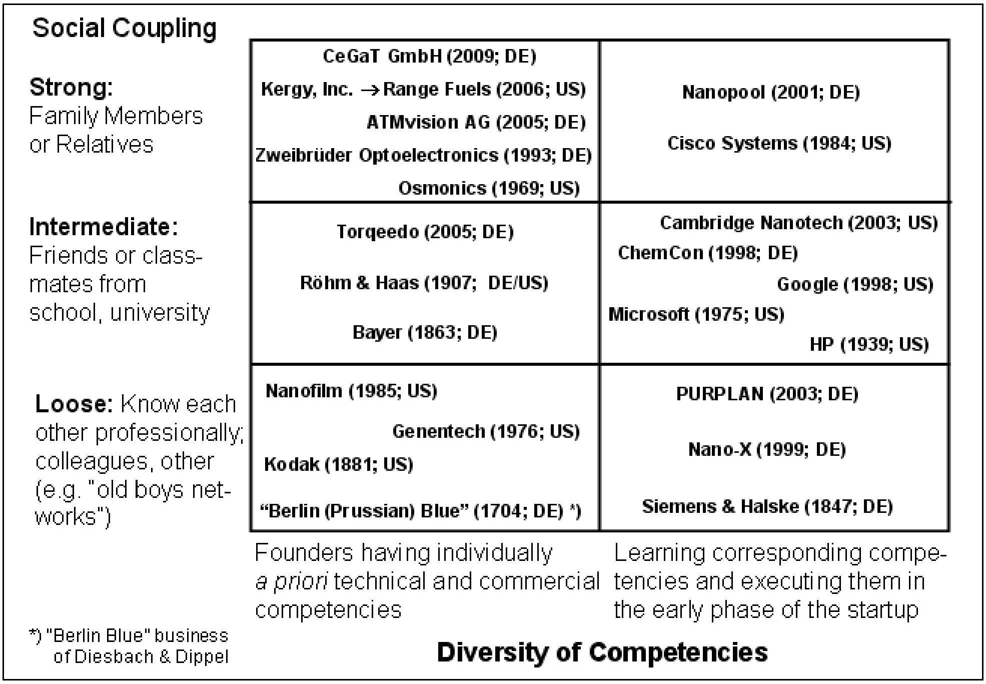


Figure I.71: Generic structure of entrepreneurial pairs based on team-internal social coupling and competencies and selected examples (DE = Germany).

Zolin et al. [2008] also point out that seeking strong ties may not always be the most effective solution in entrepreneurial group formation if the skills and abilities of these individuals do not keep up with the changing requirements of the developing business.

Furthermore, for entrepreneurial groups it is important to select team members or other members for a leadership team who are needed for the business rather than persons the team is comfortable with (ch. 4.2.3).

A *diverse* team can become creative by connecting insights, information, knowledge, experience and events that were formerly seemingly unrelated. Bingham and Quigley [1989] proposed that the activities of a venture team targeting new product development will reduce the risk in new production-oriented firms if comprised of engineering, marketing and field sales, particularly in a dynamic environment.

Runge [2006:70-71] extended that view and introduced a *basis set of specific personal operational competencies* of fundamental importance for founding and stability of (production-oriented) NTBFs (Figure I.72). This basis set reflects the anticipated future firm development (ch. 4.3.1) and growth into a medium-sized or large enterprise with correspondingly various functions (with related activities) as shown for the value chain of technology-based firms (Figure I.7).

The basis set is regarded as sufficient to found an innovative and stable NTBF, which means diversity of “generic” competencies and related activities. There is considerable evidence (and belief) that startup teams with a high level of commercial and/or sectoral experience perform better than those lacking these resources.

To cover as much as possible of the elements of the basis set of personal competencies and related activities members of an entrepreneurial group will take *roles* which may cover more than one of the basis competencies and thus represents a human resource, seen as anyone who can execute a task when needed.

Such a situation is described for three German successful NTBFs founded by an entrepreneurial triple in Table I.41 and illustrated structurally through combinations of boxes in Figure I.72. Boxes in a row represent the combination of personal operational competencies or activities, respectively, and responsibilities in one role.

In the first phase of an NTBF after foundation “General Management” (7) is often tacitly run, not explicitly attributed to one of the founders. On the other hand, we do not emphasize explicitly “human resource management” as during the start up phase and early development with only few employees any of the founders will have to deal with that if he/she wants to have a real co-worker (cf. previous text on HP; ch. 2.1.2.4).

Moreover, knowledge and experience in “management” is viewed as a personal competency that is often developed during the early phase of an NTBF through learning-by-doing (later text). The formation of firm’s functions in the course of the startup’s development will be outlined in Table I.69.

Overall, Table I.41 shows skill heterogeneity in terms of education and functional heterogeneity. One should keep in mind, however, that according to Figure I.44 around 10 percent of NTBF founders have technical/engineering and business competencies. Educational or functional heterogeneity increases the pool of cognitive resources available to a team and therefore, according to wide agreement, organizational performance.

> Skill heterogeneity should encourage a better set of alternatives to be considered by the team for decision-making. However, considering greater numbers of alternatives may increase the level of cognitive conflict within the team.

Table I.41: Founders' roles in an entrepreneurial triple in three German NTBFs.

Puron AG [Runge 2006:95-96] All from the Technical University of Aachen (RWTH)		
Education and Roles of Founder 1	**Education and Roles of Founder 2**	**Education and Roles of Founder 3**
Name: Dr.-Ing. Klaus Voßenkaul; Doctorate in membrane and module technology; Research & design, marketing and sales	Name: Dr.-Ing. Stefan Schäfer; Doctorate in seawater desalination; Production and finances	Name: Dipl.-Ing. Christoph Kullmann; Graduated in mechanical engineering; Service & piloting, purchasing and finances (procurement)
WITec GmbH (B.2) All from the University of Ulm		
Name: Dr. K. Weishaupt Doctorate in experimental physics; Managing Director Sales & Marketing	Name: Dr. O. Hollricher; Doctorate in experimental physics; Managing Director and Head of Research & Development	Name: Dr. J. Koenen Doctorate in experimental physics; Managing Director, responsible for the "rest," e.g., general management, strategy, administration, human resources, etc. a)
JPK Instruments AG (B.2) b) All became friends at the high school, all studied at Humboldt University Berlin		
Name: T. Jähnke (CTO); Diploma in physics Technology, sales & marketing	Name: Frank Pelzer (CEO); MBA Business development and finance	Name: J. Kamps (COO); Diploma in physics Production and intellectual property

a) Personal communication J. Koenen (context of guest lecture on WITec within the Technology Entrepreneuship course, Karlsruhe [Koenen 2010]).
b) Founded in 1999 by a triple of three friends from high school; later in 2000 another friend, René Grünberg (CFO), joined JPK as controller including responsibility for shareholdings.

Furthermore, social coupling effects as described in Figure I.71 show up for the entrepreneurial triples in Table I.41 who exhibit intermediate coupling. All were colleagues at a university before they founded the firm. Additionally, for WITec the three founders had already made up their minds to found a firm in the IT area. But they gave up their intentions when a new opportunity emerged in terms of a request to purchase a measuring instrument they had built ([Koenen 2010:13] and personal communication).

The probably most prominent entrepreneurial triple was the Apple Computer founding triple in 1978 with Steve Jobs as the charismatic leader who could motivate the employees, Mike Markkula, the business and marketing leader and Stephen Wozniak, the engineering leader [Dorf and Byers [2007:274]. While Jobs was a charismatic folk hero and visionary, it was Steve Wozniack who invented the first PC model and Mike Markkula who offered the business expertise and access to venture capital.

Jobs and Wozniak had met while working at Hewlett-Packard (HP) as summer interns. Wozniak possessed a passion for creating electronic devices, Jobs persuaded Wozniak to work with him toward building a personal computer. Jobs saw the opportunity, and Wozniak had the electronics skills [Dorf and Byers 2007:29].

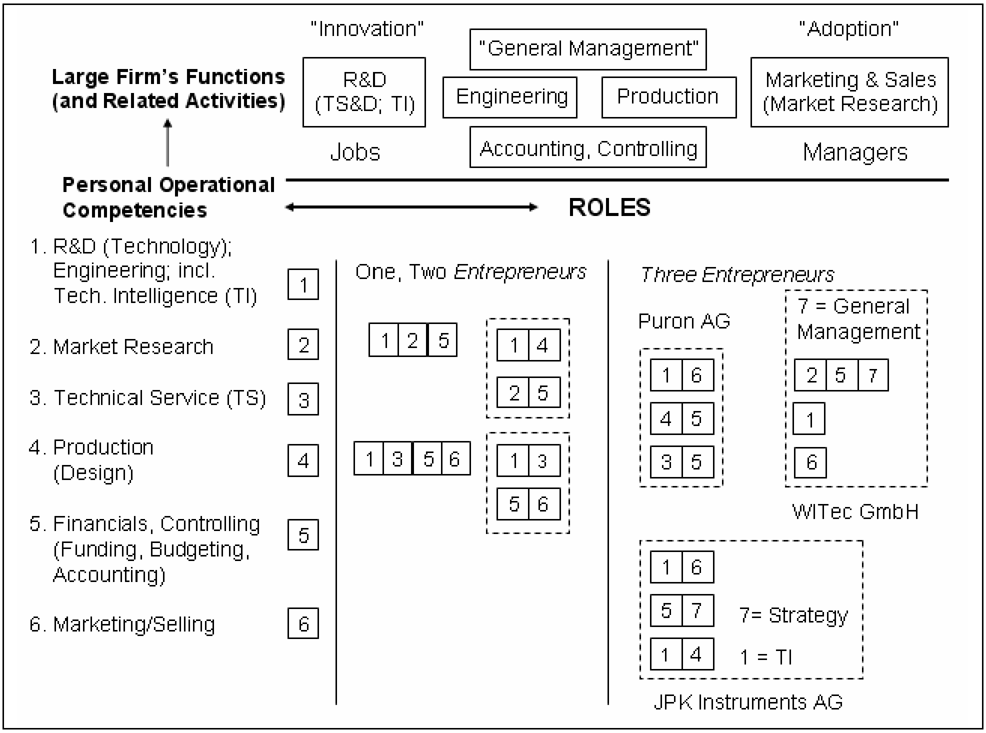


Figure I.72: Personal operational competencies as the basis for roles taken by members of entrepreneurial teams.

The ultimate entrepreneurial team with three or more members often seems to be formed in temporally distinguishable steps as described for JPK Instruments in Table I.41. But similar situations are observed, for instance, for the German firms Suncoal GmbH (B.2) with four founders and Europe's largest software firm SAP AG (A.1.4) with five founders.

When there is formation of larger teams (four or more members) there seems to be a "*crystallization kernel*" of two or, at highest, three entrepreneurs reaching out to enlarge the team by complementary talent and skills and "fit." More than three founders founders account (in Germany) for less than ten percent (Figure I.67).

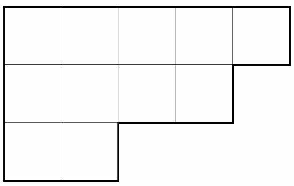
At least for technology entrepreneurship the above examples, similar to "lead investor(s)," suggest the concept of "*lead entrepreneurs*" who create the vision and then gather others about them who will share the related purpose of the to-be firm. With regard to the formation process this approach is close to the "single entrepreneur and his/her team" approach. It is rather commonly observed for serial entrepreneurs and project engineering firms' foundation by very experienced persons and correspondingly often found in the biofuels field (A.1.1).

Concerning *diversity* as an aspect of *organized complexity*, for the above entrepreneurial triples in Table I.41 with intermediate social coupling one can see that, in terms of their roles in the team, they cover almost the whole spectrum of basic *operational competencies*.

Furthermore, Puron and JPK Instruments have role owners with overlapping competencies or activities, respectively. This means, these NTBFs have teams including "*gatekeeper functionality" ("boundary spanners")* as a "glue" of the team, which will facilitate communication (ch. 1.2.3). And this reduces communication channels and presumably also reduces coordination efforts. Gatekeeper functionality is also observed for the ca. 10 percent of founders who have both technical/engineering and commercial competencies (Figure I.44).

Looking at the right hand side of Figure I.72 – WITec versus JPK Instruments from the same industry and related markets – an immediate question arises: Can we measure or, at least, compare diversity in both these firms when obviously JPK Instruments and Puron from very different technology branches and industries exhibit a perceived similarity?

Comparisons are possible, as outlined in Figure I.73, on several related levels: the arrangement of *sole boxes* and their groupings (structure, form), *boxes with attributes* (content, function) and *relations between groupings of boxes* (communication channels, which may reflect coordination efforts). The structure of (empty) boxes can be related to a so-called Young Diagram:



A Young Diagram is a bunch of boxes stacked on top of each other, where (by definition) no row is longer than the one above it.
Young diagrams with m+n boxes are in 1-1 correspondence with irreducible representations of the group S_n of permutations of n objects (which are mathematically homomorphic maps).

For the following approach focused on Young Diagrams a complement will be given in the Appendix (A.1.6).

A *permutation* of a set of distinct objects is an ordered arrangement of these objects, which can be natural numbers 1, 2, 3, … Let S = {1, 2, 3}. The arrangement 3, 1, 2 is a permutation of S. A *partition* of a positive integer n is a sequence of positive integers

$\lambda = (\lambda_1, \lambda_2, \dots, \lambda_l)$ satisfying $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_l > 0$ and $n = \lambda_1 + \lambda_2 + \dots + \lambda_l$.

For instance, the number 4 has five partitions: (4); (3; 1); (2; 2); (2; 1; 1); (1; 1; 1; 1). The partitions of the number 3 (and 2 and 1) and the related partitions using pictorially Young Diagrams are given in Figure I.73. Young Diagrams provide the "empty structural shells" which may get attributes.

We characterize the m different members of a founder group (m = 3; Figure I.72, Figure I.73) in terms of their educational levels and the various personal operational competencies they contribute to their roles out of the "basis set" of 6 or 7 personal operational competencies (if there is production/design) in the rows of the diagram. And we assume that self-reinforcement and learning curve effects (Figure I.70) have "converged" to a stable and coherent team.

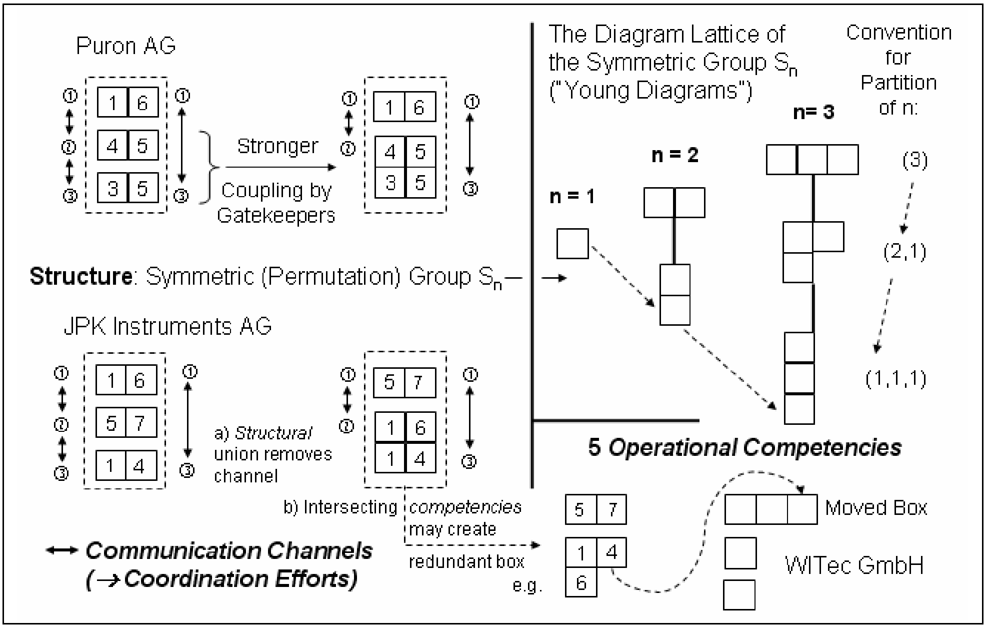


Figure I.73: Reducing barriers of communication channels and coordination efforts via gatekeeper functionality in an entrepreneurial team.

Basic assumptions are that the related group patterns can be interpreted to have meaning – and may reflect qualitatively real effects:

- Personal *operational competencies* for roles and *coordination* represent important (intangible) resources of the team.
- *Coordination efforts* within the leadership team decrease with decreasing number of founders.
- *Gatekeeper functionality* reduces communication and coordination efforts.

Furthermore, gaps between rows of boxes reflect needed communication channels which will induce coordination efforts and indicate weaker coupling resulting in increased coordination efforts (Figure I.73, lower right).

According to these propositions, for instance, Puron and JPK Instruments exhibit identical box and coordination structures, but different role distributions (attributes). The distribution of attributes out of a basis of seven basis attributes represents a "*variation on a structure*." Such differences will show up on the level of behavior, decision-making, action and execution in different environments and affect new venture performance.

For the Diagram Lattice Ruch [1975] emphasized a classification character and introduced a greater (or equal) relation with respect to Young Diagrams (Figure I.74). This induces a partial order of Young Diagrams which, however, would be relevant only for *structural considerations*, but can be extended to cover also personal operational competencies – *attributes* (A.1.6). These two qualities are usually accessible to observation from outside the firm.

We *tentatively* attribute significance to the partial order of Young Diagrams assuming a greater diagram to represent a more positive influence on entrepreneurial behavior based on a rationale referring to the simplest cases. Generally, any diagram with n cases has a maximum and a minimum which are represented by just one row of boxes versus only one column with n boxes – one person versus n persons.

Attributing personal operational competencies to the boxes, as shown in Figure I.72 (middle) for a solo entrepreneur and an entrepreneurial pair, one would suppose that the cognitive power of grasping external events or revealing opportunities and, hence, decision-making is better for a pair than that of the two isolated persons. The full spectrum of cognitive insights of the pair with different competencies can only be build if both the persons are simultaneously exposed to the effect/opportunity and communicate/coordinate effectively. But that will, on average, occur rarely.

Hence, a solo entrepreneur with "all" needed personal competencies may have the optimum cognitive power. A question for this conception is whether it is conceivable in reality. But it is, or at least was, the prototype being William Henry Perkin (A.1.2).

The greater or equal relation for the Young Diagrams (by moving boxes upward; Figure I.74) is illustrated in Figure I.73 (lower right) for the JPK/WITec cases by the curved arrow and related diagrams in Figure I.74 for overall five competencies. The formal difference between both these representations is a lacking gap between the box-rows in the last case. The emerging issue would be: assess increased cognitive power versus reduced coordination issues.

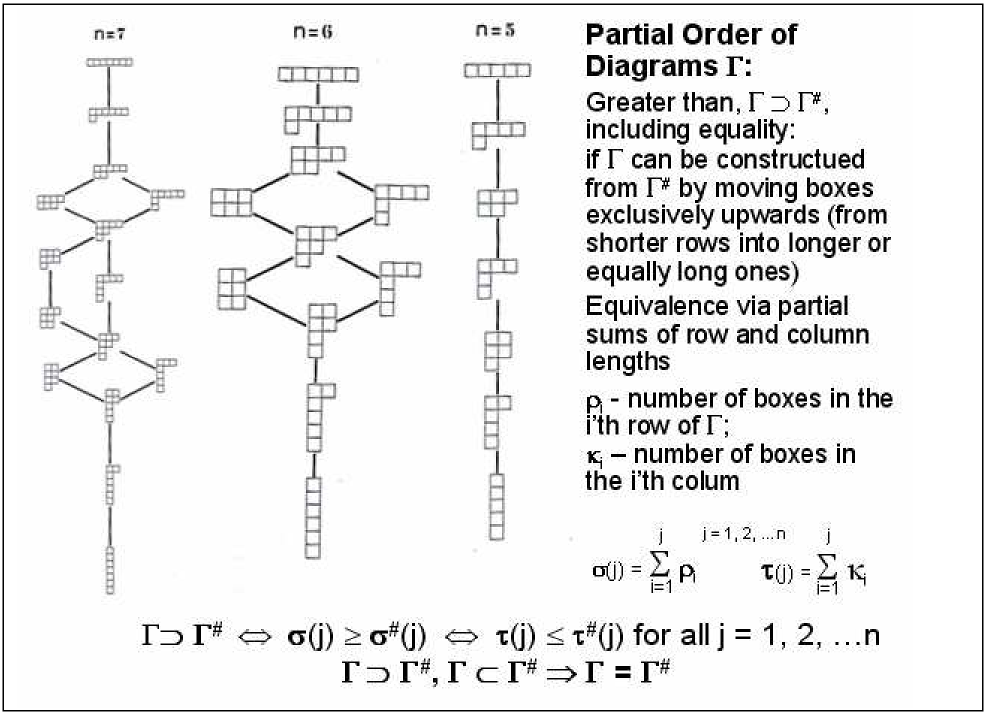


Figure I.74: Introducing partial orders of Young Diagrams according to Ruch [1975].

If one accepts an "*ideal entrepreneurial constellation*" to be the single entrepreneur with all the needed personal competencies for technology entrepreneurship and that such a solo entrepreneur is in principle more efficient than two or more persons with the same competencies distributed over the i members of the team (a single person has no communication and coordination issues a team with i members has) effectiveness and efficiency Ef may decrease monotonically (Ef(i) $\geq$ Ef(j) for all i <¸j.

Correspondingly one could say comparing teams with m members and a compatible and similar distribution of competencies the team with the larger Young Diagram should perform better. However, the author is well aware that such a constellation for the extremely complex and fast changing field of technology is very rarely found in reality.

A more strict discussion of *similarities* and *team or firm constellations*, respectively, is discussed in the Appendix (A.1.6) referring to structure and attributes of key resources of startups (personal operational competencies, experience and financial resources).

Furthermore, a single focus on the “internal” cognitive power of a startup’s founder team disregards any enhancing network effects of the startup. Particularly RBSUs as spin-outs from universities or research organizations usually keep networks with parent organizations (and correspondingly often base their location selection to be “close” to the parent (Figure I.49)). This may formally extend the founder team’s potential concerning “*knowledge and advice resources*” (Figure I.125, Figure I.169).

The founder team may extend its web of resources by location in a technology or science park (ch. 1.2.6.2) or build contacts to the nearby “business world” (as described by Dean Spatz of Osmonics [Runge 2006:91). Finally, a founder team may create an Advisory Board for its firm.

Hence, there is often a web around the founder team, rarely visible to an outsider, which magnifies the team and its performance. That means *companies are often built by a number of people with talent who are surrounded by supportive networks*. *Going beyond recruiting* exceptional talent, *many successful entrepreneurs bring in advisers (Advisory Board), investors and even early customer relationships*. Building out this network of alliances massively increases the size and probability of a positive result (ch. 3.4).

In the research specific to entrepreneurial groups, no factor was cited in the literature as important to entrepreneurial firm performance more often than *team skill heterogeneity*. Yet, skill heterogeneity has seldom been measured in entrepreneurial groups [Ensley et al. 1998]. Moreover, the author is not aware of research results on team performance or team skill heterogeneity for an NTBF sample (NTBF in the sense of the present treatise). And what is measured often refers to performance of the whole firm as an indicator of performance of the founder team.

Using a sample of 88 firms with 196 individual entrepreneurs drawn from the *Inc*. 500 December 1994 list of firms research of Ensley et al. [1998] explored the effects of entrepreneurial group skill composition on new venture performance. Teams ranged in size from two to four members.

The chief statistical tool used for testing the hypotheses was hierarchical regression analysis. As only some minor parts of the sample correspond to our definition of NTBFs, results are less interesting than the measuring approach. Furthermore, the relation to firm growth does not account for change of the team within the first five years of existence and does not account for organic growth versus non-organic growth (Figure I.127, Figure I.128) and does not differentiate experience levels within the founder team.

As dependent variable revenue or sales growth of the firm was used and related to five independent variables.

- Skill heterogeneity,
- Team size,

- Educational degree,
- Major,
- Functional area.

50 percent held bachelors degrees, 33 percent held masters degrees, and almost 5 percent held doctoral degrees (cf. also Figure I.63). Thirty-two percent majored in business, 6 percent in accounting, and 13.2 in engineering. Team skill heterogeneity was determined by given measures from existing literature.

2.1.2.6 The Gender Factor for NTBFs

"With 3% of venture capital being invested in women CEOs and only 5% more going to women founders, the cause to celebrate those who succeed is self evident"
Pamela Marrone, Founder of AgraQuest and Marrone Bio Innovations [Sierra Angels 2008]

In Germany the proportion of foundations by women in the high-tech sector with about 8 percent is considerably lower than their proportion in all the foundations (ca. 17 percent "pure" female foundations, 7 percent mixed gender foundations). For technology entrepreneurship one observes a "gender gap."

A "female foundation" is defined if the "managing directors" (a female entrepreneur or team) have a majority of women. If the same number of men and women comprises the management or leadership team, the firm is associated with that gender that has the majority of ownership [Metzger et al. 2008].

The low proportion of female technology entrepreneurs is also reflected by the author's NTBF cases. Just seven cases of female entrepreneurs (Pamela Marrone (AgraQuest, Marrone Organic Innovations), Pamela Contag (Cobalt Biofuels; Table I.96), Jill Becker (Cambridge Nanotech), Saskia Biskup (CeGaT; B.2), Katja Heppe (now Katja Richter; Heppe Medical Chitosan; B.2), Christine Welder (ASCA, B.2), Hannah von Hoerner (vH&S) [Runge 2006:444,482-484) are considered in more detail.

The author is not aware of the proportion of female founders in the technology area in the US. As Germany differs not very much from the Masculinity-Femininity Index from the US (Table I.38) and considering the motto of this sub-chapter one is tempted to estimate that the German figures represent approximately also the situation in the US.

In Figure I.75 the proportion of female entrepreneurship in the various technical sectors is shown. Notably, there is a higher proportion of female founders with both technical and commercial competence than for male founders (Figure I.44). Foundations of technology-based firms are relatively rare in the high-tech sectors and particularly software. There are relatively more foundations in technology-based services.

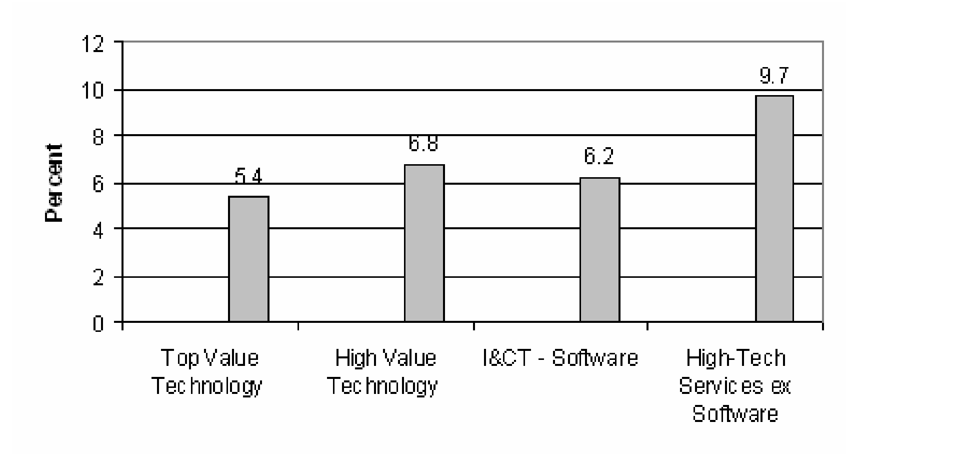


Figure I.75: Proportion of female foundation in the various technology sectors in Germany [Metzger et al. 2008].

Women mostly have to balance their work with their family life. And they still face long-outdated stereotypes about the types of companies they run. And they are assumed to be more likely to be turned down for bank financing (which, however, could not be supported for female entrepreneurs in Germany [Metzger et al. 2008]).

Concerning the level of education of founders (Figure I.45) female and male technology entrepreneurship does not differ markedly [Metzger et al. 2008]. Compared with male foundations those by women occur more often by single (female) entrepreneurs [Metzger et al. 2008; Creditreform - KfW - ZEW 2009]. But it can well be that the finding is due to an increased proportion of “the entrepreneur plus team” approach compared to the entrepreneurial team approach.

The literature relevant for the current subject on gender issues mainly deals with management style and is rather controversial. With regard to technology entrepreneurship, as expected, few contributions are available.

Summarizing relevant research results [Seymour 2000; Heffernan 2007; The New York Times 2009] do show some differences, although only “on the average.” But, as with all averages, there are many exceptions; there is a sliding scale of masculinity-femininity as there is with the MTBI or KAI dichotomies. Determination and passion is something common to many successful women entrepreneurs [Ainsworth 2008].

In Table I.42 a summary of outstanding relevant features for female entrepreneurship is given, partly contrasted with the polar features of men. Often women approach the entrepreneurial process in a different manner from men. In the end, finding a balance between the two gender styles may be one key to success for entrepreneurship.

Table I.42: Seemingly relevant female features for entrepreneurship [Seymour 2000; Heffernan 2007; The New York Times 2009].

Vision, Values and Firm Culture
Women tend to look for meaning more than men at work (no surprise, men go for pay and status more often); they often think about what values their company will stand for even before they know what the company will do. Culture is a very important part of business. For most women, their mental model of a company is a living organism; most men's mental model is a machine.
Leadership and Management
Women are less "bossy," they are more collaborative and democratic than male managers. Compared with men, women use a more positive approach by encouraging and urging others rather than a negative approach of scolding and reprimanding them. (Women tend to be interactive leaders, basing decisions on who has the most information. Male style of management tends to be command and control – top-down decision-making. The people at the top know best and tell everyone else what to do.) Power is about orchestration, being the conductor for a symphony, very different from the widespread military model of leadership of issuing orders, far from following the ego mode of leadership. Women are more inclusive and build consensus to reach decisions. In general women take fewer risks than men.
Human Relations and Networking
Women build value by developing people (Figure I.121). Men are more task-oriented and women are more people-oriented. They are natural relationship builders. Better able to interact well with others (build and nurture good relations).
Operations
Female entrepreneurs are very good at improvisation. That is not to say that they are bad planners, but that they are comfortable with the degree of improvisation that entrepreneurship demands. There is lots of anecdotic data that women are more flexible, are multi-taskers and tend to be comfortable sharing power and information.

Successful female entrepreneurship is often associated with "*transformational leadership*." Transformational leadership includes charisma (communicating the purpose and importance of a mission and serving as a role model), inspirational motivation (exuding optimism and excitement about the mission's attainability), intellectual stimulation (encouraging others to think out of the box), and individualized consideration (focusing on the development and mentoring of subordinates as individuals).

Dorf & Byers [2007] have used the case of female (start-over) entrepreneur Pamela Marrone and her first founded firm AgraQuest, Inc. to illustrate and illuminate the issues raised in each chapter of their textbook. We also looked into AgraQuest [Runge 2006:189]. To illustrate key characteristics of female entrepreneurship we inquired furthermore into Pam's new firm (Marrone Bio Innovations, Inc. founded in 2006) and another female entrepreneur, Katja Heppe from Germany (Heppe Medical Chitosan GmbH, founded in 2005, Table I.43; B.2).

As with all averages, there are many exceptions. In particular, Katja Heppe provides an "atypical" feature of a female entrepreneur: Katja Heppe focuses on assertiveness and hierarchical thinking and emphasizes the fact that "*she* is the leader of the firm and not part of a team." [NEnA]

Table I.43: Examples illustrating key characteristics of female entrepreneurship.

Vision, Values and Firm Culture
"I was driven by a vision and a dream of what I wanted to accomplish – to change the world through pesticide products that are safer and effective." [Ainsworth 2008] (Pamela Marrone; biopesticides); Marrone ties her passion for natural chemicals to a gypsy moth infestation at her home in rural Connecticut when she was seven; chasing dreams of developing natural pest-killers [Downing 2007]. We communicate openly and honestly, respect the views of others and minimize internal politics. Empowered employees, treated fairly, are productive employees. We involve all employees in the company's strategy, goal setting and decision-making. (Marrone Bio Innovations, Website 8/2010; Values – no. 3) We have a culture of accountability, continuous learning, coaching, and mentoring for personal and professional growth. (Marrone Bio Innovations, Website 8/2010; Values – no. 5). Mistakes are tolerated if the situation is analyzed, lessons learned and the same mistake is not repeated [Vosmek 2009]. "I live for my idea" – a bright future for chitosan applications and nanotechnology." [NEnA] (Katja Heppe, chitosan and its applications); "You do not get rid of chitosan's fascination" ("Man kommt nicht los vom Chitosan") [Köhler 2005].
Leadership and Management
We believe in diversity. A diverse work force and diverse opinions working together in teams result in better decision-making. (Marrone Bio Innovations, Website 8/2010; Values – no. 4)

Human Relations and Networking
Pamela Marrone: Hire people who share your values. Hiring individuals who are technically competent but do not share the values of the company's leaders can have dire consequences. Put your value statement up front, have new employees sign it, and tell them that you expect them to live by it. [MBI] "I'm starting up again really determined to find investors that do share our values." [Hopkins 2006] Every new investor and employee is required to sign a comprehensive statement of mission, vision, and values. [Miller 2007] Katja Heppe: Concerning networking with other founders and specifically those nearby the firm's location in the technology park: "All stick together and all will also help each other." ("Es halten alle zusammen und es wird auch untereinander geholfen.") [Kemna 2007]
Operations
The *company's founder and key team* are experienced at quickly bringing products to market. (Marrone Bio Innovations, Website 8/2010; Business Strategy) "We are impressed by Pam Marrone's track record of building successful biopesticide companies, *the experienced team she assembled*, said Sean Schickedanz, General Partner of Clean Pacific Ventures [MBI 2007]. "I supervise science, but I am incompetent in the lab. Don't get me in there," she said with a laugh. "If I was in there, they would kick me out. At Monsanto, they recognized very quickly that I was supposed to be in management and leading people in a science-based business." [Krauter 2007]

Female (academic) entrepreneur Pamela Contag of Cobalt Biofuels (Table I.96) can be viewed as a "*stage-oriented* entrepreneur" concentrating on only selected phases (or activities) of a technical innovation process from innovator to adopter when the entrepreneur concentrates usually all his efforts (full-time) to bring the offering to the customer (Figure I.180).

As Cobalt's president and chief executive officer Pamela said, "I generally invent and develop technology and then take on investors who ultimately direct the company. I put all my energy into the demonstration of the technology and business model." "Entrepreneurial spirit has to do with necessity," she said "The job needed to be done, and I was in the right place at the right time." [Ainsworth 2008]. Hence, after having raised $25M she withdrew to CTO to hand over commercialization to investors and a professional management.

This is similar to Karen K. Gleason, an associate dean of engineering for research at Massachusetts Institute of Technology. She said her entrepreneurial spirit was sparked by a desire to commercialize coating technology developed in her lab. To accomplish that, she co-founded GVD Corp., which stands for Gleason Vapor

Deposition in 2002 in Cambridge, Mass. The company was built around technology that enables ultrathin layers of polytetrafluoroethylene (trademarked as Teflon by DuPont) to be coated on micro- and nano-sized substrates.

As the technology allows coatings to be applied at cooler temperatures, it can be used on organic materials such as polymers rather than only on inorganic materials such as silicon. Given her responsibilities at MIT, however, Gleason must play a somewhat limited role in GVD. The company's co-founder and president, Hilton G. Pryce Lewis, who earned a PhD in Gleason's MIT lab, runs the company's day-to-day operations. That leaves Gleason free to "ask the bigger questions and think about the more long-term issues," she said. [Ainsworth 2008].

A corresponding attitude is also found with the professors Rick Lathrop and Wes Hatfield, co-founders of CODA Genomics which became Verdezyne, Inc. (A.1.1.6). Hatfield's favorite quote is: "Do good science and leave management to professionals."

2.1.2.7 Visions, Missions and Values

In the literature, even if focusing on entrepreneurship, most discussions of visions actually refer to a "corporate vision" [Dorf & Byers 2007:60]. Referring to Table I.43 it emerges that there may be mutual interrelations between the business idea (and revealing an opportunity) and a vision. For new firms vision is a notion associated with a personal and a firm level. On the *personal level* a vision, close to a dream, hope or desire, respectively, may even be associated with passion or obsession and may have a political or societal direction. Remember Martin Luther King's "I have a dream."

For entrepreneurship and innovation vision and dream can turn into *obsession*, as seen, for instance, by the twin founders of Zweibrüder Optoelectronics GmbH (B.2): "We were *obsessed* with light and lamps, full of ideas, and frequently worked far into the night. … We proudly present the results of *passion*, *endeavor* and 18 months of research and development." But obsession and entrepreneurship can cross borders of morality (ch. 2.1.2.8).

In the context of entrepreneurship there may be a path, a direction, from a personal vision or dream to a corporate vision of a (to-be) founded firm which may last several to many years – as there may pass several years between a business idea and actual firm's foundation (Figure I.76). In entrepreneurship a firm appears as a means to make a personal vision true through interconnections to the idea and/or opportunity. Furthermore, if an entrepreneurial firm is founded by a team, the team may share the vision of one or two leading entrepreneurs or the whole team may create a vision that fits all team members' input.

The individual vision relates essentially to the future and (ethical) values of the individual, whereas the corporate vision may additionally refer to the purpose the firm has been founded for and consequently will refer to "success." It answers the question, "What will success look like?" It is the pursuit of this image of success that really motivates people to work together.

The corporate vision is assumed not to change over a rather long time period, but it is adjustable as conditions warrant. The corporate vision we are interested in refers to an NTBF (not elder than twelve years). A structured discussion on visions based on enduringly successful (large) companies is presented by Collins and Porrs [1996] and shall not be further tackled in this book.

Visions of the entrepreneur are often strongly related to personal experiences, emotions and attitudes and also related to the reasons why to become an entrepreneur (Table I.39). Some examples for this situation are given below.

> As an undergrad engineer Dean Spatz was early on engaged in how to create potable drinking water from brackish South Dakota groundwater. Years later, he founded the membrane separation company Osmonics, Inc. and said "I made the decision to start the business myself because I was totally committed to building this technology … and applying it to all sorts of different areas." [Runge 2006:91]
>
> Similarly, as a young German engineer Viktor Dulger (then founder of Prominent GmbH) was caught by the vision to develop new components to improve provision of drinking water worldwide and simultaneously to make sure to use the environmental resource water sparingly [Runge 2006:74].
>
> And Pam Marrone (Table I.43) ended up with the following vision for Marrone Bio Innovations, Inc. We will be the world leader in natural product innovation. We will make natural, effective, safe, environmentally friendly products the mainstream future of pest management.

Finally, in Germany the retired engineer Heinz Rath (an R&D leader in the automobile industry and inventor, assumed to be the father of disc brakes) was struck by the horrible pictures of children terribly wounded by land mines. He decided to look for help, in terms of mine cleaning. He and (also elder) coworkers realized the vision and constructed an operational prototype of a mine cleaning vehicle for civilian (but also military) use which was fully tested with highly positive results and acceptance by the German army.

Rath did not know how to advantageously commercialize his machine and sought partners who did that job after co-founding the firm MineWolf (B.2), similar to a stage-oriented entrepreneur (ch. 2.1.2.6).

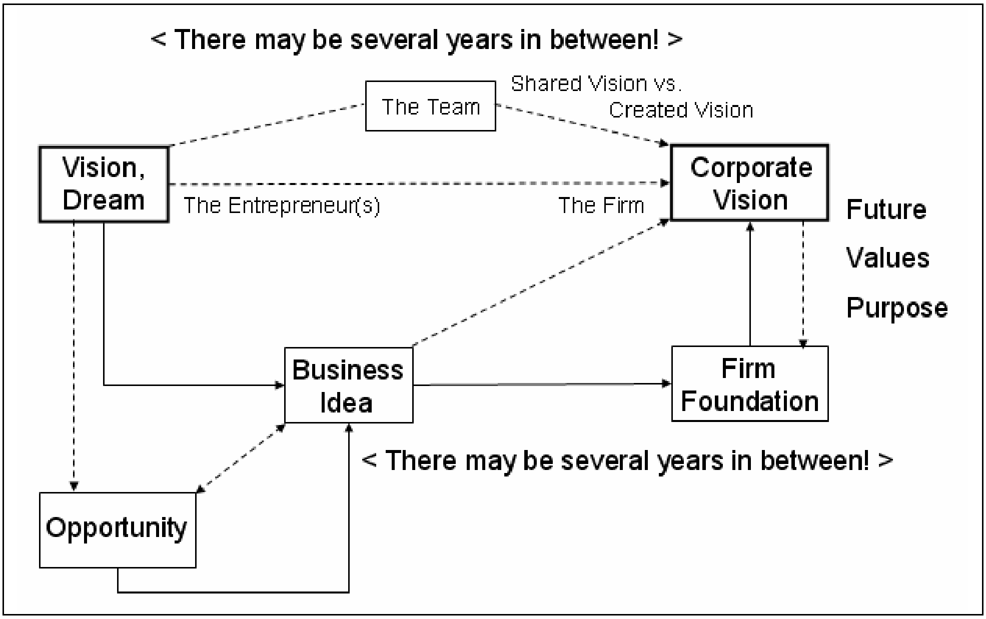


Figure I.76: The context of visions of the individual entrepreneur(s) and that of the later founded firm.

In a firm values are principles of employees' behaviors. Values of a firm may change over time. Those which are independent from time are *core values*. Core values are identified if subjected to the question: If circumstances changed and penalized us for holding this core value, would we still keep it?

> **Corporate vision** is a short, succinct, and inspiring statement of what the organization intends to become and to achieve at some point in the future.

A corporate vision should challenge and inspire the firm's employees to follow its purpose and know what its success will look like through explicit statements.

- It should be unique, special to the enterprise.
- It should be consistent with the organization's values.
- It should be realistic and credible, well articulated and easily understood, appropriate, ambitious, and responsive to change.
- It should orient the group's energies and serve as a guide to action.

The entrepreneur(s) should be able to communicate the corporate vision such that all the employees understand and internalize the message. Vision, energizing people and communication (including listening) are key components of leadership.

The vision as a dream of an entrepreneur is often driven by "precedents of success" (Table I.39). For instance, in the US Amgen has grown into a biotechnology industry giant and a biotech entrepreneur may ask: Is there going to be another Amgen? There has not been another Amgen since Amgen. That is a little like people who bet big in software on the next Microsoft. There was not a next Microsoft, but Google [Pisano 2006].

The reason that the firm exists is its "*core purpose*." Like the core values, the core purpose is relatively unchanging and for many firms endures decades or even centuries. The core purpose is generally expressed in a mission statement. However, after firm's foundation the vision and purpose of that firm may change with changing ownership, for instance, when venture capitalists take control of the firm or when the founders change intentionally the business direction or business model, respectively, to adapt to new environmental conditions or after having revealed a more promising opportunity.

Generally, a **mission** answers the questions: Why does our organization exist? What business are we in? What values will guide us? Correspondingly, a mission statement is a formal, short, written statement of the purpose of a company or organization.

- A mission can help companies to focus their strategy by defining some boundaries within which to operate.
- Organization follows mission!
- It can define the dimensions along which an organization's performance is to be measured and judged.

It should be a clear and succinct representation of the enterprise's purpose for existence. It should incorporate socially meaningful criteria addressing concepts such as the moral/ethical position of the enterprise, public image, the target market, products or services, the geographic domain and expectations of growth and profitability.

For instance, the mission of the NTBF MineWolf Systems AG (B.2) is

> Our mission is to provide safe, reliable, fast and cost-efficient mine clearance solutions to our customers worldwide.

Under the heading "transforming chemical and fuel industries with biotechnology" one reads, for instance, for Green Biologics Ltd. (Table I.95)

> Green Biologics Ltd (GBL) provides world leading technology, based on advanced fermentation biotechnology, for the production of renewable butanol and other chemicals from waste and agricultural by-products. GBL is based near Oxford and serves markets around the world, generating royalty and other revenues by adding significant value to customer operations.

Basically, the mission takes an intermediate position in the hierarchy vision – mission – objectives. Missions can be expressed in very abstract terms, whereas **objectives** are "operational"; that is, their definition must imply methods by which they can be measured [Van Gigch 1974:74].

2.1.2.8 Ethics in Technology Entrepreneurship

Basically, "*ethics* encompasses the study of the actions that a responsible individual ought to choose, the values that an honorable individual ought to espouse, and the character that a virtuous individual ought to have. For example, everyone ought to be honest, fair, kind, civil, respectful, and trustworthy. Besides these general obligations that everyone shares, *professionals have additional obligations* that arise from the responsibilities of their professional work and their relationships with clients, employers, other professionals, and the public." (Emphasis added) [Loui 2009]

What is the role of ethics in technology entrepreneurship? Entrepreneurship is not all about personal financial gain. It concerns crafting a lifelong plan to make a positive impact on society. *Personality and character* do matter.

Entrepreneurship is about the creation of socio-economic value, enduring value, which requires integrity and ethics. In *entrepreneurial capitalism* business ethics is an integral part of life that reflects the values of each participant. A culture of accountability, dependability and professional trust starts with the founding person(s). Rather than following, for instance, a "Code of Ethics" which has been set up in a large firm by an internal process and subjects the employees to the code, in a new firm the founder(s) establish and live the behavior of the firm (Figure I.120). Their ethical values shape those of the firm.

Entrepreneurs face complex ethical problems of the individual and of the firm embedded in corporate values:

Individual level include:

- Conduct all employees, business dealings with integrity,
- Treat all stakeholders (including investors and other backers), collaborators and trade partners (suppliers, customers) with respect, fairness and honesty at all times and expect the same in return.

Firm level (corporate responsibility) will focus on:

- Your name!
- Corporate identity
- Corporate optics and perceptions
- Brand management
- Honesty in communication and advertisements
- Honesty in gaining competitive information, in conducting technology intelligence [Runge 2006:804-806].

Most studies on entrepreneurs' ethics are conceptual and theoretical and the few empirical studies are mostly confined to descriptive analyses listing examples of unethical behavior. Some more to the currently discussed cases shall be added. The emphasis of the cases is on the early stage of entrepreneurship (Figure I.15), covering business idea, “concept summary” [Dorf and Byers 2007:50-51] or business plan, respectively, acquisition of resources and first customer contacts and, hence, concerns entrepreneurial activities during a critical period. With regard to Facebook, for instance, the question of the origins of a business idea has been raised (Box I.9) which tackles a general issue of ethics in entrepreneurship.

Resource acquisitions from investors or other backers, one key purpose for writing a business plan, are another area of (un)ethical behavior. Recent examples of unethical behavior and misconduct are particularly striking for the biofuels area (A.1.1). It is estimated that about 10 percent of biofuel firm *founders are knowingly making promises they cannot keep* [Waltz 2009].

Producers of next-generation biofuels using non-food (cellulosics) renewable materials are finding it increasingly tough to attract investment and ramp up production to an industrial scale (A.1.1). For instance, a federal jury in the US ruled that the firm Cello Energy of Alabama, a plant-fiber-based biofuel producer, had defrauded investors [Davis and Russell 2009]. Cello was expected to supply 70 percent of the 100.7 million gallons of cellulosic biofuels that the Environmental Protection Agency (EPA) planned to blend into the US fuel supply in 2010.

The alleged fraud will almost certainly prevent the EPA from meeting its targets in 2010, analysts said [Davis and Russell 2009]. Cello’s inability to produce even a fraction of what it expected have spooked private investors, which could further delay technology breakthroughs and derail the government’s green energy objectives.

When seeking investors for Cello Energy in 2007, Jack Boykin, an entrepreneur with a background in biochemistry, said Cello had made diesel economically in a four-million-gallon-a-year pilot plant from grass, hay and used tires. What is more, he told investors he had successfully used the fuel in trucks, according to testimony in a federal court case in Mobile, Ala. He said he had invested $25 million of his own money.

An Auburn University agronomy professor advising the Bush administration on green energy endorsed his technology. Alabama paper-and-pulp executive George Landegger and Vinod Khosla, the well-known venture capitalist (A.1.1.5), separately invested millions in seed money into Cello and had plans to invest or lend more.

A lawsuit disputing the ownership stakes of investors produced Mr. Boykin’s revelation, in a 2008 deposition, that he had never used inedible plant material, such as wood chips or grass, in his pilot plant despite claims otherwise. Construction of his full-scale facility in rural Alabama moved forward anyway. Khosla representatives took samples of diesel produced at the new Cello plant and sent them off for testing. The results showed no evidence of plant-based fuel: Carbon in the diesel was at least 50,000 years old, marking it as traditional fossil fuel [Davis and Russel 2009].

The EPA was not told about the test, and continued to rely on Mr. Boykin’s original claims when it asserted in the Federal Register in May that Cello could produce 70 percent of the cellulosic fuel targets set by Congress that are due to take effect in 2010.

The jury returned a $10.4 million civil fraud and breach-of-contract verdict against the Alabama entrepreneur in favor of Mr. Landegger, one of the investors. Work on the plant has been suspended. Several weeks after the verdict was delivered, Mr. Boykin presented evidence that he had tested fuel from the plant and it did contain cellulosic material. He was seeking a new trial. Mr. Boykin declined to comment, but his lawyer said his client denies committing fraud. The carbon testing, he said, reflected only an early stage quality-control test during startup trials. It would be premature to conclude, said in an email, that Cello's fuel-making process is a failure [Davis and Russell 2009].

Biofuels made from algae provide also marked cases. Some companies have promised impossible amounts of oil, based on speculation, raising millions from unwitting investors. Only a handful of algae companies have realistic business plans or proprietary technology. Read Waltz [2009] on that:

> "Pitching an algae company on inflated numbers is surprisingly easy. Present your scaled-up yields at meetings filled with VC investors hungry for the next renewable fuel. For flair, paste Photoshopped images of giant ponds of algae onto your presentations and your website. Then, when people ask to see your facility, tell them it's top secret."
>
> Some overconfident companies have already crashed. When the Cambridge, Massachusetts-based GreenFuel Technologies was founded in 2001, its claims were so overblown that they 'became a joke.' 'They had no technology – nothing except PR for outrageous claims repeated often enough to sound believable to some poor souls who bought into their fibs.'
>
> Whether the *algae charlatans* will be exposed before the DOE sinks taxpayers' money into their companies is another question." (Emphases added)

Many experts assume that viability of commercial algal biofuels is a longer way off from commercialization than claimed by breathless algae startup press releases. And this is emphasized further from another aspect:
"Bottom line – in our opinion the reality of economically viable algae fuel production is still quite a few years in the future – unless someone finds a truly novel short cut through the Laws of Thermodynamics and basic economics." [Wesoff 2009]

GreenFuel Technologies has been suggested by Rapier [2009b] to serve as a poster child for *hype gone amok*. Accordingly, GreenFuel, which arose out of research done at MIT, was the highest-profile company (and very well-funded) working on algal biodiesel. They were winning awards for innovation and had gushing articles appear in the mainstream media – but some of us recognized that they were stretching the truth. Their claims violated various laws of thermodynamics (cf. also discussions of Range Fuels and Coskata in A.1.1.3).

> Ethical conduct in negotiation-style communication, for instance, production or revenue projections in a business plan, must clearly show that they reflect expectations of the entrepreneur made in good faith explicitly differentiating the basis of the projection in terms of facts, assumptions and opinions.

A "tricky" ethical problems for entrepreneurs has been discussed by Witt [2006:14-15] referring to the Swiss/German firm MineWolf Systems AG (founded in Germany as MineWolf Systems GmbH; B.2). Based on the product, the mine-clearance machine "MineWolf," the firm offers a wide range of demining machines and services to customers in countries with contaminated land in Europe, Africa, the Middle East and South America. Customers are armies, governments, EU and UN, and humanitarian non-governmental organizations. The firm's foundation was based on a vision and dream of the German retired engineer Heinz Rath to free civilians in those countries from the terrible woundings and fatalities resulting from the land mines. As a product and its utility MineWolf has highly ethical value.

On the other hand, customer locations are usually in politically very instable countries, such as Bosnia, Angola, Sudan and Afghanistan. To be effective here country-specific habits have to be followed, which often means corruption as contacts to and deals with governments or military customers are only possible via "intermediaries." In Africa, for instance, transportation of the mine clearing vehicles over land is full of stops for "controlling persons and vehicles" requiring sometimes bribery according to strict assessment of behavior.

Witt [2006:14-15] argues that this should not be viewed as unethical. He interconnects the highly humanitarian intentions of operation with the requirements to operate in regions in crisis often without any possibility to pursuit ethical behavior in the strict sense.

Another issue of ethics is industrial espionage rather than technology intelligence which is particularly striking, if governmental organizations contribute significantly (Box I.7). This is not only an issue of ethics in entrepreneurship, but demonstrates the broad involvement of governments in all aspects of entrepreneurship – to the good and to the ugly.

Box I.7: Technology entrepreneurship, innovation and industrial espionage.

In 1999 a case of industrial espionage involving the German firm Enercon GmbH, the fourth-largest wind turbine manufacturer in the world (Figure I.150, Figure I.151), received very much publicity in Germany by an article in the renowned German newspaper Die Zeit [Schuler 1999; Machatschke 2008; Daly 2010]. [47]

One of Enercon's key innovations is the gearless (direct drive) wind turbine in combination with an annular generator. This was unlike most other wind turbines, which use a potentially less reliable gearbox in order to increase the rotation speed of the generator. Enercon was prohibited from exporting their wind turbines to the US until 2010 due to alleged infringement of a patent of Kenetech Windpower. On the other hand, Enercon claimed their intellectual property was stolen by Kenetech Corp. (Windpower, Inc.) and patented in the US before they could do so.

In 1996 Kenetech filed for bankruptcy, and Zond Systems acquired the related patent rights. Zond was later acquired by Enron, and later Enron was acquired by General Electric (GE Wind Power).[47] Recently Enercon made a cross patent agreement with its competitor General Electric.

Enercon received a written injunction in 1995 from a district court in San José and from the US Department of Commerce, claiming Enercon had infringed patents of Kenetech Windpower Inc. And Enercon's founder and CEO Aloys Wobben had to appear in Washington and was questioned for two weeks.

Here, Wobben and its American lawyers got access – possibly by mistake – to the evidence of the opponent. Apart from a multiplicity of photos, which showed the complete internal design of the Enercon E-40 wind turbine there was also a report of Kenetech's employee Ruth Heffernan in which she described in detail how she spied the Enercon plant together with her Dutch Kenetech colleague Robert "Bob" Jans and the German Ubbo de Witt:

According to Schuler [1999] and many other sources in Germany and the US the industrial espionage involved the US governmental organization NSA (National Security Agency of DOD) and involved ECHELON, a network maintained by the NSA and the UK's very own related service. Gathering economic intelligence became a main, yet unofficial directive after the end of the Cold War in the early 1990s, for members of the so-called UKUSA Alliance.

In short, Kenetech sent its engineers out to spy and succeeded in patenting the competitor's technology in the US (but nowhere else in the world, as everyone else honored the original Enercon patent), preventing Enercon from selling turbines in the US until 2010).

What is documented is that Kenetech employees Ruth Heffernan, Robert "Bob" Jans and Ubbo de Witt climbed up an Enercon E-40 turbine in 1994 and documented its inner workings over the course of an hour. Furthermore, the trio apparently was able to access the turbine itself by disabling the security system. A journalist told Mr Wobben the NSA had previously intercepted security codes from Enercon and handed them over to Kenetech Windpower. Detailed information concerning Enercon was passed on to Kenetech via ECHELON.

But after that, Enercon was defying the US and refused to sell turbines there as the founder/owner Aloys Wobben was holding a pretty big grudge against the Americans and, furthermore, Enercon can afford to ignore the US. He told friends that he shall never touch American ground again. Additionally Wobben avoids China for business [Machatschke 2008]. Furthermore, after that "trauma" Wobben let Enercon patent almost everything they develop. Currently, Enercon holds ca. 40 percent of wind turbine related patents in the world (more than German Siemens and US General Electric together).

The final remark of Daly [2010] concerning the issue is:

"To cut a long story short – competitive intelligence is commonplace and has a long and very dirty history. All Western allies have been spying on one another for decades, even for centuries." "Why then, may one beg, is there such an outrage about China?" (competitive intelligence here means industrial espionage; cf. also Box I.2)

Entrepreneurial Obsession and Morality

Referring to images, ideas, or intentions that force themselves into the subject's consciousness against their will, and which momentarily deprive them of the ability to think and sometimes even to act properly is *obsession*. Such an irresistible urge, often carried out against the performer's will or better judgment, is sometimes observed as a preoccupation in science and entrepreneurship.

> Depending on crucial decision situations (ch. 4.2.2) for internal drivers of scientists or engineers there may be a fine line between ambition, goals and goal achievements and obsession.

Two examples from Germany are notable in this context: Manfred Baron von Ardenne (1907 – 1997) and Wernher von Braun (1912 – 1977), both working after World War II (WWII) for the winners of WWII, the Soviet Union (USSR) or the US, respectively. Both were caught by science and technology as the essential and passion of their lives. Both were obviously not driven to create wealth based on their talents.

These cases tackle two fundamental questions. "First, are scientists and engineers merely "hired guns," who provide technical services to whoever employs them? Second, are scientists and engineers responsible for the uses of their creations?" [Loui 2009] Looking at the particular definition of the notion "hired gun" the Internet Free Dictionary provides a sliding scale concerning ethical aspects:

1. One, especially a professional killer, who is hired to kill another person.
2. One hired to fight for or protect another.
3. One with special knowledge or expertise, as in business, law, or government, who is hired to resolve particularly difficult or complex problems.

After Hitler's dictatorship both Von Braun and von Ardenne had available different paths for their further lives and activities.

Just before the end of WWII and the Soviet Army was about 160 km from von Braun's V-2 rocket site Peenemünde in the spring of 1945 von Braun assembled his planning staff and asked them to decide how and to whom they should surrender. Afraid of the well known Soviet cruelty to prisoners of war, von Braun and his staff decided to try to surrender to the Americans [Wernher von Braun].

"He arranged to be captured by the invading Americans, using his importance to German rocketry to avoid harsh treatment and retribution for his work on the V-2 program." [Crowley and Trudeau 2011]

On the other hand, von Ardenne stayed in his laboratory in Berlin when the Soviets conquered Berlin in May 1945. Having recognized the relevance of von Ardenne his laboratory was first placed under special "protection" by the Soviets. And in early summer 1945, before the Americans marched into Berlin-Lichterfelde, it was dismantled and transferred together with Ardenne and the majority of its employees to the Soviet Union [Hoffmann 2009].

Naimark [1995:249] interpreted this, according to the author's opinion, as if von Ardenne had another real choice vis-à-vis the Soviets:

Very few of the ca. one hundred scientists who were taken to the Soviet Union in the first weeks of the occupation by the Soviets seriously protested against their fate. "Ardenne … seemed most taken with the chance to continue running his laboratory, since opportunities for their kind of scientific work did not exist in postwar Germany."

In an obituary also the New York Times [New York Times 1997] emphasized him to be a "*German Nuclear Physicist"* and "a key to the Soviets' success in creating a nuclear bomb" rather than presenting him also as one of the great inventors of the 20th century.

Without holding a degree or even a certificate for leaving school and having studied only briefly at the University of Berlin, von Ardenne was largely self-taught. When he died in 1997 von Ardenne held ca. 600 patents and was the author of countless books and publications. His fields of activities and fame included electron microscopy, medical technology, nuclear technology, plasma physics, and radio and television technology.

In the re-united Germany Manfred von Ardenne got a rather intensive controversial assessment, being essentially negative [Hoffmann 2009; Brosin 2011], but probably not fair when compared with assessments of Wernher von Braun who had chosen the "right side" in the emerging "Cold War."

Also negtively seen to become an honorary citizen of Dresden in September 1989 before the fall of the Berlin Wall in Western Germany Manfred von Ardenne has been characterized as a "safe traveler" between worlds. In addition to his life's work an image of a man is presented who adapted with almost chameleon-like smoothness to the respective political systems.

Thus Manfred von Ardenne has been labeled an almost ideal typical representative of a supposed "technocratic innocence" as well as a beneficiary of three dictators or dictatorships, respectively – Hitler, Stalin and the SED (Sozialistische Einheitspartei Deutschlands; Socialist Unity Party of Germany), the ruling party of the German Democratic Republic (GDR) [Hoffmann 2009].

At the end of the description of von Ardenne's life on the home page of the von Ardenne family "successor" firm, VON ARDENNE Anlagenbau GmbH," one finds a hint how difficult it is to assess Manfred von Ardenne's personality appropriately.

Without doubt, Manfred von Ardenne was not only a charismatic scientist and thinker. Looking at his life reveals many facets of a personality which in this context are very difficult to do justice to ("Fest steht, dass Manfred von Ardenne nicht nur ein charismatischer Wissenschaftler und Denker war. Ein Blick auf sein Leben offenbart viele Facetten seiner Persönlichkeit, denen man in diesem Kontext nur sehr schwer gerecht werden kann.") [VON ARDENNE]

Manfred Baron von Ardenne

If not stated otherwise the following description uses the reference to VON ARDENNE covering information from the homepage of the re-built VON ARDENNE firm and the associated Wikipedia articles.

Manfred von Ardenne, born in 1907 in Hamburg, was an *inventor-entrepreneur*. He was the oldest of five children of a wealthy, aristocratic family of Prussian/German officers. His father, Egmont Baron von Ardenne, was appointed to the Ministry of War in Berlin in 1913, and the family moved into a rented apartment in Berlin-Hasenheide. From Ardenne's earliest youth, he was intrigued by any form of technology, and this was fostered by his parents. For instance, they cleared for him the best room of the apartment making it Ardenne's first "Private Laboratory for Radio Technology" [VON ARDENNE].

Instead of following school, he conducted his own experiments, built models and circuits, tinkered and took measurements. At a school competition, he submitted the model of a camera and an alarm system and won the first prize. His lack of interest in class had an effect on his achievements and he left Berlin-Tempelhof secondary school after he did not pass an examination. Von Ardenne subsequently changed to the Friedrich-Realgymnasium, which he left in 1923 with an intermediate degree ("Primareife"). In 1923, aged only 16, von Ardenne registered his first patent for a "method for sound selection, especially for the use of wireless telegraphy." [VON ARDENNE].

The patent was for an electronic tube with multiple (three) systems in a single tube instead of three separated tubes which cut cost to a third for applications in wireless telegraphy. Ultimately, these were *one of the first integrated circuits of the electronics* history.

He pursued the development of radio engineering with the entrepreneur Siegmund Loewe, who ran the Berlin radio firm Loewe and became his supporter and mentor. Based on Manfred von Ardenne's multiple system electronic tube invention Loewe introduced in 1926 a cheap mass-produced radio receiver "Loewe-Ortsempfänger OE333" [Schild 2009].

Since 1924 Manfred von Ardenne earned his living by selling his first books and technological developments and discoveries (patent sales and publication income). With his earnings in 1925, von Ardenne substantially improved the broadband amplifier (resistance-coupled amplifier), which was fundamental to the *development of television and radar*.

Since 1925 von Ardenne was known for his idea of the multi-system electron tube. The two German radio pioneers Georg Graf von Arco and Geheimrat ("Privy") Walther Nernst urged Manfred von Ardenne to study. Thanks to their help he enrolled at the University in Berlin in 1925, without an Abitur graduation from a German Gymnasium, a requirement to enter a German university.

He attended lectures on physics, chemistry and mathematics. After four semesters of basic studies and perception the university system to be inflexible and outdated impatience grabbed him. He left his formal studies, went back to his private research, became an autodidact and devoted himself to applied physics research.

In 1928 having obtained his heritage with full control of how to spend it, Ardenne established his private research laboratory in Berlin-Lichterfelde, to conduct his own research on radio and television technology and electron microscopy. At the age of 21, he founded the "VON ARDENNE-Laboratorium für Elektronenphysik" (VON ARDENNE Laboratory for Electron Physics) which he led until 1945.

With the development and adoption of his multi-system tubes for radio reception, with the construction of new special oscillograph tubes and broad band amplifiers on behalf of renowned electrical companies he generated the economic basis for his institute ("contract R&D").

In the late 1920s collaboration between the firm Leybold in Cologne and Ardenne was set up via the company "Leybold und Ardenne." To separate Ardenne's research activities from production processes around 1934 the "Leybold and von Ardenne Oscillograph Company" was founded in Cologne and Berlin. For reasons of capacity this firm was affiliated in 1937 to the Siemens & Halske electro-giant [Radiomuseum].

Until its forced closure in 1945 von Ardenne's laboratory was the birthplace for pioneering contributions to television technology, image conversion, electron microscopy, scanning microscopy, isotope separation and electron and ion beam technology.

On 14 December 1930, von Ardenne achieved the breakthrough to a *fully electronic television* as an alternative to the electromechanical scanning using a Nipkow disc with *the first usage of the flying spot scanner*. In August 1931, at the Berlin Radio Show (now IFA – Internationale Funkausstellung), Ardenne gave the world's first public demonstration of a television system using electron beam tubes for both transmission and reception. This event – reported in the New York Times on August 16, 1931 and illustrated by a picture, provided by Schild [2009] – became *the first fully electronic television in history*.

Further significant developments of von Ardenne included

- in 1934 the electron-optical image converter for infrared night vision devices and the X-ray image amplifier,
- in 1937 developing and building the first high-resolution scanning electron microscope– which until today remained an essential tool in many areas of research in microbiology, cell physiology and genetic engineering,
- in 1939 producing the magnetic universal electron microscope which would maintain its preeminent status until 1950.

On a side-track Ardenne already dealt with something else: In Lichterfelde he ran an accelerator for nuclear transformation and a plant for electromagnetic separation of isotopes. This means, he tinkered with technologies that could become relevant to make atomic bombs. He achieved

- in 1941 the construction of the van de Graaff Neutron Generator,
- in 1943 the construction and testing of a cyclotron with a 60 t magnet for tests for particle acceleration.

But this work was not funded by the mighty Albert Speer and his Ministry of Armaments or by the Reich Research Council, but by the Postmaster General Wilhelm Ohnesorge [Hoffmann 2009] who, according to Hoffmann, had an own plan to build a German atomic bomb.

The von Ardenne family had no sympathy with National Socialism. When Hermann Göring invited Manfred's father to take up a leading position in the NSDAP Party, he refused categorically. Egmont Baron von Ardenne had got to know the later Reichspostminister (Postmaster General) and physicist Wilhelm Ohnesorge during the First World War (WWI). Later, Manfred von Ardenne made use of this contact as a source of funding his research work and for securing the existence of his laboratory, but without any kind of political background. He also turned down an invitation from his benefactor to join the Nazi Party.

After WWII and a "protection" document for Ardenne's lab by the Soviets an offer was made to Manfred von Ardenne to set up and lead a technological-physical research institute which would work for the Soviet Union on electron physics, nuclear-physical measurement, magnetic isotope separation and mass spectrometry. Von Ardenne agreed. And in early summer 1945, before the Americans marched into Berlin-Lichterfelde, von Ardenne's lab was dismantled and transferred together with Ardenne and the majority of his employees to the Soviet Union to Sinop near Sukhumi. Here, he and other German specialists had to stay for ten years.

But after the dropping of the atomic bombs onto Hiroshima and Nagasaki, von Ardenne and other leading German scientists were captured for the network of Soviet nuclear armaments and von Ardenne was obliged to cooperate in the Soviet nuclear program. From then on political events determined his research work. The Soviet side was obsessed with closing the gap and being able to catch up and compete with the US.

According to von Ardenne the dreaded head of the Soviet Secret Service Beria (Berija) tried to entrust the project to von Ardenne during a meeting. But von Ardenne succeeded to wriggle out according to arguments emphasizing the development of the isotope separation process for obtaining nuclear explosives, such as uranium-235, to industrial standards.

"Isotope separation is the real and very difficult bottleneck for development. Therefore, I propose that isotope separation alone should be the main task of our institute and the German specialists, and that the leading nuclear scientists of the Soviet Union that are sitting in front of me should bring about the development of the atom bomb."

Von Ardenne was made head of Institute A in Sinop, a suburb of Sukhumi. Goals of Ardenne's Institute A included: 1) Electromagnetic separation of isotopes, for which von Ardenne was the leader, 2) Techniques for manufacturing porous barriers for isotope separation, for which Peter Adolf Thiessen was the leader, and 3) Molecular techniques for separation of uranium isotopes (creating highly enriched uranium-235), for which Max Steenbeck was the leader. At the suggestion of authorities, Ardenne eventually shifted his research from isotope separation to plasma research directed towards controlled nuclear fusion.

In addition to experimental nuclear physics, the institute in Sinop was still concerned with electron microscopy and special tasks for electronic measurement techniques. In 1948, with the Duoplasmatron device, a strong-current ion beam source with double focusing through non-homogeneous magnetic fields was created, which is still used today in particle acceleration and as a correcting drive mechanism in space travel.

In 1947, Ardenne was awarded a Stalin Prize for his development of a table-top electron microscope. In 1953, before his return to Germany, he was awarded a Stalin Prize, First Class, for contributions to the atomic bomb project. The money from this prize, 100,000 Rubles, was used later to buy the land for his private institute in the German Democratic Republic (East Germany).

Considering all Naimark [1995:249] describes the roles of the Germans in face of the Soviets as follows:

"By any number of measures, the Soviet programs in atomic and rocket science, the extraction of uranium, and the adoption of German technology were a great success. On August 23, 1949, the Soviets exploded their first atomic bomb – to the great surprise, shock, and dismay of their American rivals, who were certain that they had denied the Russians the material and scientific wherewithal to accomplish such a complex task. The Soviets later developed the first intercontinental ballistic missile and put the first satellite in pace. Clearly there would have been a Soviet space program without the Germans and a Soviet atom bomb without Wismut and the

German physicists. But there is no question that German science, technology, research methods, and material were important, if not indispensable, to these accomplishments."

Under the name Wismut after WWII the Soviets took ownership of German uranium mines and exploited them. The labor-intensive methods of uranium extraction required tens of thousands of workers, but the Soviets were in no mood to improve conditions so that workers would be enticed into the mines. Instead, forced labor was brought to the region and subjected to humiliating and unbearable physical circumstances. The mining operation was turned into a death march [Naimark 1995].

After having completed his mission in the USSR already in the early 1950s von Ardenne started planning a return to Germany. However, he and the other German specialists had to stay again some years to "cool" their nuclear physics knowledge. During this period they could deal with scientific issues of their choice [Hoffmann 2009].

Von Ardenne could have had the opportunity to move to the West [Hoffmann 2009]. But it became clear that he only had a future in East Germany if he did not want to give up his complete plant, equipment and personal properties which were all brought to the Soviet Union in May 1945. Furthermore, he could keep his not inconsiderable Ruble assets – just only the Stalin prize was endowed with 100,000 Rubles. Furthermore, his annual salary was much higher than what could be reasonably spent in the Soviet Union. All this money could be converted into East German Marks at a favorable exchange rate [Hoffmann 2009].

Initially, two villas in the Dresden district of Weißer Hirsch became the location of the newly founded Forschungsinstitut Manfred von Ardenne. Today they house the management offices of the firm "VON ARDENNE Anlagentechnik GmbH."

On 24 May 1955, Manfred von Ardenne arrived with his family and a team of 30 scientists and staff in Dresden and set to *work under privileged conditions* almost immediately after his arrival. Notwithstanding the prevailing socialistic reason of state, von Ardenne was able to push through a *private* legal status (!) for the new institute, which remained in place up to the 1990 German Re-Unification in spite of countless restrictions.

At the beginning, the focus of the work was on electron, ion, nuclear physics and electron microscopy, and later in medical electronics as well as basic research in biomedicine. The institute pursued research in close connection with industry. Industrial facilities using melting, cutting and coating were developed for various materials, all based on electron and ion sources. With the electron-multi-chamber furnace and the plasma jet torch for cutting metals pioneering work emerged again here. Von Ardenne worked also on cancer research and treatment till the end of his life.

There was a really private “Research Institute Manfred von Ardenne” (Institut Manfred von Ardenne) with the goodwill of the SED leadership. The institute had several privileges and benefits, such tax privileges, lucrative government contracts, and granting extensive research autonomy. Walter Ulbricht welcomed von Ardenne with a Russian luxury sedan as a gift [Hoffmann 2009].

Walter Ulbricht was General Secretary of the Central Committee of the Socialist Unity Party (SED) of the GDR, as such the *de facto* leader of East Germany, from 1950 to 1971. The People’s Chamber (German: Volkskammer) was the unicameral legislature of the German Democratic Republic (East Germany). From its founding in 1949 until the first free elections on 18 March 1990, all members of the Volkskammer were elected from a list controlled by the Socialist Unity Party of Germany (SED), called the National Front.

In 1957 Ardenne became a member of the “Forschungsrat” (Research Counsil) of the GDR. From 1963 to 1989 von Ardenne acted as a member of the People’s Chamber (“Volkskammer”) and a member of the Cultural Alliance Group (“Kulturbund-Fraktion”). He confessed to the GDR state and thanked Walter Ulbricht regularly at international conferences for the public support of his scientific work [Kunz 2008]. Despite his functions Ardenne set aside political statements largely. He was committed to the East German state [Hoffmann 2009].

But there was one outstanding event. He made a suggestion to the GDR’s Secret Service (Ministerium für Staatssicherheit, MfS) to “humanize” the GDR border regime. Refugees leaving the GDR via its border (or walls) should be shot with an anesthetic rather than with live ammunition. This all was forgotten after fall of 1989. Ardenne now belonged to those who publicly demanded a reform of the GDR society, in particular, the rejection of bureaucratic centralism and a move to a market economy [Hoffmann 2009; Brosin 2011].

By 1989, the Manfred von Ardenne Research Institute had grown into an internationally recognized facility for applied research and development, with more than 500 employees. It was able to finance itself by selling its results. Customers for new industrial applications of electron beam and plasma technologies were the East German state industry as well as exports essentially to the countries of the Eastern bloc. Furthermore, the Institute received grants from several ministries of the GDR. But the institute had to keep extremely high stocks of material and machine components which represented an unusually high debt. This was necessary to put into effect short-term projects underlying the economic conditions planned by the state and for export.

Both circumstances – dependence on the state industry sector and the high amount of stock – turned out to be fateful in summer 1990 during setting up the German economic and monetary union: The old state industries disappeared within a few weeks, and signed, mostly long-term contracts were broken unilaterally. The stock of components and materials became worthless overnight. Their devaluation to zero was set against the loans taken out which remained.

The related missing amount of 7.5 million Deutschmarks appeared to be an impassable barrier, out of which salaries for 500 employees had to be paid in Deutschmarks, and further bank loans with interest and repayment installments were taken out against the old debts. The layoff of nearly 60 percent of the workforce was unavoidable and called for redundancy payments for which the Ardenne family had to take out new loans.

The staff was reduced to 220 employees, and the institute was split into three companies. The firm VON ARDENNE Anlagentechnik GmbH survived as the *de facto* successor of the von Ardenne institute. VON ARDENNE Anlagentechnik GmbH was re-established under the market economy in 1991, with Dr. Peter Lenk as managing director, an employee of the former research institute since 1962. 65 especially experienced members of staff with knowledge of the scientific and technical tradition of the former institute were recruited.

The von Ardenne family invested a startup capital of 200,000 Deutschmarks as 100 percent shareholder. Survival was through re-negotiating the contracts with the few remaining old customers from the former Eastern bloc as well as with clients from Japan, Korea and Taiwan, also with the help of the “Treuhand Agency” as well as companies from former West Germany. “The German Treuhand Agency” was leading the re-organization of the socialistic economy, industry and research organizations of the former GDR (cf. also the fate of the IGV research institute in A.1.1.4).

During 1991-2004 VON ARDENNE was a niche player in much diversified market segments with small growth potential; its revenues developed from <€1 million to €46 million. With a new business model focusing on the architectural glass and solar markets revenue increased to €166 million in 2008 and the number of employee increased from 240 to 500 [Schild 2009]. For 2011 VON ARDENNE Anlagentechnik showed revenues of €192.5 million with 650 employees and an export rate of 78.4 percent.

The rapid development of the company was based on utilizing innovations, such as *applying multiple layers with exceptional optical, thermal and mechanical properties and certain structures* on any substrate in a vacuum. And also the production of electron beam guns with beam power of up to 1.200 kW for the production of highly reactive and refractory metals in electron beam multi-chamber furnaces gained increasing international importance.

Based on expertise in plasma and electron beam technologies built over decades VON ARDENNE is now a customer-oriented worldwide leading manufacturer of equipment for industrial vacuum processes of plasma and electron beam technologies. It develops and manufactures systems for the micro- and nanometer-thin coating of glass, metal and plastic foil.

VON ARDENNE equipment is in operation in more than 50 countries around the world. The company holds more than 300 patent families worldwide. Key competencies are the thin-film technologies for photovoltaics and architectural glass, the electron beam technology as well as research and development.

Manfred von Ardenne probably was at the wrong time at the wrong place. If he had been captured by the Americans rather than the Soviets or had he, at least, chosen West Germany rather than East Germany when he relocated from the USSR to Germany, a discussion of his life and acknowledgement of his life's work would likely be far more in the direction of one of Germany's great inventors of the last century.

Whereas Manfred von Ardenne was committed to inventions, applications, and innovation around electron physics Wernher von Braun appears really as a person who behaved as was needed to advance his own interests and survival. Particularly, he *appears to have been obsessed by the realization of just one goal, space flight* to the moon at any cost. And von Braun, indeed, became the father of modern rocketry, and a hero to some and villain, specifically a war criminal, to others.

Wernher von Braun

"Few figures in recent history inspire as vigorous ethical debate as Wernher von Braun (born 1912), the architect of both the Nazi V-2 missile program and later the United States Saturn V missile program." [Crowley and Trudeau 2011:2]

Assessments of his life's work and controversies depend actually on who did it and when (context), such as government-related persons or agencies or scholars or whether his technical or personal activities and behavior are emphasized. Concerning technology and innovative, entrepreneurial and leadership aspects there is no doubt that "Wernher von Braun (1912–1977) was one of the most important rocket developers and champions of space exploration during the period between the 1930s and the 1970s." [MSFC]

On the other hand, von Braun appears as a moral chameleon who behaved as was needed to advance his own interests and survival. Particularly, he appears to have been obsessed to the realization of space flight to the moon at any cost – a main character who was highly adaptable to shifting moral and political environments and used war as an opportunity to marshal rocket development resources.

In the literature there is a broad variety of authors in the US and Germany with opinions Pro-von Braun and Anti-von Braun listed by Crowley and Trudeau [2011]. Crowley and Trudeau provide a balanced picture that von Braun's life was not as simple as to allow black or white characterizations. In particular, they emphasize the historical context of von Braun's biography who grew up in a Germany that was in turmoil between the two world wars, in the German Weimar Republic and the Nazi state, and focusing as well as on his family background.

The (English and German) Wikipedia article: “Wernher von Braun,” is relatively critical comprising his time as a Nazi and presents both sides of the story [Wernher von Braun], of whether he was an ardent Nazi or just an apolitical opportunist. The following outlines will just refer to this article and the “ethical analysis” of Crowley and Trudeau [2011], if not stated otherwise.

Concerning technical achievements of von Braun Crowley and Trudeau [2011:38-39] argue as follows:

“Wernher von Braun was raised as a patriotic Prussian, from a culture of military and political service, and his ready acceptance of military funding for his research was therefore a natural outgrowth of his upbringing. His development of the V-2 and its use against British, French and Belgian cities was in and of itself no more immoral than the actions of many engineers, of various nations, who developed weapons which were used in the war.” “The V-2 program, on its face, was no less moral, and of far lower magnitude in its effects, than many similar actions by the allies.”

The significance of role model, particularly of parents, has been emphasized for entrepreneurship (ch. 1.2.2, ch. 2.1.2.4, ch. 4.2.1, ch. 4.2.2) and similarly von Braun’s parents both influenced him significantly, but in different ways. The fact that after WWI his family’s status and comfort were directly negatively impacted by the Weimar Republic and its left-wing policies surely impacted the young von Braun.

Von Braun’s father Magnus was a right-wing Prussian Junker, much more dedicated to the Kaiserreich’s conservative politics than those of the Nazis. Magnus von Braun was the primary source of much of his son’s political views. Throughout Wernher’s young life, Magnus was an ardent conservative, a devout monarchist, and a Prussian elitist. But overlaying his firm position behind the Hohenzollern monarchy Magnus was more broadly opposed to democracy in general, especially the socialist-controlled democracy of the Weimar Republic [Crowley and Trudeau 2011:6,7].

Though he obtained his conservative, nationalist political views from his father, it was his mother Emmy and her family to whom von Braun owed his interest in the natural sciences and, of course, astronomy. Emmy grew up in a family wherein love of science was nourished and she attempted to create a similar setting for her sons. In 1925, for his Lutheran confirmation, his mother gave him a telescope instead of the gold pocket watch traditional for those in his class. The gift was a huge hit, inspiring a love of astronomy in the young Wernher which would last a lifetime [Crowley and Trudeau 2011:8]

In 1928 his parents moved him to the Hermann-Lietz-Internat (also a residential school) on the East Frisian North Sea island of Spiekeroog. There he acquired a copy of “Die Rakete zu den Planetenräumen” (1929) (By Rocket into Interplanetary Space) by rocket pioneer Hermann Oberth. Space travel had always fascinated von Braun and motivated him to commit himself to physics and mathematics to pursue his interest in rocket engineering.

In 1930 he attended the Technical University of Berlin, where he joined the “Verein für Raumschiffahrt” (VfR, the “Spaceflight Society”) and assisted Willy Ley in his liquid-fueled rocket motor tests in conjunction with Hermann Oberth who has greatly influenced him. Oberth was not only a leading proponent of the possibility of using rockets to reach space; he also introduced von Braun to the idea of rockets delivering explosives or poison gas payloads to enemy cities in future wars. Although he worked mainly on military rockets in his later years space travel remained his primary interest [Crowley and Trudeau 2011:9].

Von Braun also studied shortly at ETH Zurich. Before von Braun’s return to Berlin the leading rocketry journal was closed due to lack of funds. As the lack of funding became a more general issue for the field, some of the society, including von Braun, turned to government funding, primarily from the military.

Thanks to rockets being one of a small number of areas of military research allowed by the Versailles Treaty, the desired funding was readily found. Then referring to military for further funding was quite natural for von Braun [Crowley and Trudeau 2011:9].

There are three key morality issues which emerged in the context of von Braun’s life.

- His membership of the NSDAP Nazi party, the National Socialist German Workers’ Party,
- His affiliation with the SS organization, and
- His role during the production of the V-2 rockets, when prisoners from the concentration camp Mittelbau Dora were used as slave labor under horrific conditions and, according to official SS documents, as many as 12,000 slave laborers died from illness, beatings, hangings and intolerable working conditions during the production of the V-2.

More people died building the V-2 rockets than were killed by it as a weapon. The death toll, mentioned above, caused by the V-2, including the deaths of slave laborers, is estimated to be 20,000 for the entire war [Crowley and Trudeau 2011:9].

SS stands for Schutzstaffel (which literally means “protective squadron’). It became Hitler’s personal bodyguard and was later headed by Heinrich Himmler and expanded considerably. It assumed sole responsibility for running the concentration camps and organizing the Holocaust. It became a central element in the Nazi terror apparatus and ran its own security service SD (SS security services). After 1945, the SS was banned in Germany, along with the Nazi Party, as a criminal organization. The SS was distinguished from other branches of the German military, the National Socialist Party, and German state officials by its own rank structure, unit insignia, and uniforms.

Von Braun officially applied for membership in the NSDAP on November 12, 1937. He began in the SS as an Untersturmführer (second lieutenant) and was promoted three times by Himmler, the last time in June 1943 to SS-Sturmbannführer (major). Von Braun claimed this was a technical promotion received each year regularly by mail.

His claims of indifference and lack of political interest are backed up by much of the available evidence.

In 1933 all faculty with leftist political views or Jewish ancestry were expelled from von Braun's university. This was followed by significant pressure on all students to either join the Party or at least to join Nazi-affiliated organizations.

First, he only joined the SS after significant pressure was put on the university, after seeing his professors expelled around him. Second, he only joined when a probationary membership which he could back out of was possible. Indeed, as soon as this probationary period was over, he dropped out of the organization, and was not part of the SS again until he rejoined in 1940. This rejoining of the SS was allegedly again due to pressure from the Nazi establishment. According to von Braun, and backed up by other anecdotal accounts, he received an offer of SS membership as Untersturmführer, and it was stressed to him that it was a "very definite desire of Himmler" that he joins [Crowley and Trudeau 2011:18-19].

"This complicity in the Holocaust, no matter how superficially he himself may have been involved, was a black mark. Though von Braun was hardly the only German to turn a blind eye to the atrocities of the Nazis, he was face-to-face with slave laborers on a daily basis." "In the end, though, the evidence suggests that his worst crime was to be so driven by his passion for space flight that he ignored and accepted the actions of others around him." [Crowley and Trudeau 2011:39]

After WWII "from the beginning, von Braun's new life in the US revolved around bringing the technical expertise of his Peenemünde group to bear on the US military's rocket program. Largely through his and his group's efforts, the US recovered from early losses in the space race to eventually land men on the moon, an event still seen as one of the defining moments for humanity.

Coworkers in NASA have consistently claimed that this would not have happened without von Braun at the helm of the Saturn V program." "The US government, in this context, had an interest in not focusing too long on any potential blemishes they might find in his career for the Nazis." [Crowley and Trudeau 2011:39]

Crowley and Trudeau [2011] do not only focus on von Braun, but stress furthermore the ethical issues of the US outweighing the advantage which could be gained during the Cold War from using the rocket expertise of the German engineers against the Soviets who were the first to successfully insert Sputnik into earth orbit and then sent Yuri Gagarin into space.

"In the process, the Nazi pasts of those involved were largely ignored and, in some cases, actively rewritten. The second component of any ethical discussion of the life of von Braun, then, is the moral choice faced by the United States when balancing the pasts and actions of a group of people which it saw as a potential technical gold mine.” [Crowley and Trudeau 2011:39-40]

“Despite the horrors of World War II and the Holocaust, by the early 50s the United States was in a growing stand-off with its erstwhile ally of convenience, the USSR, and was willing to forget the past injustices committed by Nazi scientists and engineers in exchange for an advantage in its new rivalry.

Wernher von Braun, then, represented a trump card which the United States could not afford to ignore and was eagerly obtained and employed in the Saturn rocket program. The conflict between the desire for justice and the need for skilled engineers for the Cold War was ultimately decided in favor of acquiring an advantage against the Soviets, a decision which has been questioned by many ever since it was made public.” [Crowley and Trudeau 2011:3]

Disregarding the ethical issues of the US the lesson given by Crowley and Trudeau [2011] to all engineers and scientists is:

“No scientific or engineering work takes place in a vacuum, and although von Braun’s situation is an extreme example, it is still illustrative of the responsibility of all engineers to not only ensure their work itself is ethical, but that the context of their work is ethical. Wernher von Braun’s desire to put men into space was in and of itself a worthy goal, but by integrating himself into the Nazi establishment in order to achieve it, he allowed his work, overall, to become tainted.” [Crowley and Trudeau 2011:41]

2.1.2.9 Conceptual Particulars of Applied General Systems Theory for Observation, Measurement and Practice

So far, using GST as a framework emphasis was on the *founder persons and personalities and the systemic context* they are active in and have to make decisions and act. Apart from references to macro-statistical results for presenting selected aspects of technology entrepreneurship cases of new technology ventures were used essentially to specify macro-level results and develop structural and functional particulars of the subject or raise related questions.

After dealing with why to become an entrepreneur, with motivations, *goals and purpose* (ch. 2.1.5.6; Table I.39, Table I.40), one was led to the entrepreneur’s *expectations* and visions and after firm’s foundation to the startup’s mission (ch. 2.1.2.7). Operationalizing the mission in terms of objectives was presented as the basis to *measure* the level of achieving the goals.

Descriptions referred essentially to structures and attributes and even when development processes of human activities were presented their characters as “snapshots” or sequences of separate, individual stages with fixed attributes exhibit deficiencies with regard to a GST approach. A first example of tackling system dynamics was introduced for team formation (Equation I.5, Figure I.70) taking the systemic effect of self-reinforcement into account.

The current approach to entrepreneurship combining the micro- and macro-level recurrently shall interrelate *observation* (and related description and interpretation) of single cases to *measurement* (ch. 1.2) – and ultimately understanding and “prediction” concerning development of individual NTBFs. Hence, it requires being clear with related notions and concepts within the GST framework.

Observation comprises an object/subject and a process, act or instance of noticing or perceiving. Fundamentally, observation relates to a procedure whereby the senses (of sight, sound, touch, smell or taste) generate data and information about the entity. In our approach when referring to cases and the data and information they provide it means observation of single new firms.

As with many concepts in our culture and education, we tend to fall well short of fully appreciating what terms truly suggest and at times, the apparent confusion and contradictions that they may evoke. This is particularly relevant for GST which deals with “hard” and “soft” sciences and also the notion “*prediction*.”

The below outline concerning fundamental structures will not only hint at key differences between “hard” and “soft” sciences and position expectation against prediction. It will later be used metaphorically for the (semi-)quantitative description of new firms’ developments (ch. 4.3) referring specifically to *operators and operands – states* (ch. 4.3.4).

In “hard” science, for instance, in quantum theory of the atomic or molecular level an experimental setup refers to an *observable* E, say energy, to be measured for a *state* ψ of a system arranged to be a *closed system*. To relate or predict something you can observe in the laboratory the “*expectation value*” of the measurable quantity that will be calculated by a specific quantum theoretical approach.

Quantum theory does not, in fact, predict the result of individual measurements, but only their statistical mean. This predicted mean value is the *expectation value*. Only the statistical mean of the measured values, averaged over a large number of runs is a quantity reproducible within experimental error.

Very basically, for a metaphorical approach (ch. 4.3.4), we shall be using the function/vectorial (“bra > and < ket”) representation of quantum mechanics for states. A given (mathematical) *operator* $\mathcal{H}$ acts on a system with a set of *allowed* states ψ_i characterized by an “observable,” *numerically* measurable (here energetic) quantity E_i (Equation I.6). The bra-ket notation of quantum theory relates the notion $<\psi_j|\psi_i>$ to a certain degree to the “inner product” of common vector spaces.

The set of values E_i of the operator represents all the possible results that could be obtained for the allowed states if the associated physical observable were to be measured. In the mathematical structure of quantum theory for a measurement only a probability distribution of associated states $|\psi_i>$ with values E_i will be encountered and the expectation value E, roughly speaking, represents the (probability-weighted) average value of the results of many repetitions of the measurement of an observable, with each measurement carried out on one of very many identically prepared copies of the same system, called an ensemble.

The state functions $|\psi_i>$ describe the current state of an ensemble of components (for instance, elementary particles, atoms and electrons) and, when subjected to interactions *with known external forces* due to measurement, the possible states. In this way, we have, for instance, a "ground state" of a system and interactions with light may result in transitions into "excited states" whose (energetic) expectation values will be predicted by quantum-theoretical calculations.

Equation I.6

$$\mathcal{H}\,|\psi_i> = E_i\,|\psi_i> \text{ and } i = 1, 2, \ldots n;\ E \rightarrow \text{(probability-weighted) average value of } E_i$$

$$<\psi_j\,|\psi_i> = 1 \text{ for } j = i \text{ and } 0 \text{ for } j \neq i;\ <\psi_j\,|\ E_i\,|\psi_j> = E_i <\psi_j\,|\psi_i>$$

These considerations as metaphors will become relevant when using cybernetics (ch. 4.3.4) to deal (semi)quatitatively with developments (growths) of startups (ch. 4.3.5).

For soft sciences measurement (ch. 1.2.1) refers to the output (and outcomes) of "soft" systems and methods to evaluate complex alternatives. Specifically, "a decision-making activity … designed to accomplish an objective" is a measurement [Van Gigch 1974:141].

Soft sciences, mostly dealing with *open systems*, rarely provide the possibility to repeat an experimental setup for several successive measurements. A *metaphoric interpretation of Equation I.6 for a human-activity system* (a firm) embedded in other systems with which it interacts means human action and behavior of and in a particular subsystem.

This subsystem has certain prerequisites for operation with respect to a goal and is associated with "expectation value(s)" *constrained by factors over which the subsystem (and an observer) has no control and which induces uncertainty or risk*, respectively. This ends the analogy for our context. But, even this constrained analogy suffices to become important in the context of growth of NTBFs (ch. 4.3.4 – 4.3.6).

For the "soft" field of entrepreneurship we introduce the term "expected value" – not necessarily a numerical value – as a differentiation from expectation value. The **expected value** is used as a notion to describe qualitatively or quantitatively the *immediate or future outcomes or results of human activities* related to particular purposes or goals, respectively, and made explicit, for instance, in a business plan, based on

- Premises (such as, initial situation, variables and parameters (ch. 1.1.2) and constraints),
- Assumptions,
- Facts, and
- Opinions.

Checking to replicate the values of the first “measurement” of a firm founder, which is his or her expectation, by others with related expertise or (personal) interest in the outcomes or results, such as subject matter experts or investors, represents additional measurements. And all these may deliver values of outcomes/results which on aggregation may become expected values (cf. ch. 4.1; Box I.17).

Figure I.77 illustrates the key conceptual differences between an expectation value and expected value as understood in this book. A special kind of measurement in social sciences by a panel of experts is used when initial individual expected values are enforced to converge to just one expected value by a special process, for instance, the Lockean Delphi method (Box I.17).

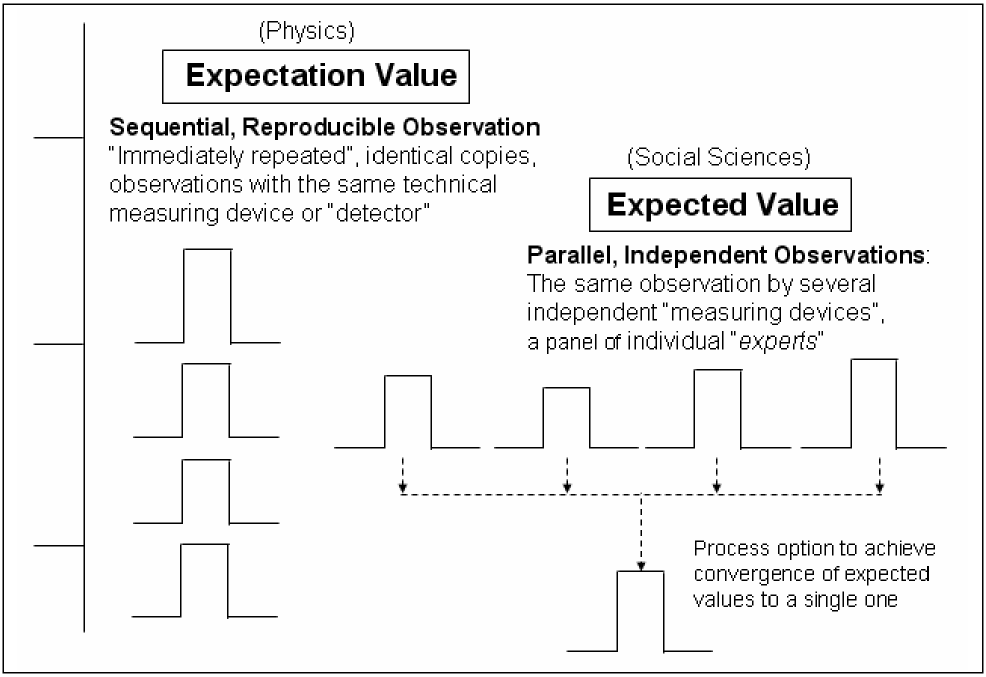


Figure I.77: Expectation values and expected values in “hard” and “soft” sciences.

In particular, when we speak of expectation we shall associate this with an evaluation by just one person, such as an entrepreneur, a venture capitalist or banker or an outside researcher. An entrepreneur’s evaluation may be complemented by an evaluation of another person or group of persons (a founder team). This may occur in the course of generating a business plan or when an entrepreneur participates in a business plan contest and matches his/her expectations with the feedback he/she got from a review team. The combined and "agreed" upon outcomes may lead to an "expected value," provided the individual assessments do not differ significantly ("disagreement").

In this line Autio [2005] constrains "high-expectation activity" to "all start-ups and newly formed businesses which expect to employ at least 20 employees within five years' time" (ch. 4.1).

For entrepreneurship the notion *expected value* is associated with the qualitative or quantitative socio-economic value any stakeholder in a particular entrepreneurial activity or process may generate. This may be wealth for a firm's founder, big reward for an investor or jobs for the government and may be derived, for instance, from an "income projection" or number of to-be created jobs. Expected value is also a customer perspective. Customers of products or services have expectations about what they will receive in terms of expected values from the supplier.

Expectation as associated with the entrepreneur(s) is influenced by the personality, by self-confidence and (internal) locus of control (Table I.31) and finally related to certitude (or even overoptimism).

> But the key concept for an outside observer which fundamentally hinders prediction-like statements in entrepreneurship is not only the open system character of a new venture and the many influences it is subjected to by the environment but also volition (2.1.2).

Volition is the more or less free and conscious personal choice and decision-making of the entrepreneur (ch. 4.2.2) (and his/her internal or external "advisors") to initiate actions and behavior, done by an act of will for further development of his/her new firm toward reaching their goals. [40] Such decision and action situations can only be associated with expectations or expected values of an observer and discredits "predictions" to be made on the basis of known initial (starting) configurations, variables and parameters.

GST as our basis refers to *open, human-activities systems* and is *teleological* rather than causal in character associating directions with intention, purpose or aim. The current book puts much emphasis on *explaining and understanding rather than "predicting."* Therefore, specifically in the interconnection to its dichotomy "praxis," we refer therefore to the original Greek notion "theoria" (θεωρία, literally, to view or witness something) as contemplation, as *comprehending by watching* and presenting sets of *observable facts* and by *revealing relation to one another* deriving principles from a body of facts and thus increasing knowledge. [48]

Basically, prediction would be associated with an initial (starting) conditions of a state, "laws" or equations of development or motion to deliver an end. Expectation is *per se* associated with an end, a goal or a view of success as an entry, then mentally going back to a start and generating a statement about *the level of achieving the goal*.

Therefore, we shall speak in the following of “prediction” only in a context of closed systems or, if a system is open *per se*; but its constellation can be regarded as “nearly closed” and “stable” for a given period of time. Otherwise we shall refer to expectation or expected value(s). This actually includes even quantitative treatments utilizing cybernetic approaches (ch. 4.3.4).

Prediction is closely related to the “reason why” perspective; expectation reflects “reasons for thinking that” (Figure I.2) as the very complex systemic phenomenon of (technology) entrepreneurship does not guarantees that for explanation or understanding all relevant factors have been taken into account.

Expectation [48] means looking forward to an event. *In case of uncertainty and risk, as for entrepreneurship,* it is about to what is considered *the most likely to happen*. An expectation may be a belief that is centered *on the future, it may or may not be realistic, and it may be achieved or not.* It is a *prospect of a future reality*. Expectation thus exhibits an association with foreknowledge (ch. 1.2.3; 4.1). For the domain of open, purposeful systems theory does not tell us what *must* happen, it tells us what *can* happen (is expected to happen).

“Prediction” for open systems can occur, for instance, if future events or observable values can be legitimately obtained by “extrapolation” of the past.

“Theoria cum praxi” – the motto of the Preface – and the reference to GST provide also some semantic and epistemological issues which require further clarification. It starts with the notion “theoria” or “theory.” As partially outlined, most people immediately interconnect “theory” implicitly with meaning used in current *natural science and technology* – and applied to *closed systems.*

The focus is on a particular part of reality and the base is on “scientific, paradigmatic” beliefs which are created following the “*scientific method*” emphasizing the complementarities of experiment and theory [Runge 2006:212-214]. Usually, a theory contains descriptive and explanatory statements on reality. Explanatory elements are assumed to refer to *linear causality* (if – then). This forms the basis for predictions and also leads to recommendations for actions. For a domain of applicability a theory tells us what *must* happen.

“Praxis” is the process by which “theoria” is enacted and in Ancient Greek the word praxis (πρᾶξις) referred to *activity engaged in by free men*. “Praxis” for Aristotle, for instance, includes *goal-directed action,* although it sometimes also includes the condition that the action is itself part of the end. When referring to action under uncertainty action of and in open systems should be combined with “*expectation*” (Latin expectare – “await, hope”).

In a *continuously changing world* praxis refers to an important implicit time dimension. “Praxis” means “*current practice*,” practice established during the previous fifteen to twenty years. And “praxis” must clearly differentiate the specific structures and processes used presently from those which are independent from time (and location) – the *generic* structures and processes (Preface, ch. 1.2.1).

Praxis means also referring to the wealth of empirical observations, evidences and data that are relevant for the subject under consideration irrespective of the particular (scientific) discipline and approach which have revealed them when dealing with the related empirical situations. Furthermore, all these empirical observations or evidences should be fed back into the theory.

Our approach to praxis focuses on the *operational validity* (actionability and usefulness) and refers to the extent to which empirical and research results are operationalizable through concrete actions. Our interpretation of the operational validity measure means 1) the identification of the critical NTBF variables for given parameters of the environment driving productivity or performance (“survival and growth”) and 2) the identification of the rough interrelations of how productivity or performance is being driven by variables and parameters – that is, the relationship between changes of certain characteristic levels to changes of productivity/performance. Finally, we shall also make explicit reference to obvious and common mistakes and pitfalls to be avoided when putting entrepreneurial intentions into practice (ch. 4.2.3).

Practice can be measured, at least, on an ordinal scale (sequential order), so that *recommendations* or proposals derived from theory or observations may become “best practice.” [49] A **Best Practice** is a technique, method, process, activity, incentive or reward that is believed to be more effective at delivering a particular outcome than any other technique, method, process, etc. when applied to a particular condition or circumstance and time period. Correspondingly, one may think of a *least practice*, for instance, the minimally required practice to achieve “survival” of a startup.

For (technology) entrepreneurship expectation is related to what is perceived as “***success***” by the founder(s) of a new firm (Figure I.1; ch. 4.1). Expectation may be associated with the end, but may also relate to steps or leaps (“stepping stones”) towards the goal – Aristotle’s actions being itself part of the end.

But while proceeding gradually “cross-roads,” for instance, induced by effects in the environment, may be encountered so that new or changed goals (directions) are intentionally decided upon or “unforeseen circumstances” require or suggest redirection. Success of entrepreneurship, hence, is associated with a *continuous* journey towards the achievement of a goal or purpose and related decisions and actions including change of a predetermined goal into a new goal.

These views of expectation and success induces two philosophical associations tackling the puzzling issue of asymmetries of entrepreneurship research between statements before (“will achieve,” *ex ante*) and after (“has achieved,” *ex post*) action.

1. There is a direct similarity to the German philosopher Arthur Schopenhauer’s key idea of his main work “Die Welt als Wille und Vorstellung” (translated

usually as “The World as Will and Representation,” but the German term “Vorstellung” would perhaps be better translated as “conception”).

2. Furthermore, paraphrasing the Danish philosopher Soeren Kierkegaard, who once said, “Life must be lived forward, but can only be understood backwards,” one can say that “entrepreneurship must be pursued forward, but can only be understood backwards.”

As a summary, a GST framework of a theoretical approach to entrepreneurship will operate with “*teleological categories*,” such as intention, strategy, need in the sense of wish (in German Bedürfnis, Wunsch) contrasted with need related to demand. Once we place a phenomenon within a teleological category we are provided with a very general pattern of expectations which may remove much of the surprise which might have been generated by the phenomenon under examination.

For this context we shall therefore introduce the notion of “teleological relations.” A **teleological relation** is a systemic relation that may express propulsion towards a target, an end or induce activities towards an end (a goal or purpose or function). A teleological relation is often associated with expectation and in this way represents a mental or material “move forward,” a “driver,” and can be represented as *a directed graph* as shown for the innovation → adoption relation (Figure I.26). A special expression of this teleological relation for a firm would be to see and treat customers as partners. More examples include the following relations.

- Vision → success,
- Intention(will, obsession) → behavior,
- Strategy → plan,
- Resources → financing (or endowment with personnel),
- Technology → application,
- Innovator (supplier) → adopter (customer).

Teleological relations refer to starting and completing purposeful activities and are often associated with *perspectives*. Examples for expressions of such perspectives have already been introduced, such as technical value versus market value (ch. 1.2.5.2; Figure I.25). A systemic view of the major part of Figure I.1 for (technology) entrepreneurship in terms of teleological relations is given in Figure I.78.

If there is a strong mutual influence of the components on each other representation by a bidirectional graph would be more appropriate. For instance, success and expectation may exhibit such a situation. Referring to the common saying that “success breeds success” one can assume that expectations will be synchronized.

Teleological relations can induce structural principles. Considering entrepreneurship and innovation as a result of strategic orientations and decision-making and planning and execution one may think of corresponding classification principles to deal more general with related firms or NTBFs, respectively.

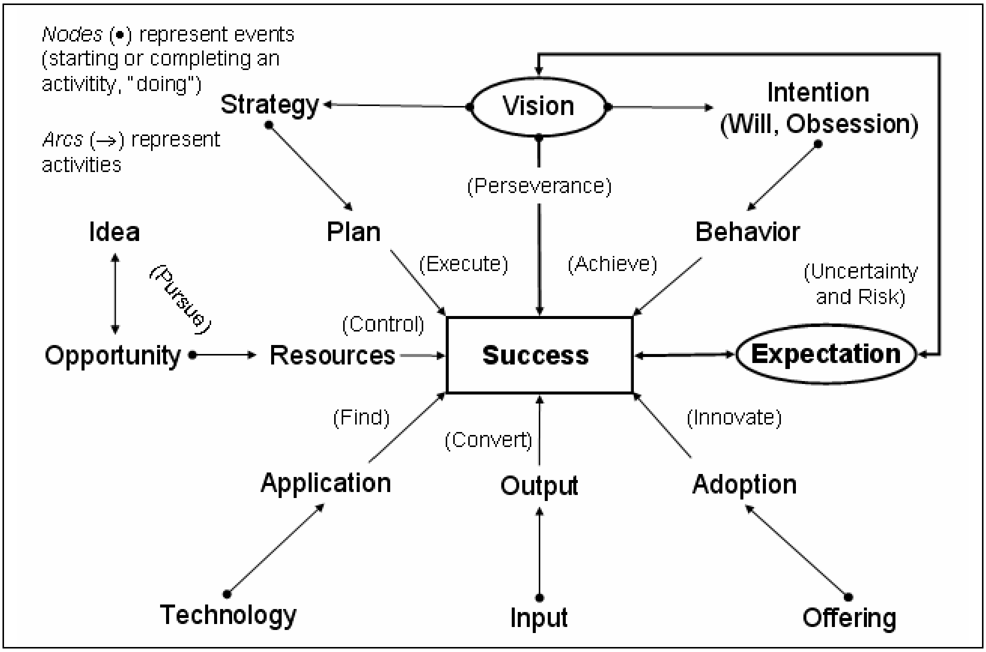


Figure I.78: Teleological relations as determinants of entrepreneurial expectation and associated entrepreneurial success.

Clustering according to ***strategic groups***, defined by Michael Porter as "a group of firms pursuing similar strategies along strategic dimensions" (ch. 1.2.1), provide a means to classify firms – irrespective of industries – into defined groupings based upon the strategies which *they choose to execute*. Firms within a strategic group are assumed to be sensitive to their interdependencies and are therefore likely to respond similarly to external events or competitive changes (cf. Hidden Champions, ch. 4.1.1).

2.2 The Corporate Entrepreneur – the Intrapreneur

In the GST approach the *generics* of structures, processes and personalities and principles of entrepreneurship are not different whether an individual starts his/her new venture or entrepreneurship and innovation occur in large existing firms. To account for specific differences, particularly in attitude, behavior and activities, *overall corporate culture* including *corporate politics* is seen as a key firm-specific conditioning factor (Figure I.17) that let the corporate entrepreneur or intrapreneur occur as a metamorphosis following a certain trajectory, but leaving certain personal traits and behavior (almost) unchanged.

For instance, persistence is a typical supportive generic personal trait of an entrepreneur (Table I.31). This morphs into "*adaptive persistence*" in the corporate environment (which is used in a different sense by Gergen and Vanourek [2009]). In the corporate environment obstacles to overcome do not only include “normal” ones of getting acceptance of a business idea and getting necessary resources for the related project. But the intrapreneur’s approach to achieve the goal must be adapted to the fact that the “normal” obstacles are usually overlaid by firm-specific culture, processses, bureaucracy and politics.

Corporate entrepreneurs have a fundamental constraint.

> Corporate entrepreneurs are employees who, furthermore, have to behave and act in line with an undersigned (legal) contract with the firm!

Particularly, corporate entrepreneurs have, at best, only partial ownership of intellectual properties, such as patents they have generated. Furthermore, corporate entrepreneurs have only little power or influence to enforce patenting of inventions they made if the employer does not want that or want to use other means to protect the intellectual property.

The metamorphosis of an entrepreneurial personality into an intrapreneur is, in principle, *reversible* as the many cases of employees in large firms or even small firms leave the parent firm for different reasons (Table I.39, Table I.40) to start their own, independent business (Figure I.17, Figure I.20, Figure I.64).

Dealing with intrapreneurship serves several purposes.

- On the one hand, it is an extension of a universal concept of entrepreneurship and provides insights *how certain given constraints may or will not influence appearance and development of new ventures by “original entrepreneurs.”*
- On the other hand, it provides scientists and engineers some insights into the “realities” of research and innovation in large companies and the spectrum of experiences they can gain – to start their own firm.
- Then, corporate entrepreneurship and innovation provides close similarities with VC-based new firms (Figure I.134) or JVs of SMEs and large firms requiring huge amounts of investments (A.1.1) expressed, for instance, also by comparing Figure I.79 and Figure I.180.
- A further dimension when entrepreneurs operate “under constraint” of a VC-based startup is given by control and ownership (of the firm Table I.74) and lifting of scarcity of resources (ch. 1.2.1) to a considerable degree.
- Finally, intrapreneurship in and innovation by large firms provide many examples for learning about interactions with customers.

Furthermore, intrapreneurship is an interesting area of research because it focuses on the psychological behavior of a character in identifying why this individual goes beyond the duty of what is required of him/her or why the individual goes against what is told or even commanded to him/her (ch. 2.2.3).

Corporate entrepreneurs' involvement in internal corporate innovation refers to all three types of innovation (Figure I.21) and may include organizationally different approaches to R&D, executed in a Business Research unit or Corporate (Central) Research unit [Runge 2006:717-720].

The distinction between corporate managers and corporate entrepreneurs, in particular with regard to striking differences in personality, has been emphasized already (ch. 2.1.2.1). It is not intended to discuss how to combine both personality types to the concept of "The Entrepreneurial Manager" [Morris et al. 2008:13].

Except "firm's foundation" intrapreneurship follow the key categories for entrepreneurship given in Figure I.1. Outstanding features of corporate culture with regard to effects on intrapreneurship include the corporate level, but also the business and functional level.

- Risk-taking versus risk averse culture [Runge 2006:626, 742-743]
- On the strategic level "Planner Leaders" or "Planner Followers," which is "planning to influence trends" or "planning to satisfy trends" [Runge 2006:17]
- Innovation or technology leader versus innovation or technology follower; leader versus "follow-the-leader" [Runge 2006:742-743]
- The balance between autonomy and control; the *innovation climate* to commercialize the "right" ideas and findings which *balances freedom* of creativity, imagination, action and personal development and *discipline* in executing structured corporate approaches and work processes
- Freedom to act and freedom to fail (of employees).

When discussing intrapreneurship it is particular interesting to see how on the one hand corporate management and on the other hand corporate entrepreneurs lift constraints of corporate environments to see which specific features of behaviors emerge and which can be assumed to correspond to those attributed to (solo-)entrepreneurs (ch. 2.2.3).

How *risk avoiding attitudes* ingrained in corporate culture and related behaviors and strategic directions of executive management of a firm also creep into employees is a known tactical process [Runge 2006:626]. The desire to avoid risk is a big obstacle to being an innovative company. "Innovative" scientists and intrapreneurial researchers may demonstrate to take risks by declaring that they are working on new, cutting-edge technology and programs in an emerging area.

However, their research may be high risk to the company, but it has low personal risk. Researchers may avoid personal risk by mimicking colleagues in other companies or may refer to results of market research companies. If a new technology does not work, it is hard to assign individual blame because the entire industry or the "opinion leading company" made the same mistake.

As a result, in risk avoiding firms researchers are more likely to focus on incremental improvements or take the role of the "follower" rather than targeting breakthrough innovation. A similar approach of solo-entrepreneurs occurs when they copy others (Table I.49, Table I.50).

The topic of corporate entrepreneurship encompasses essentially four types of phenomena and the processes surrounding them:

1. The generation of new businesses within existing organizations or corresponding business units, that means internal corporate innovation or new product development (NPD), new business development (NBD) by internal units, internal venturing of employer-initiated innovation projects through off-budget funds or the "*build" process*" [Runge 2006:598-610];
2. The generation of new businesses formed outside the auspices of existing organizations, new business development (NBD) by "external" units and corporate spin-offs, or learning new technologies through alliances with and corporate venturing in promising NTBFs – the "*cooperate* process" [Runge 2006:683-694] in a "networked economy" (Figure I.20, Figure I.51);
3. The acquisition of technologies and other competencies by acquisition of other firms, in particular, NTBFs – the "*buy* process" [Runge 2006:694-702];
4. The transformation of organizations through renewal of the key ideas and activities on which they are built, which is strategic renewal or *business model innovation*.

Referring to entrepreneurial or innovative, respectively, activities within a large firm (the "*build* processes," above no. 1) in the chapter "Corporate Initiatives" Bhidé [2000] provides a rational and objective evaluation for what brings about the dilemma of large innovative companies to establish control systems to protect owners (including shareholders) and place limits on their executives' discretions. Bhidé's main points together with related discussions [Runge 2006] are summarized in Box I.8. To overcome the constraints outlined in Box I.8 large firms currently follow essentially the cooperate and buy processes.

Box I.8: Why large firms are driven toward incremental innovation and how related strategy and behavior are enforced.

<u>1. How the endowments and constraints of corporate decision-makers determines the natures of the opportunities they usually pursue</u>

Corporate decision-makers have access to significant amounts of capital and the incentive to invest in new initiatives. The combination of available (huge) capital and extensive internal control (protection against the abuse of managerial discretion) and requirements of efficiency (controllers: "make the most of it') leads companies to undertake initiatives that require large initial investments and involve relatively low risk.

It encourages companies to pursue projects where their distinctive competencies and capabilities to evaluate and manage "objective" risk have the most value. This directs the focus to *incremental innovations*, often involving Business Research units, and attempts to build judgment into the process rather than into the people [Runge 2006:654].

2. Why corporations rely more on prior search, strategy and planning

Point 1 leads to initiatives and (R&D and innovation) projects and simultaneously risk minimization approaches as corporations must continue to innovate or competition will erode their positions.

Systematic search for businesses and opportunity identification rather than opportunity recognition or discovery (ch. 3) concentrates on *big projects* that can provide the growth they need based on a portfolio of research/innovation projects that guarantees short-term growth and long-term survival. This leads to concentration of investments that hold the promise of actually high profit ("*cash cows*") and short-term acceptable profits ("*grow with the market*," "*invest for growth*") [Runge 2006::641-642]. And corporate decision-makers require evidence not just for why a new initiative can be expected to make a profit, but also for why the size of the opportunity is large enough to meet corporate requirements.

This is associated with extensive planning and execution control preferentially according to "standardized" research or innovation work processes based on multi-level teamwork, coordination and project stage-based decision-making (Figure I.79). All this together minimizes failure, but requires much time.

3. Company Success and Strategies to keep and attract customers

Large firms need visible success, not just with regard to their survival, but also with regard to growth and financing growth, for instance, by investors or profits through customers. Unless a new product results from a direct customer request, large firms must focus on sales to existing customers and on a high probability to attract new customers. This means, the firm on introducing a new product must have created with potential customers a general perception of what they can expect in terms of value for money, quality, ongoing support etc.

For large firms time and efforts also enter the popular business heuristic: Selling to existing customers is more profitable than cultivating new customers; maintaining customer loyalty is less costly than adding new customers.

The "dense" control system of corporations does not mean that there are no risk-taking or R&D efforts associated with uncertainties about the outcomes. Whereas entrepreneurs take "calculated risk" (Table I.31) which is more or less qualitative and relate to their tolerance for ambiguity, large corporations refer mostly to *quantitative* approaches based on various dimensions, such as well-defined risks, "quantitative" market data and return on investment projections.

Risk aversion of corporations emerges mostly as risk avoiding strategies referring preferentially to factors or processes perceived by the firm to be controllable. This means, in particular, investing in technology, products and production processes rather than human capital of individuals (intrapreneurs) who can leave the firm and, moreover, may join competitors. For a company, this leads to a more or less documented "catalog of criteria" for selecting and funding innovation projects to achieve a given payoff including "no go" criteria (cf. "judgment in the process," Figure I.79; ch. 4.2.2).

The nature of R&D efforts and their directions, for instance, organized according to a Corporate (Central) Research unit and/or Business Research units [Runge 2006:717-721], is even determining exploratory (discovery) research. "*Exploratory research*" is a type of theoretical or experimental research conducted because an intended direction or problem has not been clearly defined.

Exploratory research helps determine a research design, data collection and selection of subjects etc. Valuable explorations may lead to a "proof-of-concept" (PoC) or demonstrate that an envisioned approach or problem solution is not feasible. It may also give more evidence that an idea should be followed or reduces the uncertainty for an anticipated research direction. Exploratory research may cover both basic and applied research. Exploratory research contributes to the technology strategy through R&D project selection as well as finding new project ideas (Figure I.80).

Exploratory research often takes either of two paths, "probes" or "thrusts." Thrusts mean we have already a lot of activity in and want to make progress in a selected direction; probe means, we do not exactly know what to do, but we know that we have to do something. Thrusts may involve cooperative R&D efforts with external partners. Probes of exploratory research for finding research directions are entirely internal activities ("*build*"), either because there are no external sources working on the related fields or the firm wants to keep its respective activities as a secret and avoid any contacts to external organizations.

The last situation is often associated with an entry into and development of "new-to-the-firm" technology. Probes include often also research activities to be characterized as "walking in the fog" or looking for "footsteps in the fog." Probes may create a number of results with little constraining contexts for which it is not immediately clear what to do with them [Runge 2006:726-727].

For large chemical companies, as a rule of thumb, the probability of successful offerings reaching the market after passing the corporation's "routines" is 5 – 10 per 1,000 (0.5 – 1 percent). But also across industries this can be paraphrased adapted to the well known fairy-tale "The Frog Prince" to R&D projects and cited by Runge [2006:652]:

> "R&D has the task to kiss 100 frogs in order to get 1 prince!"

Corporate entrepreneurship is often associated with a paradox: firms look for entrepreneurial thinking and acting when often they have or even create simultaneously barriers to entrepreneurship or innovation, respectively. You can learn, for instance, what kind of personnel firms are looking for their innovation activities:

- For them {people} to be successful in our industrial environment they need to have the following qualities – "entrepreneurial thinking," …
  (Degussa– now Evonik Industries [Runge 2006:437]).
- Thanks to a high level of innovation, creativity and entrepreneurial thinking Merck is the number one in Liquid Crystals worldwide. (Merck KGaA; [Runge 2006:438]).
- Entrepreneurial rather than "green eye-shade" people (Henkel AG & Co. KGaA; [Runge 2006:437]).
- *Thinking and acting* entrepreneurially is synonymous with decision-making, creativity, accountability and further development (Altana AG; [Runge 2006:229]).

While these requirements address all employees it is important to note the outstanding situation for researchers and scientists. Research culture is one of the factors why "research is the most difficult to manage of all functional activities" and "R&D management" is confronted with particular challenges. Research scientists and engineers, while sharing many attributes with highly trained people in other professions, have some characteristics that are more associated with them than with other professionals. The most striking, more or less explicit cultural features of research and science professionals are given by Runge [2006:628].

2.2.1 Corporate Culture, Shaping Elements and Processes for Intrapreneurship

The new (academic or engineering) employee or potential technical entrepreneur, respectively, hired mostly for the R&D or Engineering function of the firm, is subjected essentially to conscious learning about the firm in phases. Simultaneously largely unconscious conditioning and internalizations take place.

Early Learning Phase (0 – 5 years with the company):

- Administrative features;
- Organizational features, such as
  mission and values, power distance, hierarchical versus flat structures, relationships between corporate functions,
- Behavioral features, such as
  the do's and don'ts, how to communicate and behave, work habits, how to complain;
- Acquire new skills, diversify experience
- Decide if you and the firm are compatible

- Decide as a researcher or engineer for the career to follow the "Scientific (Technical) Ladder" or "Managerial Ladder" [Runge 2006:611-612].

Later Learning Phase (6 – 15 years with the company):

- Political features (power and influence structures and personal and functional conflicts or even infights);
- Competencies of the firm's employees and whom to ask for help, advice, etc., entering a Community-of-Practice (CoP);
- Career development and pro-active networking;
- Know your "freedom" for initiative and actions
- Know which buttons to press.

The fundamental environment for the intrapreneur he or she enters as an employee is given by the vision, mission and values of the firm – but sometimes the new employee has to find out how seriously corresponding statements have to be taken or whether there is considerable lips confessions.

A key factor in strategy elaboration and assessment of business ideas and project proposals and implementation is the very specifics of *organizational policy*. "Politics will be instrumental in the success of future entrepreneurial initiative within an established company." [Morris et al. 2008:39,295]. Hence, there is a need of corporate entrepreneurs for also political skills (in addition to presentation and negotiation skills) focusing on hidden structures of power and influence (ch. 1.1.2) in the organization and characterized in the above list of learning as "which buttons to press."

At the beginning, the intrapreneur is usually limited in terms of influence and formal power and needs to build visibility, credibility and reputation by achievements. In the end, it boils down essentially to building informal networks with influence and participating in formal groups and teams and securing endorsements of senior management (at least one level higher than the current boss, for instance, Research and/or Business Directors) and other influential players.

Learning about functional politics and infights is usually against the attitudes and characters of scientists or researchers. Difference in functional cultures between the R&D and Engineering Departments versus the Marketing Departments (ch. 2.1.2.3) does not only show up in communication problems, but sometimes also in politics about the "leading role" for corporate innovation [Runge 2006:779, 782-785].

Frictions between R&D/Engineering Departments with personnel often highly interested and experienced in computers and their use and the requirements of special "research or engineering computing" and the rigidity of formal processes of the Data Processing (IT) Department emphasizing "office and business computing" may also be observed in some large firms [Runge 2006:735-737, 918].

Major differences between startup and corporate entrepreneurship are presented by Morris et al. [2008:35-40] and are selectively shown together with other aspects based on experiences of the author and documented in his book [Runge 2006] in Table I.44.

Table I.44: Major differences between the entrepreneur's situation for startup and corporate entrepreneurship [Morris et al. 2008:35-40; Runge 2006].

Startup Entrepreneurship	Corporate Entrepreneurship
The Entrepreneurial Personality: Dreams, Decisions and Actions	
Entrepreneur has the vision, mission and values and defines success	Company (executive management) has the vision, mission and values and defines success
Entrepreneur "owns" the innovative idea, identifies him-/herself with the business concept and, if applies, has intellectual property rights	Company "owns" the idea and the concept and, if applies, intellectual property rights through compensating the "inventor" according to company standards or national law
Entrepreneur (and selected partners) decide on pursuit of the business idea and opportunity and entrepreneurial firm's foundation	Corporate "Selection Committee" decides on pursuit of idea and project proposal (NPD or NBD) based on risk, strategic fit and other firm-specific criteria unless a "heavyweight manager" [Tidd et al. 2001; Runge 2006:714] or sponsor [Runge 216:730, 748-749] pushes the project (Table I.98)
Entrepreneur follows his/her "subjective" strategy (strategy logics, Table I.33)	Entrepreneur's initiative (mostly) has to fit corporate strategy developed by a given strict management process
Entrepreneur owns all or a considerable portion of the company	Entrepreneur is an employee; owns at best a marginal portion of the firm
Entrepreneur can focus on small or niche markets	Entrepreneur will have difficulties to get through project resources targeting a small or niche market; such markets do not fit growth requirements of large firms (ch. 2.2.2)
Entrepreneur takes the risk; strives for mitigating or avoiring risk	Company takes the risk; entrepreneur may risk career unless company encourages risk-taking and accepts failure of employees; company follows risk management process

Entrepreneur's startup exhibits high vulnerability towards many factors: strong dependence on external factors, one key employee leaving the startup may be the end, one supplier failing to deliver or one customer paying very late or not at all may lead to a disaster, any delay in technology development or production scale-up may have dramatic consequences	Entrepreneur's project usually does not induce a dramatic vulnerability for the company
Potential rewards for the entrepreneur are theoretically unlimited	There are usually limits on financial rewards intrapreneurs can receive – except there are company rules to provide a share of profit gained through an intrapreneur's developments for the firm
Entrepreneur decides on the level of his/her firm's growth rate	Entrepreneur's project is (mostly) associated with requirement of distinct growth
Entrepreneur decides on stopping innovation project	Selection Committee or high level management decides whether and when to stop the innovation project (cf. Bootlegging; ch. 2.2.3); difficulties in stopping a (pet) project of a heavyweight manager
Entrepreneur from research (RBSU!) may use a "grace period" before entering reality in terms of a legal firm (incubation, ch. 1.2.6.2)	Approved entrepreneurial initiative will immediately start the project in line with corporate procedures
Entrepreneur creates the firm's culture and during the early state may develop employees	Entrepreneur has to accommodate to corporate culture and internalize it
Entrepreneur affects employees' behavior by power and influence	Entrepreneur is usually limited in terms of formal power in the organization (but can gain influence)
There is (almost) no organizational politics in startups	Entrepreneur has to learn politics to be instrumental for the success of an entrepreneurial initiative and the personal career; need to build political skills

Table I.44, continued.

Entrepreneur usually works in "flat" organizations	Entrepreneur works in different organizational settings, from "flat" to often hierarchical structures [Runge:2006:379-382]
Entrepreneur is engaged in "open-ended" entrepreneurial activities – from idea/opportunity to firm growth	Entrepreneur is engaged in time-restricted entrepreneurial activities, the "project," or even only selected stages of an innovation process when team composition is changed accordingly (ch. 2.1.2.1)
The Entrepreneur and Other People	
Entrepreneur's creativity is not blocked by path dependencies on technology trajectories or search paths for problem-solving	The theory of path dependency suggests that corporate competencies define the technology and search paths for its future
Different significance of team; usually entrepreneur selects team members	Team compositions are often determined by available manpower in the firm's business unit rather than through a selection by the project initiator(s) or intrapreneurs, respectively
Has (usually) employees committed to success working towards a common goal	R&D (particularly in a Business Research unit) may report to Business Unit Leader committed to his/her promise of profit by the end of the year; short-term profit vs. long-term perspectives Divisional managers are assessed against profit performance. When being told to launch new products and spend money for R&D what does the poor man do? He goes for quick profits.
Builds and relies essentially on a network of people external to the NTBF	Builds and relies for "success" (career) essentially on a network of people internal to the firm
Entrepreneur has people to (pro-actively) talk to from a large diversity of knowledge domains and broad spectrum of experiences to get advice from	Entrepreneur has many people to talk to, but these are largely from the corporation and have been conditioned by the firm's internalities

Corporate Innovation Directions and Process Execution	
Severe (human and financial) limitations of resources; scarcity of resources, but entrepreneur has a large number of potential financial sources, not just a corporation's budget	Access to a variety human, financial and operational resources including R&D services including technology intelligence, patent department, procurement, marketing, market research and sales and customer base
Speed of decision-making	Longer approval cycles, often overlaid by politics
Flexibility in changing direction	Rules, procedures, corporate standards, bureaucracy, power groups and politics: "how things are done here"

Consider that in a startup/NTBF the entrepreneur, scientist or researcher, will be engaged principally in "open-ended" entrepreneurial activities and over the years may have become the CTO (or CSO) of the NTBF. In a large firm the researcher will be confronted with a very different situation and path to CTO/CSO. Apart from the fundamental difference of working in Corporate (Central) Research or Business Research of a particular business unit [Runge 2006:718-722], for career reasons, there often is switching from R&D to Marketing and back again to R&D as well as transfer to other locations, mostly in different countries.

The assignments of employees to an innovation project according to competencies and phase of the project finds an analogy with switching leadership for different phases of the project by different involved function, in particular, R&D versus Marketing. The corresponding approach is a "pacelining model" used in the chemical and pharmaceutical industries described by Runge [2006:664-665].

This means, that an intrapreneur striving for activities from idea and grasping opportunity to an offering as the end (as for a new firm) may be cut off from this "holistic" kind of entrepreneurial process. The significance of imagination and creativity for the beginning of an innovation project and the requirements of people with other qualities at later stages has been presented from an industry point of view by Runge [2006:752] (Table I.45).

Table I.45: Whom it needs when [Runge 2006:752].

Stage of a Project	Skills of Players
Idea Generation and Collection	Aggressively *Creative R&D People* "**Can imagine everything**"
Project Idea Development	Creative R&D People "**Can imagine the potential"**

Pre-Project (Proposal Development)	New Business Development Team "**Sees the potential, are willing to do it**"
Application Development	R&D, Application Technology, Marketing "**Team knows the value of cash**"
Product Development	Application Technology, R&D, Marketing, Production "**Strongly focused on sales**"
Commercialization	Marketing, Production, Application Technology, R&D "**Enjoys the fun of profit**"

Furthermore, in the context of portfolio management, Runge [2006:641-643] describes how business unit assessment, life-time phases of their offerings and types of researchers in line with the life-cycle stage of the offerings may be connected with consequences for allocation of human and financial resources. Different classes of business need different types of researchers so that "optimization activities" will have to be associated with moves of R&D people within the firm – or even to the outside, if the business is sold or shut down.

"Core competency" has been defined (ch. 1.1.1) as a central variable for innovation! It is the one thing that a company can do better than its competitors; an area of specialized expertise that is the result of orchestrating complex streams of technology and work activity and processes, including unique relationships with customers, suppliers, research, development or marketing partners, and operational agility or unique business practices.

An organization's competencies reside in its culture including valuation (criteria by which decisions about priorities are made) and corporate governance and processes. Without conscious change (or even disruption) competency development tends to be path-dependent. This means, an organization's capabilities define its disabilities!

The downside of "core competencies" are "**core rigidities**." Core rigidities may block the mindset of the organization focusing on the *status quo* and past success and "filtering" the signals according to whether they *fit into the status quo*. Signal filtering prefers "confirmation of own prejudices." "Past success" includes the business model, the management style and decision-making, problem-solving, prioritizing, the attitudes and mindsets, behaviors and processes and "routinized procedures" ("how things are done here").

Core rigidities are ingrained in corporate culture. They refer to capabilities and processes that exist essentially independent from the people who work in the organization (Box I.8, Figure I.129). They influence decision-making, change of project direction and resource allocation. Core rigidities are not specifically related to organizational structure, for instance, only to hierarchical-mechanical organizations [Runge 2006:722]. Routines are also found in "flat" and innovative organizations like 3M, HP or (German) SAP.

Core rigidities represent barriers for disruptive technical, but also organizational innovations They prevent even well-managed companies from developing disruptive innovations (or technologies) until it is too late [Christensen 1997; Tidd et al. 2001:316; Runge 2006:626]. And they show up in myriad "idea killers" when discussing ideas or project proposals to turn them down. A selection out of ninety-nine idea killer, a not necessarily exhaustive list presented by Runge [2006:754], is given in Table I.46.

Table I.46: A small selection of idea killers.

They'll never buy it.	We'll never find the time to do it.
We tried that before and it didn't work.	Let's meet on that some day.
Doesn't fit the system.	Let's be realistic.
It's not up to our standards.	Just leave it with me. I'll work on it.
Are we ready for this?	Come on now, get serious.
What will they say upstairs?	Great idea – but not for us.
It sounds too simple.	It'll never fly.
It sounds too complicated.	That would step on too many toes.
It'll cost a fortune.	That's really fantastic, but …
Has anyone ever done anything like that before?	How in the world did you come up with that?

In-house corporate innovation (a "build process") mostly proceeds via a project. Projects are undertaken for the purpose of developing systems, either to create new ones or improve existing ones. A **project** involves a single, defined purpose, end product or result, usually specified in terms of resources (cost), schedule (time), and performance requirements. Projects in industrial environments include, for instance, projects for production/manufacturing, R&D, Engineering, software/I&CT, or organizational settings.

A project includes:

- A start and finish
  (a *project path* is a sequence of connected activities that leads from the start to the end; a project may also be executed in terms of sub-paths representing a network)
- A goal and objectives
- A life-cycle (the course of a project – a set of activities of finite duration)
- Human ("project team") and financial resources
- Activities that are essentially unique and non-repetitive and need coordinating

- Use of resources, which may be from different organizational sub-units
- A single point of responsibility, the project manager (leader)
- After completion review (assessment) of project execution, results and outcomes and learning options.

Project environments are characterized by complexity, level of change, uncertainty and risks and projects are executed with various organizational structures related to the task, but also to the executing organization, the firm.

Projects can be initiated (started) for various reasons and can be characterized as follows.

- Problem-driven (competition, crisis, …)
- Change-driven (new needs, growth, change in business orientation or external environment, …)
- Opportunity-driven (exploit new technology, ...)
- Compliance-driven (change existing technology or offering to comply with new regulations or law)
- Legacy-driven (unfinished, postponed work, part of a previous plan, …).

In the context of technology entrepreneurship innovation projects and New Product Development (NPD) and New Business Development (NBD) projects are of particular interest, not only when discussing intrapreneurship, but outlining the scope of specific knowledge and experience people could have gained in the industrial environment when they leave the company to found their own firm.

Many cross-industry studies have shown that innovation stimulated by market needs or technical opportunities (demand pull versus technology push) show a rather constant proportion of about 70:30 [Runge 2006:759]. Furthermore, it was found that in industry in most cases the *person(s) having an idea and the one(s) revealing a related opportunity are different* (ch. 3.2).

With binding idea and opportunity and then creating a "concept summary" Figure I.79 depicts a *generic structure* of the steps of the process found in large firms for new product development (NPD) projects and incremental innovations in terms of a "Stage-Gate®" or also named Phase-Gate process. This is, with more or less modifications, an industry-widely used archetype process streamlined for project selection and execution and reducing uncertainty as a *corporate-specific and corporate-wide process*. As a *structured process* in terms of a sequence of phases or "stages" it is conceptualized to have "*decision points*" ("gates") after the end of each stage and, after *review* (by a selection team or committee), to decide *whether and how to proceed* with the process [Runge 2006:653-654].

However, in Figure I.79 an "*ideal process*" is outlined. Corporate realities of culture, politics, interference by "heavyweight managers," etc. may modify this approach. The distortion of such a process as seen often by executive management is shown by Wheelwright and Clark [1992].

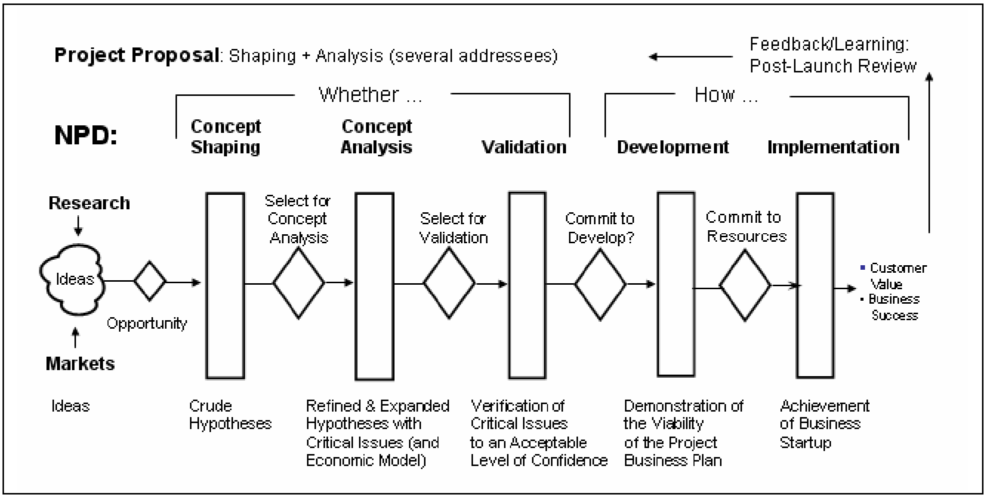


Figure I.79: Outlining the typical Stage-Gate® process for new product development (NPD) or innovation in industry.

Idea and opportunity form mostly the basis for a "*project proposal*" for industrial innovation, which is intrapreneurship, focusing on issues of *whether* to pursue the project and *how* to do it. Submission of a project proposal by the originator(s) to related management is usually via a document with a given strict structure or an electronic form requiring answering (usually in cooperation with or help of people from the marketing department) a given set of questions which ultimately ends up with a "*project business plan*."

This is structurally very similar to a "business plan" created by entrepreneurs to found their own firm. An outline of the structure for such a document or form and outline of content are given below.

- **Opportunity Summary** (Summarize opportunity hypothesis)
- **Value Proposition (Win-Win)** (One sentence):

1. **Market/Customer Need:**
   Describe your hypothesis of the need and identify the customer type or market group with the need (Sources of information!) – 12+ questions to be answered
2. **Product/Service:**
   Describe the product or service which you hypothesize will satisfy the market need (Sources of information!) – 12+ questions …
3. **Competitive Advantage:**
   Describe how "our firm" could gain and sustain an advantaged position at potential customers (Sources of information!) – 12+ questions …

4. **Market Attractiveness:**
   Describe why this market would be attractive to any potential supplier –12+ questions ...
5. **Business Attractiveness / Strategic Fit:**
   Describe why this specific opportunity is attractive to "our firm's" businesses – 12+ questions …
6. **Value Potential** (Value management, economic analysis; entry).

This list shows that idea, opportunity and project assessment in industry usually require "*strategic fit*" which often constrains heavily pursuit of disruptive technologies or innovations, respectively.

Operationally **competitive advantage** means, when a firm sustains profits that exceed the average for the industry; the firm is said to possess *competitive advantage over its rivals*. Essentially, competitive advantage enables the firm to create superior values (ch. 4.3.3; Table I.75) for its customers and superior values and profits for itself. Generally, two basic types of competitive advantage have emerged:

- Cost advantage
- Differentiation advantage (deliver values that exceed those of competitive offerings).

A lucid case of intrapreneurship, addressing biobased chemicals or plastics, is the story of Patrick Gruber, innovator of polylactic acid (PLA) plastics at privately owned US giant Cargill and now CEO of the NTBF Gevo (Table I.99) [Benda 2003]. A further very lucid article by C. Benda (http://www.cargill.com/news/00_08_cd.htm: *Mission Possible!*. Cargill News International) is no longer accessible on the Web.

2.2.2 Large Firms' Problems with Disruptive Innovation

Large companies have great difficulties how to deal with emerging technologies and disruptive, but also sometimes discontinuous innovations. Disruptive innovations are difficult to deal with, because they do not only require new resources (and competencies), but they (often) conflict with the organization's processes and values (also a different value proposition). Breakthrough innovation needs persistence and continuity and people is the key for disruptive innovations – "exceptional characters" – intrapreneurs).

There are some *intrinsic factors* which lead to an "innovator's dilemma" of successful large firms [Christensen 1997]. Disruptive innovations are distinctly different from incremental innovations executed by strict processes. Hence, they create some situations conflicting with attitudes, drivers, ideas and activities of the firms' intrapreneurs and shall be re-visited. As already mentioned there are *routinized work processes and issues of core rigidities* (Box I.8).

A particular dilemma occurs, if a firm comes up with a disruptive innovation which actually will replace a current successful product (issue of "cannibalization").

Large successful firms need to grow, not just to maintain, for instance, their share price, but also to create opportunities for their employees. And as they grew larger they need increasing amounts of new revenue just to maintain the same growth rate. Hence, it becomes progressively more difficult for them to enter new, smaller markets even though they may promise to become large markets of the future. To maintain their growth rates, *large firms must focus on large markets*. Most large firms adopt strategies of waiting until new markets are "large enough to be interesting" leaving the door wide open to quick acting startups.

On the other hand, startups often prefer niche markets, as they do not have a very significant innovation or access to much capital which would allow pursuing opportunities likely to generate large profits, such as high-volume production. Niche markets usually do not require much working capital or up-front investment. In this way startups also avoid competition from large, well-established companies [Bhidé 2000:39-40].

Sound market research and detailed, good planning followed by execution and control according to plan are fundamental to corporate innovation processes. But firms whose resource allocations according to strategy and amounts of investments demand quantification of market size and financial return before they enter the market get paralyzed when faced with disruptive technologies and offerings. *They demand market information that does not exist* – except for some few well-defined cases [Runge 2006:715-717].

Furthermore, reliance on the Marketing Department and market research may often lead to erroneous assessments, for instance, for Hewlett-Packard's HP35, the world's first hand-held scientific calculator combining both integrated circuits and light emitting diodes (LEDs). Though market research conducted by the Stanford Research Institute (SRI) suggested the product would fail because of its small size, this innovation ultimately created the calculator industry [Runge 2006:714].

Finally, *for disruptive innovations,* rather than a claim of the Marketing Department, *early market learning is the responsibility of R&D and the related innovation teams*. In the early phases researchers and scientists, also in seek for applications, are used to talk to potential customers and business unit managers, but usually they are not aware that such activities are market learning. Cases in which market learning was outsourced to strategic partners or consultants ended often in disappointments and regret [Runge 2006:782].

Another issue facing large firms with new technologies and offerings is that established *firms' leading customers generally do not want, or cannot, use at first a disruptive technology* that may be *overshooting the performance that established markets demand* (Figure I.88). But even when emerging (new) technologies and related offerings have been identified, established firms tend to fall into common traps listed by Runge [2006:731].

Overshooting is one of the biggest mistakes technology entrepreneurs make at the initial stage of identifying business opportunities. People think everybody in the market likes them. If they like the product, everybody else will. Sometimes – and too often – entrepreneurs, and especially entrepreneurs with an engineering background, are too focused on the engineering features or technology features of the particular product rather than on the need that they are trying to fulfill. Very often, also entrepreneurs – particularly smart entrepreneurs – are overwhelmed by the technological aspect, and they pay too little attention to what the customers want.

Innovative (large) firms must respond to future and disruptive technology and market opportunities, even if they cannot meet the challenges alone! What can they do to cope with the situation? When managers determine that an organization's capabilities are not suited for a new task they are faced with several options through which they can create or acquire new capabilities (technical or/and organizational). There are some "standard" approaches to tackle the issue.

The "build" process:

Try to change the processes and values of the current organization, but be aware of core rigidities. This is usually accompanied by large efforts of "*unlearning*" which means discarding something previously learnt or trained in, like an old habit. Unlearning is about moving away from something rather than moving towards something. The ultimate usage spectrum or applications for disruptive technologies are unknown in advance. Exploratory research may be used to test market assumptions in advance of expensive commitments.

Spin off an independent organization and develop within it the new processes, products and values that are required to solve the new problem may be a solution. The issue is how much distance from the "mainstream" is necessary and achievable.

The "cooperate" or "buy" processes (Figure I.20, Figure I.51)*:*

Cooperate with or acquire a different organization whose processes, products and values are a close match with the new task. Alliances are with partners from industries and academe or occur as joint ventures (JVs).

"Hybrids" options:

Spin off an organization to deal with future businesses or areas outside current businesses. This organization, such as the German "BASF Future Business GmbH," identifies business and/or technological threats or opportunities; it sets up "build, cooperate or buy" processes [Runge 2006:554,555,698] or a New Business Development (NBD) process. Such an organization usually incorporates a "corporate venturing" arm to invest in promising (in the sense of high-expectation) startups or NTBFs. Corporate venturing may be the entry into an ultimate acquisition of the supported firm (hte AG, Solvent Innovation GmbH, A.1.5, B.2 – Closure Medical [Runge 2006:39,98-103]).

Create a project-like temporary organization for technical and market development with the options (at project end) to integrate it into an existing business or to run it as a separate (subsidiary) organization (“spin-off”). This type is found with German Evonik Industries (formerly Degussa) and its Creavis unit which establishes “project houses” [Runge 2006:556,699,729].

NBD [Runge 2006:722-730] may be nurtured inside or outside the current organization and is a major route to corporate renewal and growth (beyond NPD). But NBD is a notoriously risky proposition. It is not only associated with high risk and uncertainty for the firm. Working in NBD units puts also employees at higher risk of failure and, hence, cannot be viewed as a “good career move,” unless the company put in place a defined career path and employee development plan to attract particularly bright and entrepreneurial people with combined technical and commercial minds for such jobs, which mean “intrapreneurs.” To develop a company of sufficient size out of an NBD initiative will take five to eight years.

Targeting directly intrapreneurs:

Large firms have often programs to develop and fund innovative ideas from employees through an *internal venture arm* when the particular (assessed) good idea does not fit clearly within any of the firm’s business units. Such corporate “funds” for innovation projects are usually organized through sources available to executive management off the “normal” budget. Past examples from the US cited by Runge [2006:777], include Boeing’s “Chairman’s Innovation Initiative,” the DuPont “$EED PROGRAM,” Dow Chemical’s “Science and Technology Exploration Fund” (STEF) [Runge 2006:777] or in Sweden Perstorp’s “President’s Fund” [Runge 2006:463].

Very special expressions of intraprenurship in large firms with minimal constraints are observed for 3M and Google. 3M is famous for its “15% rule” developed in the 1950s that allows virtually anyone at the company to spend up to 15 percent of the workweek on anything he or she wants to, as long as it is product-related [Runge 2006:374].

Google’s model is letting engineers spend about 20 percent of their time on projects outside their main job. But Google’s 20 percent time seems to function more as an attitude and self-motivation – that new projects should be spawned by whoever has the best ideas, not who is in what place in the hierarchy, and the culture is based on this fundamental belief. Like many tech companies, the vibe is that if you have an idea you should follow it, but not to the detriment of other responsibilities. Time for 20 percent projects is protected, but more by individuals than by managers. [Berkum 2008; Hof 2008].

“Google’s culture has a resistance or even distrust, of hierarchy – they often use voting, peer review, and debate to make decisions or decide which new projects and features to add. With that structure the 20% time idea makes sense as they want self-motivated creatives putting ideas in the hoper for others to review, evaluate, or contribute to, rather than waiting for executives to spend weeks making big vision documents and marketing plans, dividing things up into smaller and smaller pieces, before allowing creatives to make (creatively constrained) contributions." [Berkum 2008].

Some companies are also recruiting staff with very different perspectives to spice up their knowledge mix. And, for instance, the Danish enzyme maker Novozymes actively *recruits experienced entrepreneurs* [Bessant et al.].

Situations for the emergence of corporate entrepreneurship are summarized in Table I.47.

Table I.47: Where and how entrepreneurship appears in firms.

Internal R&D	*"Build"* innovation constellations in-house, in Corporate (Central) Research or. Business Research [Runge 2006] Provide special R&D funds, outside "normal" budgeting for projects outside current business [Runge 2006] Exploration research – thrusts and probes [Runge 2006:726-727], see also the champions approach (Table I.) Allow employees to use part of their time to follow own "innovation activities" as long as they are related to current firm's business or strategy (for instance, 3M, Google)
R&D Alliances	The "*cooperate* process"; Alliance or JV with NTBFs (A.1.1) [Runge 2006] Especially contract research Academic-industry relations, common labs or firms with universities (A.1.3)
Acquisition	The "*buy* process"; firm acquisition (often the "exit" of corporate venturing; Puron (Table I.41; [Runge 2006:95-96]), hte AG and Attocube AG, B.2))
Innovation Processes	Incremental innovation – StageGate with special expressions A "sponsor process" ([Runge 2006:748,749]; Table I.98) Disruptive innovation and intrapreneurial bootlegging (ch. 2.2.3)
New Venture Endeavors	Internal ("intra muros") or external ("extra muros") future business organizations, including corporate venturing [Runge 2006]; New Business Development (NBD) [Runge 2006] and GameChange [Runge 2006:771-773]

Table I.47, continued.

Champion Situations	Intrapreneurship originating from any person(s), level or department; employees (often a pair from R&D and Marketing) having shaped and analyzed an innovative concept (related to an existing business) look to sell a related project proposal to management
Spin-Offs	Shifting responsibilities to organizations small enough to get excited about challenges and initially small wins while the mainstream company grows along its major tracks; example: Pergo [Runge 2006:462]
Ad hoc Project and Venture Teams	Secret projects; BMW, for example, has experience with what it calls "U-boat projects," which run along below the surface of formal management approval. The Series 3 Touring car came into being not because of a formal product plan but as a consequence of efforts below the radar screen [Bessant et al.]: "Skunkworks" [Runge 2006:696]

2.2.3 Bootlegging in Large Firms

There is only a fine line between entrepreneurship and insubordination.
Robert Nardelli, CEO Home Depot

Intrapreneurship is a fascinating area of research because it focuses on the psychological behavior of a character in identifying why this individual goes beyond the duty of what is required of them. This is particularly lucid with regard to "*bootlegging*" which is a time- and location-independent phenomenon of (often breakthrough) innovation and an expression of entrepreneurship in firms.

Specifically, *bootlegging is independent from national and corporate culture and found across many different industries*. Originally the notion referred to concealing hip flasks of alcohol in the legs of boots in the US during the Prohibition period in the 1920s ("smuggling"). Now it is used with different meaning for different contexts, but mostly has an illegal touch or misconduct. Wikipedia refers to "secret innovation within an organization." [50]

However, **bootlegging** will be defined as research in which dedicated and highly committed individuals secretly organize and push an innovation process through. It is an entrepreneurial bottom-up activity, *without the official authorization of the responsible management*, but usually for the benefit of the company. It is about *ignoring and defying superiors and peers*. Bootlegging should not be confused with skunkworks (Table I.47).

> Bootlegging and related successful innovation occurs inside large companies *despite the system* and despite rather than management against the official direction!

Often the main reason for the occurrence of bootlegging is attributed to the lack of “free space” for creativity. In particular, rigid planning and bureaucratic processes in firms is seen to ignore the nature of experimental trial and error research. However, we prefer a different explanation, as the bootlegger often already worked on the corresponding innovation project and is told to stop it by management.

We suggest that the roots of bootlegging are in the people’s entrepreneurial personalities – characterized by courage, conviction, risk taking, perseverance and achieving. When it comes to innovation, the key point is this:
People *get the courage to try new things* and pursue these and bring them to success, not because they are convinced to do so by a wealth of analytical evidence but because they feel something *viscerally* which drives their conviction. It is just that until you feel something in your gut, until you have experienced it and know it to be true, you simply will not have the courage to act. This is illustrated by five cases with paradigmatic stories described in Table I.48.

> Bootlegging represents essentially those traits of entrepreneurs that are least influenced by conditioning factors of an organization.

This interpretation is further supported if one looks at the possible consequences of bootlegging which is associated with large uncertainty and risk for the bootlegger. The spectrum covers from forgive – reward to no forgive, no reward, blocking or stopping the career, costing the job. This spectrum is represented by Chuck House and Klaus Grohe:

- Chuck House (HP): “It never occurred to me that it might cost me my job.” “And in the case of Packard management it even celebrated the mistakes.” [Sutton 2007]
- Klaus Grohe (Bayer AG): When he was told to stop his R&D project, he rejected that and was transferred for disciplinary reasons (“Das habe ich abgelehnt und wurde strafversetzt”). In the end it cost Grohe the career (“Mit den Chinolonen habe ich meine Karriere verspielt” – “With the chinolones I lost my career”) [Neubauer 2006]

As a corollary for teaching entrepreneurship it follows from bootlegging that there are a lot of skills you can teach would-be entrepreneurs, but you cannot give the person what they need most: burning desire.

Table I.48: Selected examples of bootlegging in large firms.

Firm, Time and Location	**Case**
3M, 1920s; US	3M's Richard G. Drew noticed that painters on automobile assembly lines had trouble keeping borders straight on the two-tone cars popular at the time. Back to the laboratory he invented the masking tape. Drew asked an executive for permission to buy a $37,000 paper maker which would improve the masking tape. The manager told Drew to hold off for a while, since finances were tight. Few months later, Drew took him into his laboratory to show him the paper maker, working away and producing a vastly improved masking tape backing. Drew had simply submitted a blizzard of $100 purchase orders, amounts he was authorized to spend on his own, over six months [Runge 2006:461,749].
HP, 1969; US	Hewlett-Packard's Charles (Chuck) House, who persisted in prototyping and pushing extra large screen computer monitors despite being directly told by company co-founder and CEO David Packard to knock it off. Needless to say, the product became an important success. House was forgiven [Sutton 2004; Sutton 2007; Schrage 2010].
Perstorp AB, 1970s; Sweden	By the end of the 1970s Perstorp launched "Pergo®," one of its most important products (1980: first laminate flooring sold in Sweden). Pergo is a laminate floor, and its creation resulted from Perstorp's long know-how in the areas of laminates and chemistry. The Pergo® brand is one of the world's strongest in the hard flooring category. When employees suggested using laminates on floors the idea was turned down by R&D General Manager Nordberg. However, the "innovating guys" went behind the back of Nordberg and got a grant from another funding source of Perstorp, the Research Foundation. They had some tests done by a renowned outside institute showing the outstanding performance of such floor laminates. Only then the President's Fund provided money to finance a project for laminated floor panels. In 2001 Pergo was spun out of Perstorp [Runge 2006:462-464]. In 2007 Pergo was acquired by German Pfleiderer, AG, a leading manufacturer of engineered wood products.

Bayer AG 1980s; Germany	Billions in revenues for German Bayer AG were achieved on the basis of the class of chemicals called chinolones, in particular, the broad-spectrum antibiotic Ciprofloxacin (tradename Ciprobay or Cipro), a fluoroquinolone. The inventor, Klaus Grohe, developed it during the 1980s. Also the related antibiotics Baytril for animals and Moxifloxacin (tradename Avalox) for the respiratory system were developed by the Grohe method. Grohe holds numerous patents for Bayer. Grohe worked already for several years in Bayer's pharma research when in 1975 his boss retired. The new boss asked Grohe to stop his previous projects, but Grohe rejected that and was transferred for disciplinary reasons to the Agriculture Department. Here he continued in the clandestine to pursue " his chinolone project" for the benefit of the firm [Neubauer 2006]
Merck KGaA, end of 1960s; Germany	Already at the beginning of the 20th century Merck was a supplier of liquid crystals (LCs) to university laboratories and continued to be one on a low level. By the end of the 1960s a group of chemists wanted to revive the LC field when first potential applications of LCs for display technology became apparent. However, this group did not meet interest of Merck management. Only few believed in Darmstadt in a commercial future for the substances relevant at the interface between chemistry and physics. In an act of "loyal disobedience" " with persistence and perseverance the believers had to run "underground research characterizing their field by a play on words as "überflüssige Kristalle" (in German LCs is "flüssige Kristalle", but "überflüssig" in English is "superfluous.") [Hofmann 2010; Osterath and Guggolz 2013]. Merck now is the world leader of LC technology with sales €833 mio. in 2009 and a profit of €225 mio. [Hofmann 2010]. By 2002 Merck had a market share of ca. 60 percent of the total liquid crystals market [Runge 2006:455].

3. IDEAS, IDEATION AND OPPORTUNITIES

As soon as the mind targets a goal
a lot will come to meet him.
Johann Wolfgang von Goethe

Sobald der Geist auf ein Ziel gerichtet ist,
kommt ihm vieles entgegen.

An idea is a conception covering any human thinking and activities, in particular, science, technology and business. In daily language the word "idea" is generally used to name the subjective contents of our own minds. According to Webster's Online Dictionary: [51]

> An *idea* is an entity (as a thought, concept, sensation or image) actually or potentially present to consciousness; it means what exists in the mind as a representation (as of something comprehended).
>
> The notion idea may also apply to a formulation of something seen or known or imagined, to a pure abstraction. It may be perceived as a sudden thought, inspiration or a brain wave – a flash across the mind.

Hence, an idea may be perceived as a chance or surprise for the individual induced by an event.

Most of the confusion in the way ideas arise stem from the use of the term "idea" to cover both the *representation percept* and the *object of conceptual thought*. For entrepreneurship it is not sufficient to just have an idea – you need to have a design (decision and action plan) of how that idea can be realized and exploited. As, in the context of entrepreneurship we related intelligence to actionable knowledge (ch 1.2.3) we are interested in "*actionable ideas*" and specifically "*business ideas*." Actionable ideas refer essentially to the teleological relation idea $\rightarrow$ opportunity (cf. also Figure I.78 and Equation I.7).

Many discussions rely on the entrepreneurial personality in terms of traits (ch. 2.1.2), constructs and behavior. But, we want to avoid abstract constructions as far as possible and cling to observation and examination of the evidence of the phenomena with no prepositions and with a minimum of theoretical constructs and explanation. Overall the pair "*idea and opportunity*" will largely be associated with observable processes, events and exposure.

Concerning semantics in the context of idea and opportunities we shall use the notion "revealing" as a general term to be specified according to underlying activities or processes – of the mind and the person(s). In particular, it will be shown that it is meaningful to relate revealing opportunities to the following distinguishable processes or events, respectively:

- Recognition
- Identification
- Discovery
- Creation
- Serendipity
- Chance, Luck.

Furthermore, *categorization of opportunities* will be used as a way to describe and structure the exceptionally large number of the practice of generating ideas and revealing opportunities for technology entrepreneurship.

The current chapter will look into ideas and opportunities for technology entrepreneurship and intrapreneurship in large technical companies. Apart from execution fundamental differences between the two areas concern opportunity evaluation and feasibility (Figure I.87). Differences emerge, for instance, with regard to

- The connectedness between idea and opportunity, whether both are associated with the same person or with different persons
- Technology push versus market pull orientation
- Type of innovation
- Class of technology and exploiting opportunity
- Number of offerings (products), one or few (2-4) versus many (> 10)
- The level of formalization of the idea generation process (ideation).

3.1 Business Ideas and Problem-Solving

For entrepreneurship we find it useful to specify a "**business idea**" as being actionable and being a relevant sub-category associated with the following *processual* features.

- A business idea acts as the basis for detailed considerations and targeted inquiries concerning a related *commercial opportunity*, for a decision of firm's foundation or to pursue a new business of an existing firm and it is associated with *expectation* (Figure I.78).
- A business idea is associated with *implementation – execution*. For a startup the assessment of the significance or *value* of the idea is coupled to execution – with a disproportionate ratio which puts high weight on execution.
- Execution for the realm of technology entrepreneurship is coupled with 1) associated *contextual* insight in and options for *applications* in "real life" and 2) characteristics of the commercial *opportunity*.

And there is a *key attribute*. Though it may cover value for the individual and also social value a business idea must generate *financial value* and, for technology entrepreneurship, any valuation of an idea refers always or at least largely to expected financial reward (or "socio-economic value").

Execution is also relevant in fine arts: not the idea, but execution or performance of the idea represents the art. In so far patent language reflects this aspect concerning "*prior art*" (of technology).

In this treatise when we speak about ideas we shall always mean either "business idea" or an idea in the realm of science or technology. It is these kinds of ideas – entities of thought – that in advanced societies provide a legal right to the exclusive (commercial) use of an idea in terms of an invention and a *patent*. The prerequisite of an object, a process or an application to become patentable relies essentially on examination of three criteria. Apart from "novelty" and "non-obviousness" ("not obvious to a person skilled in the art") it is particularly usefulness (*demonstrating utility*).

For entrepreneurship, in contrast to science, the idea is not a standalone construct. It is to be seen as interconnected to a (socio-economic) time-dependent opportunity or to problem-solving for a technical or socio-economic situation.

A business idea may erupt in a given (technical-commercial) context with several perceived variables or components, for instance, through instantaneous association, pattern recognition, analogy, metaphor or combination of information, technologies or events. Special examples of inducing ideas by exposure include *customer visits* [Runge 2006:749] or attending *presentations* or reading a *seminal paper* [Runge 2006:454] or applicability of a technology for other purposes (cf. the Post-It® story of Art Fry and 3M).

Generally, an idea can only be evaluated (measured) quantitatively after the fact via related behavior, execution and effects, for instance, foundation of a "successful firm" or establishment of a successful business (ch. 4.1).

A priori assessment against explicit goals, which is assessing future results, will occur on a different level referring to an execution plan or overall business plan or comparisons of entrepreneurial configurations (ch. 4.3.6). It focuses on *measuring expectation* in terms of "likelihood," for instance, assessing "promising NTBFs" or "high expectation" firms' foundation (ch. 4.1; 4.3.1; Box I.17). Note that Bhidé's [2000:25] "promising startups" correspond to *Inc.* 500 companies which sell to other businesses [Bhidé 2000:51]; it does not relate "promising" to expectation.

For a given domain (for instance, a market), a context, and for a particular period of time (t_0) a technical business idea of a technology venture can be characterized in terms of set theory through intersections (Equation I.7) where t_0 represents the time period of the "Window of Opportunity" (Figure I.4 and particularly Figure I.92). Context may include personal disposition and traits, prior experience, national or corporate culture, "Zeitgeist," etc.

For an idea or a discovery to become a business idea requires *revealing* an associated *opportunity* or, ultimately, requires *opportunity creation*, as reflected by a technology push approach (Figure I.26, Figure I.27) or by a disruptive (radical) innovation.

Application of technology requires *usefulness* – and usefulness for adopters (customers) may additionally require *necessary infrastructure* for application (Figure I.92).

> For innovation through technology it is important to note that *one person's data may be another person's information* (and vice versa), as that person may interconnect and associate the data differently in the context of his/her cognition space (ch. 1.2.3, Figure I.18).

For instance, the recognition of an opportunity for an innovation is highly dependent on the individuals' characters as it requires interconnecting different pieces of data and information. Correspondingly entrepreneurial people perceive opportunities that others fail to see or see them before most others do.

Equation I.7:

$$\{\text{Technical Business Ideas}\} \subseteq \{\text{Technical Ideas}\} \cap \{(\text{Applications} \cap \text{Usefulness}) \cap \text{Offerings}\} \cap \{\text{Opportunities } (t_0)\}$$

Equation I.7 contains implicit statements. Business ideas may result from individual cognition and behavior or environmental situations and conditions or both – and timing. And revealing opportunity is associated with finding useful applications for a market or creating a market or even an industry and shaping the offering correspondingly (product, service, etc, Table I.3, Figure I.27).

Opportunity is about *socio-economic values*, primarily for the entrepreneur(s) or innovator(s) and the adopters of their offering. The socio-economic value for the entrepreneur(s) may be related to what is perceived as his/her view of "success" through firm's foundation (ch. 4.1) – and this may not be wealth or only wealth.

If only economic value is considered opportunity means "*market opportunity*" and customers. And the concept of *customer value* must consider what customers receive (benefits, utility, quality, reputation etc.; ch. 1.2.5.2, Table I.13) from a purchase and use of the offering as compared to what they pay (price, cost).

> According to the famous US-investor Warren Buffet "*value is what you get, price is what you pay*."

Hence, market opportunity can be interpreted as *the likely acceptance of a supplier's value proposition* (Figure I.26) in terms of an offering (product, service etc. in a market) or a solution of a problem. However, there may be, and not so rarely, a mismatch between the supplier's value proposition and the customer's value perception (Figure I.25).

Prospective customers may or may not be able to articulate their needs, interests or problems. Hence, opportunity may appear as an imprecisely-defined market demand or need which may require iterative interactions between supplier and customer for clarification or there may be *latent* needs the customers themselves are not aware of. But, even if prospective customers cannot do so, they may still be able to recognize the value to them in something new when they are presented with it and have its operation and benefits explained – demonstration to anticipated customers.

Looking at the entrepreneur the relation between idea and opportunity has two aspects.

- The entrepreneur is *externally driven*. He or she reveals an opportunity and later decides to become an entrepreneur and to create a venture as a means to pursue the exploitation ("*opportunity entrepreneur*"). The entrepreneur uncovers problems to solve, needs to fulfill, disclose a "latent" need or responds to an explicit demand.
- An alternative path is *internally driven*. The entrepreneur founds a firm or has the absolute will to found a firm and looks for an appropriate opportunity to subsequently achieve his/her goals. Correspondingly, entrepreneurs engage in a search for opportunities with assessing opportunities, with filtration of opportunities, massaging of ideas, and elaborating ways of exploitation ("*opportunistic search*"). This may be the situation of "*necessity entrepreneurs*" (ch. 2.1.2.4) or entrepreneurs pursuing opportunistic adaptability.

Explicit demand may correspond to be asked by others to sell a particular entity or produce something or provide a service (as observed for German WITec GmbH (B.2), IoLiTec GmbH and Solvent Innovation GmbH (A.1.5 – B.2), Attocube AG (B.2), the US firm Cambridge Nanotech, Inc. – or PURPLAN GmbH (Box I.21)).

A study of Hills and Shrader [1998, Table 3] including technical and non-technical entrepreneurs found, for instance, that generally 59 percent or 75 percent of investigated entrepreneurs strongly or partly agreed that they "knew who the first customers would be before introducing our first product/service."

When looking intentionally for opportunities one can consider

- Direct opportunity: the matter/problem at hand
- Relational opportunities: solve it for others too.

In shorter terms, Olson [1986] states that innovation or change can either be "a gap looking for a solution or a solution looking for a gap." Although both of these approaches can produce innovations, each tends to emphasize just one of the two areas that have been suggested as being important for successful technical innovation. That is, *technology push* emphasizes the internal area and *demand pull* (or *market pull*) the external area.

Ideas occur when an individual becomes aware of an important gap or a difference between the existing state of affairs and something more desirable. In other words, an *unfilled need is perceived* or a *mismatch is recognized* occurring as a *problem.*

For entrepreneurship *a business or technical idea must be communicable* to and shareable with the members of a firm's foundation team or other people, notably "advisors" or financial backers. In so far, the *representation of the idea*, that often is not complete or finalized, will undergo further refinements or even distinct changes.

Moreover, modification of an original idea and fit to an opportunity may even occur after firm's foundation when to-be entrepreneurs or founders discuss strategies or negotiate with financial backers or venture capitalists or corporate venturing managers how to further develop the startup. Also for intrapreneurship a technical or commercial idea *must* be well elaborated and communicated: In a firm you must "sell" your idea in line with corporate strategy to management.

In technology entrepreneurship the idea may evolve over a long time and may be "open" for consideration and discussion before it materializes through a new firm. This is contrary to the Fine Arts where often the idea is tightly connected with the artist and is almost complete; and it is the representation or materialization, for instance, in a painting.

A business idea may become "*latently entrepreneurial*," if it had been with a person (or firm) for a relatively long time, even years. Then, by a *perceived opportunity, news or a triggering event*, it may initiate entrepreneurship (cf. Figure I.15) or a new business. An example is the case of Algenol Biofuels, Inc. in the US, when a dissertation became the basis of firm's foundation decades later (A.1.1.4, Table I.91). Correspondingly, Runge [2006:481-482] describes the situation of a "deferred idea" of Otto Röhm in his company Röhm & Haas (Rohm & Haas in the US) when his dissertation of 1901 became the origin of the Plexiglas® (polyacrylate) innovation introduced in the early 1930s in Germany and then the US.

Other examples are provided by the German NTBF Magnetfeldtechnik Resonanz GmbH, a 2007 Awardee of the German Founders' Award ("Deutscher Gründerpreis"), when the founder could not implement commercially his idea of an electromotor to increase efficiency of power generation by wind turbines as the needed multiple-phase control electronics was not on the market as a purchasable component.[13]

Concerning corporate entrepreneurship, one can put the case of the polytetrafluoroethylene (PTFE; Teflon®) innovation of DuPont just before World War II into that class [Runge 2006:21]. Although the remarkable properties, very low coefficient of friction, great chemical inertness, etc., were soon recognized, these could not be exploited for several years because the material resisted processing by conventional techniques. It had to await the development of powder metallurgy techniques.

Latently entrepreneurial ideas may not only be associated with conditions of technology, but may be also *economically conditional*. For instance, referring to a moving value of a constraint related to the Window of Opportunity carbon nanotubes were very expensive and mostly used for research purposes in universities and industry [Runge 2006:542]. Opportunities became relevant with time when production of nanotubes has become cheap enough for large-scale use as components in materials.

Opportunity with a moving target is broadly discussed when the cost of producing biofuels is related to the price of mineral oil per barrel (A.1.1).

In science the issue of *coincidence of ideas* or the *origin of an idea* tackles essentially fame and reputation of the involved person(s) [Runge 2006:755-756], but in the business world this may boil down to dispute or even litigation concerning “ownership,” patents and financial gain or compensation.

The issue of the originator of a (business) idea in the Internet age where myriad ideas are floating publicly around has become particularly complicated as illustrated by the ConnectU against Facebook case (Box I.9). The case underscores the difficulties in pinpointing the originators of ideas on the Internet, particularly for social networking sites. “One thing about the Internet is that most ideas are developed collaboratively in the Internet space, and one thing that was difficult in this matter was trying to parse what was an original idea they had and that somebody else had taken advantage of.” [Levenson 2008]

Box I.9: Coincidence? Or who is the originator of the business idea and its execution?

Mark Zuckerberg started Facebook, Inc., a social networking site, while he was a student at Harvard University (Box I.15). In 2004 ConnectU, a company founded by classmates of Zuckerberg, filed a lawsuit against Facebook, claiming that Zuckerberg had broken an oral contract for them to build the Facebook site, copied their idea, and used source code that belonged to them [Stone 2008; Stone 2009; Levenson 2008].

The Facebook-ConnectU case, which undermined the reputation of the founder Mark Zuckerberg for ingenuity and honesty, was a publicity nightmare for the social networking site. Zuckerberg’s former Harvard classmates, the identical twins Cameron and Tyler Winklevoss and Divya Narendra and ConnectU founders, fought right to the end, settling the dispute in mediation, then contesting the settlement and battling with the lawyers who had represented them in the talks.

According to the ConnectU founders they enlisted class mate Mark Zuckerberg, a student in the 2nd year of study, to help them build a social networking site for college students. But Zuckerberg dragged out the work for several months, they said, and eventually began ignoring their e-mails. In December 2003, he e-mailed ConnectU’s founders, telling them: “I’ll keep you posted as I patch stuff up and it starts to become completely functional.” In February 2004, Zuckerberg launched Facebook. Contending that their idea had been ripped off, the ConnectU founders launched a battle that started at Harvard’s disciplinary board and eventually reached federal court.

In February 2008, it was reported that a settlement was reached between Facebook and the ConnectU litigants. Facebook would pay $65 million to the plaintiffs [Levenson 2008], most of it in Facebook stock, and $20 million in cash. ConnectU’s law firm, Quinn, had asked for $13 million in legal fees. [52]

ConnectU is to this day a small player in online social networking. Zuckerberg dropped out of Harvard and moved to Silicon Valley a few months after launching Facebook. He, in the middle of twenty years, in 2010 was looking at a $4 billion fortune given a climbing Facebook valuation of around $15 billion, according to Forbes Magazine's estimates of the world's richest people [Buley 2010], but lately skyrocketed. The value of Facebook has become a topic of media obsession, as if it were a publicly traded firm. By July 2011 the question was raised: is Facebook worth $100 billion? The fact that it is a private company and its value has this much coverage is a sign in itself. Facebook will probably take years to prove how much it is really worth.

Facebook's IPO, which was highly anticipated by investors as a crowning moment for the Web and social networks boom (ch. 3.4), was a disaster by combination of technical glitches and overhyped expectations. In May 2012 Facebook began trading on the NASDAQ Stock Market, raising $16 billion for the company and valuing it at $104 billion. Facebook's stock opened at $42.05 and fluctuated between $45 and $38 throughout the day. It closed barely above its IPO price, at $38.23. Since then the stock has fallen continuously. By mid of September 2012 it closed at $21.52, down 43 percent from IPO price leaving Facebook's valuation at $58.5 billion.

Was the legal battle between the Winkelvoss twins and Mark Zuckerberg over? No, it was not. There continuously was the claim that Zuckerberg stole the idea of Facebook from ConnectU. After Facebook announced the settlement, but before the settlement was finalized, lawyers for the Winklevosses suggested that the hard drive from Mark Zuckerberg's computer at Harvard might contain evidence of Mark's fraud. Specifically, they suggested that the hard drive included some damning instant messages and e-mails. [Carlson 2010]

What seems to be clear is that "information uncovered by Silicon Valley Insider suggests that some of the complaints against Mark Zuckerberg are valid." [Carlson 2010] On the other hand, it was Zuckerberg who turned to Silicon Valley and succeeding to catch venture capital to finance and grow the fledgling business of Facebook (Box I.15).

Apart from all these issues, the question of who is the originator of a business idea is basically sometimes a question of ethics of entrepreneurship (ch. 2.1.2.8).

Though an idea may be attributed to a single person it may be by no means singular or unique. It may have been "in the air." It may have originated in line with the "Zeitgeist." Science and technology is full of examples for (temporal) *coincidence of ideas or discoveries* [Runge 2006:755-756] and those having the idea became aware of that not very much later. And there are very often ideas that are "revived" years or decades or even centuries later.

Coincidence in the business world often may emerge from strong competition and ultimately result in non-compete covenants. A very prominent historical example by the end of the 1930s refers to the case of US DuPont and German I.G. Farben (BASF) related to Nylon (now called Nylon-6-6 or Polyamid-6-6) and Perlon (now called Nylon-6 or Polyamid-6) [Runge 2006:416-417].

Concerning startups a recent example refers to the German SkySails GmbH & Co. KG (Figure I.103, B.2) and KiteShip Corp. in the US. They arrived at the same business idea concerning how to save Diesel fuel when propelling large vessels on the basis of Diesel combustion engines and wind power. Concerning Internet firms a prominent example of coincidence concerns social networks for professionals (ch. 3.4.2) offered by German Xing AG (B.2) and US LinkedIn (B.2).

Hence, idea generation can occur unconscious or conscious, unintentional or intentional [Runge 2006:758-762]. It is an *individual-level phenomenon* or *small group-level ("team") phenomenon.* It occurs without or with a particular goal in mind (*problem-solving*) over a time period of thinking or at a point of time. It shows up

- spontaneously; a sudden thought, insight or association or flash of mind or in a reflex even without thinking or serious reflection (*recognition*);
- by systematic search processes with/without computer support (*identification*);
- by discovery,
- by serendipity (search for red – find blue; chase rabbits – catch bear);
- by structured approaches called "*ideation*" involving team sessions or intelligence activities.

A central aspect in forming ideas is *synthesis of information* (creativity: unification of seemingly unrelated data, facts, ideas or concepts!). Therefore, *search and retrieval of information* and *activation of one's knowledge* is often associated with idea generation. An intentional structured process to generate ideas is called "*ideation*" (ch. 3.3) and it is usually combined with a search whether the emerged ideas already exist and are published (ch. 3.3).

Opportunities and Problem-Solving

In the business context an opportunity is often associated with a problem (② ↔ ③ in Figure I.80). In our context we shall focus essentially on problem-solving situations involving science or technology as a means. Having revealed a problem initiates looking for a solution by a search process (③ → ④ and ④ → ⑤ in Figure I.80) or "having or generating" an idea for a solution (③ → ① and ① → ② in Figure I.80) to grasp the opportunity (the *demand pull* situation).

In case of *technology push* the connection of an idea to the opportunity may result from a search process for a useful application of the technology (Equation I.7; ①). But after relating this to an opportunity (① → ② and a probably a PoC a new problem (③) may occur, like scaling-up from the lab to production.

The *search process* for problem-solving, which will vary by industry, may inquire into existing information or knowledge about solving the problem and it must look to answer three basic questions:

- Has the problem (at least almost) been solved already earlier – 1, 10, 50, 100 or more years ago?
- Has it been tackled unsuccessfully; how and why probably has it failed?
- Has the problem an identifiable "generic structure" and is there a related generic solution available in a different technology domain?

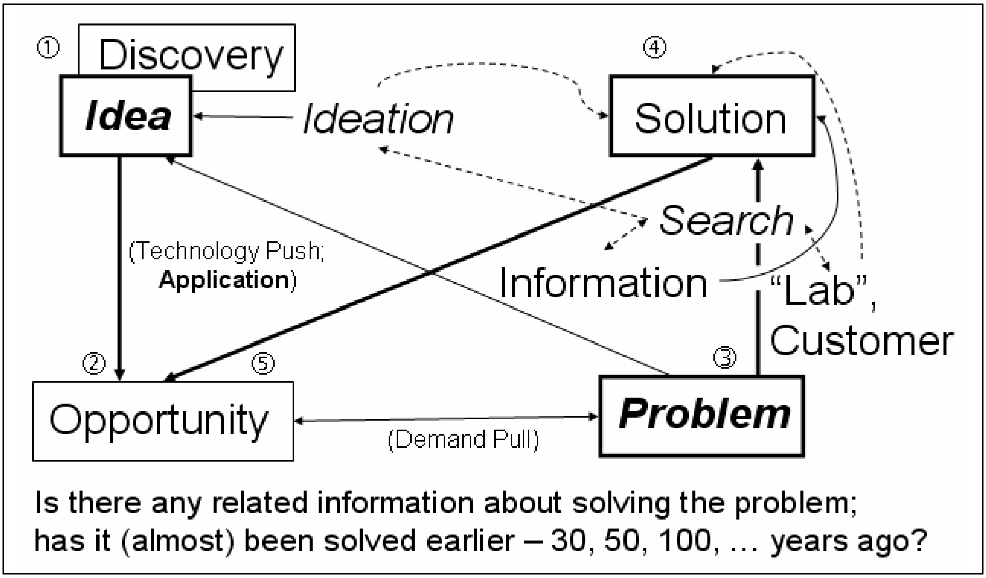


Figure I.80: Interrelations of idea, opportunity and problem-solving for innovation and entrepreneurship.

Then there is *search* for problem-solving *by experiments or tinkering* in the laboratory. Here "lab" does not only mean being active in the firm's laboratory. It can also mean to enter a market and, if necessary after contact with customers, make changes.

Apart from idea, discovery and problem-solving opportunities in the technical area (ch. 3.2) may start with being associated with a simple "*concept summary*" that becomes more elaborate as entrepreneurs develop and demonstrate the concept (Proof-of-Concept; A.1.1). This process involves pro-active efforts, often in the laboratory, to match an offering or offered problem-solution with the ultimate business requirement.

As in technology and business a problem is a difference between actual conditions and those that are required, desired or accepted. The solutions may be exact or approximate. The approach to problem-solving, hence, follows an algorithm ("programmed") or a heuristic (ch. 4.2.2) or is *satisficing* (ch. 4.1) both referring to non-programmable problem-solving.

A problem can often be paraphrased by a *question* and, hence, problem-solving corresponds to the *answer(s)*.

> A key feature of problem-solving is that usually the person or group is known who will likely adopt ("purchase") the offered solution. However, more than often formulating the problem by the adopter (customer, client) lacks precision so that the first offering of the solution does not fully meet some "latent" requirements of the adopter. Hence, problem-solving may (or should) proceed via feedback loops.

Ideas may sprout out of business strategies, technology exploration, new product planning, and product improvement/modification or technology intelligence. In large firms most activities are related to customer work and work on immediate issues within current businesses. Their generation is intentional and purposeful and can be characterized mostly as being *re-active* focusing on *"problem-solving" for incremental innovation* [Runge 2006:616]. *Pro-actively* searching for (current or future) opportunities and generating related ideas is the other facet of intentional behavior.

Specifically, in (technology) intelligence an "*information problem*" is a step in a process that involves a clear statement of the topic to be investigated *and* the expected results.

On the other hand, undirected reading (mostly technical or scientific literature) and thinking ("*browsing*") may lead unconsciously to idea emergence or discovery. **Discovery** describes a novel observation or finding of something already existing and must be differentiated from serendipity (ch. 1.1.2).

In general, a **problem** is an issue or obstacle ("pain") which makes it difficult to achieve a desired goal, objective, purpose or state. It refers to a situation, condition or issue that is yet unresolved. In a broad sense, *a problem exists* when an individual becomes aware of a significant difference between what actually is and what is explicitly or implicitly desired.

In particular, a "**Holy Grail**" is a great and unsolved challenge or problem in a particular industry or a scientific/technical discipline. Achieving a Holy Grail has enormous implications with regard to innovation or associated firm's foundation. In that case the entrepreneur or innovator knows from the beginning that he/she is addressing a very large market opportunity and do not feel compelled to answer any market size question by detailed figures when the person is on his/her way to pursue.

A Holy Grail of science does not necessarily provide very big "big rewards" commercially. For instance, the US startup SiGNa Chemistry LLC (B.2) has developed and patented a method for making alkali metals and their derivatives an essential part of industry's toolkit by encapsulating them in nano-structured porous oxides and removing their hazards.

Alkali metals are enabling materials that have been under-utilized due to their dangers and difficulty in handling. SiGNa's products have solved the problems of safety and cost efficiency, which represented the most significant scientific breakthrough in reactive metals in over 100 years. From a science point of view SiGNa, founded in 2003, has achieved a Holy Grail. However, SiGNa, with 20-25 employees by 2010 and revenues of ca. $2.5 million as the best estimate, shows good, but not exceptional growth.

The many different ways outlined to go for a solution of a problem in Figure I.80 may generate the impression that, at least one solution can be found. But, the interference of industry as well as science and technology policy with innovation and entrepreneurship often generates “wicked problems.” A **wicked problem** is a phrase used in social planning (and for systems emphasizing the question “what do the systems do”) to describe a problem that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize [Rittel and Webber 1973].

Moreover, because of complex interdependencies, the effort to solve one aspect of a wicked problem may reveal or create other problems. There are no “solutions” in the sense of definitive, objective and mostly not even satisficing answers [Rittel and Webber 1973].

By now we have come to *realize that one of the most intractable problems is that of defining problems*, of knowing what distinguishes an observed condition from a desired condition and what distinguishes an explicitly formulated problem and an implicitly derived, latent problem and of locating problems (finding where in the complex networks the trouble really lies).

Furthermore, an opportunity may show up as an answer to a question. But, using a story, actually a Gyro Gearloose comic (in German Daniel Düsentrieb), on “efforts to build a perfect forecasting device” [Runge 2006:844-848] it has been lucidly illustrated that if you start off with *the right questions*, you are more likely to find the right answers. But start off with the wrong questions, and you are lost from the beginning. This is about “framing the problem.”

One of the *fundamental barriers of problem-solving* is the tendency of mankind’s thinking in terms of finding the solution within the boundaries of a *perceived constraint* system. But the solution may be found lifting this mental blocking.

This is illustrated in Figure I.81 by two well-known examples. Here regularities or constraints, respectively, are assumed to exist that actually are not given, namely, the line drawing must always be kept within the border of the square defined by the dots (circles). In the second problem restricted to connecting the nine circles/dots by three lines the other blocking is semantic: disregarding the spatial extension of the circles and assuming the lines to cross the circles rather than just touching the circles will be the trick.

In many cases ideas for innovations or change originate with communication about a need (or demand), followed by search for technical possibilities to meet the need.

Informal and oral sources provide a large part of key communications about both needs and technical possibilities. And communication about a need is often by someone other than the person who generated the idea for an innovation, a customer or a user (*separation of idea generation and revealing opportunity*).

In the corporate environment a study showed that ca 12 percent of the information that evoked ideas was the result of search by the innovator, as opposed to 25 percent during problem-solving. *Oral sources* were important both during idea generation (45 percent of all information) and during problem-solving (32 percent of all information). The typical approach to problem-solving is to address first a colleague who knows or might know or who knows someone who could know. All this points to *a more active and structured search for information during problem-solving* [Runge 2006:758-762].

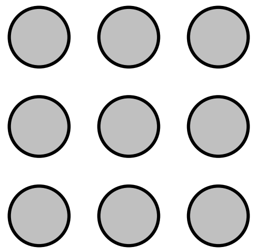
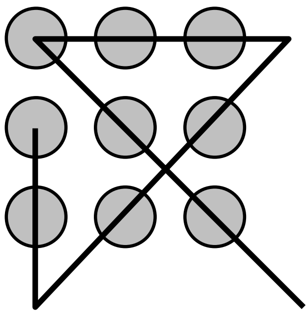
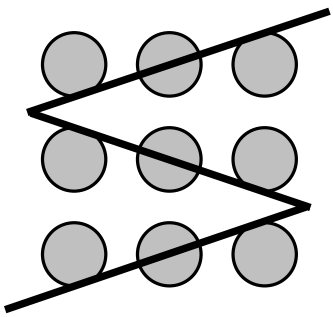
	**Problem**: Connect the nine circles (dots) by exactly no more than four lines with one stroke without interruption (without lifting the pencil). No dot must be touched twice; the lines are allowed to cross only once.
	**Solution**: To find the solution laws or regularities are assumed, solutions to be found within the system that are not part of the task, the question or kind of inquiry. The *answer or problem solution does not (implicitly) require to stay within the system* defined by the arrangement of the nine dots. The solution is found crossing the borders to find the solution on a higher real or conceptual level.
	**Problem:** Same problem, but connect the nine dots by exactly no more than three lines. **Solution:** Set dots equal to circles. There is *no restriction that the lines cross the circles*; the given problem is solved if the line touches or crosses the circles.

Figure I.81: Crossing the borders of a (conceptual) system for problem-solving.

A survey on idea generation in companies identified “innovation stars” as those picking up ideas from a *wide range of sources both internal and external*. It was also found that innovative companies are more likely to see *ideas as a resource in their own righ*t and may seek to exploit even those that do not fit with current business operations:

“An idea that cannot be used right now could still be sold or traded, or could even be given away to generate good will. At the very least, such ideas should be kept under review to spot new Windows of Opportunity further down the line,” as does 3M. [Runge 2006:758].

Idea Revival and Idea Recycling

Above it was emphasized that in the technical area problem-solving must inquire into whether the problem has been solved already earlier. Correspondingly, a special but common problem-solving situation in technology innovation and entrepreneurship is “*idea revival*” based on *structurally existing ideas* to fit a new opportunity resulting from changed societal, political, socio-economic and/or scientific and technical conditions. For the entrepreneurs the related constellation is often associated with high expectations concerning reward.

For instance, two current situations represent such constellations, the cases of *biofuels* and *biobased chemicals and plastics* (Box I.1, A.1.1) and the *electrocar or generally electric vehicles* case (Box I.10) which can be viewed as *recycling* rather than revival of ideas.

> The cases of, for instance, electrocars and related batteries, wind turbines (ch. 3.3.1), biofuels and biobased chemicals and plastics (A.1.1) show that *technology entrepreneurship is often associated with “waves” (steps) of technical progressions.*

Then. recycling means here a process by which old ideas (and related entities) are revealed, then assessed concerning fundamentals of technical concepts and structures and finally adapted to new technical possibilities to produce new entities of the same kind. Electric vehicles are a special aspect of the more general subject of “electromobility” (emobility; ch. 3.2.1). And also for photovoltaic (solar power, ch. 4.3.5.2) and wind power (Table I.60, Figure I.103) much “new” is already old.

All these developments can be viewed to reflect *technology trajectories* and seen as *structured idea generation* (ideation, ch. 3.3).

Box I.10: Recycling the ideas for electric vehicles [PBS 2009] [53]

Electric cars are a variety of electric vehicles. The term “electric vehicle,” EV, refers to any vehicle that uses electric motors for propulsion, while “electric car” generally refers to road-going automobiles powered by electricity.

While an electric car’s power source is not explicitly an on-board battery, electric cars with motors powered by other energy sources are generally referred to by a different name: an electric car powered by sunlight is a *solar car*, and an electric car also powered by a gasoline generator is a form of *hybrid car*. Thus, an electric car that derives its power from an on-board battery pack or fuel cell(s) is called a *battery electric vehicle* or *fuel cell vehicle*, respectively.

Fuel cell vehicles (FCVs) mostly run on hydrogen gas rather than gasoline and emit no harmful tailpipe emissions. These vehicles are still in development, and several challenges must be overcome before these vehicles will be competitive with conventional vehicles.

Electric cars enjoyed popularity between the end of the 19th century and early 20th century, when electricity was among the preferred methods for automobile propulsion. Developments occurred largely parallel in Europe and the US (Figure I.82, Figure I.83). In the US around 1900 40 percent of automobiles were steam vehicles, 38 percent electric vehicles and 22 percent petroleum vehicles. In 1901 in New York there were more than 50 percent electric vehicles.

Advances in internal combustion engine technology – a greater range of gasoline cars, quicker refueling times, transportation for short- and long distances, the rising petroleum (oil) industry and the establishment of the necessary petroleum infrastructure (Figure I.172, A.1.1.2), along with the mass production of gasoline vehicles by companies such as the Ford Motor Company, which reduced prices of gasoline cars to less than half that of equivalent electric cars – led to a decline in the use of electric propulsion.

In 1966 in the US Congress introduced the earliest bills recommending use of electric vehicles as a means of reducing air pollution. And in the 1970s concerns about the soaring price of oil – peaking with the Arab Oil Embargo of 1973 – and a growing environmental movement resulted in the Western world in renewed interests in electric cars from both consumers and producers. But after oil prices decreased drastically related commercial activities slowed down a lot.

Currently again, in the context of increased societal “green” awareness, fighting air pollution, climate change and a number of associated worldwide policy programs (Box I.1; Box I.22) automakers are investing heavily in electric vehicles, mainly battery electric vehicles, but also fuel cell vehicles.

One of the current biggest remaining hurdles for mass-market adoption of electric cars – cost – has everything to do with technology: the battery technology, that is, to reduce cost by increasing energy density (Figure I.83) and availability of the related charging station infrastructure. For fuel cell vehicles the cost issue is largely associated with hydrogen production and safe storage as well as the necessary “fueling” infrastructure.

Regretfully, one century later the performance (travel range, speed) of electric vehicles remained as they were in the 1890s (Figure I.82). Despite promising signs, the electric car will need to navigate a bumpy road before it can become a viable option for many drivers. Challenges to mass adoption include high sticker prices, limited battery life and travel range, and building standardized charging stations and other infrastructure to support electric vehicles.

Electric cars enjoyed popularity between the end of the 19th century and early 20th century, when electricity was among the preferred methods for automobile propulsion. Developments occurred largely parallel in many European countries and the US (Figure I.82, Figure I.83). In particular, Edison worked on improving performance of batteries for commercial automobiles (Figure I.83).

With the advance of the 20th century advances in internal combustion engine technology – a greater range of gasoline cars, quicker refueling times, transportation for short- and long distances, the rising petroleum (oil) industry and the establishment of the necessary petroleum infrastructure (Figure I.172, A.1.1.2), along with the mass production of gasoline vehicles, which reduced prices of gasoline cars drastically – led to a decline in the use of electric cars.

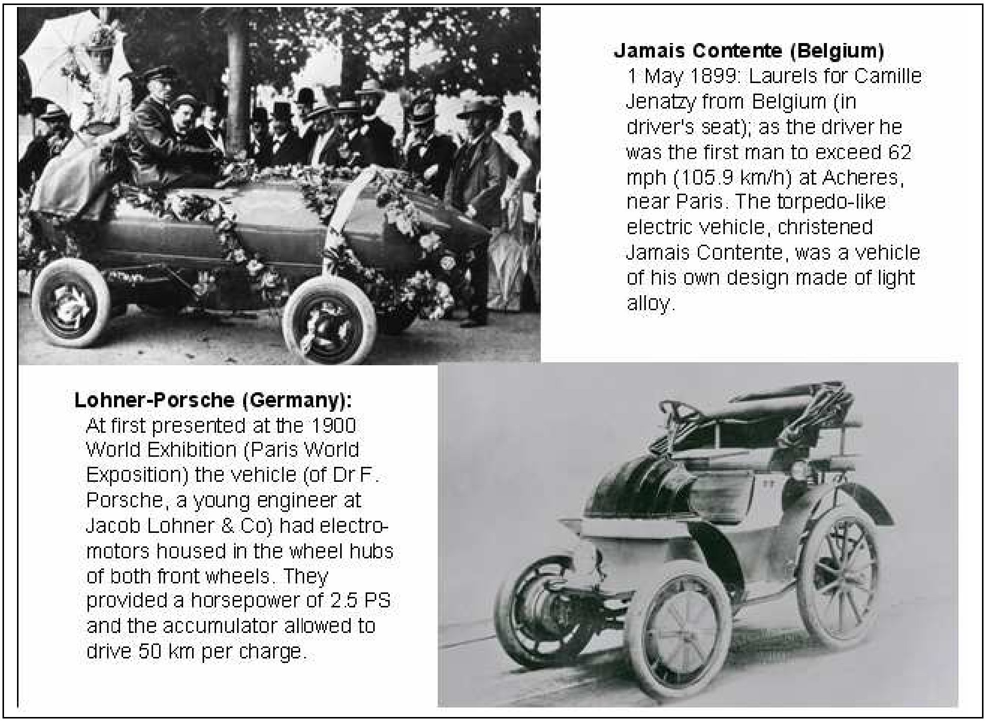


Figure I.82: Recycling ideas for electric vehicles of various designs and performance. Soures: [PBS 2009] and Note 53.

From a technological point of view it is interesting to note that currently (at least in Germany) there are development activities concerning small two-seated cars with electro-motors and electric auxiliaries in the wheel hubs for the Asian megacities – following the Lohner-Porsche (Figure I.82).

The electric vehicle case does not only provide an example for “recycling ideas,” but illustrates also the prototypical transition dynamics when a new technology emerges that may substitute an old one. This dynamic is called the “**Sailing Ship Effect**” [Runge 2006:255,256] and it refers to a “*hybrid*” situation (Figure I.85) and a competition process between two technologies, one ‘‘old’’ and the other ‘‘new’’. The advent of a new technology usually stimulates a response of the incumbent technology (for instance, more R&D for the old one), so that the latter may survive for an “unexpected” long period (Figure I.22).

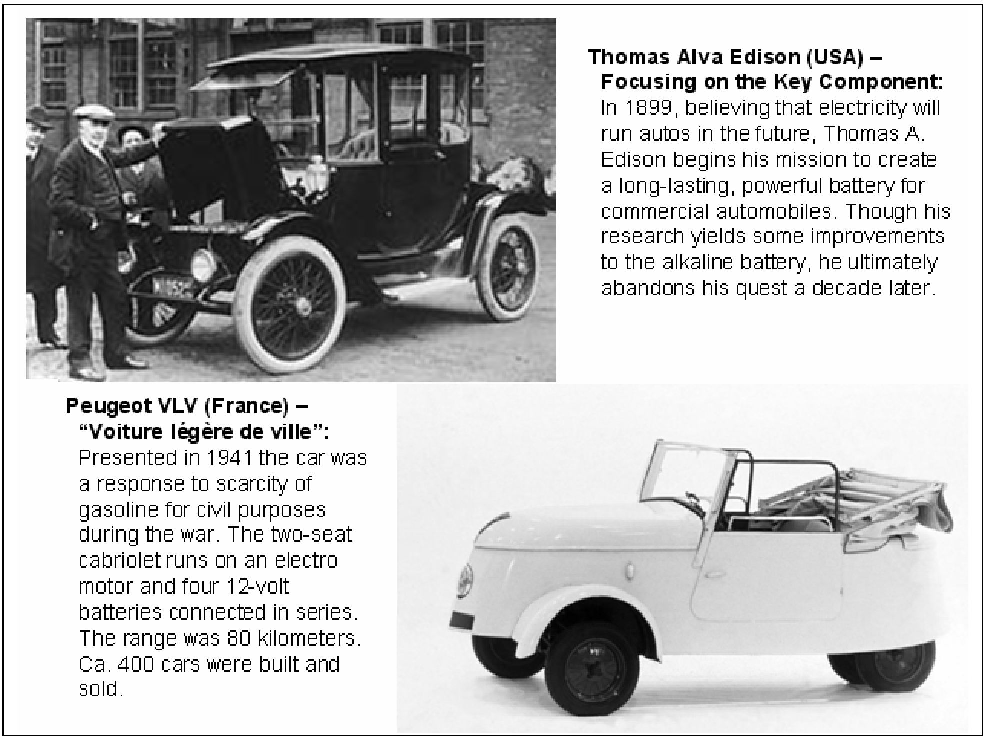


Figure I.83: Recycling ideas for electric vehicles emphasizing batteries and responding to gasoline scarcity. Source: [PBS 2009] and Note 53; “Edison and the electric car” through courtesy of Division of Work & Industry, National Museum of American History, Smithonian Institution.

The hybrid case and its related notion is illustrated by the transition of wind power to steam power when, two centuries ago, large engines were put on sailing ships crossing the Atlantic utilizing either steam power or wind power (or both) (Figure I.85). *Hybrid technologies represent technological evolution*.

That is, just as in the shipping world, the steam power innovation did not instantly led to the disappearance of sailing ships but instead *triggered a whole series of improvements* in that industry. This means that after an innovation there is a period in which all sorts of ideas and designs are thrown around before finally a "*dominant design*" (ch. 1.2.5.1; Figure I.100) settles out and the industry begins to develop in one direction and mature.

Hybrid vehicles (Figure I.85) or particularly cars represent the technological transition step between different "propulsion technologies" for surface transportation from coaches or carriages with horses and postillons (coach drivers) to new propulsion technologies (Figure I.30). In case of cars or railroads there was a new propulsion technology. In this transition *just one component is changed* – the *propulsion technology*. Early design and layout of the cabins of the old vehicle, however, was kept largely for the cars (Figure I.30) or the railway wagons, respectively.

This can be viewed as a **component innovation**. It entails changes to one or more components of a product system without significantly affecting the overall design. This is different from *architectural innovation* which, generally, requires changes in the underlying components as well as changing the overall design of the system or the way components interact.

A lucid example of retaining shapes and designs paralleling the introduction of the railroad is the steam bus, also called steam carriage – lifting restrictions of railway tracks of connecting locations (Figure I.84). Steam buses were one of the first vehicles without pulling animals that could use any road to reach an endpoint just changing the propulsion technology for a stagecoach.

Since 1830 some of these rebuilt stagecoaches ran in London. Correspondingly, early steam-powered vehicles designed for carrying passengers were more usually known as steam carriages. For private use they were too expensive. In 1833 a regular steam carriage service in London marked the beginning of the mechanically propelled bus [Gould].

Figure I.84 exhibits the drawing of the British engineer Richard Trevithick's steam vehicle "Puffing Devil" from 1801 which kept the shape of a carriage for the passenger cabin (cf. a related picture with this design from around 1830 by ADAC [2011a:21]).

Richard Trevithick (1771-1833) invented the world's first full-scale, working steam locomotive (1803) and launched the world's first passenger steam train in 1804. The Puffing Devil was unable to maintain sufficient steam pressure for long periods, and would have been of little practical use. But in 1803 he built another steam-powered road vehicle called the London Steam Carriage, which attracted much attention from the public and press [BBC].

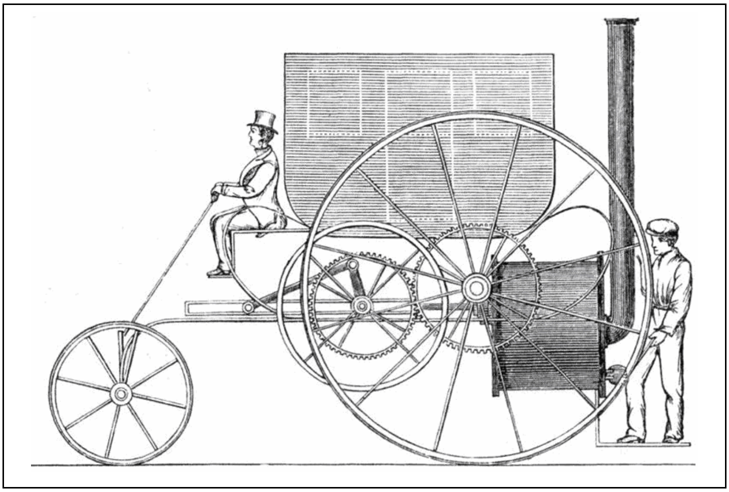


Figure I.84: Schematic drawing of Richard Trevithick's steam vehicle "Puffing Devil" from 1801 keeping the design and layout for passenger cabins of carriages/coaches [BBC] (Drawing from Wikipedia).

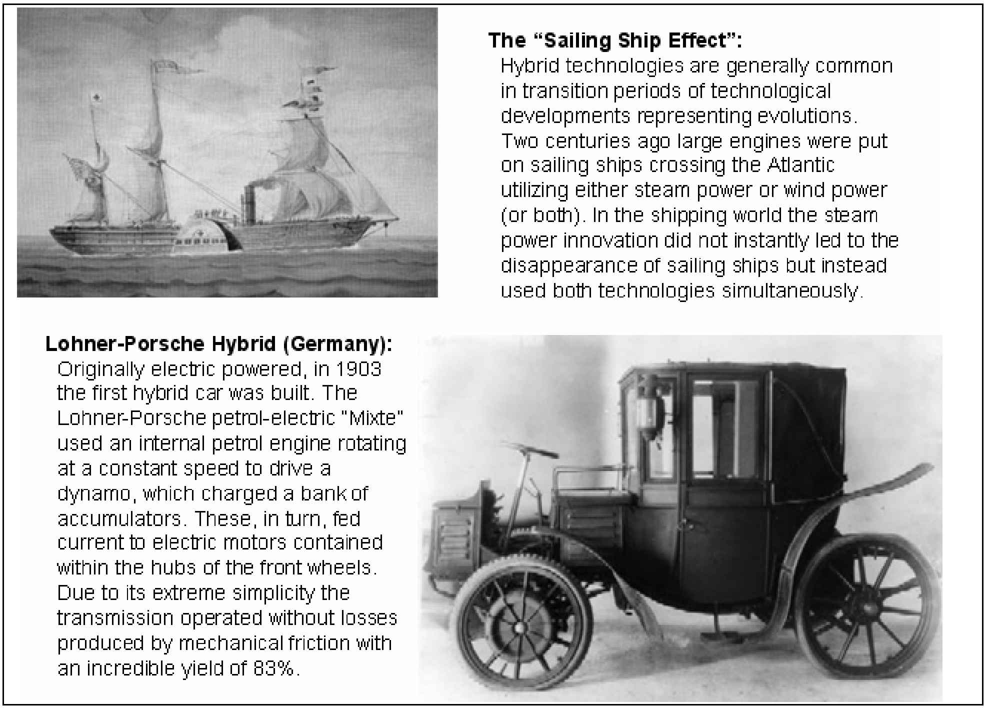


Figure I.85: The "Sailing Ship Effect" illustrated for a "hybrid car" combining a combustion engine and an electro-motor (Source: Hybrid-vehicle.org).

Moreover, during the considered technological transition phase several new technologies competed with the old one (stagecoaches), in particular, electric cars powered by batteries and cars with internal combustion engines driven by gasoline.

The Lohner-Porsche *hybrid* from 1903, electric car powered by a gasoline generator, even combined two new technologies against the old one and thus marked a step toward a "dominant design" (Figure I.100). Hybrid cars did not appear again until the in 1960's and 1970's. The current emphasis on battery electric vehicles as well as fuel cell vehicles indicates that the run for the dominant design is not yet over.

> For development of technology *a disruptive innovation based on disruptive technology may initially have lower performance than incumbent technology*. In this case the first automobiles were much slower than horse-drawn coaches or carriages.
>
> Often disruptive technologies work by offering, at least initially, little in the way of performance, but plenty in terms of cheapness, convenience and ease of use [Christensen 1997].

With regard to solve our current transportation energy needs belief in the ability of biofuels (A.1.1) goes back as far as 1925 when automobile pioneer Henry Ford said in an interview with Christian Science Monitor: "The fuel of the future is going to come from fruit like that sumac out by the road, or from apples, weeds, sawdust – almost anything." [Mukhopadhyay 2011e]

Recycling of ideas is found all over the industries. For instance, the fundamentals of tablet-PCs and of Apple's current iPad have been developments with Xerox (PARC) as were also the computer mouse and the graphical user interface.

In 1968 computer scientist Alan Kay's vision and conceptualization for a device, called the *Dynabook*, was a portable notebook sized device capable of displaying text and dynamic graphics with contrast ratios similar to that of a book. The device was envisioned as an educational tool and geared towards children, as evidenced by a 1972 research paper titled "A Personal Computer for Children of All Ages" that Kay published while working at the PARC [Edible Apple 2011].

A special situation with expectable immediate success in the market occurs if problem-solving relates to *lifting a monopoly* which dominates a highly lucrative market or, at least, let emerge an alternative supplier who will gain enough market share. A classical example is lifting the Chinese monopoly for porcelain in Europe when in Germany von Tschirnhaus and Böttger succeeded in producing porcelain based on "reverse engineering" in 1708/1710 (ch. 3.3). Another recent example of lifting a monopoly to initiate entrepreneurship by working on problem-solving is described by Runge [2006:46-48] in Box I.11. Currently there are efforts in Europe to fight the Chinese quasi-monopoly concerning rare earth metals which are fundamentally important for electronics by recycling of electronics scrap (A.1.5).

Box I.11: Lifting a monopoly as a perceived lucrative opportunity for entrepreneurship.

Hydroxylamine (HA) is a highly explosive chemical compound. Until the year 2000 there were only two suppliers of semiconductor-grade hydroxylamine (HA) in the form of "hydroxylamine free base" (HAFB) on the global level, Nissin Chemical of Japan and BASF (Germany). BASF already started up its new HAFB production facility in Germany in early 1999. At that time HA containing strippers for semiconductors dominated the market. HA-free base producers did not exist in the US, which consumes almost 50 percent of the global demand.

Hydroxylamine, which was (almost) a non-US monopoly, hence, was seen as an excellent business opportunity. In the US minor HAFB quantities were offered by small to medium sized companies on the basis of contract manufacturing. On the other hand, the startup Concept Sciences, Inc. (CSI) planned to become the first company in the US to manufacture this product in commercial quantities. Grasping the opportunity was backed by a supply agreement with Ashland Chemical Company. CSI had to weigh essentially production risk (high) versus market risk (low) when deciding whether to go ahead.

When CSI began its first distillation to produce HAFB in its new facility by February 1999 an explosion killed and injured people, and destroyed a large area. Moreover, in June 2000 the Nissin Chemical HAFB plant had also an explosion with fatalities and destruction of the plant. This changed the supply side for the US dramatically. As a result the semiconductor industry was affected by the interruption of the hydroxylamine (HA) supply chain and BASF remained as the only source for this material and had an (almost) complete monopoly on the basis of its very safe production process.

3.2 The Idea and the Opportunity

In the field of observation, chance only favors the prepared mind.
Louis Pasteur (1822-1895)

Equation I.7 provides *set-theoretical interconnections* of business ideas and opportunities for NTBFs. In Figure I.78 (business!) idea and opportunity are displayed as a *teleological relation* represented as a bidirectional graph. This relation shows up (observably) if an individual or group pursues their view of "success" (ch. 4.1) with related expectations and intention induced behavior in terms of firm's foundation or new business development. This attributes differing roles to the individual(s) and the systemic components of the environment including timing (Figure I.4, Figure I.92).

Results for privately held *Inc.* companies and engineering-type NTBFs from very close industries in Table I.49 and broadly defined German NTBFs (Table I.50) indicate that the majority of offerings by new technology-based firms to be essentially *betterments*, in particular, providing cost reductions and *imitations* (close substitutes). This means, actually it requires for the *entrepreneurs to have considerable market knowledge*. Furthermore, previous industry experience and educational background show up markedly as the basis of technology entrepreneurship.

Relatedly an example from the (chemical) industry [SpecialChem4Coating 2011] provides insights into the factors to develop new product innovation and solving technical problems in existing firms. Results of a broad questionnaire indicate that the most important factor is industrial experience far ahead of creativity and tracking the scientific and technical literature (including patents),

- Industrial experience (42.3 percent)
- Creative talent (24.2 percent)
- Reading current literature (18.1 percent)
- Using the Internet (7.8 percent)
- Education background (5.0 percent).

Table I.49: Origins of startup ideas of 1989 *Inc.* 500 founders and revealing opportunities [Bhidé 2000:54].

<table>
<tr><th colspan="3">Origin of Idea to Found New Firm</th><th>Percent</th></tr>
<tr><td colspan="3">Replicated or modified an idea encountered through previous employment</td><td>71</td></tr>
<tr><td colspan="3">Systematic search for business opportunities [1)]</td><td>4</td></tr>
<tr><td colspan="3">Discovered serendipitously [2)]
Built temporary or casual job into a business (7%)
Wanted as an individual consumer (6%)
Happened to read about the industry (4%)
Developed family member’s idea (2%)
Thought up during honeymoon (1%)</td><td>20</td></tr>
<tr><td colspan="3">Other</td><td>5</td></tr>
<tr><th colspan="4">Revealing Opportunities (Telephone Interviews, US) [Chandler et al. 2004]</th></tr>
<tr><th>Item</th><th>Electrical Measurement Instruments</th><th>Surgical Medical Instruments</th><th>Total</th></tr>
<tr><td>Number of companies</td><td>7</td><td>15</td><td>22</td></tr>
<tr><td>Had resources and systematically searched</td><td>0</td><td>0</td><td>0</td></tr>
<tr><td>Created a new product and are educating consumers</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td>Fortuitous discovery [2)]</td><td>3</td><td>4</td><td>7</td></tr>
<tr><td>Had few resources and</td><td>2</td><td>8</td><td>10</td></tr>
</table>

systematically searched			
Had prior industry background and / or educational background	5	13	18
Sample: from Dun & Bradstreet database using SIC codes; age of NTBFs: 2-6 years, mean age of 4.6 years; mean number of employees was 5.5; sales: $82K to $2.8M.			

1) Not clear whether this covers technology push approaches.
2) No differentiation between discovery and serendipity here.

Systematic search for business opportunities obviously represents a minor path for technology entrepreneurship (for *Inc.*-type startups). According to Bhidé [2000] most of the *Inc.* sample firms do limited research and analysis. And lack of research leads to *opportunistic adaptation*. Reasons for not studying more include

- Lack of money
- Opportunity costs not high
- One third of founders had been fired or quit.

On the other hand, the above data on product innovation in large firms indicate that systematic search (reading current literature and Internet: ca. 26 percent) compares directly with creative activities.

Early market learning of the innovator and seeking applications by the innovator and educating and training the adopter/customer is likely to be associated with a technology push or disruptive innovation situation (ch. 1.2.5.1).

Concerning Bhidé's US sample only 12 percent of the *Inc* founders attributed the success of their companies to "*an unusual or extraordinary idea*," and 88 percent reported their success was mainly due to the "*exceptional execution of an ordinary idea*." They typically imitated someone else's ideas that they often encountered in the course of the previous job. Innovation was incremental or easily replicated.

About 10 percent of the founders of *Inc.* companies claimed they started with unique product ideas [Bhidé 2000:39]. This position is closely related to the figures of the observation of "created a new product and are educating consumers" in Table I.49 and the items "no substitute available" and "novelty for market" in Table I.50.

Based on members of the Chicago Area Entrepreneurship Hall of Fame (EHF; technical and non-technical) Hills and Shrader [1998] studied exceptionally successful entrepreneurs (EHF, 53) versus randomly selected entrepreneurs (RSE, 187) to find that there were more similarities than differences. For this sample only 29 percent agreed that "the idea for (their) business was mostly technology driven" – in line with finding in industry that innovation results to ca. 30 percent from a technology push approach (ch. 1.2.5.1).

The same study found that for entrepreneurs (both EHFs and RSEs) "the most important thing is to believe in the idea" (EHF 56 percent "strongly agree" and 29 percent "partly agree" versus for 41 and 38 percent for RSEs). This stresses *perseverance*

(Table I.31) as an important entrepreneurial trait or orientation which involves sticking to a belief or idea; that is being steadfast or loyal.

Table I.50: Characteristics of offerings as the basis for NTBF foundation (in percent).

	High-Tech Foundations (Germany) 1) [Gottschalk et al. 2007]	***Inc.* 500 Sample** 2) **(US)** [Bhidé 2000:32]
Identical or close substitute available		58
Substitutes that differ in function, price or value		36
No substitutes available		6
Using own patents	12 (24)	
Reduce materials' cost	23 (24)	
Reducing cost of per-sonnel	24 (29)	
Novelty for market	26 (32)	
Process innovation 3)	50 (58)	
Increase capacity (output)	55 (53)	
Product imitation	56 (58)	
Increase quality	85 (87)	

1) Survey data from 2006, multiple answers possible; in parentheses: spin-outs, otherwise high-tech NTBF foundations.
2) *Inc.* 500 founders from 1982-1989.
3) Process innovation is largest for NTBFs of the software area.

Concerning differences between new ventures Table I.50 shows that spin-outs (RBSUs) rely much more on own patents compared to the overall statistical NTBF sample (from 2006).

For NTBFs innovation and innovativeness (Table I.10) is key to get and keep competitive advantage. In this regard Creditreform et al. [2009] inquired into German NTBFs that were founded in 2005-2007/2008 concerning innovation and R&D activities and into the innovation level of products contributing most to the sales in 2007.

They observed that 11 percent of firms founded between 2005 and 2008 launched as the first one a particular product "new-to-the market." Novelty was regional (4 percent), national (5 percent) and global (2 percent). Among the 2005 – 2007 sample 29 percent launched a product perceived to be new by the firms' founders (product innovation); 15 percent of the sample introduced 2008 new production processes in the firms.

A special situation for innovation or technology entrepreneurship and opportunity is *problem-solving as a challenge*, for instance, in terms of a statement, such as "it cannot be done that way." The classical example is from 1895. Eight years before Orville and Wilbur Wright took their home-built flyer, cranked up the engine, and took off, Lord Kelvin, a very powerful man of science and the President of the Royal Society of England, declared: "Heavier-than-air flying machines are impossible."

At that time the general opinion was expressed by the New York Times (editorial of December 8, 1903): "The flying machine which will really fly might be evolved by the combined and continuous efforts of mathematicians and mechanicians in from one to ten million years." [Kraft 2005]

The brothers Wright, did not only tinker and experiment, but carefully observed how birds enjoyed a perfect balance among the forces of lift, draft and gravity, a balance they were learning how to emulate together with their own human ingenuity and perseverance [NASA 2003].

They focused on unlocking the secrets of control to conquer "the flying problem." The key was to find decomposition into a number of subsets within the overall problem. The subsets included wing design, propulsion and power, balance and control, and flying skill [Kraft 2005]. This implementation of function found in Nature is currently termed *bionics or biomimetics* which is imitation *as a means of generating ideas.*

It is interesting to note that the brothers Wright where not the first to fly. Aviation pioneers in several countries were working on the problem. Overwhelming evidence shows that history's first manned, powered, controlled, sustained flight in a heavier-than-air aircraft was in 1901 by Gustave Whitehead, a German immigrant to the US (born as Gustav Weisskopf). "The Wrights were right; but Whitehead was ahead." [John Brown] A vision as a challenge is also found in chemistry (A.1.2, Table I.100).

Another example from the 1930s is provided by the Nylon-Perlon case [Runge 2006:415-417]. Here, in the US DuPont, the Nylon inventor and producer, claimed that Nylon (now called Polyamid 6-6) cannot be made from the chemical ε-caprolactam. But BASF (then I.G. Farben) in Germany took the *challenge* and succeeded in making an equivalent product from ε-caprolactam called Perlon (Polyamid-6).

A recent case is found in the biofuels area. In a conversation with Professor Frances Arnold of the California Institute of Technology, venture capitalist Vinod Khosla suggested that "you can't do that with synthetic biology economically yet." She disagreed, and as a response Gevo, Inc. was founded (Table I.39, A.1.1.5; Table I.99).

More Paths to Opportunities: "Open Opportunity"

Opportunity as a central concept of entrepreneurship has been related to idea (ideation) or/and problem-solving (Figure I.1, Figure I.80, later Figure I.87). Problem-solving refers to a domain (customer, market, industry) for which the underlying (commercial, technical, social) problem is more or less explicit among members of the domain and which thus provides an option for an "opportunity to be disclosed to an entrepreneur." This includes opportunities based on "latent needs." But it represents also a limitation, a more or less closed technical and socio-economic group of organizations and to-be members.

On the other hand, "o*pen opportunities*" for entrepreneurship can be characterized by very *broad societal awareness* of a problem demanding solution and often promising big reward for the solution. They are public and there is a wide awareness among potential people by exposure.

Typical examples include lifting the Chinese monopoly by von Tschirnhaus and Böttger in Germany in 1708/1710 concerning porcelain (cf. also Box I.11) or renowned German chemist Liebig's conviction around 1840 that "tomorrow or the day after tomorrow someone will discover a process ... to make the wonderful dye of *madder* or helpful *quinine* or morphine from coal tar" (ch. 2.1.2.2). This was the basis of the organic chemical industry, first the dye industry through Perkin in 1856 (A.1.2, Perkin & Sons) and later the pharmaceutical industry, essentially by German Bayer AG.

Currently, there are obviously open opportunities originating in public awareness and related political actions in CleanTech (Table I.52), in particular, in biofuels (A.1.1), photovoltaic (PV; solar cells), wind power and electromobility etc. For entrepreneurship these open opportunities lead to an outburst of ideas how to exploit these. One way is to revive or recycle old ideas along technology trajectories as discussed above for electrocars and for biofuels in the Appendix (A.1.1). The situation is associated with heavy competition (Figure I.34, Table I.17) and usually associated with a "race" that may enforce speed-based innovation.

Open opportunities addressing technology specialists may emerge also by "technology roadmaps" (Box I.12) which are developed and regularly updated for industries or special technologies. A **Technology Roadmap** is the document of the output of a technology roadmapping process at either the corporate or the industry level. It identifies (for a set of product needs) the critical system requirements, the product and process performance targets, and the technology alternatives and milestones for meeting those targets.

Technology Roadmapping is a *needs-driven technology planning process* to help identify, select and develop technology alternatives. It brings together a team of experts to develop a framework for organizing and presenting the critical technology planning information to make the appropriate technology investment decisions and to leverage those investments. The critical step in roadmapping is to get the participants to identify and agree on common product needs [Garcia and Bray 1997].

Box I.12: Roadmaps as tools for revealing opportunities for innovations or entrepreneurship.

Technology roadmapping is an important tool for collaborative technology planning and coordination for corporations as well as for entire industries. It is a specific technique for technology planning, which fits within a more general set of planning activities.

As a result of technology roadmapping, a company or an industry can make better investment decisions because it has better information, particularly to identify critical product needs that will drive technology selection and development decisions. Some companies do technology roadmapping internally as one aspect of their technology planning (corporate technology roadmapping). However, at the industry level, technology roadmapping involves multiple companies, either as a consortium or an entire industry (industry technology roadmapping).

“Roadmaps” are timelines and indicate a direction for product and technology development and document the decisions a team of experts has made to pursue one of many possible routes. They require understanding the macro-level of technology evolution (IP, patents!), external drivers (regulations, markets, demands) and how this may intersect with or is influenced by other economically relevant factors (social and technology; regional effects).

They indicate when technology is likely to become competitive (with existing ones) and cost-effective and how much pressure there will be by (functional) alternatives (substitutive technologies), and may comment on pace of commodization [Runge 2006:458-460].

Roadmaps may be based sometimes on quasi-laws for their outlooks. For instance, there is Moore’s Law (for the semiconductor chip sector) based on the observation that since 1965 the number of transistors per square inch on integrated circuits had doubled every year since the integrated circuit was invented. Moore predicted that this trend would continue for the foreseeable future (but currently it has an eighteen month doubling period).

The “International Technology Roadmap for Semiconductors” (ITRS) is used, for instance, to “synchronize” the innovation and R&D efforts of the chemical industry with the needs and development pace of the semiconductor industry.

Similarly, other technology areas build their roadmaps on some “laws.” For instance, for flat-panel displays (FPD) and the related roadmap (US Display Consortium (USDC) – “Global FPD Industry 2003: An In-depth Overview and Roadmap”) there is Nishimura’s Law (average screen area of FPD panels), Kitihara’s Law (the number of bits needed to specify the image on the screen), Odawara’s Law (panel prices; each doubling in the cumulative area of flat panels produced results in a cost reduction of 22-23 percent). Other roadmaps or similar documents are available for

- Organic Light Emitting Dioxides (OLED), the USDC – “International OLED Technology Roadmap: 2001-2010”
- Photovoltaic (PV), with roadmaps created in the EU, US and JP
- The US Vision 2020 (December 2003) [Runge 2006:538, 549] is associated with roadmaps for many areas (for instance, an R&D Roadmap for Nanomaterials By Design).

In particular, in 2002 in the context of a concept for a biobased economy [Runge 2006:849-873] the Biomass Technical Advisory Committee created a “Vision for Bioenergy and Biobased Products in the United States” [Runge 2006:855] emphasizing biofuels and bioproducts like biobased chemicals, which drove innovation and entrepreneurship (A.1.1).

Specifically the US DOE Biomass Program identified twelve building block chemicals (A.1.1.6) that can be produced from plant sugars and serve as key feedstocks in future biorefineries [Runge 2006:872].

The technology roadmapping process has three phases given below [Garcia and Gray 1997].

Phase I. Preliminary activity
1. Satisfy essential conditions.
2. Provide leadership/sponsorship.
3. Define the scope and boundaries for the technology roadmap.

Phase II. Development of the Technology Roadmap
1. Identify the “product” that will be the focus of the roadmap.
2. Identify the critical system requirements and their targets.
3. Specify the major technology areas.
4. Specify the technology drivers and their targets.
5. Identify technology alternatives and their time lines.
6. Recommend the technology alternatives that should be pursued.
7. Create the technology roadmap report.

Phase III. Follow-up activity
1. Critique and validate the roadmap.
2. Develop an implementation plan.
3. Review and update.

Electronic chemicals and materials are the fundamental technology at the heart of today’s electronic products. Developments in photoresist technology are the thrust to pack more and more capability in integrated circuits and printed circuit boards. Basically there is belief in a roadmap. For instance, companies found that CMP slurries (chemical mechanical planarization and silicon wafer polishing) processes are essentially in line with what ITRS predicted.

Although the International Technology Roadmap for Semiconductors is charted by the industry's top scientists with the best of intentions, reality sometimes intervenes to change its course [Runge 2006:142-147].

That happened in the photoresist industry emphasizing low dielectric constant (low-k) material for insulation to prevent "cross talk" and competing process technologies, SOD ("spin-on dielectric") or CVD ("chemical vapor deposition"), for the deposition of material on the top of a silicon wafer. Since 1997 a technology roadmap for semiconductors identified low-k dielectrics as crucial to keeping Moore's Law.

Dow Chemical committed to the innovation of a new synthetic low-k material that would target the given market needs. Dow researchers defined the polymer composition for the material and, by the second year of operation, the research team publicly introduced the SiLK semiconductor dielectric resin to the industry (relying on SOD). And Dow felt that the timely implementation of this technology enabled Dow to produce an innovation for the semiconductor industry for years to come.

In 2000 spin-on materials jumped out as a front-runner when IBM announced that it had picked Dow Chemical's SiLK polyphenylene polymer as its low-k dielectric. Dow's semiconductor materials group expected SiLK to capture about one-third of the low-k market for the (then 130 nm chips) and industry seemed to be leaning toward SiLK and other spin-on materials in the wake of IBM's announcement.

SiLK took a public relations hit when IBM revealed that it would instead use the rival small molecule CVD technology for its next generation (90 nm) chips. The 2001 edition of the roadmap predicted that low-k materials will become standard at the 90-nm technology node. According to Dow, IBM confirmed the production viability of SiLK, and even used it for some chips, but decided to switch "for business reasons." SiLK got some bad press because of the IBM decision.

This followed a decision by the world's second largest foundry, Taiwan-based United Microelectronics Corp. (UMC), to drop SiLK in favor of the small-molecule CVD Coral process. Then TMSC – Taiwan Semiconductor Manufacturing Co., the world's No. 1 foundry, also committed to CVD at 90 nm and, finally, industry consensus settled on CVD. Dow had lost out at the 90 nm chip technology.

SiLK's slippage is a testament to how *economies* of scale, not technological merit, *often dictate who wins and who loses* in the *manufacturing* marketplace.

A currently special form of form of "open opportunities" for problem-solving are so-called "*ideagoras*" on the Web in the sense of social networking for "*collaborative innovation*" ("Science 2.0"). Ideagoras ("marketplaces for minds") represent a way of self-organized collaboration for innovation. They offer companies access to a wealth of new ideas and uniquely qualified minds, a fuller solution set of possible answers is quickly obtained – with comprehensive IP protection.

For instance, InnoCentive® established a Web-based community matching scientists ("solvers") to relevant R&D challenges ("seekers") facing leading companies from around the globe. It is *an online forum enabling major companies to reward scientific innovation through financial incentives*. Ideagoras expose challenges to participants from both within the field and across many other fields allowing infinite creativity to be applied. NineSigma works in a similar way.

An entrepreneur can check "Active Projects" of ideagoras to get a feeling for "real world" problems or whether someone is sought to work on solving a problem coming close to the one he/she envisions as the basis of firm's foundation. An example from chemistry is outlined in Figure I.86.

Many studies have shown that search for knowledge to solve a problem is quite "local." Problem holders only access knowledge that they are familiar with and rarely do they go outside of their fixed views of the problem or personal knowledge bases. "*Knowledge proximity*" reflects that such innovative activities may sprout out of the technologies innovators are currently involved in, and *over time learning and knowledge generate new knowledge close to the existing one* (ch. 3.3.1).

There is a similar exposure effect for RBSUs. It is often the field of science and the related experience of the scientist that, via revealing a useful application, leads to looking for a related opportunity for firm's foundation (Equation I.7).

On the other hand, Lakhani et al. [2006] inquired into the effectiveness of the problem solving process at InnoCentive analyzing hundreds of challenges posted on the site. Accordingly nearly 30 percent of the difficult problems posted on InnoCentive were solved within six months. Sometimes, the problems were solved within days.

In their survey they asked the Solvers if the problem they created a solution for lies inside their field of expertise, at the boundary of their field of expertise or outside their field of expertise to come up with a notable finding.

The secret was *outsider thinking*: The problem solvers on InnoCentive were most effective *at the margins of their own fields*. Chemists did not solve chemistry problems; they solved molecular biology problems and *vice versa*. While these people were close enough to understand the challenge, they were not so close that their knowledge held them back, causing them to run into the same stumbling blocks that held back their more expert peers.

> Problem-solving requires the application of knowledge, heuristics and perspectives. In many cases a problem that is difficult under one heuristic or perspective pair may be relatively easy under a different heuristic/perspective pair.

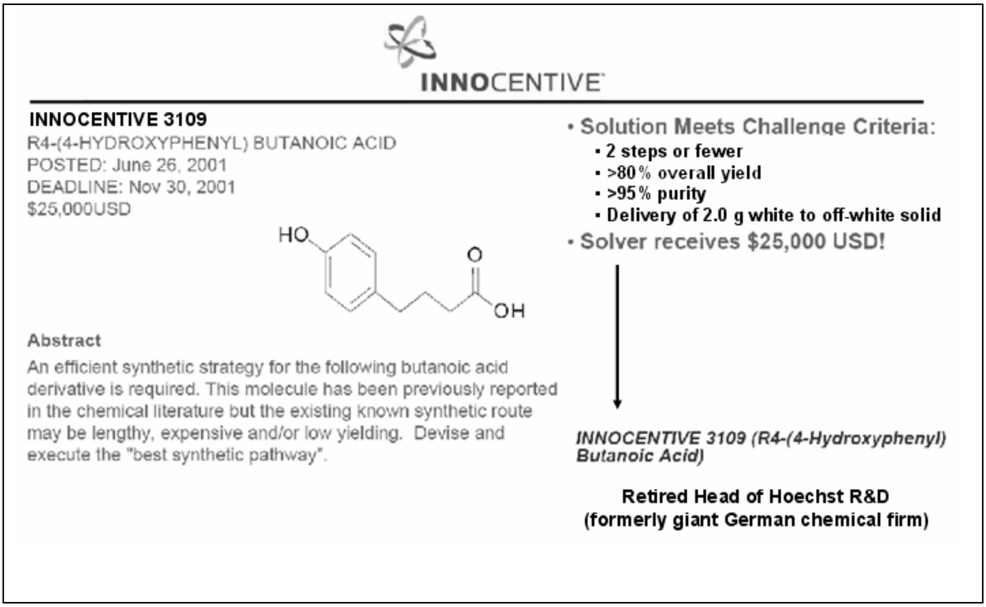


Figure I.86: Illustrating the operation of an ideagoras [Carroll 2005].

Opportunity Identification and Recognition, Discovery and Serendipity

Current research literature [Butler 2004] focuses mainly on the situation that the originator of an idea/discovery simultaneously identifies or has already identified the opportunity and goes to exploit it. Most discussions refer implicitly to revealing market (or product) opportunity. The literature deals mainly with the entrepreneurial personality (ch. 2.1) where traits and behavior of entrepreneurs are discussed and put these into the special context of opportunity exploitation through firm's foundation.

According to the present systems approach and model (Figure I.16, Figure I.17):

- At least for technology entrepreneurship, having an idea and having or revealing a related opportunity is not necessarily bound to the originator of the idea.
- One can expect the approaches to reveal an opportunity to be different for and in startups/NTBFs and large firms, at least, with regard to their relative importance.
- Holistic thinking and principles of Gestalt perception ("we tend to order our experience in a manner that is regular, orderly, symmetric, and simple") and cognition will be used to deal with revealing opportunity as will rational processes. [54]

Having an idea and revealing commercial opportunity emphasizes the fact that the available *combined technology and commercial (market) knowledge* is advantageous for successful venture creation, independent from whether it is in one or several minds, as expressed in the concept of the "entrepreneurial pair" or the "founder team" (ch. 1.2.6.1, 2.1.2.5).

We also assume that revealing opportunities is often really several learning steps over time, rather than a one time occurrence [Hills and Rodney 1998]. This means that revealing opportunity is a *process over time* and should be approached accordingly. For example, time should be allowed for discussing perceived opportunities among relevant persons (founder team, advisory board, family and friends etc.) and having the time to evaluate opportunities.

Following Shane [2000] we assume that *individual differences influence the opportunities that people reveal and how their entrepreneurial efforts are organized*. In line with Ardichvili et al. [2003] and Baron [2004] we differentiate conceptually having or generating ideas (by one or many persons) and *revealing the opportunity* from the *firm's foundation* and *commercialization* process steps to exploit the opportunity. This is illustrated in the left part of Figure I.87 versus the right part with Opportunity Evaluation, Offering Option(s) and Feasibility connecting both parts. Feasibility does not only refer to access resources, but may also include first contacts with (potential) customers testing the offering(s).

Such an approach focuses only on a business or market opportunity and regards "start a business" as an issue of feasibility rather than regarding a business or market opportunity and "an opportunity to start a business" as two "opportunities" as Gaglio [2004:123] does.

Evaluating an opportunity is at least qualitatively associated with the ways to make money, for instance, in terms of a "*revenue model*" (ch. 1.1.1.2). On the other hand, feasibility including needed (financial and other) resources relates primarily to a "*commercialization model*" (as part of a business model).

The opportunity with regard to exploitation and (big) future reward may depend on the possibility to finance necessary large investment and simultaneously to convince related financial backers. When it comes to decision after a feasibility analysis (Figure I.87) there will emerge a balanced decision between personal goals (ch. 4.1) and the level of exploiting the commercial opportunity based on risk and the availability and accessibility of resources (ch. 4.2.1, ch. 4.2.2).

Evaluation of a full-blown (business) plan for a new business or for acquiring and restructuring an existing business is often referred to as ''due diligence.'' It means that individuals involved in decisions to commit resources for further development, investment or acquisition will exercise (or have exercised) ''due diligence'' in their evaluation.

A special step of evaluating an opportunity may occur if a person who envisions a relation to an opportunity but is uncertain about the situation goes for confirmation of his/her outlook. The historically prototypical situation is given by Perkin (A.1.2), who realized that the colored solution he prepared offers serendipitously an opportunity to provide the first synthetic dye in the world for large scale "industrially" coloring fabrics. Furthermore, he got advice what to improve with his anticipated offering before entering the market.

As the market need becomes more precisely defined in terms of benefits and value sought by particular users, and resources become more precisely defined in terms of potential uses, the ''opportunity'' progresses from its initial form and a business concept ("*Concept Summary*") begins to emerge. This concept contains the core notions of how the market need might be served or the resources deployed. As this more precise and differentiated business concept matures, it grows into a business model, which juxtaposes market needs and resources.

Figure I.87 focuses on *idea and revealing opportunity preceding firm's foundation*, but incorporates also the reversal process – *firm construct before revealing opportunity* – given in the upper left through dashed lines (opportunistic search).

Additionally, the figure takes opportunity creation via *technology push* into account (a dashed arrow) as it is often associated with a search for applications (cf. Nanopool GmbH [Runge 2010]). Specifically, Reid Hoffman, the key-founder of the US professional social network LinkedIn first decided to make an "impact" as an entrepreneur before looking to start a firm and eventually become a very high-level investor-entrepreneur (ch. 3.4.2.1; LinkedIn – B.2).

> Figure I.87 does not only show implicitly that *idea* and *opportunity* may be separated, but also that both idea and revealing of opportunity by the founder or a member of the founder team may be separated also from founder-controlled *execution*. This is often the case for VC-based startups (cf. the biofuels industry; A.1.1).

Opportunity creation means to create new offerings which deliver value superior to those currently available and may be associated often with creating new markets and/or new industries by disruptive (radical) innovation.

Revealing opportunity is described in this model here essentially as an individual level phenomenon. But it is reported that networked entrepreneurs revealed significantly more opportunities than solo entrepreneurs. Corresponding small-group synergies of teams for idea generation is used for ideation (ch. 3.3)

The process model will be used essentially as a framework for putting revealing opportunity in the technology area into its context. However, it is often difficult to clearly separate revealing opportunity and commercialization activities. It should be noted that the steps to action after opportunity being defined presented by Dorf and Byers [2007:28] are very similar to the ones in Figure I.87 to exploit the opportunity.

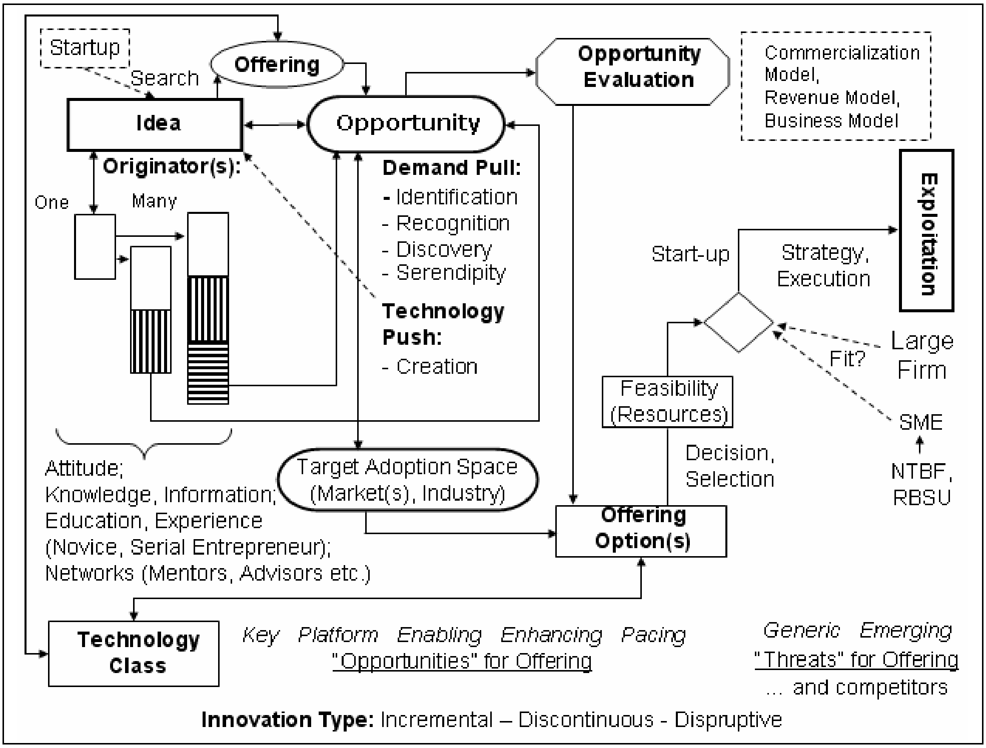


Figure I.87: Linking an idea to opportunities and their exploitation.

Technology entrepreneurship is usually accompanied not only by revealing opportunities for just one offering. For technology entrepreneurship certain technology classes (Figure I.87, Table I.51) provide different, sometimes very many options to serve a variety of offerings, applications and markets. Particularly platform technologies provide corresponding options sets (cf. IoLiTec GmbH, A.1.5, B.2).

It may be possible for to-be entrepreneurs to identify multiple market opportunities prior to the first market entry of their emerging firms. If they elect to do so, they therefore have a choice of which market to enter first. The different technology classes provide to a certain degree promising opportunities or more likely obvious threats – for their competitors.

For instance, an offering based on an *enhancing technology* concentrates on existing products and markets and mandates for success very close contacts or even cooperation with customers as the many successful examples of chemical nanotechnology firms active in surface coatings show (Nanofilm LLC in the US or Nanogate AG, Nano-X GmbH – B.2 – and Nanopool GmbH in Germany – B.2, B.3).

On the other hand, an offering based on a *generic technology* may not only address known customers and markets, but additionally attacks directly competitors whose offerings are the target of replacement. Correspondingly, the entrepreneurial firm's offering as a substitute must expect heavy competitive responses by the incumbents and, hence, there are pronounced "threats" for their offerings.

A particularly broad spectrum of options is provided by a platform technology which allows more than one product to be developed or developing one product for several markets/applications. A "*platform technology*" allows achieving customer diversity and product multiplication and be economically at it. It is a set of shared assets that enables the company to penetrate a new customer segment or create new products with limited marginal investments in comparison to competitors with no such advantages.

The interrelation between technology class (Table I.12) and offering(s) of a startup or NTBF in Figure I.87 represents specific constellations with given basic implications for opportunity exploitation and related caveats or threats (Table I.51).

Table I.51: Relating technology classes to opportunities and threats.

Technology Class (Fields of Opportunities)	**Basis of Opportunity (Example Firms)**	**Caveats and Threats for Exploitation**
Platform One technology, many applications, products, markets	Many applications and particularly niche markets can be pursued according to competencies and resources, find them; many options for alliances with other (small and large firms); selling NTBF to large firm e.g. IoLiTec GmbH, Solvent Innovation GmbH	Beware of losing focus; competition can be overviewed and largely avoided
Enabling New functions for existing products; a required piece of technology for a specific other one	Customers known (probably also markets) e.g. WITec GmbH, JPK Instruments AG	Technical service and customer training important Often little competition
Enhancing Improving performance including quality for an existing offering (incremental shifts)	Markets mostly known, customers known or to be envisioned e.g. Nanofilm LLC, Nanogate AG, Nano-X GmbH, Nanopool GmbH	Strong customer orientation (or even cooperation) and technical service required; strong competition (with small and large firms)

Table I.51, continued.

Technology Class (Fields of Opportunities)	**Basis of Opportunity (Example Firms)**	**Caveats and Threats for Exploitation**
Pacing (in German Schrittmachertechnologie) A piece of technology that determines the function of another technology and/or determines the rate of implementing another technology	A technological area which represents a limiting factor (step) in the progress of a particular program (project or innovation). Pacing technology may currently be not available or applied but can potentially "change the game." Currently lignocellulose feedstock (LCF) conversion is pacing for a biobased chemical industry (A.1.1.6). For separation technology filtration and centrifugation are key technologies, membranes/reverse osmosis are pacing technologies. Pacing means technology development-determining or rate-determining; also with regard to scale-up or material processing technology	
Generic One function, product, system by many technologies; implementation of an end through different technologies	Biofuels against petrofuels; types of biofuels against each others, same biofuels from lignocellulose feedstock versus algae feedstock (A.1.1); batteries versus fuel cells for emobility; direct methanol fuel cell versus hydrogen-driven fuel cell; Closure Medical [Runge 2006: 39,98-103]	Heavy competition to be envisioned; heavy reactions by incumbents
Emerging An important future technology		Beware of the Window of Opportunity, overshooting – and experts' opinions on chances of technology If disruptive markets are only known for special (defined) situations; markets/customers to be developed by technology developer

There is a certain link between a generic and an emerging technology. If, for instance, a new (emerging) technology may replace an old technology for particular applications and functions, the emerging technology acts like a generic one.

If providing a particular offering, say a product, and developing a new product which can replace the old one the corresponding generic relation may become **cannibalization.** In marketing strategy, cannibalization refers to a reduction in sales volume, sales revenue or market share of one product as a result of the introduction of a new product by the same producer. While this may seem inherently negative it can be effective, by ultimately growing the market, or better meeting customer demands.

There is an example of cannibalizing for the lighting area. It is the company US LED Ltd. (Table I.81, Figure I.165) which is about to switch its neon-based channel letters to LED technology. Whereas neon once had an almost complete monopoly on illuminating channel letters, for corporate IDs and building identity programs on the sides of building, high-tech LEDs are now emerging as an alternative lighting source.

Their overall features of high brightness, lower cost in terms of energy efficiency and a long operation life of at least sixteen years per unit with no maintenance make them very attractive as lighting fixtures. LEDs provide *point lighting*. On the other hand, for *area lighting* OLEDs would be better suited rather than point lighting LEDs. Think entire lighting ceiling tiles rather than spots (Figure I.148, Figure I.149).

Revealing an opportunity is linked in the literature to notions like *identification, recognition* or *discovery* often used interchangeably. However, we want to differentiate these notions not only with regard to semantically appropriate meaning and consistent use (action of the mind versus behavior), but with regard to different associated processes as a basis of the model in Figure I.87. Moreover, this differentiation adds to the issues of what can be taught (and what not) in entrepreneurship courses.

Semantics concerning the above three notions often center around the point that discovery cannot be planned and must have occurred accidentally [Fiet et al. 2004] and, hence, is different from opportunity identification or recognition.

Discovery in our context is a novel *observation or finding of something already existing* and we regard discovering opportunity (or a solution for a problem) as an *accidental event*. In science and technology discoveries emerge often from the domain of technology applications or transferring principles from Nature to applications. An example situation is the finding that a (known) technology, process, product or effect can also be used as …, can also be used for …, can serve as …, etc. Such a new link leads often directly to a related business opportunity which, however, requires recognition, by the "prepared mind."

Dorf and Byers [2007:31] provide an example as serendipity referring to Clarence Birdseye [55] what would fall under the category of "discovery" in our understanding (and definitely not serendipity). He observed a phenomenon. While ice fishing at -40°C fish froze rock-hard, yet, when thawed they were fresh and tender.

He immediately interconnected this discovery with the fact that the frozen seafood sold in New York was of lower quality than the frozen fish of Labrador, and saw that applying this knowledge would be lucrative. This is an exact representation of the Pasteur motto of this chapter (3.2). After having learned by further clarifying experiments that speed at which the food is frozen is the key, the further developed flash freezing process created a multimillion dollar industry.

"*Browsing*" is an activity favoring opportunity discovery [Runge 2006:758-759]. It is an exploration of a body of information, based on the organization of library collections or scanning lists, rather than direct searching and was always common practice of science and technology. Glancing through a book, journal or the library shelves in a casual way is now complemented (or largely replaced) through browsing database records or computer files or navigating through Web pages.

Moreover, informal browsing is considered most appropriate in the context of *creativity stimulation*. "*Browsing*" or "*searching*" in one or several repositories are alternative methods of research. And there is no substitute for *fortuitous discovery or problem-solving* by browsing or navigating, and this has been stressed again and again for science, technology and innovation.

Accident (or "luck") is rarely observable, but often introduced by an observer of a feature or phenomenon which cannot be classified or understood within the framework of the observer, usually due to lack of information. A reliable classification of an opportunity detection as accidental can at best be achieved by an explicit statement of the relevant person.

But even if it was luck, a structured interview may not lead to such a statement because the interviewee may tell, intentionally or unintentionally, his/her own, probably "distorted," story about the event. At worst, when discussing ways of revealing opportunities on the basis of a given classification, "accidental detection" may represent an undefined and unexplained "rest" of an incompletely observable system. Therefore, we shall treat "accidental detection" under the heading of discovery, but be aware that it could be a theoretical construct.

Opportunity recognition is, at least partially, a *cognitive process* that may proceed unconsciously. If it is assumed that the recognition of new business opportunities does involve cognitive events and processes experienced by individuals, o*pportunity recognition can be related to a moment of insight that an idea (or problem solution) has a current or future socio-economic potential.* It may stem from systems thinking, resulting from answering the question what is connected with what and what can be connected with what?

Recognition exhibits two notable interconnections to "remembering/recall" and "pattern recognition" [Baron and Ensley 2006] and, hence, relates it with the own lived constellations of experience of human beings. Cognitive psychology explains human behavior broadly by examining the "*cognitive frameworks*" that are used to interpret (how to see) the world and change attitude, behavior and activities accordingly.

We shall cling to that model as it does not only allow treating individuals and their entrepreneurial activities, but allows also proceeding to a systems level where cognitive frameworks of a founder team can be combined synenergitically and cognitive frameworks can be assumed to be shared by a large number of employees in firms – but not by all – by conditioning through corporate culture. The “exceptional persons” keep their cognitive frameworks essentially and may emerge as intrapreneurs.

The concept of cognitive frameworks has a systemic origin with components, interrelations and structures as it establishes a (holistic) system of reciprocation which is a relation of mutual dependence or action or influence over time. A cognitive framework of an individual appears as an internal mental counterpart of a state which is induced by perceiving a situation as the external counterpart. An example of a cognitive framework in action is going for a confirmation of one’s own prejudices.

A lucid contribution to this concept stems from Goethe when in the Preface of his Scientific Studies and his Theory of Color he said: “If the eye were not sunlike, the sun’s light it would not see.” An alternative translation would be: “If the eye were not sunlike, how could we see the light” (original German: Wär’ nicht das Auge sonnenhaft, wie könnten wir das Licht erblicken? Alternatively:…, die Sonne könnt’ es nie erblicken – it could never see the sun) and when he referred to the ancient Greek principle that “only the equal will recognize the equivalent” (nur von Gleichem werde Gleiches erkannt).

The concept of cognitive frameworks, hence, stems from the assumption that cognitive abilities are shaped by the interaction with the environment and seem to have emerged in resonance to the structure of the (sensory, intellectual and knowable) environment and can metaphorically be represented by a photographic negative of reality [Riegler 2002].

Meaning arises as a result of relating a new piece of knowledge or experience to the existing network of already made experiences rather than to entities in the world. And we have a mutual interplay between the cognitive apparatus and the information it stores and retrieves. Note that “information” only makes sense for the individual who integrates it into the framework, the existing context and network of schemata. People tend to notice information that is related to information they already possess.

And also here Goethe is helpful to illustrate this by saying: “Everyone only hears what he/she understands.” (in German “Es hört doch jeder nur, was er versteht.”).This perspective of cognition reverses the information-processing paradigm. We can no longer speak of information input. Rather, we may conceive of “perceptive interaction on demand” of the cognitive apparatus. The global picture is that cognition acts independently of the environment. It merely requests confirmation for its ongoing dynamical functioning.

Also *pattern recognition* can be assumed to be related to “cognitive frameworks” viewed as “prototypes” [Baron and Ensley 2006]. *Prototype theory* suggests that *through experience individuals acquire prototypes*, cognitive frameworks representing the most typical member of a category. Prototype models of pattern recognition further suggest that, as individuals encounter new events or objects, their existing prototypes play an important role in the perception of these events or objects and in the detection of connections between them.

In essence, prototypes serve as templates (forms, guides), assisting the persons who possess them to notice links between diverse events or trends and to perceive recognizable, meaningful patterns in these connections. In part, this process involves comparison of new events or objects with existing prototypes. If the match is close, these events or objects are recognized as fitting within the prototype. If, instead, the match is not close, the events or objects are not perceived as fitting within this cognitive framework. In this way, role models for entrepreneurship (ch. 1.2.2, ch. 2.1.2.4, ch. 4.2.1, ch. 4.2.2) can play an important input for generating cognitive frameworks.

A particular situation which stresses the importance of *individual experience* for revealing opportunities is observed when comparing first-time ("novice") entrepreneurs and serial entrepreneurs. It has been found [Ardichvili et al. 2003; Baron and Ensley 2006; Ucbasaran et al. 2003] that entrepreneurs' *personality traits* (Table I.31, Table I.32)*, prior knowledge, experience* (ch. 2.1.2.4) *and network contacts* [Fiet et al. 2004] show up as antecedents of entrepreneurial alertness to business opportunities.

In particular, Ardichvili et al. [2003] cite evidence ''that entrepreneurs who have extended networks identify significantly more opportunities'' than solo entrepreneurs." Here *alertness* is seen as Pasteur's "*preparedness of the mind*" to generate ideas and/or reveal opportunities when confronted with certain constellations of the observable environment.

Additionally, Shane [2000] showed, by in-depth case studies of eight sets of entrepreneurs who exploit a single MIT invention that entrepreneurs *reveal opportunities related to the information that they already possess*. In addition to experience we regard also education (Table I.49) including technical and entrepreneurship training as important factors. An interesting example of grasping and exploiting opportunity in the context of networking and cognitive frames is described for the German Lars Hinrichs, the founder of Xing, a social network for professionals (Xing AG, B.2; ch. 3.4.1.2).

Evidence from comparisons of novice and experienced entrepreneurs has also shown that *pattern recognition*, the cognitive process through which individuals identify *meaningful patterns in complex arrays of events or trends,* is a key component of opportunity recognition. This includes static (structural) and dynamic (developing, emerging) patterns [Baron and Ensley 2006].

Meaningful is first of all meaningful for an individual or as Goethe put it: "Everyone hears only what he understands." (in German Es hört ein jeder nur, was er versteht). And this relates also to the crucial role "*cognitive frameworks*" play [Baron and Ensley

2006], which are developing through the individuals' unique life experiences including, for instance, conditioning of people in firms by corporate culture.

In this way an entrepreneurial idea may not be necessarily considered an opportunity after an evaluation on its perceived desirability and feasibility. However, the related piece of information may be stored in a person's cognitive framework that may be triggered again in response to a particular event or a specific chunk of information and may become an opportunity later.

> Cognition theories refers to templates (forms or guides), assisting specific persons to recognize connections in terms of a key-lock interrelationship where the key acts like a stimulus. This aspect of pattern recognition theories suggests an intriguing explanation for the fact that particular business opportunities are revealed by specific persons but not by others.

A final remark concerning opportunity recognition concerns the systems approach by initiating additionally a metaphorical connection to the biological concept of learning and "*appetitive behavior*" ("Appetanz" in German) introduced by American ethnologist Wallace Craig. Accordingly, though variable in form and expression, higher organisms including human beings often do not wait for the occurrence of given triggers for their behavior. Depending on individual personal needs or dispositions or moods they even search for those. And this is a further momentum for learning – what the triggers or "weak signals" might be [Runge 2006:829]. This factor is paraphrased by Drucker [56] "The entrepreneur is always searching for change, responding to it and exploiting it as an opportunity."

In the context of appetitive behavior, Johnson [2001] refers to fact that individuals choose situations on the basis of their personality and other dispositions. Furthermore, he presents evidence that people strive to enter particular kinds of situations in order to express preferred behaviors, and he mentions to assert (without presenting evidence) that the situations people choose reinforce the behaviors within those situations.

That means reinforcement creates the temporal stability of situation-selection behavior. A "situation-free" behavior is a behavior or activity that suddenly erupts in the complete absence of a triggering stimulus. And we, therefore, hypothesize that appetitive behavior plays a role for the phenomenon of "serial entrepreneurship."

In addition, McCline et al. [2000] even introduced a measure, "entrepreneurial opportunity recognition" (EOR), which is modeled after the attitudinal approach and providing an indicator for the potential to correctly classify entrepreneurs from non-entrepreneurs. EOR reflects tendency of the entrepreneur to reveal opportunities.

Whereas *opportunity recognition* puts more emphasis on *actions and processes in the mind*, *opportunity identification* provides a strong focus on *behavior and processes and activities* that can to a notable portion be taught and learned.

Identification is a *process* through which one ascertains the identity of another person or entity. Identification requires that the verifier checks the information presented and available against all the entities it knows about. The process of identification is to map an unknown entity to a known entity, or probably accepted model, so as to make it known. Opportunity recognition may be related to opportunity identification via the "*paradox of searching*": If you do not know what you are searching for, but recognize it, when you find it.

We regard **opportunity identification** as a *conscious and rational process* to deliver at least one option that provides for human beings a direction from one state to another, the end, in terms of a framework of means.

The process represents a largely intentional mapping of an offering with socio-economic value. It is characterized by an array of relevant, usually given (supply) variables by a person or group of persons – the to-be entrepreneur(s) – against a system of adoption (buyers, markets, industry) defined by relevant demand parameters and against already existing or potential suppliers (competitors) of that offering, a similar or an equivalent offering to generate one or several options to exploit the opportunity and achieve the persons' goals.

Opportunity identification is often associated with identifying many opportunities from which the "most promising" one has to be selected or a set of opportunities has to be established which are assumed to be pursued according to defined priorities (ch. 3.2.2, Figure I.93, Figure I.97). In its simplest expression it is a segmentation-based approach when an idea or solution of a problem in terms of an offering with a spectrum of features is mapped against a *checklist* of relevant, required *commercial or social* criteria or features predefined for a particular domain.

Opportunity identification relies essentially on a conscious *search process* for *data, information, knowledge and foreknowledge* as is problem-solving (Figure I.80). Proactively searching for (current or future) opportunities is a facet of intentional behavior. Openness to *experience* and *information propensity* may influence opportunity identification by facilitating access to and detection of information (sources *and* channels) useful in the opportunity detection process.

An example (from the author's involvement a large firm) is a combined search for ideas and opportunities in the ion exchange resins business following a "Knowledge Discovery in Text Databases" approach [Runge 2006:946,961]. These resins are used, for instance, for water treatment. The start was a search for applications and "lead users" described in patent and scientific literature databases based on trade-names of Dow Chemical's ion exchange resins (and those of competitors) to reveal how these products are used, whether there are new uses not known to Dow and how related products are assessed concerning performance and applications.

For scientists and engineers *searching for information* for prior art and scientific or engineering progress ("current awareness") as well as problem-solving in scientific and technical paper-based, CD-ROM-based and electronic (Web-based) literature is quite common as is browsing. Searching also the patent literature is even a prerequisite, if an invention or to-be innovation for entrepreneurship shall be legally protected by a patent. For to-be technology entrepreneurs, therefore, searching additionally commercial literature is not a principally new process, but novelty may be associated with contents and terminology [Runge 2006:758-762].

> Whether opportunity recognition or identification for the technology area, both processes often have to be linked to a subsequent search and identification process, namely whether the technology or parts of the technology or opportunity are legally protected by a patent.

This is to avoid "re-inventing the wheel." But in a study for the Small Business Administration (SBA) on the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) grants it is reported that 40 percent of grant applications coming through SBIR and STTR actually were soliciting funds to pursue an investigation into something that had already been patented [Martin and Bloch 2004].

Serendipity has been introduced as *finding something unexpected and useful while searching for something else* entirely. Hence, "serendipitously revealing opportunity" relates to opportunity identification, but is seen as an own category, as it may require resources and processes which may be not available for exploitation at the time of detection.

Opportunity by the Perfect Product or Being First to Market?

Concerning ideas and opportunities a decision about which product with what specifications to produce is not about economizing with given resources, but rather about recognizing the kinds of products customers will be willing to buy, the kinds of goods available technology and resources can produce, and resources that can be assembled by the entrepreneur. ''It is the successful identification of relevant ends and means (rather than the efficient utilization of means to achieve ends) which makes the 'right' decision on product quality'' (B. Kirzner cited by Ardichvili et al. [2003])

Opportunities seen from the perspective of prospective customers represent value sought and that usually means valuation by the customers according to features they are offered in comparison to features they are explicitly aware of or, worse, they can explicitly state as being "nice to have, but not needed to have." Such a perspective of "*overshooting*" must direct entrepreneurs to move away from analyzing *what is* and considering of *what is possible* to *what are the minimal requirements* perceived by customers to accept the offering (but keeping extensions in mind for later business expansion).

As introduced by Clayton Christensen [1997] the notion of **overshooting** means that companies try to keep prices and margins high by developing products with many more features than customers can absorb. Who has ever used all of the features in

Microsoft's Word, for example? In the entrepreneurial context overshooting means more features and/or higher performance than the customer is ready to pay for based on his current explicit needs.

On the other hand, overshooting the market by a firm can open the way for innovations or new firms that are cheaper and simpler to take root. Once such a disruption takes hold, on the societal level it typically enables a larger customer population of less-skilled or less affluent people to do things in a more convenient, lower-cost setting or on the industrial level, for instance, to shift production from developed to developing countries.

For research and innovation one should generally be aware of a fine line between **customer-driven** and ***customer-oriented*** approaches. Customer-orientation addresses a broad scope – current and future customers' wants and needs, actual and latent needs, actual and potential customers, and customers-of-customers whereas a customer-driven approach focuses essentially only on current demands and needs, actual, spelled out needs of actual current customers [Runge 2006:614, 781].

The most frequent mistake that people tend to make is to think everybody in the market likes them. If they like the product, everybody else will. Sometimes – too often – entrepreneurs, and especially entrepreneurs with a scientific background, are too focused on the scientific/engineering features or technology features of the particular product rather than on the need that they are trying to fulfill (Figure I.88).

Furthermore, people who are creative tend to emphasize the newness of an idea but newness and novelty is considered a high risk to the person assessing the idea and opportunity. It would be better to emphasize the benefits of this new idea rather than the newness.

For instance, "what customers want isn't necessarily what you or your engineering team wants to build," a co-founder of US firm inDinero said. She related her company's early struggles in aligning the desires of the engineering team with customer feedback and requests for features [Mah 2011].

> As a rule of thumb, the selling chance of a product is determined to 70 percent by the definition of the requirements ("specifications").

The problem that entrepreneurs tend to launch only when their product or service is perfect has the consequence that waiting undermines the ability to evaluate whether the idea works as quickly as possible, so that you can correct course.

Generally, the product process changes from allowing adjustments to product specifications to being highly standardized: As time goes on, emphasis shifts from quick product change for performance improvement, to product enhancements and variations to boost sales, and finally to gaining cost efficiencies through standardization.

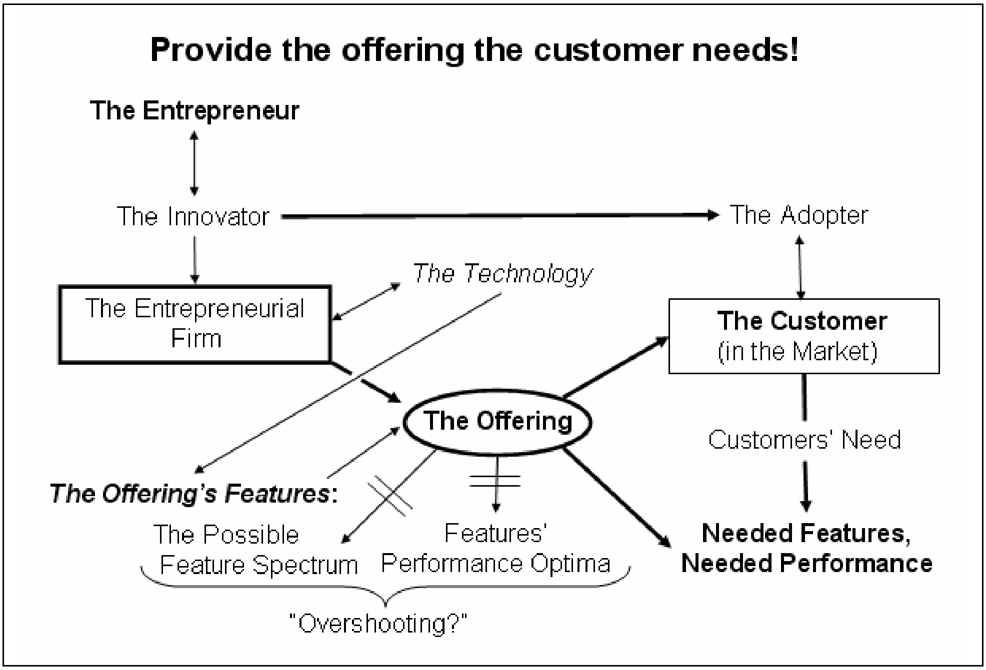


Figure I.88: The fundamentals of revealing opportunities – avoid "overshooting."

The most important thing for a new company is to sell its products. In particular, the company founders – not a sales team – should be the key to try to turn a profit, as they will learn firsthand about their product's shortcomings and usability. Great entrepreneurial scientists and engineers directly understand what their customers need (Hidden Champions, ch. 4.1.1).

The basic idea is that, once in the market, one must be prepared to quickly adjust a new product or service to what the market requires. The importance of *customer feedback* is clear.

All this suggests that the value of *qualitative "immersion" in a marketplace cannot be replaced by formal market research*. "Entering a market with a new product or service demands flexibility and responsiveness in the expectation that changes in strategy will be required. As helpful as business plans and feasibility studies may be, there is a danger if they lead to over-commitment to a specific product or service and strategy. Necessary changes should be expected." [Hills and Shrader 1998]

When **opportunity creation** is the purpose of entrepreneurial or innovative activities the central issue will be the appropriate timing within the timeframe of the Window of Opportunity (Figure I.4, Figure I.92). Conventional wisdom says being first to market creates a competitive advantage. [57] But reality is more complicated. Some industries reward first-movers with near-monopoly status and high margins. Other industries do not offer similar rewards, allowing late-movers the chance to compete more effectively and efficiently against early entrants.

> Being the "first-mover" (first to market) to gain competitive advantage does not allow generalization!

For technology entrepreneurship "first-mover" issues concerns only the relatively small proportion of startups which are about to deliver a new offering (new-to-the-market) or disruptive innovation (new-to-the-world) and to create an opportunity, create a market or an industry (Table I.49, Table I.50). The related new firms are often RBSUs. First-mover advantage is usually associated with technology leadership.

First-mover advantage can be instrumental in building market share, but this may or may not translate into business success – as the phenomenon of overshooting suggests. This means being the first to offer an innovation in a particular market does not guarantee commercial success with that innovation. This applies to single firms but also to a group of firms as well as to a country's industry.

For instance, in the 1970s the Xerox Palo Alto Research Center (PARC) developed innovative computer technologies, such as the mouse pointing device and the graphical user interface and introduced these into the market. But it was not Xerox which benefited from these essentially. It was Apple commercializing these innovations and, moreover, finally market domination and financially gigantic gain was achieved by Microsoft with its Windows operating system and related office programs (Figure I.144).

And after William Henry Perkin established the synthetic dye industry in 1856 in the UK (A.1.2) many other people grasped related opportunities and the UK together with France dominated the worldwide dye market until around 1870. Then German firms took over the global dye industry gaining almost a monopoly [Runge 2006:266-269, 275, 293/294].

The consequence for technology entrepreneurs in this situation is that they evaluate whether they should enter a market first or wait on the sidelines. The decision when to enter a market is an almost irreversible one, so it is a very important one.

Tozzi [2009] reports on a study which suggests that a decision when to enter a market depends on how hostile the learning environment is; that is, how much entrepreneurs can learn by observing other players before they launch compared to what they learn from participating after they enter.

Accordingly, in "a hostile learning environment," entrepreneurs gain relatively little benefit by watching others. For example, if the relevant knowledge is protected as intellectual property, studying the market before entering would not yield much advantage. In these situations, the trade-off favors entering early. But in less hostile learning environments, where entrepreneurs gain valuable information likely to increase their success just by watching other companies, companies benefit from waiting and learning lessons from earlier players."

Such market considerations do not only apply to a "when" question, but also to "what" issues. Entrepreneurs play a fundamental role in bringing new technologies and related offerings to the market. The empirical results presented by Gruber et al. [2008] offer insights regarding *early-stage choice among opportunity options in new firm creation.*

First, they revealed that *serial entrepreneurs have learned through prior startup experience to generate a "choice set" of alternative market opportunities before deciding which one to pursue in their new firm creation*. The analysis indicates also that those entrepreneurs *who identify a "choice set" of market opportunities prior before market entry* gain performance benefits by doing so. However, it is not only the output for a target market, but also the input which may be the focus, or an additional focus, for a choice set (Figure I.184, Table I.97).

The entrepreneurs' endowments and constraints influence the types of opportunities they can profitably exploit. Large corporations tend to pursue initiatives with large initial investment requirements and low uncertainties. Intense assessment of options for new business is common in large firms. This is seen, for instance, for ExxonMobile before the firm entered the algae scene via cooperation regarding biofuels (A.1.1.4). ExxonMobile's approach can be characterized as a "thinktank-approach."

The approach of *multiple opportunity identification prior to entry* and selecting the most favorable input/market opportunity for the creation of a new technology firm is confirmed in various ways in the biofuels field.

For instance, before founding algae-based biofuels firm Sapphire, Inc. (A.1.1.4; Table I.93) the founders had extensive discussions about the options before they decided to pursue algae-based biofuels and which type of product. Identifying a very large "choice set" of application and market opportunities prior to market entry is illustrated explicitly by the German NTBF IoLiTec (Ionic Liquid Technologies GmbH, A.1.5, B.2) for the "ionic liquids innovation."

Ionic liquids can be viewed as a *platform technology* (Table I.12, Table I.51) with a very large number of commercially relevant applications as is shown by IoLiTec founder T. Schubert (A.1.5). He listed 26 specific applications clustered into six different business areas. Having a choice set of opportunities requires setting priorities. And the setting of priorities means usually making hard choices among conflicting goals or (sub) goals.

But publicizing and illustrating the broad spectrum of applications for ionic liquids was not only meant to show what choices IoLiTec (B.2) could make from existing options and which ones it finally made. The spectrum of applications was additionally made public to prevent any entrant to patent a particular application and thus constrain IoLiTec's further expansions into other applications of interest to them.

3.2.1 Hierarchies for Segmenting Macro-Trends for Revealing Opportunity

Our general systems views and particularly *firm's foundation as systems design* (ch. 5.1) bring up two important partially interconnected aspects. Systems design is *future oriented* and its methods contrasts to "*systems improvement*" and its emphasis is on *seeking opportunities*, currently and in the future, as described by Runge [2006:522-523].

Seeking opportunities for systems design may rely on "technology intelligence" and "commercial intelligence" (ch. 5.2). Seeking opportunities generates *a "choice set"* of alternative market opportunities, an "*opportunity landscape*," before deciding which one to pursue for new firm creation. Assessing the choice set to reveal the most promising ones may induce consideration of opportunity costs.

Systems Improvement:	***Systems Design:***
Solving problems	Seeking opportunities
Determination of causes of deviations between intended and actual operation (*direct costs*)	Determination of difference between actual design and "optimum design" (*opportunity costs*)
Explanation of past deviations	"Prediction" of future results

Opportunity cost is central to the whole study of both economics and business as it is at the heart of the decision-making (ch. 4.2.2). **Opportunity cost** is widely used in business planning in evaluating capital investment. A company measures the projected return against the anticipated return it would receive on a *highest yielding alternative investment that contains a similar risk profile*. It is the cost of foregoing (give up, sacrifice) the optimum alternative.

For "opportunity entrepreneurs" opportunity costs may come up contrasting the opportunity with the existing employment and the potential it affords. Dorf and Byers [2007:42] present a numerical example for getting opportunity cost for such a situation. For a "necessity entrepreneur" there may be no alternative.

Issues of determining opportunity costs are general difficulties in using costs for a valuation scheme. For instance, there is the lag between the time at which costs (inputs) must be expended and benefits (results) are accrued. Also the danger of underestimating the former and overestimating the latter makes cost valuation risky. Another issue is whether two considered alternatives are subject to the same external threats and, if threats become operative, will be affected to a similar extent [Van Gigch 1974:106].

Currently, "*incorporating the future*" into an entrepreneurial or innovation approach or program follows usually a *top-down* approach from megatrends to actually selecting ideas and initiate/develop offerings. "Predicting" the future looks for answers concerning, for instance, the following questions:

- What and where is the best opportunity?
- What action will you take?
- How will customers respond?
- How will competitors reply?

Seeking (current and future) opportunities means opportunity identification by a systematic, structured and "systemic" approach which is invariably bound to the *foreknowledge* part of intelligence (ch. 1.2.3, Figure I.18). For technology innovation and entrepreneurship with markets and industries in mind, this deals with "technology forecasting," foresight, technology trends, prediction, prognosis, etc. in an appropriate systems' context.

Whereas systematic search for business opportunities and firms' foundation is observed only for a relatively small part of NTBFs with large resource requirements for such an exercise it is quite common for innovation processes (and intrapreneurship) of large firms.

Fundamental issues of forecasting or predicting the future and their relationships to asking the right questions has been outlined and illustrated by Runge [2006:844-848] referencing and reprinting a Gyro Gearloose comic from 1956 (in German Daniel Düsentrieb).

"*Technology forecasting*" (TF) is understood as the continuous *monitoring of technological developments* leading to an *early identification of promising future applications* and an assessment/validation of their potentials. Generally, TF aims at identifying areas of large potential and examines *conditions of emergence*, development and *diffusion* of technological innovations and is a *tool to assist decision makers* aiming to optimize the use of R&D and other resources at a strategic level. A key contributor to technology forecasting or monitoring is "technology intelligence."

TF will be differentiated from "*technological forecasting*" which refers to outlines of technological advance and may be defined as "the prediction of useful machines" or the "prediction of useful technological capabilities." It is also concerned with consequences of technology on socio-economic systems. In this regard "technological forecasting" is related to "directed evolution" of technology and "*technology assessment* (TA)." [Runge 2006:525, 532-536]

Future socio-economic broad trends based on attitudes and future behavior and activities are often considered as "*foresight*." TF, TA and foresight are characterized by different scopes, but each of them overlaps with the two others. In this way, they represent different entry points into the area (TA) [Runge 2006:525-526].

To systematically look for or reveal, respectively, specific opportunities means considering fundamental, macroscopically observable developments of the various subsystems, called *megatrends*. That is, inquiring into hierarchies of megatrends, starting at the highest level with the Societal System or a combined "socio-economic system" (Figure I.13), its interactions with subsystems and "reactions" by the subsystems.

That is, by analyzing societal trends identify offerings that will be needed in the future thus generating opportunities in particular markets and industries. Then look into (supportive) interactions of these by policy and deal with other related forces influencing these.

A "*trend*" is a quantitatively or qualitatively observable expression, development or pattern of change over time in some variable of interest and is usually reflected as an *extrapolation from the past and present into the future*.

A quantitative example of a trend of relevance for entrepreneurship is presented in Table I.53 as it shows a trend which exhibits an increasing focus of technology venture investment in CleanTech startups. Knowing this, a technology entrepreneur intending to finance firm's foundation by venture capital outside this domain and others in focus could infer that he/she must present an excellent business idea and/or compelling opportunity to attract VCs.

Extrapolation requires medium-term stability of the system under investigation and no significant "events" which due to their strong forces induce discontinuity (a jump in the trend) or even a disruption ending the trend. Discontinuity may mean slowing a trend's development or creating counter-forces. For example, the events of September 11, 2001 ("9/11") in the US temporarily stopped growth and slowed some aspects of globalization. In this regard, the issue is in how far the current Great Recession and its aftermaths exert major or even disruptive effects in currently discussed trends.

A .major single event is usually not predictable and may be either

- a **unique event** (one time occurring), such as the German Re-Unification or in the US the "9/11" event or
- a **recurring event** (multiple times occurring, but point of time not predictable), such as cyclicality of economies or appearances of devastating hurricanes at the Gulf Coast of the US.

Events with low probability of occurrence but high impact changes are commonly called "wild cards," such as pandemics. Wild cards may exert positive, negative or mixed impacts.

The notion **megatrend** is commonly used to indicate a widespread (more than one country) trend of major impact, composed of sub-trends which in themselves are capable interactions and of major impacts [Runge 2006:532-537]. For example, global climate change will have a major impact on all the countries of the world, and can be disaggregated into global atmospheric warming, sea-level rise, decrease in stratospheric ozone, etc. Another megatrend is the rise of the middle class in developing countries, such as Brazil, India and China.

Global megatrends are usually differentiated according to economic, ecologic and socio-cultural aspects. Key megatrends affecting, for instance, the chemical industry are discussed by Runge [2006:533].

The business-related view of a megatrend emphasizes a general shift in awareness, thinking, attitude or approach including technologies affecting countries, industries, and organizations. In these kinds of megatrend there is a great deal of intelligence, particularly, the foreknowledge we have about the future (ch. 5.1).

A (mega)trend requires longevity. A **movement** is a group of people with common believes and ideology who try together to achieve certain general goals. It achieves only influence when it turns into a "mass movement." Over time it may become a larger trend or even a megatrend. For instance, the "greens" around the world started in the 1970s as a movement to become 30-40 years later the "green megatrend."

The megatrend or a major trend can be a starting point for opportunity identification. But often there is enforcement if several megatrends or major trends intersect. This means that *big opportunities often emerge when several strong trends intersect or even converge* (Figure I.91). Note, however, that a megatrend must not be confused with a driver.

Selecting the proper variable or indicator, respectively, to characterize a (mega)trend is important to assess future developments so that one can take advantage of it, for instance, as an entrepreneur, intrapreneur or an investor.

Figure I.89 has been used by venture capitalist Vinod Khosla.[Khosla 2009a] using the Morgan Stanley High Technology Index [Meeker 2001]. Accordingly the Internet expanded steadily, one investment after another. And even when the bottom fell out (Dot-Com Recession), winners like Amazon, eBay and Yahoo kept the momentum going. Except for the "dot-com event" there was near linear growth.

The Morgan Stanley Index assumes the health of the technology IPO market to be an important gauge in monitoring the robustness of the environment for technology investing and the creation of new industries. On the other hand, after 2005 net traffic increased exponentially reflecting mass usage for communication, business and networking.

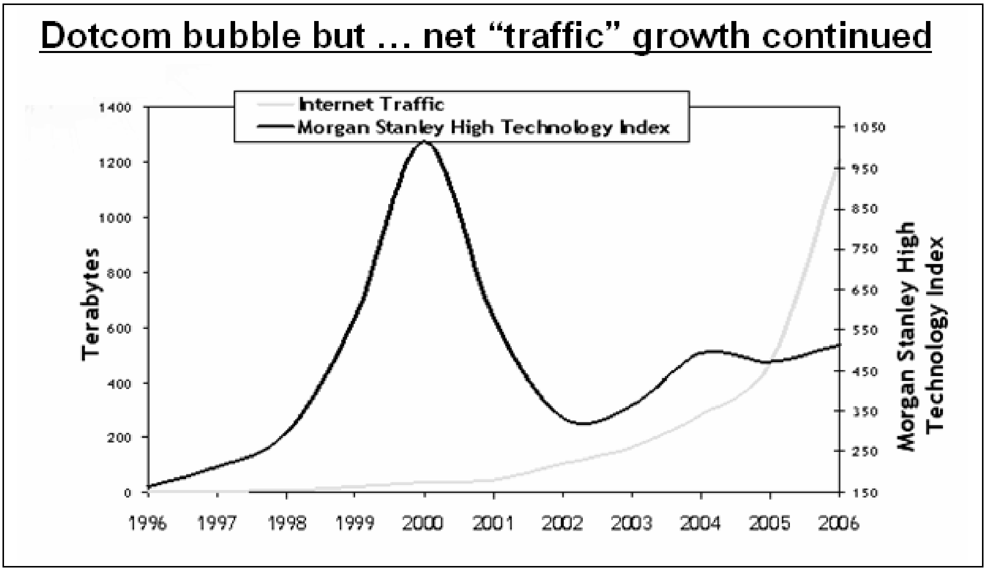


Figure I.89: Example to choose the right indicator to reveal a macro-trend [Khosla 2009a].

Megatrends are our knowledge about the probable future (foreknowledge). They are the forces that define our present and future worlds, and the interaction between them is as important as each individual megatrend. In our context it is notable that technology expands the "art of the possible," but we cannot predict what will happen. Market and political forces, the "realities of the market," may even bring down an operationally supreme technology (Box I.12).

Futures researchers and intelligence professionals always work with three types of future: the *predictable*, the *possible*, and the *preferred or recommended* one, respectively. The possible and the preferred ones are worth considering when we use megatrends in our strategic work with the future.

Megatrends express what we presume with great confidence to know about the future. Megatrends, hence, are viewed as certainties. Every megatrend can be set aside, but can suddenly and fundamentally change direction through "*wildcards*" – events that are unlikely, but that would have enormous consequences.

Nevertheless, they always contain elements of uncertainty through the effects on and reactions of systems' components, companies, organizations and individuals, or through wildcards. Moreover, they can contain elements of conservation or counterforces, such as the anti-globalization movement or a population's attitude and policy program that is anti-genetically modified organisms and plants.

Megatrends are often identified *ex post*. That means the trend is revealed by "trends of data." However, for early detection in the absence of data patterns revealing big changes are important. Leaders or higher management, hence, must identify patterns of change and initiate corresponding actions to exploit related opportunities.

An option to look at megatrends of industry is *Kondratiev waves*, which are also called Kondratiev cycles. In economics, a Kondratiev wave is a term for *a regular S-shaped cycle in the modern industrial world economy*. Fifty to sixty years in length, it consists of an alternation of periods of high sectoral growth of industries based on particular technologies with periods of slower growth (Figure I.90). The pattern is more visible in international production data than in individual national economies and concerns output rather than prices.

The Russian economist Nikolai Kondratiev (1892-1938) was among the first to bring forward these observations in the 1920s. According to the innovation theory, these waves arise from the clustering of basic industrial innovations concentrated in certain areas that launch technological revolutions. These in turn lead to rapid growth and economic expansion, with the appearance of many new branches of industry and new economic activities. Kondratiev's ideas were taken up by Joseph Schumpeter in the 1930s. The theory hypothesized the existence of very long-run macroeconomic and price cycles, originally estimated to last 50-54 years.

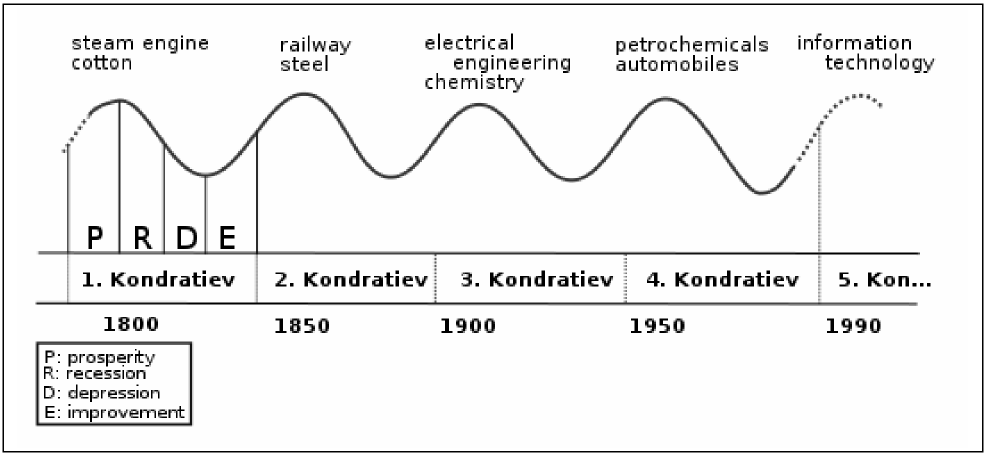


Figure I.90: The Kondratiev waves according to Wikipedia [58].

Recent views cited by Runge [2006:534-535] hypothesize that the long cycles of industrial innovation are becoming shorter. Schumpeter's long economic waves are suggested to shorten from 50-60 years to around 30-40 years for the current (fifth) and following wave. In this view one assumes the following waves.

1. 1785-1845 (60 years): Water Power, Textiles, Iron
2. 1845-1900 (55 years): Steam, Rail, Steel
3. 1900-1950 (50 years): Electricity, Chemicals, Internal-Combustion Engine
4. 1950-1990 (40 years): Petrochemicals, Aviation, Electronics
5. 1990-2020 (30 years): Digital Networks, Software, New Media.

It seems that the fourth and fifth Kondratiev cycles have an overlay of a constellation of megatrends which simultaneously are drivers: organic chemistry based information technology and renewable energy, such as organic semiconductors, organic solar cells (organic photovoltaic (OPV), organic light emitting diodes (OLED), vegetable oil and biobased chemicals and derived biomaterials and biofuels.

The market for energy is huge. At present, the world's population consumes about 15 terawatts of power. (A terawatt is 1,000 gigawatts, and a gigawatt is the capacity of the largest sort of coal-fired power station.) *That translates into a business worth $6 trillion a year* – about a tenth of the world's economic output – according to John Doerr, a venture capitalist who is heavily involved in the industry. And by 2050, power consumption is likely to have risen to 30 terawatts.

Scale is one of the important differences between the anticipated energy boom, if it materializes, and its recent predecessors – particularly those that relied on information technology, a market measured in mere hundreds of billions. Another difference is that new information technologies tend to be disruptive, forcing the replacement of existing equipment, whereas, say, building wind farms does not force the closure of coal-fired power stations.

In this line, for the development of the chemical industry rather than using a linear "wave model" Runge [2006:536] has introduced an "escalation model" resembling a build-up process.

Formal methods for opportunity identification emphasizing change as an opportunity look particularly into trends of the following subsystems:

- Societal and political trends,
- Industry trends,
- Business trends,
- Technological advances and trends.

On the technology and industry level *the value system shapes the drivers of the megatrends.* Current processual megatrends include

- *Miniaturization*:
  Nanotechnology as well as micro- and nano-systems technology, for instance, microreactor technology in chemical production;

- *Digitization*:
  Digital networks including the Internet and TV (analog to digital transmission); integration of media channels (data, voice, video); convergence of laptops and cellular phones; paper-based documents to digital form (computer files, new media) and electronic-only documents; access to and distribution of electronic information and documents;
- *Multi-functionality and Convergence*:
  Instruments and devices (Figure I.105) and products including "intelligent products or materials" (ch. 1.2.3, [Runge 2006:41-42]);
- *Decentralization and Mobility*:
  Energy (photovoltaic-solar cells and solar thermics, wind turbines, combined heat and power plants (CHPs), fuel cells and batteries);
  diversification of energy sources (standalone versus networks and grids; industrial and private), private rooftop photovoltaic, private wind turbines, mini-CHPs;
  communication (cellular phones, laptops, smartphones), wireless communication;
  water treatment and supply (purification, devices at home versus pipe network provision);
  mainframes versus PCs;
  workplaces of knowledge workers (office versus home) and work organization, such as research (global R&D, global teams, myriad ways of organizing R&D-networks, cooperation etc.).

The transition of *lighting* which is already happening for light emitting diode (LED) technology (Figure I.165, Figure I.166) and organic light emitting diode (OLED) technology (Figure I.148, Figure I.149) is one of the last analogue-to-digital transitions. It is estimated that currently LED/OLED products account for just 1 – 2 percent of the overall very huge lighting market (Table I.81). It is generally expected that digitization will change the lighting market similarly to digitization of the camera market at an average growth of ca. 30 percent.

Megatrends may be founded on industrial behavior, activities and believes as well as (societal) attitudes which may be taken by the policy system enforcing directions of the industrial as well as the science & technology systems (Figure I.34, Box I.22, A.1.1).

For the Western developed countries including Japan very fundamental megatrends include "*sustainability*" as well as a *"green" attitude* [Runge 2006:261-265] which translates into related actions of society, policy, business and industry and drives developments, such as

- "*sustainable development*,"
- stopping or even reversing climate change and
- individual "environment aware" behavior of citizens.

Cited by Runge [2006:263], according to the Bruntland Commission Report (1987), "*sustainable development*" is

> "development that meets the needs of the present world without compromising the ability of future generations to meet their own needs."

Basically, sustainable development targets *balancing ecology and economy*. In our context related individual behavior has emerged. For instance, in terms of the *Environmental Entrepreneurs* (E2) movement in the US. [59] In technology entrepreneurship it is reflected by the focus of entrepreneurial activities on so-called "clean technology" and specifically "renewable energy" [Burtis 2006].

"Clean technology" or **CleanTech** is not an industry but a mixture of technologies leading to offerings like products and processes in compliance with principles of sustainability, fighting climate change, saving natural resources, replacing current and soon ending resources by renewable ones and behaving respectfully in our natural environment in line with a "green" attitude or belief, respectively.

For industry that means particularly greatly reducing or eliminating negative ecological impact and, at the same time, improving the productive and responsible use of natural resources. While there is no standard definition of CleanTech, and rarely can be a consistent one, we shall follow Lux Research [60] in using an operational description putting the emphasis on five top-level target segments: (renewable) energy, water, air, waste and sustainable development. CleanTech in this sense is characterized in Table I.52 together with examples in terms of target areas, technologies and processes.

Table I.52: CleanTech introduced descriptively through target segmentations. [60]

Top Level	Emphases	Examples
(Renewable) Energy	Generation, storage, efficiency and distribution infrastructure Generation by ▪ Wind ▪ Solar ▪ Hydro/Marine ▪ Biofuels and biogas ▪ Geothermics	Photovoltaic and organic solar cells; fuel cells/batteries; lighting (LED and OLED); biofuels; hydrogen storage; electromobility (e-mobility); software management of the decentralized power grid of the future – the "*smart grid*"

Water	Purification, treatment and management	Potable water by desalination; purification and re-use of process and waste water; membrane separations
Air	Air quality	Cleanup and safety; emissions control, avoiding or reducing VOCs and HAPs
Waste	Avoidance, conversion and re-cycling	Manufacturing/industrial proc-esses; waste-to-biofuel, waste-to-biogas
Sustainable Development	Biobased economy, Energy efficiency, Materials recovery, recycling and degradability; Transportation & logistics	Biorefineries, biobased chemicals, biomaterials, bioproducts; agriculture (e.g. biopesticides, aquaculture) and nutrition (e.g. algae-based food additives); environmentally responsible information technology (IT)

In particular with regard to energy aspects one can differentiate

- *Energy efficiency* which concerns a particular process to get a particular result (product, service, etc.) as measured by the reduction of energy needed for the result;
- *Energy systems* (cf. Figure I.104) which concern a system of “energy input or resources,” a conversion process and outcomes, results and benefits for energy users, as displayed structurally in Figure I.5. In this regard energy efficiency is a particular facet of the conversion process as is “energy management.”

The quest to solve global energy problems often focuses on improving the energy supply, such as by building wind farms or growing crops for biofuels. But energy efficiency refers, for instance, also to lighting (Figure I.148, Figure I.165, Figure I.166), building with isolation from heat loss, but also improving currently used production processes

A new study [Peach 2011] highlights options for cutting the amount of energy that is needed in the first place tremendously, by 85 percent. The emphasis would be improving the design of passive systems in buildings, vehicles and industrial equipment, such as the furnaces used to melt iron ore for steel production. A passive system, such as a building’s insulation or a vehicle’s shape, does not require external mechanical power to operate.

CleanTech is currently one of venture capital’s “darlings” as discussed in detail for biofuels (A.1.1, Box I.6.). The “exploding” amounts of investments in CleanTech are given in Table I.53. Due to the Great Recession in 2009 investment in CleanTech firms fell from 2008 levels, but was recovering strongly in 2010.

Table I.53: Annual CleanTech investment in North America, Europe, Israel, China, & India [CleanTech Group 2009] (* – and more recent data fromCleanTech Group)

Year	Investment ($mil.)	Year	Investment ($mil.)
2001	506.8	**2006**	4,519.1
2002	908.3	**2007**	6,053.2
2003	1,259.6	**2008**	8,465.5
2004	1,321.9	**2009**	6.1 *
2005	1,994.1	**2010**	7.8 *

North America's share of clean technology venture capital was down from 72 percent in 2008 to 62 percent in 2009, a four year low. The top clean technology sectors for venture investment in 2009 are presented in Table I.54.

Table I.54: Top venture capital clean technology sectors in 2009 [CleanTech Group 2009].

Technology Sector	Amount Invested	% of Total
Solar	$1.2 billion	21%
Transportation (including electric vehicles, advanced batteries, fuel cells)	$1.1 billion	20%
Energy Efficiency	$1.0 billion	18%
Biofuels	$554 million	10%
Smart Grid	$414 million	7%
Water	$117 million	2%

A fundamental trend of CleanTech is *electromobility* which does not only refer to electric vehicles (ch. 3.1; Box I.10). It covers also e-bikes ("pedelecs"; pedal electric cycles and electro-scooters ("e-scooters").

Currently it targets short distances in and around cities and leisure/tourism, sports and recreation, such as electro-caddies for golf or electric vehicles for disabled persons (wheelchairs, low-speed electrocars to be driven without a driver's license) as well as electro-motors for boats (Torqeedo GmbH – B.2), yachts or as auxiliary power supply for recreational vehicles or other recreational facilities (SFC Energy AG [Runge 2006:331-335,623]). Military applications of fuel cells is a special aspect of e-mobility and German SFC Energy AG in which the US chemical giant DuPont has a stake in plays a key role here [Runge 2006:333-334].

Innovation and entrepreneurship in e-bikes addresses broad segmentations by distance, customers and usage, such as “normal” people in cities, people in leisure and tourism or sports (electro-mountainbikes), and transportation according to load weight (postal services). Concerning technology basic options are batteries versus fuel cells as well as location of the power source, for instance, housed in the wheel hub of the front wheel as in the Lohner-Porsche electrocar of 1900 (Figure I.82).

There are various performance requirement for electromobility, such as charge (volts of batteries) and time for charging, recharge period, weight, life time, safety, disposability, low-environmental-impact solutions for low-voltage power needs (1.5 to 3.0 volts), distance range for cars, etc., depending on application. Widespread infrastructural requirements for e-mobility through cars, such as charging stations like fuel stations and standardization for charging devices and plugs are still missing.

In contrast to the policy-driven market of electrocars the e-bike market is largely an attitudinal market (Table I.15) having customers with good or high purchasing power. In Germany and the Netherlands accounting for ca. 50 percent of the European market which also lead globally the e-bike markets there are myriad suppliers, usually established producers of conventional bicycles, and heavy competition is observed. High-level and luxury hotels in European German-speaking regions offer e-bikes to their clients and surrounding recreational areas have established the necessary infrastructure of charging stations.

There is strong adoption in Western Europe and China, but sales remain low in the US [Greene 2009]. Though in absolute terms on a low level the market of e-bikes in Germany grows significantly. In 2009 ca 150,000 e-bikes were sold in Germany which is ca. 4 percent of the overall €13 billion German bicycle market (items sold and revenues from e-bike tourism). In 2010 ca. 200,000 e-bikes were sold and in 2011 310,000 were sold. Germany has the largest market for e-bikes in Europe. Good e-bikes are expensive (starting with €2,000, up to €4,000) and sometimes they are regarded as a status symbol [ADAC 2011b].

The underlying technologies are batteries, mainly lithium-ion batteries or fuels cells which also play a key role for consumer electronic devices like tablet computers, notebooks, camcorders, portable TV’s and MP3 or DVD players and mobile phones or smartphones.

Additional use of batteries or fuel cells is for power storage and, in particular, uninterruptible power supply (UPS) for power critical facilities, such as hospitals. Fuel cells of various types and particular applications are available [Runge 2006:325-33`]. For instance, the German NTBF SFC Energy AG produces the direct methanol fuel cell (DMFC) and offers also methanol cartridges for filling, but the future of fuel cell cars targets hydrogen-based fuel cells. And the US NTBF SiGNa Chemistry (B.2) offers mobile-H2™ for hydrogen fuel cells looking to develop lightweight, safe hydrogen solutions to power mobile electronics.

US NTBF A123 Systems, Inc., founded in 2001, a green-technology favorite and listed on NASDAQ, used proprietary Nanophosphate® electrode technology to produce lithium-ion batteries. The new, highly active nanoscale material initially developed at Massachusetts Institute of Technology (MIT), with low impedance has a competitive advantage over alternative high power technologies. It claimed that cell and nano-structured electrode designs lower cost/watt and cost/watt-hour, they have higher voltage than other long-life systems, enabling lower pack cost. Their long life would lead to reduced life-cycle and system costs resulting in greater overall price-performance.

However, private industry customers did not respond so well for battery firms like A123 Systems. Major investments in battery manufacturing – supported in large part from US Recovery Act funds – have been met with *disappointing demand from electric-car makers*. A123 has raised more than $350 million from private investors and had hefty support of the US and Michigan governments. A123 was awarded $249 million in Department of Energy grants and has used about half so far to pay for some of the costs of building a factory in Livonia, Mich. [Ramsey 2012]

Hoping to kick-start an electric-vehicle battery industry, the US provided $1.26 billion since 2009 to battery makers. Most were producing far fewer batteries than originally expected [Ramsey 2012].

A123 remained in the red: "We have had a history of losses, and we may be unable to achieve or sustain profitability." [A123 2011]. According to the A123 annual report 2011 financial data (in thousands) were: Total revenue $159,147; Total cost of revenue $249,195; Gross profit ($90,048); Net loss attributable to A123 Systems, Inc. ($257,730). A123 warned it could run out of money due to slower-than-expected sales of electric vehicles and manufacturing problems, but was rescued from collapse [Ramsey 2012].

As of June 30, 2012 the company had $47.7 million of cash and cash equivalents and was burning through $18.0 million to $25.0 million per month and had expected to fall below the $40 million minimum by August 2012. The situation: If A123 cannot satisfy the conditions offered by Wanxiang, the quarterly filing warned that the agreement will fall apart and A123 is likely to have to go into bankruptcy. The Wanxiang Group is the largest autoparts company in China, and already has a significant business in electric vehicle batteries [Herron 2012].

After failing to make a payment on a $75 million loan from Wanxiang Group that had been negotiating since August to buy 80 percent of A123 for $450 million A123 filed for bankruptcy in October 2012 and arranged to sell its automotive battery business to technology firm Johnson Controls for $125 million [Reisch 2012].

In the field of developing electrocars German Daimler AG follows both paths, lithium-ion batteries, produced in a JV Li-Tec GmbH with chemical firm Evonik Industries and also hydrogen fuel cells (for the B model). Competitor BMW offers a hydrogen-based luxury car, the BMW 7 Hydrogen. Experts' opinion and a number of studies state that within the current decade electrocars will remain niche products, one bottleneck being insufficient battery technology.

Megatrends can be used as a methodology when an entrepreneur or a company works strategically with the future. One can, for example, use them as a base in development and innovation processes, and one can use them in combination with other trends of super- or subsystems in a more specific business, technology or industry area. Other aspects segment trends according to regional criteria or a global view differentiating developed and developing nations.

> A key trend when viewing developed countries and exports to developing countries is the strong rise of the middle class with increasing purchasing power in countries like Brazil, India, China and generally Asia.

On the other hand, having identified, for instance, CleanTech as an opportunity in the West may get a serious flaw when neglecting not just competition from Asia, but how different the basis of competition may be.

One should remember how China can create firms leading in clean energy. Many countries, including Germany and the US, have systems intended to protect stakeholders which slow new development, including clean energy, compared to China. For example, when acquiring land to build wind farms, China can force relocation of people at any time, when Western countries would have to go through a long legal process. The Chinese central government is not intimidated by relocation protesters, does not have an Endangered Species Act to worry about, and is not encumbered by fierce opposition due to noise and visual pollution.

Formal methods for opportunity identification emphasize change or problems as an opportunity and can start from trends and examine them gathering lots of facts about trends, for instance, business trends and technology progress. Here, one should constantly change the view and take a "kaleidoscope approach" which means asking

- Do the answers change?
- Do the questions change?

This can be paraphrased by a quotation of Dr. Wayne Dyer (an American motivational speaker and author of self-help books): "Change the way you look at things and the things you look at will change."

One way in the context of "opportunity analysis" (ch. 3.2.2) to follow this is "Opportunity Mapping" [Canada 2009] utilizing the power of *trends' intersection*. Figure I.91 outlines a crude example starting from the convergence of three megatrends (filled circle) in Western developed societies and Japan, associated with three major *societal* directions, a “green attitude”, “aging society” and “health and wellness” relating to “anti-aging”, health, health care and rare diseases.

To help identify problems and opportunities relating the driving phenomena to the pharmaceutical industry as well as cosmetics and nutrition *industries* leads to the cosmeceuticals and nutraceuticals industry segments.

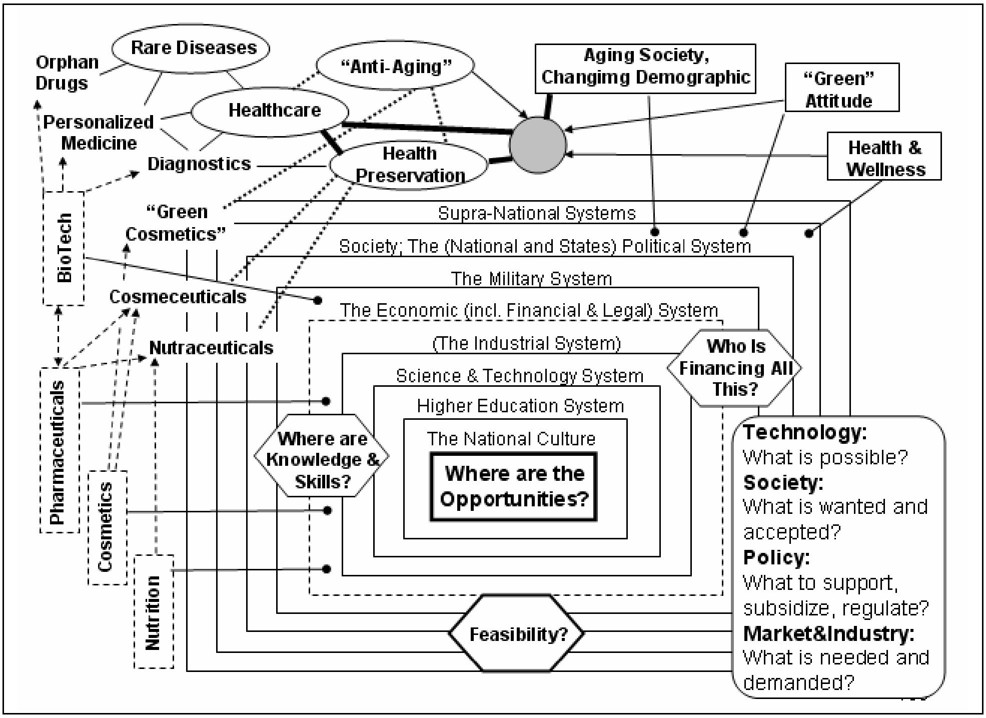


Figure I.91: How the megatrends “Healthcare”, Health Preservation” and “Aging Society” drive combining the pharmaceutical industry and the cosmetics and nutrition industries into cosmeceuticals and nutraceuticals segments.

An opportunity map results from identifying problems/ideas that sprout from the subject and continue to generate ideas from ideas and again on the basis of technical relationships or associations are connected (thin and dotted lines). Finally expose the map to a particular view, a single question: what is in for an existing firm of a particular industry or an entrepreneur on the basis of particular technologies (dashed arrows) to look for specific opportunities to be exploited.

For instance, “orphan drugs” focusing on rare diseases provide not just a segment of HealthCare through drugs for a niche, but relate simultaneously to the “personal medicines” trend. An “*orphan drug*” is any drug for the treatment of very rare diseases. These substances are only required sporadically and are highly effective even in the smallest quantities. The majority of orphan drugs are cytostatic drugs for the treatment of cancer.

In the US under the Orphan Drug Act (ODA) and administered by the Food and Drug Administration (FDA) companies that develop such a drug (a drug for a disorder affecting fewer than 200,000 people in the US) there are special legal incentives. The European Union (EU) has enacted similar legislation, in which pharmaceuticals developed to treat rare diseases are referred to as "orphan medicinal products." The EU's legislation is administered by the Committee on Orphan Medicinal Products of the European Medicines Agency (EMEA). [61]

Hence, a political incentive is a special addition to the opportunity with orphan drugs. The granting of the orphan drug status is designed to encourage the development of drugs which are necessary but would be prohibitively expensive/unprofitable to develop under normal circumstances.

As medical research and development of drugs to treat such diseases is financially disadvantageous, companies that do so are rewarded with tax reductions and marketing exclusivity (monopoly) on that drug for an extended time (in the US may sell it without competition for seven years and may get clinical trial tax incentives). German NTBF ChemCon GmbH (B.2) has grasped the orphan drugs' opportunities.

> There is often little difference between recognizing a potential business opportunity and recognizing a niche market opportunity. Sometimes people find themselves in a niche market without planning it. Perhaps there is a product or service you need but that is difficult to obtain in your area (Table I.49); so you begin providing the service for yourself.

The power of convergence for opportunities does not only show up for megatrends, but may also appear on a lower level in terms of combinations, combinations of product features usually associated with individual products into one "new" product (architectural innovation) or two industries into a new one (Figure I.91).

Figure I.91, furthermore, reflects the close interconnection of the pharmaceutical and the biotechnology industry which opens more opportunities.

Putting together the megatrends "spread and use of the Internet," "sports and leisure" and the "rising middle classes in developing countries," the widely used computer games in the developed world raises the question of whether and how computer games in developing countries can become an excellent business opportunity. Question: what is the barrier?

The answer is that sophisticated games usually require dedicated devices and associated games – usually available only for the most common languages in the world, English. These are too expensive for people in the developing world. What is the intersection concerning computers in the developed and the developing world? It is the

Internet infrastructure and the browser and the addition of multi-lingual versions (cf. German Gameforge AG, ch. 3.4, B.2).

Hence, the Window of Opportunity (Figure I.4) with infrastructural requirements (and possibly political "encouragements" and incentives) is the juncture when the necessary technological developments or trajectories, market demand and technical (and probably also social) infrastructures will meet (Figure I.92).

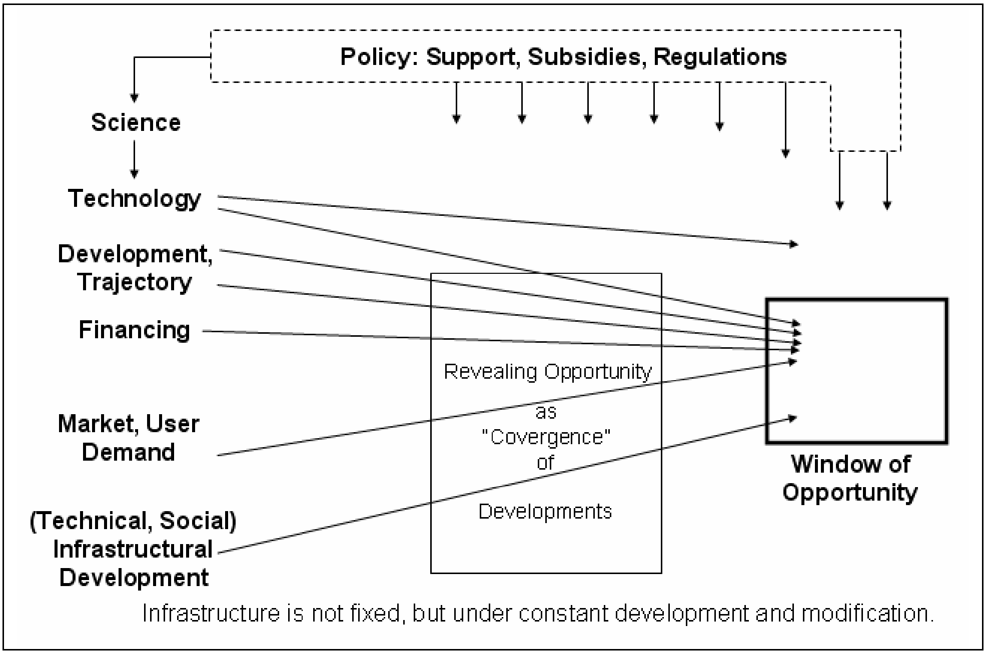


Figure I.92: The Window of Opportunity as revealed as a quasi convergence of developments, possibly influenced by policy (and societal effects).

Having identified areas of opportunity the issue of *exploiting* will emerge. This means questions of feasibility tackle upsides and downsides, such as

- What are the characteristics of the ultimate offering(s)? Is there really a market for you?
- What feature set will appeal most to customers (Figure I.88, Figure I.161)?
- Have you analyzed how successful your product or service can be? What are the uncertainties? What is the risk?
- Is there a narrow time-based Window of Opportunity (Figure I.4)?
- How might a customer's need be met (technology, generic solution)? Is this a primary need or a substitution need?
- Does your startup or company have the strength to get the job done? What are your weaknesses?

- Do you have the required resources? Do you have the scientific or technical competencies to go ahead? Can you finance your venture with own funds?
- Who are your competitors, what are they doing, and how will they likely react against your offering?

When it comes to *feasibility* assessing opportunities may become externally driven. Negotiations and consensus between entrepreneur and VC about the assessment of the opportunity are needed. The questions about resources may lead directly to look into the Science & Technology System and the financial community (Figure I.91) raising further questions: Do we have all the technology we need? Do we have to license-in technology? Can we set up cooperation with universities or research institutes to fill the gaps we have in technology? If our own funds and those of the family and friends do not suffice to exploit a revealed opportunity, will banks provide loans or investors provide capital?

Fundamental risk/reward and uncertainties considerations of an entrepreneur or an intrapreneur engaged in a new product or business development project can be presented in a "strategy matrix." This simultaneously puts risk and reward into the context of the offering's novelty in terms of the type of innovation (ch. 1.2.5.1; Figure I.21) the opportunity is associated with (Figure I.93).

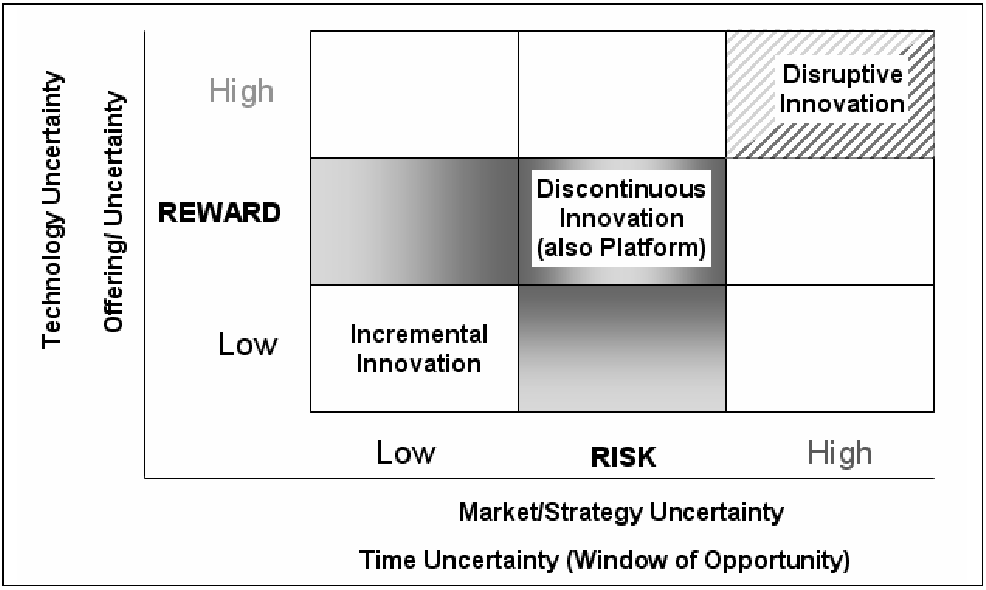


Figure I.93: Opportunity evaluation in terms of risk/reward considerations.

Decision-making and prioritization in case of *a "choice set" of market opportunities prior before market entry* must dig deeper into details – also with regard to acquisition of necessary (technical, human and financial) resources. One key concept here is *differentiation*.

Differentiation as a process is essentially a theme for firms providing several (many) offerings. This is illustrated in Figure I.91 for an environment of the chemical, pharmaceutical and biotechnological industry.

Product differentiation is a key feature of modern economies. Customers or consumers perceive the differences among differentiated products to be real and there is often approximate agreement on which ones are, and are not, close substitutes.

The "address approach" distinguishes between horizontal and vertical product differentiation. In the former, customers or consumers do not agree on the quality ranking of commodities, while in the second they do. The main assumption is that higher variants of vertically differentiated commodities require highly-skilled input. For chemical products, for instance, the definitions of product differentiation exhibit the following grades [Runge 2006:151].

- *Commodities* are the very large volume products for which there is demand and that are sold by a large number of suppliers to large number of customers, with less product differentiation and price as the major criterion.
  They cover also basic resources (coal, natural gas, crude oil and petroleum, iron ore, copper or gold) and agricultural products (ethanol, sugar, corn, coffee, soybeans, rice, wheat).
- *Differentiated Commodities* are the very large volume products that are sold by selected suppliers to a large number of customers, differentiating products based on *performance and price*.
- *Large Volume Specialties* are large/medium volume products that are sold based on technology, performance and meeting end-use requirements as the major criteria.
- *Specialties* are "low volume – high value" products supplied by a limited number of suppliers with high profit margins and high barriers to entry based on technology.

Commoditization occurs as a goods or services market lose differentiation across their supply base, often by the diffusion of the intellectual capital necessary to acquire or produce it efficiently. Digital cameras can serve as an example.

Differentiated offerings, particularly products, may occur for existing, modified or new products. Figure I.94 shows how differentiated offerings relate to type of products for several industries. Differentiation can be further driven by reference to attitudinal or policy-driven markets versus economic markets (Table I.15).

And what is seen here is that “Health & Wellness” introduced as a megatrend in Figure I.91 provides an “action field” for new and existing firms on the basis of new products differentiated in various manners.

Differentiation based on *sets of offerings*, special purpose combinations of offerings (products), can refer to “process chains,” “mosaics” [Runge 2006: 26-27] and “system solutions” (Figure I.95). Such sets of offerings with systemic characteristics are particularly effective if the individual offerings belong to different steps of the customers’ value chains.

While process chains and systems solution may bind customers to the supplier (switch costs!) the other way round, addressing process chains with (envisioned) customers, may represent large barriers for suppliers or innovators to put just one offering or product into the process system of the customer (Figure I.187).

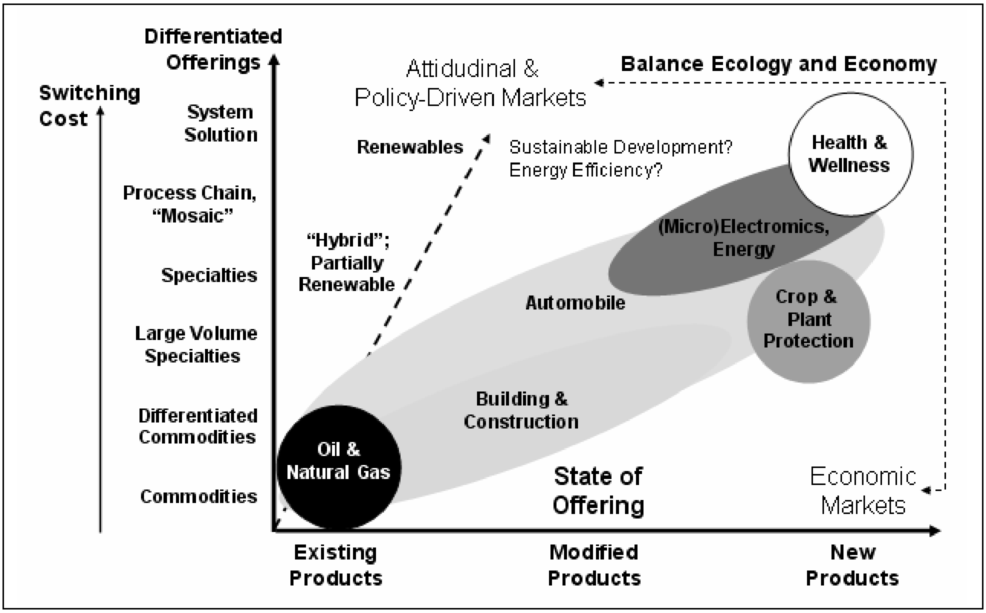


Figure I.94: Competitive advantages through differentiation from the point of the chemical, pharmaceutical and biotechnological industry.

Differentiation as a mean to reveal opportunities is not only related to output (offerings). It can also address input. Figure I.176 shows how algae as input can generate a value ladder for different offerings from “high volume – low value” to “low volume – high value.”

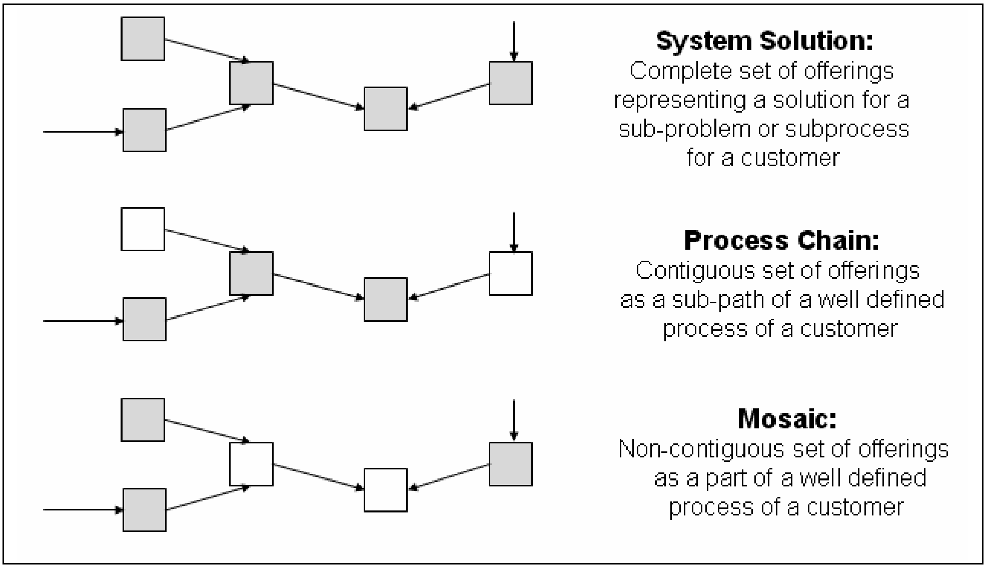


Figure I.95: Depicting sets of offerings (filled squares) as means for differentiation and competitive advantage.

Finally, differentiation can be seen as a way to *attract and, moreover, bind customers*; and as the corresponding expression one can refer to switching cost. **Switching cost**, also called switching barrier, describes any hindrance to a customer's changing of suppliers. It thus represents the reversal of customers' bargaining power as a market force (Figure I.33, Table I.16).

Prevalently switching costs are monetary in nature, but also psychological, emotional, and social cost factors. Types of switching costs include, for instance, exit cost (fees; Table I.16), search costs, learning costs, cognitive effort, emotional costs, equipment costs, installation and start-up costs and cover as well financial risk, psychological risk and social risk. Where switching costs for a buyer are prohibitively high, the situation can be modeled as a monopoly for a seller. Sets of offerings (Figure I.95) are usually strongly related to switching costs.

Switching costs are a major reason for pursuing order-of-magnitude improvements in costs, efficiencies, and benefits to the customer. This business strategy has been called "*Andy Grove's 10x rule*" and can be related to the concept of breakthrough innovation (ch. 1.2.5.1). Switching costs affect competition and can be viewed as a rough indicator of the degree of competition. [62]

Figure I.94 refers to the environmental megatrends of "*sustainable development*" and "stopping or even reversing climate change." This is particularly striking when thinking of oil and natural gas and petrofuels versus biofuels (A.1.1). The tremendously complex situation with regard to opportunity identification from a combinatorically defined option (choice) set for startups is sketched for the biofuels case in Box I.13.

Box I.13: Sketching opportunity identifications, options and feasibility for the policy-driven market of biofuels.

People with “green” and sustainability-oriented mind and environmental entrepreneurs being aware of the tremendous incentives and financial resources provided by government and “CleanTech investors” may be driven to entrepreneurship in biofuels.

The current situation of ca. 550 firms being worldwide active in biofuels with the majority being startups and NTBFs, ca. 350 firms in second-generation bioalcohols (methanol, ethanol, butanol), biodiesel and biogasoline and ca. 200 in algae as the input raw material, indicates that there are plenty of perceived opportunities identified by entrepreneurs (A.1.1). Hence, what is the essential informational basis for still identifying opportunities for to-be entrepreneurs to decide forming a new firm in such a “hot,” but extremely competitive environment?

As the basic drivers for entrepreneurs in biofuels, the market appears to be so big that a market share of only some very few percent would mean relatively big rewards. Initial funding of research, development or production in that area provides many public and private sources and cooperation possibilities (Figure I.34).

An opportunity identification process has to start from the whole biofuels value system and its interconnections with the petro-oil value system (Figure I.171, Figure I.172). The petro-oil price appears as a threshold and energy efficiencies as determined, for instance, by Equation I.20 or in Figure I.185 and carbon dioxide emission minimalization show up as constraints. To simplify discussions we shall restrict ourselves to second-generation and third generation biofuels (Figure I.34).

Having a particular technology, for technology entrepreneurs with a given goal in mind the entry into opportunity identification would cover the assessment of the current situation concerning one’s own position with regard to the related conversion (process) technology (Figure I.181, Figure I.184) and the intended output/offering (Table I.17).

This must also tackle the biomass-, waste- or algae-based input. Representative input for second-generation biofuels is listed in Table I.97. Procurement and storage of raw material widens the spectrum for opportunity identification. Conversion has to consider co-products and by-products which may provide additional revenue streams for the startup.

Fundamentally, it must be clear how to make money, what the revenue model (Figure I.183) shall look like. As the extremes revenue streams may come from production (operator/owner) of biofuels or from selling licenses to research, development or/and manufacturing firms and may be related to start a scientific/engineering approach (RBSU) or technical/engineering approach (NTBF) according to an RD&D process (Figure I.180). Figure I.185 illustrates rather than completely reflects the issues and complexity of cost and energy efficiency consideration for manufacturing second-order bioalcohols.

Though questions of intended input and output are rather straightforward some remarks concerning use of algae for biofuels should point to the complexity of revealing opportiunities also in this case.(ch. A.1.1.4).

In principle, for biofuels algae offer many advantages over traditional oilseed crops, such as corn, soybeans or rapeseed. Algae, furthermore, exhibit close connections to petro-oil. However, algae for biofuels form the bottom, the least profitable step, of the algae value ladder for different potential offerings (Figure I.176).

With regard to biofuels (Figure I.177), how to grow algae cheaply on a large scale is one of the biggest challenges facing the industry. Production costs need to come down by about a factor of 10. Here energy efficiency (including water supply, pipe material and pressure cultivation ponds) is critical. It is estimated (A.1.1.4) that it will take at least five or ten years before anyone finds a way to produce commercial quantities.

If comprehensive and detailed, the review – the “competitive technology assessment” (CTA, [Runge 2006:816-818]) focusing on the biofuels value system (Figure I.171) – would provide the list of approaches and paths followed by the various firms currently active in the field – the competitors – and gaps open to be filled by entrepreneurs. The gaps are associated with the constraint of overall energy efficiency and the cost efficiency of biofuel conversion to meet the requirement biofuel industrial production costs to be competitive with a petro-oil price of ca. $85 per barrel (valid in 2009/2010).

For firm’s foundation there is the requirement to look into all firms in the field concerning their technologies and offerings. Considering also the forces and drivers (Figure I.33, Table I.16) in the biofuels area leads to an almost full industry analysis. The description of the biofuels field given in the Appendix (A.1.1) provides a “restricted industry analysis” confined to key players.

Entrepreneur(s) will have to decide and act on a “*multi-conditional opportunity options set*”. Having competition from China and India and the *Chindia criterion* (A.1.1.1) in mind one can hypothesize that cost efficiency outbeats energy efficiency. The final step of the CTA has to inquire whether a particular identified opportunity targeted to be pursued is protected by a patent or, worse, though not closely related to the opportunity, that particular sub-processes intended to be used are patented. Specifically, if the new firm’s revenue model relies on license-out the CTA is important to identify potential customers.

Feasibility concerning production orientation for biofuels means generally needing millions of dollars. According to Figure I.87 feasibility interconnects the revealed opportunity options set and opportunity evaluation and the related offering option(s).

Feasibility does not only refer to have or to access, respectively, resources, but may also include first contacts with (potential) customers testing the offering(s).

As the to-be entrepreneur is dealing with multiple goals, open systems and rather complex situations in terms of parameters and variables it can be expected that it is not possible to reach an optimum, and it could also not be proved that the optimum has been reached. Therefore, the entrepreneur has to settle for the best feasible outcomes.

Not only profound technology and market knowledge is a prerequisite for venture intentions, but also leadership/management and technical project experiences are needed which means corresponding availability of human resources. This is documented by the many biofuels ventures following a (technical/management) “veterans” approach, a serial entrepreneur or a novice entrepreneur plus experienced manager approach from the beginning (Figure I.183).

Even if the political winds do blow steady (supporting innovation and entrepreneurship in the area), the carnage on the path to the future’s billions of gallons of advanced biofuels is likely to be great, with many companies and technologies losing out in the competition or being gobbled up by a few deep-pocketed survivors [Carey 2009].

Entering a race, such as the one in biofuels, requires exceptional self-confidence in one’s own competencies and abilities.

> One of the greatest risks for to-be entrepreneurs is the general tendency of human beings to be overconfident and expecting things to turn out better than they actually do.

Overall, spotting opportunity in the technical fields requires awareness and knowledge about the many different and combinable options which are displayed in Figure I.96.

Very specific trends and areas providing specifically opportunities for entrepreneurs in the US are summarized by Dorf and Byers [2007:32-36].

The most recent “battlefield” for exploiting opportunities is Asia, particularly China and the South East Asian (SE) countries and particularly the BRIC-States concerning the megatrend of the strong growth of their middle classes with increasing purchasing power.

For instance. as Amazon so far did not enter SE Asia, an opportunity was seen to establish recently a new venture Lazada (of German origin) in Malaysia simply by “cloning” Amazon as an online mall addressing Thailand, Indonesia and the Philippines [Peer 2013].

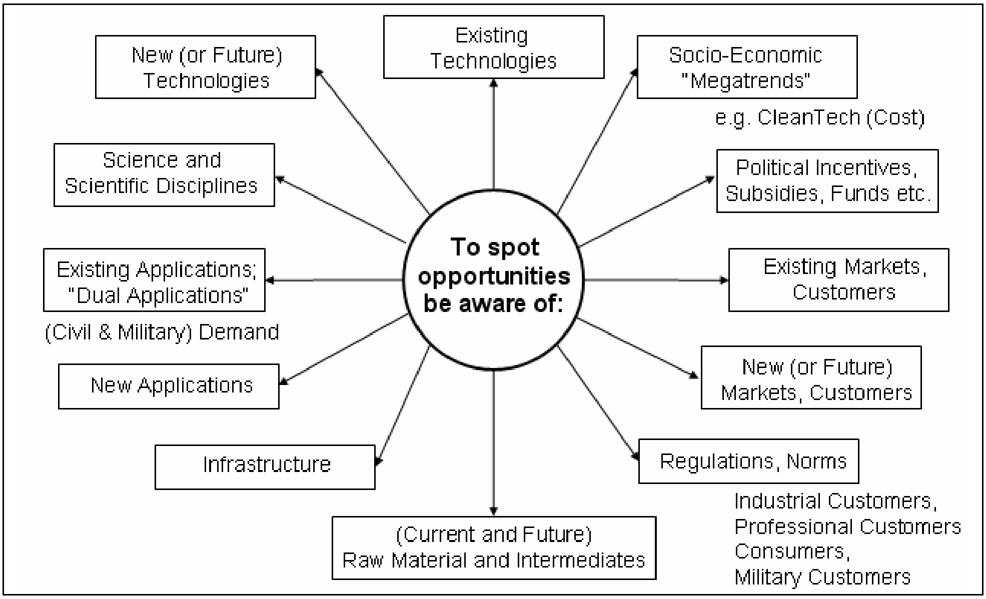


Figure I.96: Spotting opportunities for technology entrepreneurship.

3.2.2 Opportunity Evaluation and Feasibility

Ability is nothing without opportunity
Napoleon Bonaparte

As defined (ch. 1.2.1), "an opportunity is a timely and favorable juncture of circumstances providing a good chance for a successful venture." In particular, it is a tentative insight, a hypothesis, into the "real" world, a concept that is not yet verified but that if true would affirm certain facts or phenomena and their interrelationships.

It is often assumed that "a good chance for a successful venture" is related to the entrepreneur's ability, which is possession of qualities (Table I.31, Table I.32) required to get the entrepreneurial job done (achievement or accomplishment). Both, ability and opportunity are interrelated, and sometimes you just need a little opportunity or not fully exploited opportunity to get where you want to be. Finally, in the definition "good chance" relates to feasibility, the degree by which a firm's foundation can be carried out.

Questions often in the spotlight of technology entrepreneurship are: what constitutes opportunity for high growth firms, are there special opportunity constellations facilitating high growth or are NTBFs particularly able to exploit opportunity? There is a lot of scientific literature dealing with revealing opportunity for entrepreneurship. As far as the author is aware of, none of these studies examined how entrepreneurs recognized the "very good" or "big" opportunities.

Usually it is assumed that, although opportunities in a given environment may exist, the quality of the opportunity actually selected and operationalized is contingent upon the founder's ability to reveal and envision taking advantage of the opportunity. However, as emphasized at the beginning of this sub-chapter (3.2), opportunity and its socio-economic value for the entrepreneur(s) may be related to what is perceived as his/her (or their) view of "success" by firm's foundation (ch. 4.1) – and this may not be high growth and wealth or only wealth.

> An entrepreneur who revealed a big opportunity does not necessarily will pursue it, even if it would be possible for him/her according to his/her potential (ability) and having access to all the necessary resources. This means, feasibility or evaluating an opportunity may be decoupled from the decision to pursue it and the level of effort to exploit it (execution).

For instance, Bhidé [2000:32] reports that, for technology-oriented firms, founders actually attributed the success of their companies to either idea (and opportunity) or execution with a strong emphasis on execution:

- 12 percent due to extraordinary or unusual idea,
- 88 percent due to exceptional execution of an ordinary idea.

For a relatively small number of startups Bhidé [2000:39] reports that about 10 percent of the founders of *Inc.* companies (which he all characterizes as "promising startups") claimed they started with unique products or ideas.

Execution is fundamentally related to **critical success factors** (CSFs) where a CSF is the term for an element that is *necessary* for an organization or project to achieve its mission – and for a new firm to achieve its goals and objectives.

Critical success factors are those few things that must go well to ensure current and future success for a leader, manager or an organization and, therefore, they represent those managerial or enterprise areas that must be given special and continual attention to bring about high performance by execution of related current operating activities. [63]

Contrary to common belief [Dorf and Byers 2007:42] for technology entrepreneurship the review of opportunities will not always include the evaluation of alternatives. Entrepreneurs may found a firm straightforwardly, for instance,

- as they have already customers (WITec GmbH and Cambridge Nanotech, Inc. (Table I.80), IoLiTec GmbH and Solvent Innovation GmbH – A.1.5),
- out of securing a special project that can be generalized (as in case of the Wordperfect company which originated from a customized word-processing package [Bhidé 2000:34]),
- start a firm out of a previous job in the same industry (PURPLAN GmbH (Box I.21), IoLiTec GmbH, ATMvision AG, Marrone Bio Innovations, Inc. – B.2) or
- found a firm with the conviction that you can do it better than existing firms (Torqeedo GmbH, Gameforge AG – B.2).

The decision to whether and how to exploit an opportunity may be influenced basically by risk/reward consideration (Figure I.93). However, a big opportunity in terms of socio-economic value may be intentionally exploited on only a “medium level” if this fits the entrepreneur’s perception of his/her goals and “success” (ch. 4.1). Or a revealed big opportunity and the feasibility to exploit it may be impeded by poor execution (Figure I.87).

Figure I.97 contrasts two corresponding constellations in terms of a radar graph. Here, the “high growth firm” (big opportunity, big reward, excellent execution) is compared with the situation that the entrepreneur has intentionally opt for a medium (or satisfying) reward and allowing mediocre execution to exploit a big opportunity. Finally, in particular, in large firms a (big) opportunity may not be exploited if it does not fit current corporate strategy or resource allocation plans.

References to a “big” or “small” opportunity include the initial investment as well as the likely profit! A “lucrative opportunity” [Dorf and Byers [2007:46] means high benefits and low losses.

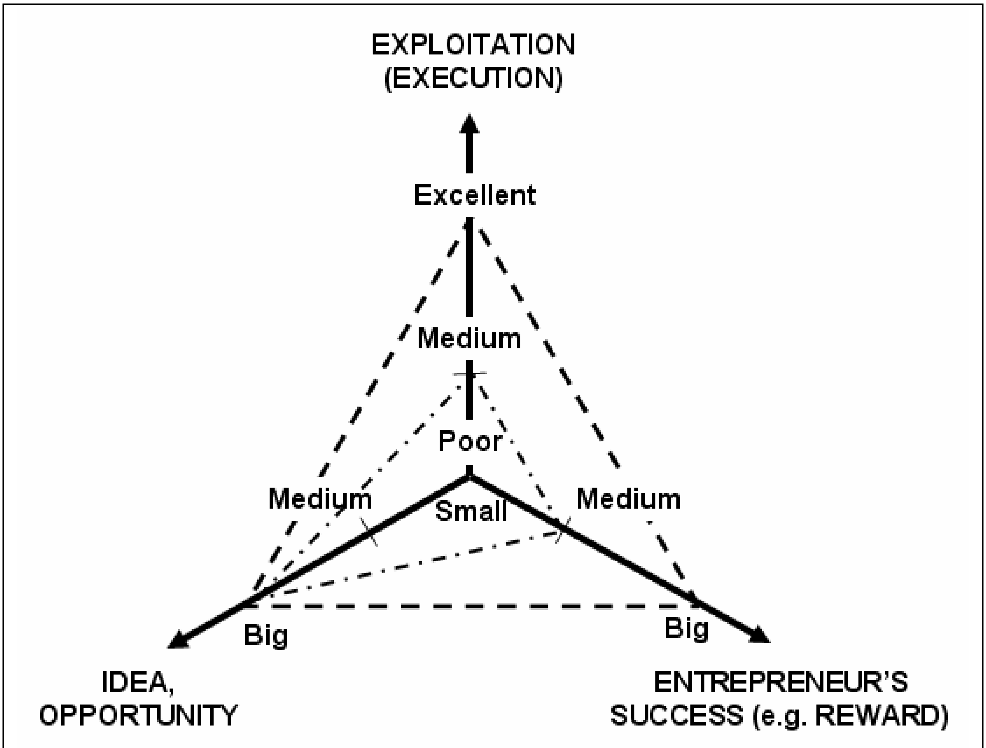


Figure I.97: Exploiting an opportunity in relation to the opportunity and the entrepreneur’s view of success.

A decision to follow a path of medium (or satisfying) reward and allowing mediocre execution to exploit a *big opportunity* has a built-in tremendous risk: As soon as the new firm with such an approach enters the related market it will induce emergence of a number of followers and, hence, competitors of all kinds and strengths which may create threats that may be or become sufficiently large to “kill” the first mover due to lacking market strength.

Figure I.97 illustrates the fundamental issue of providing general recommendations or guidelines for selecting good opportunities and relate this to later observed success of the entrepreneur(s) or the firm as a confirmation that this has been a good choice.

A comprehensive analytical approach to evaluation of opportunity, as is done in large firms (cf. ExxonMobile’s “think tank-approach,” Box I.13, A.1.1.4), is out of the reach of most technology entrepreneurs, mainly due to lack of available resources, needed time and necessary experience for this activity (ch. 3.2).

Pursuit of the opportunity for technology entrepreneurship proceeds often on four levels of *opportunity assessment*, the personal and the operational levels plus an independent check with important questions raised and to be answered (Table I.55).

Table I.55: Basic questions and activities of evaluating a technical opportunity.

- **The Value Proposition** (ch. 1.2.5.1; Figure I.26)
  Is it attractive to you, the entrepreneur, to customers, investors, employees, and other partners (who may provide networking synergies, contribute resources and mitigate risk)?
  How will you benefit? How can others benefit (lift their “pain”)?

- **Self-Assessment**
  1. Determine whether you are really suited to successfully move the idea and/or revealed opportunity into the market.
  2. What are *your own personal strengths and weaknesses*?
  3. Do you have what it takes; personal traits, operational competencies, financial resources? What skills are brought to the table? Who supplies missing skill resources?
  4. What about entrepreneurial commitment including commitment of founder team members and *the team’’s strengths and weaknesses*?
  5. Does your leadership team has the strength to get the job done?

- **Feasibility**
  Determining the feasibility of a new firm or business does not guarantee that it will be funded or implemented – too many other things outside of your control can go wrong – but it does set the stage for presenting the business to reasonable people for technical and financial participation.
  The goal of a “Feasibility Analysis” is for you personally to confirm that the pieces of the business can be put together well and consistently and well enough to present it to and discuss it with others. Key questions are

Table I.55, continued.

1. Is there really a market for you? Think of "3 M": Markets Matter Most!
2. Have you analyzed how successful your offering can be? Now and ongoing?
3. What do you have to do to accomplish the goal/objective?
4. Can your operating procedures comply with the legal regulation? Does your product require legal regulatory approval?
5. How will you get the offering(s) to the customers?
6. What resources do you need and how do you get them?
7. What are the strengths and weaknesses of the new firm?
8. What are the threats? Who are the competitors related to the opportunity?
9. What about strengths and weaknesses of competing firms, if exist?

- **Prejudices**
  Let outsiders know why this will work and be able to support what you believe in!
  No confirmation bias: "go" or "no-go" are both OK and no embarrassment with judges.

If a technology startup strives from the beginning to be externally financed, in particular, by venture capital opportunity evaluation/analysis follows a much more detailed and formalized or even standardized process. Such a process is based on a definition of what constitutes a "good opportunity" and an industry analysis of the wider environment of the targeted market including the key forces that are active (Figure I.33, Table I.16).

And a SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis will be often mandatory for decision-making whether to act – after evaluating an opportunity or opportunities, respectively.

A **SWOT analysis** as a tool may be used in any decision-making situation when a desired end-state (in terms of goals and objectives; success) has been defined. SWOT analysis is a strategic planning method used to evaluate the strengths, weaknesses (internal to the organization), opportunities (including limitations), and threats (given by the external environment to the organization) involved in a project or in a business venture. It involves specifying the goals and transforming them into objectives of the business venture or project and identifying those internal and external factors that are favorable and unfavorable to achieve that objective. [64]

In business a **threat** is a factor and force in the company's external environment that poses a danger to its well-being and competitive position. By examining threats, one can identify unfavorable market shifts or changes in technology, and create a defensive posture aimed at preserving the competitive position.

For competitors as a threat, in particular, also their strengths and weaknesses have to be assessed. This can be the basis to envision possible competitive responses when entering the market. On the other hand, any weakness of a competitor may be an opportunity for a new firm.

Basically, the forces that impact a company's ability to compete in a given market have been described by the Encapsulated Six Forces Model (Figure I.33; Table I.16) which comprises industry-internal (competitive) forces and external driver forces in the industry and which is derived from Porter's Five Forces Model.

Here a company is related to its environment and in particular to the structure of the industry in which it competes. The environment appears as a set of forces which constrain the behavior of organizational participants and to which the organization must adapt. In particular, it includes governmental economic policy.

Whereas Table I.16 focuses on unattractiveness of industry segments based on Porter's Five Forces Model Table I.56 will provide an overview of the various forces applicable primarily to existing, large firms. There is an emphasis on threats.

A company's closest competitors are those pursuing the same target markets with the same strategy. A group of firms following the same strategy in a given target market is a *strategic group*. Hence, a company needs to identify the strategic group in which it competes.

Competitors do not only mean individual firms, but also the cluster of firms from the overall *competitive group*. An example is large firms of the power industry in Germany which (in the past) simultaneously owned electric grids. For instance, they fought simultaneously against NTBFs or medium-sized companies from CleanTech (like wind energy or biogas) to feed their power into their grid, as observed for the German firm Enertrag AG (Figure I.104).

A paper of Sull and Wang [2005] provides an additional important aspect of industry forces. As outlined below, suppliers, customers, competitors, financing options and capital markets, technical and industrial evolution and government policy among others come into play. But, to further complicate matters, these factors vary in importance over time and, though with different pace, are constantly shifting – opening a crack or threatening to close altogether.

Table I.56: Expressions of industry forces according to Porter's Five Forces Model with special emphasis on existing firms.

<table>
<tr><th colspan="2">Rivalry Among Existing Firms (Competitors)</th></tr>
<tr><td colspan="2">Intense rivalry often plays out in the following ways,
"Jockeying for position" (try to get the firm in a good position in relation to others who are competing for the same opportunity or the same goal; cf. Box I.13, A.1.1)
Increasing customer/consumer warranties or service
New product or service introductions
Using price competition
Staging advertising battles
Occurs when a firm is pressured or sees an opportunity, but
Price competition often leaves the entire industry worse off
Advertising battles may increase total industry demand, but may be costly to smaller competitors
Heavy competition is more likely to occur for:
Numerous or equally balanced competitors or diverse competitors
Lack of differentiation or switching costs
Slow growth industry
High fixed costs
High logistics and storage costs
Capacity added in large increments
High exit barriers</td></tr>
<tr><th>Threat of New Entrants</th><th>Threat of Substitute Products</th></tr>
<tr><td>Barriers to entry:
Economies of scale;
Cost disadvantages independent of scale;
Product differentiation;
Capital requirements;
Expertise requirements;
Access to distribution channels (also "infrastructure");
Switching costs;
Expected retaliation;
Government policy (regulations, subsidies, grants etc.; Figure I.34)</td><td>In economic markets products with similar function limit the prices firms can charge (generic technologies).
Keys to evaluate substitute products: Products with improving price/performance tradeoffs relative to present industry products
In attitudinal markets price may not be an important factor ("green" products)</td></tr>
</table>

Bargaining Power of Suppliers	Bargaining Power of Buyers
Suppliers exert power in the industry by: Threatening to raise prices or to reduce quality Powerful suppliers can squeeze industry profitability if firms are unable to recover cost increases Suppliers are likely to be powerful if: Supplier industry is dominated by a few firms Suppliers' products have few substitutes Buyer is not an important customer to supplier Supplier's product is an important input to buyers' product Suppliers' products are differentiated Suppliers' products have high switching costs Supplier poses credible threat of forward integration	Buyers compete with the supplying industry by: Bargaining down prices Forcing higher quality Playing firms off of each other Buyer groups are likely to be powerful if: Buyers are concentrated or purchases are large relative to seller's sales Purchase accounts for a significant fraction of supplier's sales Products are undifferentiated Buyers face few switching costs Buyers' industry earns low profits Buyer presents a credible threat of backward integration Product unimportant to quality Buyer has full information

Assessing technology status and further development as the basis for offerings can be approached in detail by the established organizational processes of "Competitive Technology Assessment" (CTA) including patent assessment and analysis [Runge 2006:666,669,963].

CTA as a process of technology intelligence in large firms [Runge 2006:804] refers to *opportunity and threats* (OT of SWOT), but focuses also on self-assessment and the SW part of SWOT for competitors, similar to "Competitive Analysis" of Marketing.

After this "interlude" we shall deal with the introductory question what constitutes opportunity for high growth firms – implicitly related to a "big" opportunity. As there is likely no ultimate answer, we shall deal with a modest approach.

A "*good opportunity*" is *attractive, durable, timely* and anchored in an offering (usually a product or service) that creates or adds value for its adopter/customer.

- It embodies a sustainable barrier to market entry (for competitors) and
- It promises a sustainable competitive advantage (Table I.75).

Durability refers essentially to both opportunities and threats. On the opportunity side technology entrepreneurs can take advantage from the type of technology, such as scalability by having a platform technology. Threats are associated with the type of technology forming the basis for the firm's offerings. (Table I.51). But threats are largely associated with forces in the industry, by competitors, buyers and suppliers (Table I.56, Figure I.33) as these induce majors risks (Table I.65, Table I.66). Risk considerations can be considered in detail after having dealt with the above issues of opportunity when ultimately deciding whether to go ahead.

Timeliness is related to the Window of Opportunity (Figure I.4, Figure I.92). Evaluation to prepare decision-making to pursue an opportunity (Figure I.87) focuses on the offering, for instance, a detailed awareness and description of the product and anticipated customers, and its fit with the Window of Opportunity.

When speaking about the Window of Opportunity it appears obvious that it is related to questions of whether the customer need is real and the potential market big enough to constitute a (big) opportunity. The tougher question is whether the timing is right to concentrate resources to pursue the opportunity (Figure I.87). However, as we differentiate opportunity and feasibility (what resources we have and what other resources we need in relation to the environment) and follow a systems approach we have to consider other factors, entering the path from opportunity to feasibility, decision and execution.

Assessing *attractiveness* of a market (Y) quantitatively for comparisons and decision-making with other markets may use a scoring approach considering Table I.16 and Table I.56. It attributes values to the perceived central determinants of attractiveness on a five level rating scale (5 = extremely attractive, 2 = very attractive, 3 = attractive, 2 = somewhat attractive, 1 = not attractive) and introduces weighting factors for the relative importance of the contributing determinants (whose sum equals 1). This is shown in Table I.57. The overall process to get the data may follow "expert valuations" probably augmented by a convergence mechanism (Figure I.77).

Table I.57: Market attractiveness quantified for comparisons – an example!

Key Factor	**Rating Scale (1 – 5)**	**Weighting Factor**
Market Segment Size	5	0.50
Annual Growth Rate	2	0.15
Segment Profitability	1	0.20
Level of Competition *)	2	0.15
Market Attractiveness Score	Y = 3.3 ("attractive")	

*) Inverted rating scale for competition: 5 = very low, 1 = extremely high.

When evaluating opportunity assessing only the market without considering the super-system of the market, the industry, does not suffice. Both domains must be considered to reveal attractive opportunities to be interconnected with feasibility which correspond to a macro/micro level distinction.

Large and growing markets are important, but structurally attractive industries (in a five forces sense and/or the industry's development state, such as growing or declining) are also important. Figure I.98 exhibits this situation related to the firm's feasibility to pursue the opportunity and its execution potential. The inner circle deals essentially with feasibility and execution on the micro level.

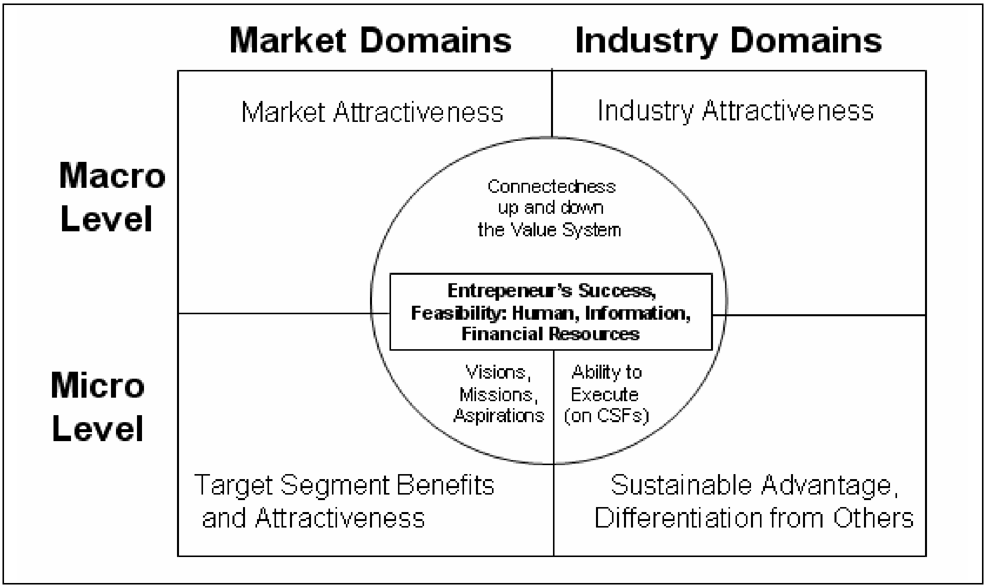


Figure I.98: Five domains of attractive opportunities connected to feasibility and execution (adapted from Mullins [2006]).

In Figure I.98 strong scores at the micro level can mitigate poor macro-level scores. But scores are not additive. Becoming a market leader in a declining industry may not be an attractive opportunity – at least not for a long time.

As a final remark, opportunity evaluation has to consider constraints which may affect feasibility in terms of (legal) regulation or industry standardization. For instance, AgraQuest must go for FDA approval in the US to bring its biopesticides into the market [Dorf & Byers 2007]. And German SCF Energy AG (formerly SFC Smart Fuel Cell AG), when looking to exploit the opportunity of direct methanol fuel cells as a power source for laptops, was confronted with the fact that the use of methanol in passenger cabins of airplanes was prohibited [Runge 2006:334,335].

Hence, the important questions about the situation of the (new) firm to be answered as part of strategy logics or strategy, respectively are:

- Firm strategies: in what businesses do we or should we compete?
- Firm level: how should we compete against particular firms (that is, direct competition against another firm)?

- Industry level (business level) strategies: how do we compete in the different industries that our businesses are in?

3.3 Ideation

Everything intelligent has already been thought before, you must only attempt to think it again.
Johann Wolfgang von Goethe

Alles Gescheite ist schon gedacht worden, man muss nur versuchen, es noch einmal zu denken.

In the business environment ideation, though originally related to systematic and structured processes of forming and relating ideas, often includes idea evaluation and, hence, connects evaluation with opportunity. Ideation proceeds as an entirely human-based process, a computer-supported process or even as an (almost) entirely computer-based process [Runge 2006:773-777].

Ideation is an individual level or small group-level (“team”) phenomenon. This conscious and intentional *structural process of idea generation* may include refining or modifying already existing ideas [Runge 2006:769-777].

Ideation on the group-level (“team”) is usually applied in existing large and giant firms as a routine exercise. Such ideation including evaluation may be combined with a “think tank approach,” as observed for ExxonMobile before they entered the algae route to biofuels (A.1.1.4).

Ideation on the individual level, however, is often not entirely individual. Often people have ideas, discuss and assess these with other persons, and not only to refine them, but sometimes also fundamentally modify them. Correspondingly, one may end up in the issue of who is the originator of the final expression of the idea (Box I.9).

The contexts of ideation will generally be found in firms of all sizes:

1. Firm’s foundation and startups
2. Established NTBFs or SMEs (innovation)
3. Existing large firms (innovation).

Fundamentally, ideation is either systematic-analytical or creative-intuitive and is summarized for the most common approaches in Table I.58. Group level approaches are used more often in existing large firms to address new offering (NPD) or new business developments (NBD) than in startups or NTBFs.

Perceived values of various ideation methods for industrial environments are given in Runge [2006:769] with brainstorming (or related meta-plan sessions) and morphological analysis as the most valued approaches.

Whereas systematic-analytical approaches emphasize rational thinking and behavior and require rational arguments to be turned down, creative-intuitive approaches are often associated with feelings and emotions and will encounter more often barriers of ideas. Thinking barriers emerge, for instance, from own psychological inertia restricting ideas and problem-solving to the own discipline or business (cf. the discussions on ideagoras, outsider thinking and Figure I.86).

Table I.58: Involvement levels of persons and approaches to ideation.

	Systematic-Analytical	**Creative-Intuitive**
Individual Level	Brain-Based and Computer-Supported: Problem-Solving Trees, Technological Trajectories, Patent Trees (Invention Trees) Attribute Mappings: Morphological Analysis, Gap Analysis Reverse Engineering Computer-Based: TRIZ (patterns of invention) [Runge 2006:774-776]; Knowledge Discovery in Text Databases (KDT) [Runge 2006:946-947, 962]	Creative Thinking (including combination of technologies, concepts, information, events etc.) Imagination (What can be?) Metaphorical Analogy including Mimicking Nature (e.g. “cleaning” based on the Lotus effect; biomimetics) What-If, challenges and comparisons Why-Not, Why-Only Analysis
Group Level	Design Thinking (ch. 5.1) Ishikawa (Fishbone) Diagrams Pareto Charts	Brainstorming or Meta-Plan session Brainwriting [Runge 2006:769-770]

The *Pareto chart* is a special type of histogram created by a group used to view counting causes of a problem perceived by each individual group member in order of severity from largest to smallest. It is a statistical tool that graphically demonstrates the Pareto principle or the “80:20 rule.”

Brainstorming is a process of *spontaneous thinking* used by an individual, but usually more often by a group of people to generate numerous alternative ideas related to a particular topic or problem. As many ideas as possible are listed before any critical evaluation is performed. For brainstorming usually the group that generates ideas also solicits them. There are many modifications in format, each variation with its own name.

Brainstorming is said to achieve rarely the non-judgmental ideal. Group pressures for uniformity undercut the process, including subtle “idea killing” during the session. Moreover, there are some people who are naturally silent or uncomfortable in a group setting. To overcome such obstacles “brain writing” has been suggested [Runge 2006:768].

A modification of these approaches is Shell's GameChanger™ Approach [Runge 2006:771-773]. GameChanger solicits ideas from any member of Shell's staff as well as from selected universities and other partners. Innovators are rewarded with a variety of remuneration schemes, should their idea become a basis for a commercial venture. GameChanger is also tailor-made for working with external fast-paced entrepreneurs and startup companies. But it is conceived essentially as a way to foster internal entrepreneurial spirit.

The *meta-plan-method* is also a popular and established method to create innovative ideas in a team session as well as to structure and evaluate them. It has some similarity with brainstorming. A meta-plan session (one big "whiteboard") involves interactive discussion facilitated by a moderator and structured to encourage the flow of ideas and information from participants. It is a card technique for collecting ideas (or creativity technique) when a group of people is working together.

"Storyboarding" as another popular technique exhibits close relationships to meta-plan techniques. Meta-plan sessions typically are used when basic directions are set, for instance, when "technology push" innovations are taken into considerations [Runge 2006:770].

In large firms, partially as a result of corporate culture and corporate rigidities, on the group level ideas may be confronted with idea killers (Table I.46) rather than skilled reasoners, who are adept at finding counterexamples to arguments. This does not only occur in firms. "Killing ideas" or suppressing developments of firms by industry incumbents, for instance, can emerge via lobbying or, in case of imports into countries, directly by policy via laws, regulations and tariffs or industry associations by standards.

An example for the role of brainstorming for entrepreneurship is provided by the US startup LS9, Inc. (Table I.99, A.1.1.5) which uses synthetic biology to develop biofuels (gasoline, diesel and jet fuel) from traditional feedstock [Svoboda 2008]. That path began unexpectedly at Codon Devices, Harvard geneticist George Church's rapid-DNA-synthesis company.

Church (a co-founder of LS9) and his lab staff had regular brainstorming sessions in which they liked to muse on out-of-the-box applications for the technology they had developed. This allowed them to redesign the genomes of existing organisms with a few mouse clicks. One day, someone suggested engineering a bacterium that could make fuel, since the lab had just been awarded a Department of Energy grant. The conclusion: "We're dependent on petroleum, so we don't need some alternative to petroleum. We need a way to make petroleum itself." "Biology can do it."

Accordingly, LS9 was staking its prospects not on inventing an entirely new biological pathway, but on exploiting an existing one. Bacteria naturally turn the sugars they consume into fatty acids, which are later converted to lipids for storage. By a stroke of genetic serendipity, fatty acids are only a few molecular linkages removed from Diesel fuel, so it has been fairly simple for LS9 scientists to tweak existing bacteria – including familiar varieties such as *E. coli* – to yield new, Diesel-producing strains. “We divert those fatty acid pathways.” Some sort of brainstorming was also the origin of US startup Sapphire, Inc. (Table I.93) and German SunCoal GmbH (B.2).

Approaches to structured idea generation or structured inventing, respectively, are found since the beginning of Western science and technology in the seventeenth century, notably in Germany.

For instance, Ehrenfried Walther von Tschirnhaus (1651 – 1708) was an eminent German scientist, mathematician, physicist and philosopher who developed the first large burning-mirrors and burning-lenses and, being also a “practical” person. He established the first glass works in the state Saxony (Germany), which was also essential for his mirrors and lenses. He was personally known to many other eminent scientists of that time, such as Christiaan Huygens and Isaac Newton and became a friend of Leibniz (1646–1716). He was also a member of the Paris Academy of Science.

In 1694 Tschirnhaus reported to Leibniz on his idea to produce porcelain to lift the Chinese monopoly for porcelain which was kept as a secret. Tschirnhaus succeeded in finding the components and the way to make porcelain (the “re-invention of porcelain” in Saxony (Germany) in 1708) which was improved and ultimately “scaled-up” by Johann Friedrich Böttger for “large scale manufacturing” (1710).

Tschirnhaus himself wrote “Medicina Mentis” (1687), a philosophical treatise of some influence that contained a methodology of scientific discovery. Prior to that Leibniz presented his “Ars Inveniendi” (“The Art of Invention”) which emphasized, for instance, *combinations* of simple concepts and *metaphors* as a fundamental element for insight and description [Runge:2006:402-405].

The famous German philosopher, scientist, mathematician, diplomat, librarian, and lawyer Gottfried Wilhelm von Leibniz (1646 – 1716) with his personal motto, “theoria cum praxi” was not only the “inventor” of the infinitesimal calculus, coincidently with and independently from Newton, or the dual (0,1) number system, but was also an innovator in the modern sense. Leibniz designed a water pump run by windmills used in Germany to pump water out of mines utilizing wind energy [Runge 2006:345].

The current approach to the “Art of Invention” is the Russian Genrikh Altshuller’s Theory of Inventive Problem Solving (TRIZ, Theoria Resheneyva Isobretatelskehuh Zadach), which is based on computers and databases for a “knowledge base.” TRIZ comprises a set of problem solving and forecasting tools based on the study of the “world’s most inventive patents” and the inventive principles used in them. TRIZ is based on patterns in a patent database and comprises the following findings:

- Definition of inventive problems,
- Levels of invention,
- Patterns of evolution,
- Patterns of invention ("directed evolution").

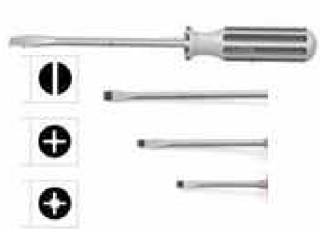
TRIZ is based on an analysis of over 3 million worldwide patents and the history of technological and social evolution, from which approximately 1,000 patterns of invention and more than 500 patterns/lines of technological, market and organizational evolution have been extracted. Related approaches are often promoted currently with the label "*computer-aided innovation*" (CAI), but with marginal success [Runge 2006:669, 774-776].

Attribute maps (or *attribute listings*) relate current attributes of an entity to possible changes of these attributes. Usually the entity is a product, device or material which shall be changed in terms of improvement of attributes (properties, functionality, shape – or image). A hand screwdriver can be used to illustrate the conceptual essentials.

A screwdriver is made up of a head or tip, which engages with a screw, a mechanism to apply torque by rotating the tip (the "twisting" force), and some way to position and support the screwdriver. A typical hand screwdriver comprises an approximately cylindrical handle of a size and shape to be held by a human hand, and an axial shaft fixed to the handle, the tip, which is shaped to fit a particular type of screw. [65] Table I.59 gives a simple example of how to change attributes of a screwdriver.

Table I.59: Simple example of an attribute map for changing design and material of a screwdriver (following Wikipedia).

Attribute	Current States of Attributes	Envisioned States of Attributes
Handle (Shape)	Cylindrical	Polygonal (increasing torque potential)
Handle (Material)	Wood	Plastics, rubber (isolating, protecting from electric shock)
Handle/head arrangement	Handle with fixed head, head with fixed length	Handle with detachable head of variable length (allows a set of one handle and several heads to be used for a variety of screw sizes and types – e.g. for one slot screws or those of cruciforms)

Attribute mapping is a special form of *general morphological analysis* (GMA) [Ritchey 2011] referring in technology in particular to multi-dimensionality of property and performance data of products versus attributes required by the market. GMA is a method for identifying and investigating the total set of possible relationships or “configurations” contained in a given problem complex. In this sense, it is closely related to typology analysis. It is a method for investigating the totality of relationships contained in multi-dimensional, often non-quantifiable problem complexes – capturing the totality of a “problem space.”

The approach begins by identifying and defining the dimensions (or variables) of the problem complex to be investigated, and assigning each of these a range of relevant “values” or conditions, for instance, performance. A morphological box (also known as a “Zwicky box”) is constructed by setting the variables against each other in an n-dimensional parameter space ($n \geq 2$). During the past two decades, GMA has been extended and also computerized to tackle the problems quantitatively or semi-quantitatively.

Morphological analysis, usually attributed to Fritz Zwicky as the originator, was first invented and already used in the Medieval by Raymond Lully (1232-1315) and described in his work “Ars Magna” [Runge 2006:362-363]. It uses two very simple processes based on common principles of creativity: decomposition and forced association. The problem is broken down into component variables and possible values identified for each. The association principle is then brought into play by “banging together” multiple combinations of these values.

Morphological analysis, gap analysis and also combinatorial methods fit particularly thinking of technical people. *Combinatorial principles* of GMA have applications in research and innovation. Combinatorics in general is a branch of mathematics that studies *finite collections of objects that satisfy specified criteria*, and is in particular concerned with “counting” the objects in those collections (*enumerative combinatorics*) and with deciding whether certain “optimal” objects exist (*extremal combinatorics*).

In essence, for ideation morphological analysis is often used in terms of qualitative “*gap analysis*.” In the simplest case two categories of independent and dependent variables are plotted as a table to find out pairs which have not been interconnected so far. These “gaps” (F-C and H-D, left bottom of Figure I.99) then become the focus of interest for further consideration and action.

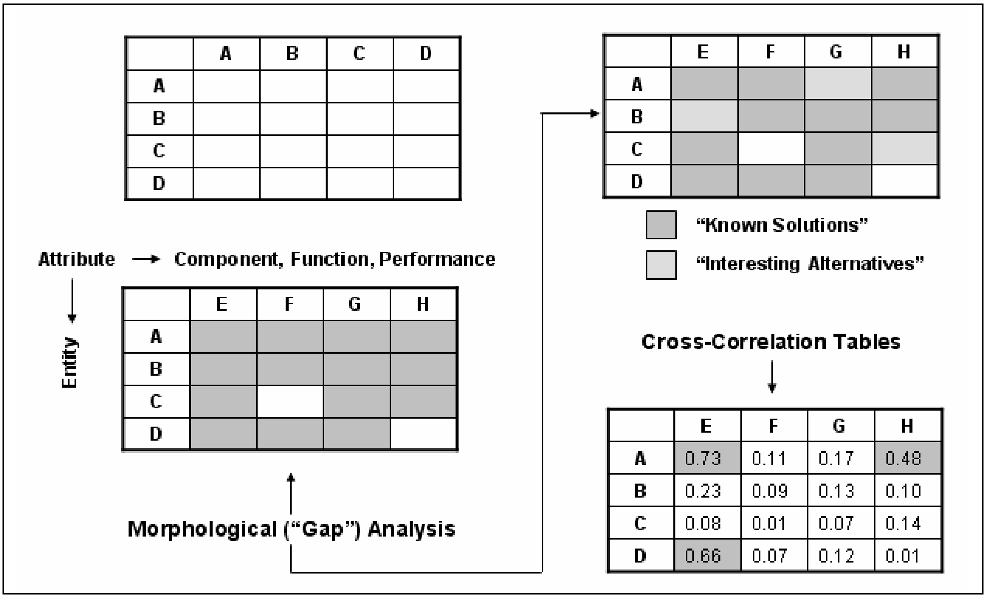


Figure I.99: Morphological analysis – Representations of categories as tables and cross-correlation tables (modified source [Runge 2006:362]).

If the evaluation of the categories’ interconnections are quantified the corresponding arrangement becomes a cross-correlation table where, for instance, particular statistical measures quantify the significance of the interrelationships (Figure I.99; lower right). Reference to this methodology is made when, rather than running as many experiments as possible, one tries to minimize the number of experiments by developing models for correlating structure with performance [Runge 2006:362-363].

Gap analysis may take qualitative and verbalized features. For instance, US-based Genomatica, Inc. (founded in 2000 and focused on new, transformative manufacturing processes that enable partners to produce intermediate and basic chemicals, essentially 1,4-butanediol (BDO)), has produced pound quantities of butadiene made from renewable feedstock (A.1.1.6).

Butadiene is used to make synthetic rubber, engineering polymers, and latex. The company points out that butadiene is commonly derived as a by-product of ethylene cracking. It argues that 1) those operations have increasingly turned to lighter feedstocks derived from cheaper natural gas rather than crude oil and 2) this has resulted in less production of C3 and C4 chemicals (as is butadiene). Genomatica then suggested that a related *“gap” of supply* will cause chemical firms to look for other sources of butadiene – its envisioned product [Bomgardener 2011].

A situation which leads directly to an ideation approach is value appropriation (ch. 1.2.5.1) when intending to take advantage from opportunities of step-stages upwards in the value system (supply chain; Figure I.11). This is an option for large firms as well as for NTBFs, for instance, described by the German NTBF PolyMaterials AG (Note 81, Chem_Entrepreneur_10_13.pdf, p. 30; B.2)

It is important to note that "competitive intelligence" processes provide important paths to ideas (and revealing opportunity). And sophisticated morphological analysis and patent assessments and patent analysis using specifically patent (invention) trees for ideation [Runge 2006:933-970; Runge 2006a] and revealing opportunities are usually done in large firms as these require expertise, time and money which is not available for startups or NTBFs.

3.3.1 More on Principles of Ideation: Technological Paths, Combinations and Transfer

Ideation and revealing related opportunity for (technical) innovation and entrepreneurship may sprout out of some few fundamental concepts of technology development. Technology entrepreneurship occurs often after having perceived a change of a technical or socio-economic technology-related or political situational factor as an opportunity for the creation of innovative offerings. In particular, there are two notable dimensions of technical knowledge to respond to these changes: "cumulativeness" and "proximity."

"*Cumulativeness*" has been referred to the fact that *learning processes* are cumulative, which means they are incremental and existing knowledge is the basis for learning and *further advancements in the area of the current technologies*. "*Knowledge proximity*" reflects that *innovative activities* may sprout out of the technologies innovators are currently involved in, and *over time learning and knowledge generate new knowledge close to the existing one, opening up new opportunities for innovations.*

An empirical analysis cited by Runge [2006:276] tends to support the hypothesis that knowledge proximity is an important factor in the process of technological diversification. Evidence is also presented that most technologically diversified firms are *persistent innovators* and that such persistence in innovative activities often occurs within the same technology because of the cumulativeness of technological knowledge.

Specifically knowledge proximity expresses also that innovation sprouts out of "core competencies." The case of the biofuels industry is a good example for "experience proximity" as management or leadership teams and "production specialists" for new firms are collected from close-by fields, such as biobased chemistry, white biotechnology or the oil industry.

The run for the *Dominant Design* for a particular technology and related offering represents a special field for ideas and opportunities for entrepreneurs related to proximity. Dominant Design on the macro level means that, over time, the number of existing and new firms in the new technology (entrants and exits) can be represented by a bell-shaped curve (Figure I.100). And the technology development for given cases can be described operationally by two phases:

- The *fluid phase,* when there is considerable uncertainty about the technology and its market; firms experiment with different product designs in this phase;
- *After a dominant design* emerges, the *specification phase* begins (when firms focus on incremental improvements to the design and manufacturing efficiency).

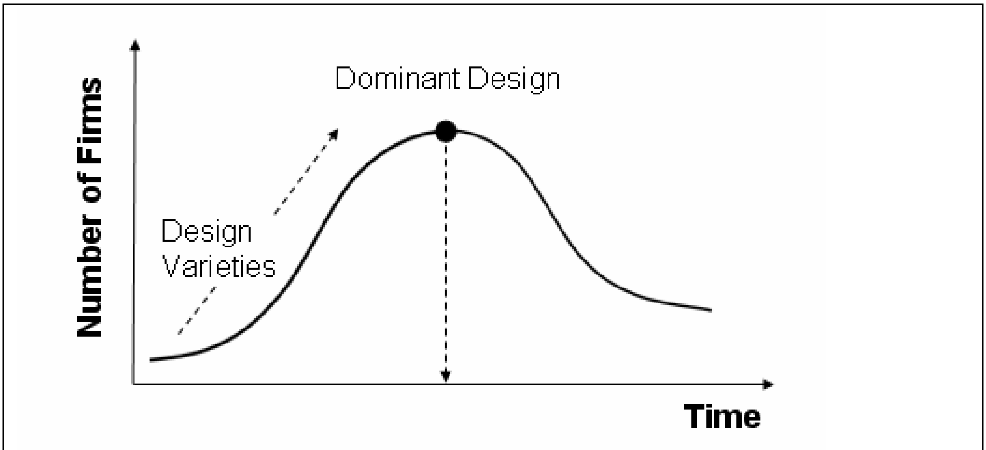


Figure I.100: Striving for Dominant Design.

On the other hand, t**echnology trajectory** [66] refers to *a single branch* in the evolution of a technological design of a product/service, with nodes representing separate designs. Movement along the technology trajectory is associated with research and development. Due to institutionalization and routinization of ideas, markets and professions, a technology development can get “stuck” within one trajectory, and firms and engineers are unable to adopt to ideas and innovation from inside, from their own intrapreneurs, or outside which relates to “core rigidity” (ch. 2.2.1).

The concept of technological trajectories which is associated with the progressive realization of the innovative opportunities of which each is associated with a paradigm can be related to “normal science” (in the sense of Thomas Kuhn’s book “The Structure of Scientific Revolutions”) [Runge 2006:431].

More specifically, trajectories of technical progress [67] are those paths which contribute to shape *the direction in which problem-solving activities move and which possess a momentum of their own*. A trajectory represents the “normal” problem-solving activity determined by a paradigm.

The concept of trajectories and paradigms underline that idea generation is often close to ideation using heuristics that include both means and ends. For a complex system's perspective, a paradigm provides *both* guidelines concerning 1) what system's elements should be the object of search and what objects should be left unchanged *and* 2) guidelines concerning the functions to be improved or changed and to be sacrificed.

A *technological paradigm* is associated with the elements that remain fixed over prolonged periods of time, thus reducing the relevant design space and guiding the search in the remaining design dimensions. In other words, a technological trajectory is made up of a series of innovation that follow in the remaining design dimension that unfolds over time within the boundaries of a technological paradigm.

Technology trajectories can often be tracked by "patent maps and trees" as a method of technology intelligence [Runge 2006:933-970; Runge 2006a]. Furthermore, as a consequence of the technological trajectory concept one should be able to observe regularities and find invariance in the pattern of technical change, which hold under different market conditions. Finally, having identified regularities and invariance within a trajectory allows extrapolating ("predicting") its further development – and to be grasped business ideas.

> Technology often has a built-in *reflexivity* (Preface). Technical change is partly driven by repeated attempts to cope with technological imbalances which it itself creates.

As a framework for describing, interpreting and confirming views of parts of the world the related paradigm of technology focuses on some key questions, starting with the kind of questions that are supposed to be asked and probed for answers in relation to this subject.

- What is to be observed and scrutinized?
- How are these questions to be structured?
- How should the results of scientific investigations be interpreted?
- How is an experiment to be conducted, and what equipment is available to conduct the experiment?

Many consistent patterns have been observed in technology trajectories, helping to understand how technologies improve and are diffused. However, for future developments technology trajectories are usually considered within a given application or a specific adopter domain (customer group).

Specifically disruptive or discontinuous "branching" rather than continuous and incremental development may occur if the technology finds new applications or other adopters. Here, in particular, the "*transfer*" from industrial or professional customers to the (mass market of) consumers is outstanding.

Prototypical examples are the automobiles associated with their use by professional users (ch. 1.2.5.1, Figure I.30) or computers or printing or copying at home. And, the Internet was originally designed during the Cold War in part to provide a technical communication network that would work even if some of the sites were destroyed by nuclear attack. The early Internet was used by computer experts, engineers, scientists, and librarians – professional users.

Often a transition of the technology to address other kinds of users or applications, respectively, is not imagined even by technology experts:

> "I think there is a market for about five computers."
> Thomas Watson, Sr. Founder of IBM, 1943
>
> Computers in the future may weigh no more than 1.5 tons.
> Popular Mechanics, forecasting the relentless march of science, 1949
>
> "There is no reason anyone would want a computer in their home."
> Ken Olsen, President and Founder of Digital Equipment Corp. (VAX Computers, 1977
>
> "640k ought to be enough for anybody."
> Attributed to Bill Gates in 1981.

People cannot imagine the future correctly as the "wrong" answer made sense at the particular time. For instance, Watson could not have known about:

- Miniaturization
- Falling costs of computer components
- Requirements for much larger main memory for new applications and modes of usage
- Simpler computer usage; user friendly, graphical user interfaces, computer usage by "laymen" (consumers)
- Networking
- The Internet.

The Internet as an enabling and generic technology has unleashed a wave of innovation. Along with the personal computer, it is perhaps the biggest disruptive technology that we have seen in our generation giving rise to myriad other discontinuous and disruptive innovations.

Disruptive technologies, allowing the introduction of completely new offerings for new applications and approaches that have the potential to create a new market or new industry or transform an existing one, work by offerings, at least initially, little in the way of performance, but plenty in terms of cheapness, convenience and ease of use. As such, they may appeal to a different class of customers, carving out new markets for themselves before going on to have the industrial Goliaths' business for lunch.

In the current context t*ransfer* can also be related to *automation* – from a manual process to a technology-based process. For instance, the normal paper-based and telephone/fax-based office work is transferred to I&CT-supported processes ("office automation").

In research and production an originally manual process is replaced by a new technology (Nanion Technologies GmbH; B.2) or an originally manual feeding and visual quality control process in production is replaced by special placement or feeding (in German “Sonderbestückung”) using inspection technologies (industrial image processing) and robotics to sort out faulty pieces (ATMgroup GmbH; B.2). Automation means improving or replacing existing processes and this implies the existence of related customers and markets.

Furthermore, transfer may also mean “squeezing” applications from the old level into the new one. An example was the transfer of the database “Mainframe Focus” to “PC Focus,” from the professional users in corporate Data Processing Departments to “power users” in the R&D Department [Runge 2006:341].

Combination, “What If” and Transfer

As NTBFs are to a large extent founded by people with higher education, particularly scientists and engineers, ideaton approaches are largely pre-formed by the discipline-related educations, related ways of thinking and tackling problems and the science and engineering cultures.

The “new idea” generation activity in terms of ideation in technology areas for a problem at hand is often associated with

- Generalizations or specializations, modifications and connection points between old and new technologies,
- “Borrowing” from other fields (analogies, metaphors, associations),
- Combining or re-examining and “recycling” old ideas, facts, concepts and developments or experiments which means intense information search processes,
- Reversing arrangements, designs or shapes or switching to “polar” arrangements (horizontal to vertical or for biotechnology polarity between aerobic and anaerobic processes – with or without interference of oxygen);
- Transferring known solutions to new applications, which is revealing the generics of problems.

Figure I.101, for instance, provides (for Germany) an overview for different technology areas about the origin of products of new firms contributing most to their sales. Here it is seen that a proven *combination* of existing technologies account for roughly one third to the offerings and new combination of existing technologies for about one fourth for top and high value technologies (Table I.1).

Utilizing new technologies from third parties will mostly refer to acquisition of IPRs, often from universities and public research institutions. It is not surprising that technology-based services stand out for using new combinations of existing technologies.

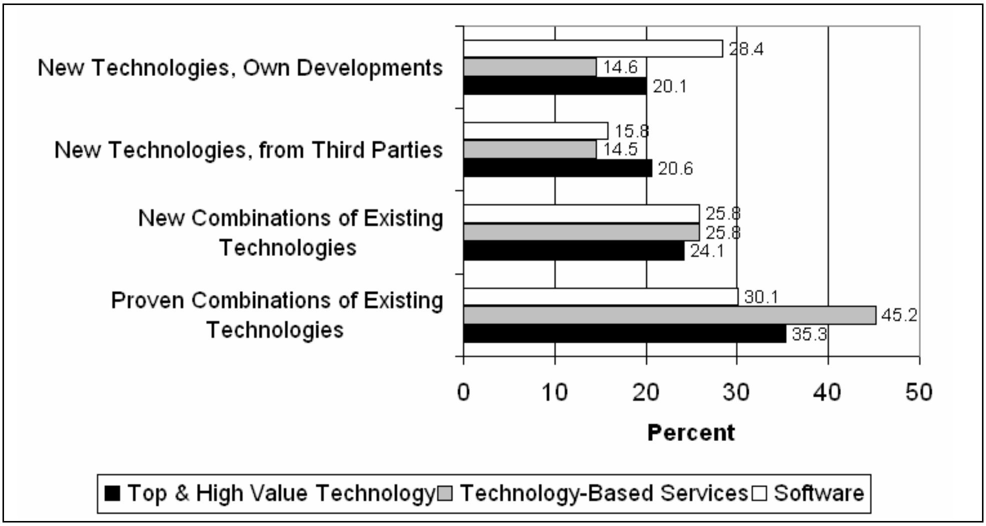


Figure I.101: Origins of products of new firms in Germany contributing most to the sales in 2007 in high-tech areas (from a 2005-2007 sample) [Creditreform - KfW - ZEW 2009].

Figure I.102 depicts the situation of origins for firms' foundation based on processes in relation to the size of the NTBFs. For both cases of "combination of established processe" and referring to existing parts or technologies using "components of the shelf" (COTS) represents an important principle to minimize component costs and development time.

COTS is an approach widely followed in the biofuels field (A.1.1), but also found for many entrepreneurial firms, such as German ATMgroup AG (B.2), Torqeedo GmbH (B.2) or MineWolf AG (B.2).

On the highest level combinations of industrial domains occur, for instance, seen for chemistry plus biotechnology ("white biotechnology"; A.1.1) or nutrition or cosmetics with pharmaceuticals (nutraceuticals, cosmeceuticals; Figure I.91)

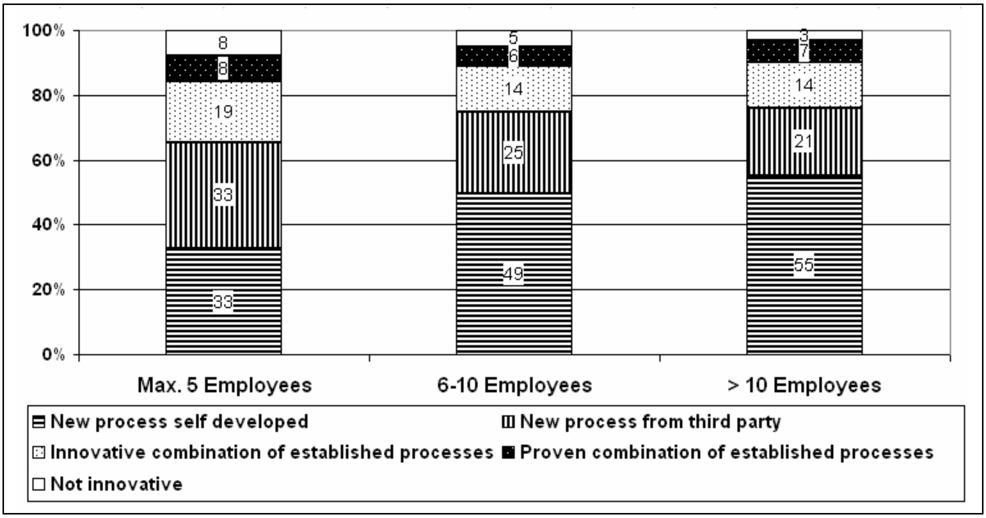


Figure I.102: Origins of processes of new firms in Germany in high-tech areas differ-rentiated by number of employees (from a 1996-2005 sample) [Niefert et al. 2006].

Lower level combinations refer to technology, functions, products, materials, instruments, devices, components or processes. Some examples from chemistry and physics for innovation or entrepreneurship include the following ones.

- Pressure sensitive adhesives (PSAs) are prepared usually by emulsion polymerization. The reaction requires surface active substances (surfactants) which can increase the kinetic stability of emulsions so that the emulsion does not change significantly over time. For polymerization the reaction requires additionally a so-called crosslinker.
  Surfactant and crosslinker are two separate kinds of chemical. A recent innovation for PSA involves a "surfmer," (one chemical combining the functions of a surfactant and a crosslinker for polymerization).
- Having two functions in one product can be observed for a coatings formulation giving simultaneously scratch resistance and anti-bacterial properties of the surface or one scientific instrument combining a near-field optical, confocal and an atomic force microscope (WITec GmbH, Table I.80 – B.2).
- A membrane reactor combines a chemical reaction facility and a membrane separation process of chemical products. Correspondingly, reactive distillation means chemical reaction plus product purification and/or by-product separation.

- Reactive extrusion means a polymer processing technique that mainly involves the use of an extruder as a chemical reactor. Polymerization and other chemical reactions associated with polymers are carried out *in situ*, while processing is in progress. "Old" polymer manufacturing methods run synthesis as a separate operation and the extruder serves only as a processing aid.
- For biofuels originally individually used thermochemical processes and bioengineering processes are combined to "hybrid" processes taking the best of both (Table I.88, Figure I.175).
- Approaches to renewable energy refer, for instance, to wind and water (hydropower). The combination of both is sea wave energy, waves generated by wind and complemented by tidal waves. In the UK the startup Pelamis Wave Energy Ltd. uses movable parts to generate electricity by waves. Power is generated in the hinged joints that connect the cylindrical tube sections of "huge sea snakes" in the water.

For the context of combination as an ideation principle **architectural innovation** is notable. It means changing the way in which the components of a product are linked together, while leaving the core design concepts and thus the basic knowledge underlying the components untouched (cf. Skystream wind turbine for a home or small business in Table I.60). However, often originally targeted architectural innovations require changes in the underlying components also.

Connections points combining old and new technologies have been introduced as transition phases of technology developments with hybrid constellations covering old and new technologies and are characterized as the "*Sailing Ship Effect*" (Figure I.85). The related effect was illustrated for hybrid cars from around 1900 with "combustion engines" and electromotors (Box I.10). With regard to the current situation of reducing carbon dioxide emission and reducing oil consumption and thus saving fuel costs recent entrepreneurship and intrapreneurship focused on opportunity and ideation *reversing* two branches of *the sailing ship trajectory*:

> Sailing ship – *hybrid: sailing/steam ship*; steam ship – diesel engine ship – *hybrid*: engine/sailing ship or Flettner wind rotor ship (Figure I.103).

Representatives are the NTBF SkySails (B.2) and Enercon GmbH, a German €3.4 billion sales (in 2009) manufacturer of wind turbines founded in 1984 (Box I.7, Figure I.150, Figure I.151). Enercon is one of the ten firms leading the global market of wind turbines and having ca. 8.4 percent global market share in 2012. It is a German Hidden Champion (ch. 4.1.1). Both, the SkySails and the E-Ship approach represent generic hybrid technologies to propel large vessels on the basis of wind power and Diesel combustion engines.

The technological essence of the Flettner wind rotors for driving ships has been recently *transferred to other wind-related applications* which simultaneously *address* *another class of customers*, particularly “personal wind turbines” for consumers [Galbraith 2008] – as a further alternative to windmill approaches given in Table I.60.

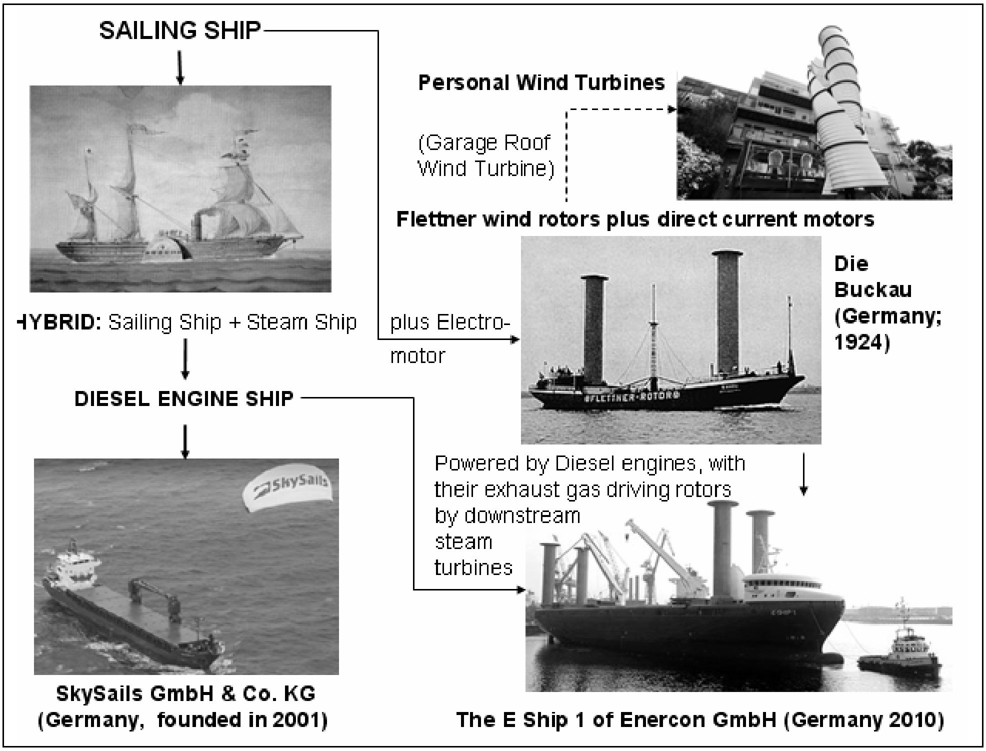


Figure I.103: The “Sailing Ship Effect” reversed – ships with hybrid propulsion power.

Recycling of ideas often means replicating historical ideas and approaches and adapting those to the state-of-the-art technology in the sense of a technological trajectory (for instance, electric vehicles, Box I.10; biofuels via syngas, A.1.1.4; photovoltaic solar energy [Ingersoll et al. 1998; Perlin 2003]). For entrepreneurship and intrapreneurship in the biofuels industry not only massive “recycling” of old ideas occur but also ideation in terms of combining long existing thermochemical processes and new bioengineering processes based on biotechnology.

The classical example of *transfer of knowledge from one field to another one* is the printing machine. Johannes Gutenberg transformed his knowledge of wine presses into a printing machine capable of mass-producing words and texts.

Transfering known solutions from one technical field to another one is found currently, for instance, when Quiet Revolution Ltd. from the UK looked for an approach to “private wind turbines” or related windmills, respectively (Table I.60). The envisioned opportunity was tapping into new customers, private and professional usage of small scale wind turbines to generate electricity (for home use and feed into grids) and commercial applications in urban sites and exposed locations.

A large options set of technical solutions for power generation through wind power in terms of turbines and rotors resulted largely from the intense scientific and technical efforts in aerodynamics initiated by the emerging airplane and aircraft industry in the 1920s and 1930s.

For such a technology the corresponding windmill-type, Horizontal Axis Wind Turbine (HAWT), has emerged with various designs (Table I.60) which can rely on experimental developments for more than a century. The transfer of (on-shelf and off-shelf) wind power from big industrial wind turbines with steadily blowing wind to private and other small scale use, however, is not only an issue of making things smaller, but has to consider quite different environment effects.

The fundamental question for private wind turbines, however, is not competition with various HAWT designs, but competition with other “end-user” oriented generic technologies for “private electricity.” This means, private wind turbines would target places with too little sunshine to allow local (standalone) power generation via photovoltaic (PV; solar cells) or solar thermal technologies. Furthermore, there should be enough wind energy in the urban environment, but *no appropriate product for local energy on the market*, which can make most use of the environment where wind speeds are lower and wind directions change frequently.

In search for a corresponding solution the UK startup Quiet Revolution could rely on developments between 1920 and 2008 [Erneuerbare Energien] focusing on basically *“polar” designs* which is *Vertical* Axis Wind Turbines (VAWTs) or rotors as shown in Table I.60 rather than *Horizontal* Axis Wind Turbines.

In the end the entrepreneurs found a solution that was to be modified only slightly, the Darrieus-Rotor of the French inventor and aerospace engineer Georges Jean Marie Darrieus (1888-1979) who was granted a related French patent in 1927 and a US patent in 1931.

Quiet Revolution modified the Darieus design by swung blades. Key aspects apart from those mentioned in Table I.60 for Quiet Revolution were that its VAWT produces 20-40 percent more energy than HAWT of comparable magnitude in a turbulent urban environment and clients should include major retailers, developers, government departments, schools and universities.

Table I.60: Selected technical options to provide small scale wind turbines by "recycling" of old ideas (from Pure Energy Systems (PES) Network [Pure Energey] and Web sites of mentioned firms).

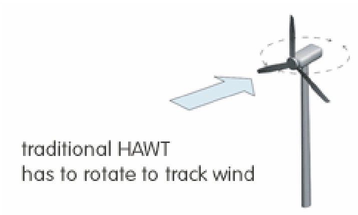
Horizontal Axis Wind Turbine (HAWT) **The Prototype since Ages: The Windmill** 		**Make it *smaller* – and what else?**
(US) Southwest Windpower's Skystream 3.7™ connects directly to the home to supply power. With a built-in inverter and no battery required, it is designed specifically for the grid-connected residential market, for a home or small business		
"Swift" micro-turbine from the Renewable Devices Group (UK) won the "Ashden Award for Sustainable Energy" in the energy generation category. Novel: it is specifically designed to reduce the noise and potentially building-damaging vibrations that come from older small rooftop wind turbine designs.		
"der wind wandler" – wind converter from MatroW GmbH (Germany). The special shape of the spiral wings allows a strong reduction in stream loss. This wind machine can deal with high rotation speeds. Different wind directions are no problem because it automatically turns into the wind. Max output of 3.5KW		

Table I.60, continued.

<table>
<tr>
<td>Vertical Axis Wind Turbine (VAWT)

</td>
<td>Vertical axis turbines have several advantages over the typical horizontal axis turbines. Generator can be on the ground for easier access, rather than up in the air. Generally begin rotating at lower speeds and are quieter. Lower susceptibility to cross-winds.</td>
</tr>
<tr>
<td>Quiet Revolution Ltd. (B.2): Virtually silent and vibration free, design is suited to both urban sites and exposed locations. The simple and robust design has just one moving part, maximizing reliability and minimizing maintenance requirements.</td>
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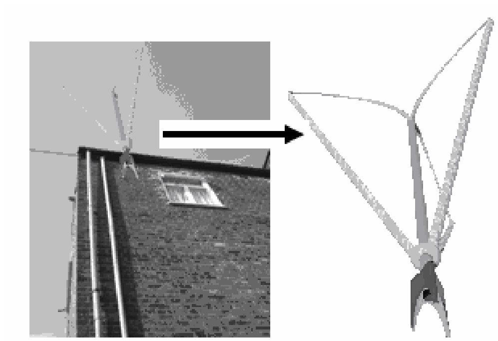
<tr>
<td>Ben Storan, a student graduating with an MA in Industrial Design Engineering from the Royal College of Art (RCA), has been working in conjunction with Imperial College to design an affordable personal wind turbine suited to the urban environment.

It uses lightweight materials, which means the turbine is more stable than other personal turbines leading to better energy capture and making it is easier to install; won top prize at the BSI Sustainability Design Awards 2007 *).</td>
<td></td>
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*) The British Standards Institution: BSI Group has grown into a leading global independent business services organization providing standard-based solutions in more than 140 countries.

VAWTs have a remarkable history. For instance, after the oil price crisis in 1979/80 and 1980 recession the German Ministry of Research and Technology (now BMWi) supported the development of a converter with plane blades (called Vavian-A). And in 1984/1985 about 20 percent of all newly built wind turbines in Germany were designed as Darrieus-systems. Similarly, there were a lot of efforts with governmental support of R&D of power generation by wind in the US [Erneuerbare Energien]. One of the outstanding firm's foundations in Germany at that time was the wind turbine firm Enercon GmbH (Figure I.103, Figure I.150, Figure I.151).

Another example of ideation for entrepreneurship and firm's foundation referring to polar thinking is to invert the physical effect of (naturally observed) osmosis in membrane environments as are found in cells to "reverse osmosis" (RO) for water treatment and particularly desalination of sea water [Runge 2006:81, 88-96].

The HAWT versus VAWT (polar) dichotomy is a special case of a more general ideation or problem-solving approach in technology entrepreneurship or innovation, respectively. Ideation based on polarity is also possible for processes. For instance, if for chemical reactions an approach useful for homogenous catalysis is transferred appropriately to heterogeneous catalysis.

"*Polar thinking*" represents a standard creativity inducing thinking process responding to a *"What If" question* when one envisions possible consequences of changing a given design of a device, technical process parameters or activities, properties of materials, etc. Here it means envisioning reversed arrangements, designs or shapes or switching to "polar" arrangements (horizontal to vertical).

Direct confrontation with a technical entity, a product, device, machine, tool, process, etc. and insight into its structure and function including *reverse engineering* may lead almost instantaneously to an idea and subsequently evaluation of a related opportunity and entrepreneurship.

The to-be entrepreneur or innovator proceeds directly to *exploiting* the given (known) opportunity based on a particular personal conviction, intention and decision reflected by an "antagonistic attitude" in terms of "I can do that better, cheaper, simpler, more specific, … differently (substitutive), …also (me-too)." This means, for the opportunity there is a knowledge base that can be accessed and used and a market as the basis for the decision to found a firm (Torqeedo GmbH, Gameforge AG – B.2).

A "comparative antagonistic opportunity exploitation" (better, cheaper etc.) is often observed in the science/technology area when a person or group leaves an existing (NTBF or large) firm to start his/her own firm or business (Figure I.20 Figure I.41) in the same domain ("start-over entrepreneurs" (Figure I.64); IoLiTec (A.1.5), Q-Cells (Figure I.152, Figure I.153), AgraQuest [Dorf and Byers 2007] to Marrone Bio Innovations, etc.) or through an MBO (AluPlast GmbH – B.2).

The implication for such an approach is that the involved person(s) feel they have enough *knowledge and experience* to take the risk of their "adventure" (ch. 2.1.2.4); they have an envisioned future of capturing competitive advantage.

A typical current thinking and approach to photovoltaic (solar cells) is to make it more efficient and cheaper: This can be achieved via lowering production cost, but also by using a different technology for the products.

For instance, US firm First Solar (Figure I.154) delivers cadmium telluride (CdTe) thin-film solar cells by coating glass with CdTe (Figure I.11). Its production costs are as low as other thin-film based techniques, but its electrical efficiency is close to the higher yields achieved using polycrystalline silicon cells (Figure I.12). In this way a ca. "40 cents-per-watt installed cost-per-watt advantage" could be achieved in relation to all kinds of silicon solar cells. The basic idea for the technology was: *treat the actual solar cell as simply a different kind of coating on glass* (ch. 4.3.5.2).

In a similar line ideation may be also associated with problem-solving related directly to large challenges or big or very risky problems, for instance,

- Lifting a monopoly (Box I.11)
- Achieve the "Holy Grail" of an industry.

"*What-If*" questions challenging creative thinking usually refer to a starting situation, device, material, etc. and inquire into comparisons with an anticipated situation which is structurally related to attribute mapping. Typical questions include:

What if:

- It is longer or smaller, purer, has higher quality (Heppe Medical Chitosan GmbH, B.2), thinner, lighter, faster, a different material;
- It is simpler, easier (for instance, making life of housewives easier – German Henkel 1878 [Runge 2006:473-474] – taking photos by consumers – Kodak 1888 [Runge 2006:470-473]),
- It does not require an infrastructure, make it independent from infrastructure and more flexible, for instance, lift dependence on railways by the steam buses (Figure I.84) or dependence on dedicated devices for computer games (German Gameforge; B.2)
- It is not, it does not; it does not require, etc.

Combination as an expression of ideation does not only occur on the industry or product/material, process, etc. level but also on the plant level. An extreme combination of almost all types of renewable energy has been started in Germany by Enertrag AG. The New Business Development of the engineering firm which is successful in the wind energy business (1993 first wind turbine plant; in 2010 ca.400 employees, €250 million revenues) claimed in 2009 to build the first *hydrogen wind biogas CleanTech hybrid power plant* in the world (Figure I.104).

It is a €21 million project, supported by the federal and state governments with €3.8 million and a recent participation of TOTAL Deutschland GmbH, a subsidiary of the French oil giant Total SA, and the Swedish utilities (power) company Vattenfall (dominating North and Middle Germany) through Vattenfall Europe Innovation GmbH each contributing €0.5 million for R&D. Enertrag strives for a competitive advantage being first to market with such a product.

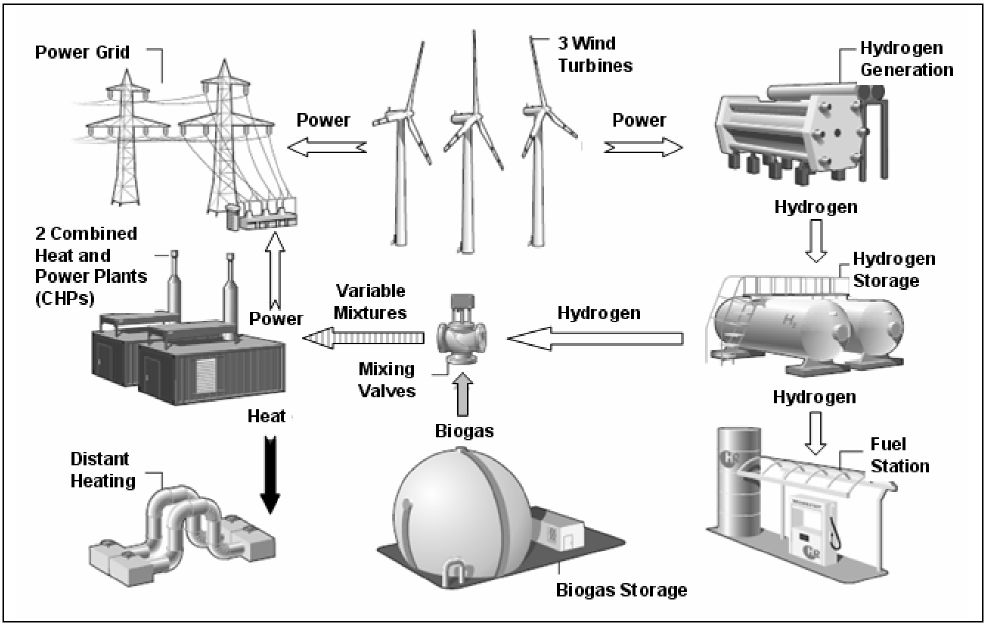


Figure I.104: The Enertrag AG hybrid power plant combining wind, hydrogen and biogas (Courtesy of Enertrag AG (translated)). [68]

The combined components of the hybrid power plant comprise

1. A grid-connected wind turbine system
2. A hydrogen generator (based on electrolysis of water; cooperation with German specialist ELT GmbH) with an associated hydrogen storage facility
3. A biogas reactor with storage facility
4. A compressor to mix appropriately hydrogen and biogas and to feed
5. Two combined heat and power plants (CHPs; in German Blockheizkraftwerk – BHKW) which may either deliver heat for a distant heat system or electrical power to be fed ultimately into Vattenfall's power grid.

If there is strong wind the generated wind power will be utilized primarily to generate and store hydrogen and secondarily to feed not needed wind power into the grid. If there is low or no wind hydrogen will be mixed with biogas, the mixture being used by two CHPs to generate electrical power (for the grid) or heat for distant heating. Furthermore, there is a monthly fixed amount of hydrogen provided to TOTAL to run a hydrogen fuel station at the new Berlin International Airport for hydrogen fuel cell cars.

In essence Enertrag's energy system approach targets the opportunity derived from the issue of storing energy which often is created irregularly when generated from wind turbines. This means, it targets the problem if abundant energy is generated, but currently not needed. Instead of energy storage by a dedicated technical device, apparatus or other unit it simply converts it into a form of the energy which can be stored through a convenient way and make it usable when needed.

For engineering projects, in particular, plant construction, the major emphasis is on fields of activities which are usually provided by different specialized firms which have different kinds of personnel with different educations and skills. An issue is the *interface between the various activities*. Often this represents an opportunity if several of these steps can be offered as one solution, which means becoming a specialist for managing the interface. Related activities will include

- Planning,
- Technology development,
- Financing,
- Plant construction,
- Services for plant management.

For instance, the German engineering firms PURPLAN GmbH (Box I.21) and Enertrag AG (Figure I.104), the last one focusing particularly through its ENERTRAG Structured Finance AG on the financing interface, represent examples for such an approach.

The most recent complex example of combination is the “smartphone” which provides functions of a personal digital assistant (PDA) and a mobile phone. One actually observes technology trajectories and convergence of various technologies towards a pocket handheld information (Web search and newsfeed; e-mail, calendar, etc.) and communication device (Figure I.105).

It typically also serves as a portable media player and, through various apps, can also be used for online games and GPS and other navigation.

Apart from combining and integrating the various technologies into the mobility device adoption of such a device depends on an appropriate *user interface*, such as a high-resolution touchscreen, which presents an additional aspect of convergence opening opportunities with smartphones on the basis of 3rd-party apps (ch. 3.4.1). Smartphones add a multi-touch interface and may be designed entirely around security, encryption and identity protection.

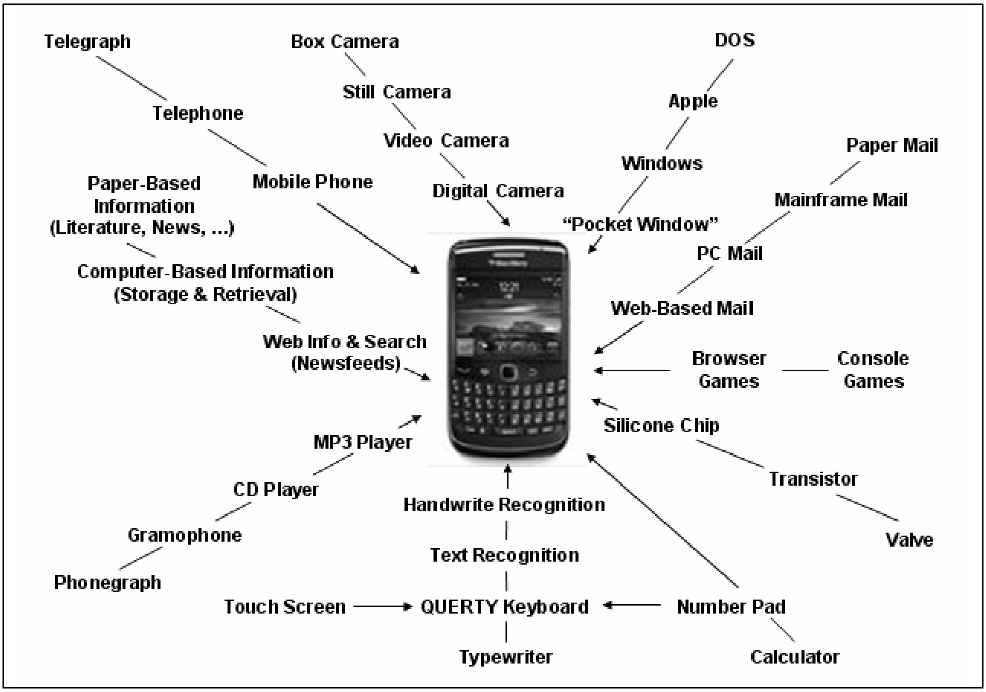


Figure I.105: Technology trajectories and technology convergence targeting mobility (additions to and modifications of Luxshan [2009]).

So far, ideation based on *transfer* for technical innovation or entrepreneurship tackled products or product material, technology or problem solutions from one field to a different one or new target field (another application), a different adopter or customer type and/or a different point-of-use, for instance,

- From one target substrate to another one:
  coatings material – from paper to temperature-sensitive plastics or from glass to metal
- From one customer segment to another one:
  industrial/professional office to home; printer, copier; mainframe computer to personal computer (Mainframe/PC Focus); from industrial wind farms to wind turbines of private and professional users (Table I.60)
- From one device to a different one:
  E-Mail/Web search from PC to mobile phone,
  Computer games from the dedicated standalone console to a general ubiquitous system (PC/Internet/Browser),
  dedicated program/application on standalone PC to ASP (Application Service Provision) Web services

- From one scientific/technical field to another one:
  aerodynamics from airplane building to wind turbines (Table I.60) and rotors and ship propulsion (Figure I.103)
- From one application environment to another one:
  solar cells from space to earth [Perlin 2003], industrial wind farms to private wind turbines (Table I.60),
  from animal use to human use.

There are two recent notable engineering examples using "transfer" concepts for entrepreneurship. One refers to the change of basic construction material for a product of the German startup TimberTower GmbH. TimberTower, officially founded in 2008, has changed the construction material of the tower of industrial- and small level wind turbines of up to 160 meter height which generally use steel or concrete to wood. The tower of wind turbines accounts for 60-70 percent of the cost of wind turbines.

The firm's foundation was based on combining knowledge of wind turbine construction with modern timber construction. A wooden tower is more stable than one made out of steel and achieves durability and resistance to environmental effects by appropriate coatings!

The patent-protected technology of the alternative tower concept refers to the obvious advantages offered by wood. The *manufacturing costs* of the timber tower are significantly lower than those of steel alternatives. The *construction method* for the TimberTower *simplifies transport logistics*, and the timber variant boasts a *better CO2 balance* than the common steel tower, which is an important ecological factor for the future.

Similar to the shift of industrial wind farms one also observes the transfer of combined heat and power plants (CHPs) from industrial customers to private and professional customers (Mini-CHP or Micro-CHP), for residential use or for hotels or public institutions. CHP systems are extremely efficient, offering combined heat and power generating efficiency of about 90 percent, compared to about 30 to 40 percent for electricity from a central power station.

In Germany, SenerTec Kraft-Wärme-Energiesysteme GmbH based in Schweinfurt, Germany, founded in 1996 as a spin-off of the company Fichtel & Sachs, manufactures the "Dachs," a small-scale combined heat and power (CHP) unit. The Dachs model successfully penetrated the German market, allowing SenerTec to develop a distribution network with 30 SenerTec Centers and 350 Partners throughout Germany. Since then SenerTec has grown to 135 employees (sales in 2009: ca. €45.5 million).

Currently, there are many suppliers of small-scale CHPs in Germany. However, SenerTec's Dachs is assumed to be the best-selling small-scale CHP in Europe (more than 20,000 Dachs CHP units sold). All of them can take advantage of the German Renewable Energy Act (Box I.22). As grid-connected ground or large roof mounted solar power plants in Germany and other European Union countries also owners of grid-connected CHPs get feed-in tariff subsidies that enable them to earn a reasonable rate of return on their invested capital.

> Generally, when a number of categories or factors changed and can be interrelated or combined and focused on a need an opportunity occurs.

A business idea generated by transfer to another customer segment is not restricted to goods (products, apparatuses, devices etc.), but includes also methods and processes. An example how a concept and the related processes is transferred from the industrial user to the private consumer level is Reid Hoffman's LinkedIn founded in 2002 (Hoffman as a co-founder) and Lars Hinrichs's Xing founded in Germany in 2003 (ch. 3.4.2).

After corporate Intranets were established at the end of the 20th century, referring to knowledge management often in terms of a "yellow pages" (directory) approach, large firms set up various networking constellations to *interconnect their professionals* ("connect people") to allow individuals to find and access other employees' professional technical and business knowledge and experience or to find potential co-workers for projects [Runge 2006:835-840]. This is conceptually essentially what LinkedIn in the US and Xing in Germany (ch. 3.4.2) are doing now on the Internet: They created *business-oriented online social networks for professionals* (ch. 3.4.2.1).

And also Facebook (Box I.9) has similar origins starting with the focus on US campuses and then reaching out to the public on the Internet (Box I.15).

3.3.2 The Fuzzy Front-End of Ideas

Idea generation and ideation usually provide a large number of potential innovations or options for technology entrepreneurship, full of opportunities and risk, the so-called fuzzy front-end (FFE). Numerous ill-defined ideas populate the FFE. There are technologies that have numerous potential, but unproven applications. At the same time, there are numerous and ambiguously stated customer requests. Ideation is often separated from the fuzzy front-end [Runge 2006:609], Figure I.79). In particular, the outcome of a brain storming session corresponds structurally to FFE.

For large firms with numerous group interactions the portion of the innovation process or new product development cycle between when work on a new idea could start and when it actually starts – the FFE – is often lengthy and typically poorly understood, but usually full of opportunities for improvement. FFE is a notoriously difficult process and it can be tricky to generate projects with sufficient size to make a difference to the organization [Runge 2006:449,608,790,791

Idea generation is a pre-project stage of innovation which enters into the fuzzy front-end (FFE). "Hype" is common in the FFE. In reality the FFE is non-linear. It requires leaps of creativity and divergence, or "branching" from the starting point ideas. In short, it requires non-linear thinking and creativity is needed because starting ideas are almost never profitable.

Activities making up the fuzzy front-end (FFE) are extremely important because their results enter into the subsequent stages of an innovation process whose stages may be formalized to any degree (Figure I.79). FFE may extend into “concept shaping” which may include early experimentation. Some crucial decisions are made during this period regarding the size of the market opportunity, the target customer(s), alignment with corporate strategy and availability of key technologies and resources. An organized “idea review” process may interrelate and cluster ideas to pass them over into a “concept shaping evaluation process.

In the context of a staged innovation process the principal goal in the FFE is to reduce the sheer number of envisioned projects to be worked on by applying a “rigorous” internal screening process. One important aspect for managing the FFE is the evidence that the idea selection process proceeds further with “good” and “bad” ideas, and it will also reject “good” ideas sometimes simply as a result of inappropriate timing. Consequently, in relation to ideation and the FFE it makes sense to archive all ideas (in a database), as 3M does (ch. 3.1), and also document the reasons why they were rejected [Runge 2006:791].

According to the innovation funnel model one has to generate a lot of great ideas to flood the portfolio; and then work quickly through them. As a rule of thumb, the probability of successful chemical offerings reaching the market is 5 – 10 per 1,000 (0.5 – 1 percent). But also across industries this can be paraphrased adapted to the well known fairy-tale “The Frog Prince” to R&D projects (ch. 2.2) and cited by Runge [2006:652]:

> “R&D has the task to kiss 100 frogs in order to get 1 prince!”

Similarly, for venture capital it is found that out of 100 business plans coming in, after extensive due diligence, only one gets funded (Figure I.106).

A situation comparable to FFE is found for (technology) entrepreneurship. For instance, In 2007 about 500 small-company business plans came through the door at BASF Venture Capital, the investment arm of the German chemical giant for corporate venturing. After an initial screening, company analysts rejected three-quarters of the plans. BASF then carried out in-depth reviews of less than half of those left and eventually negotiated deals with just a few companies [Thayer 2008].

A similar distribution was found concerning funding by the German investment fonds “High-Tech Gründerfonds” (HTGF) representing external corporate venturing (ch. 1.2.7.3). In 2012 the HTGF received 1,100 applications for funding. However, only 43 applicants got funding [Zbikowski and Brandkamp 2013].

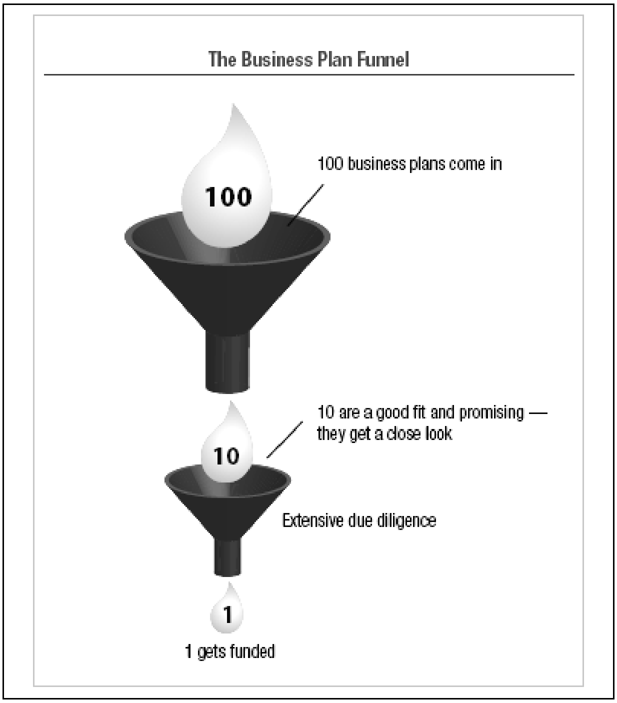


Figure I.106: The business plan funnel – the proportion of business plans getting funded. (Source: National Venture Capital Association [NVCA]).

3.4 Specifics for Software Firms and Technology-Based Services

Technology entrepreneurship in the areas of software, particularly the Internet, addresses essentially economic markets (Table I.15). When dealing with entrepreneurship in high-tech fields these areas are currently a major focus of attention.

We differentiate software for

- *Open* human-activity (man-machine) systems and
- *Closed* systems to *support technical systems* in the industrial and manufacturing sectors, for instance, process control in plants or data processing and control of industrial/scientific instruments, devices etc., image processing, high throughput screening (HTS), simulation and data post-processing in terms of statistical computations and visualization.

Software for technical systems often focuses on number crunching as observed for cheminformatics (hte AG – B.2) or bioinformatics (CeGaT GmbH – B.2). The support of organizational processes by software/databases in the research and innovation areas touches ideation (TRIZ, ch. 3.3) or support of staged innovation processes (Figure I.79), for instance, by the Sopheon software [Runge 2006:365]. In particular, there is business intelligence and related Knowledge Discovery in Databases (KDD; “data mining”) and Knowledge Discovery in Text Databases (KDT; “text mining”) for technology intelligence [Runge 2006:919,946-947, 951-963].

As a Dow Chemical employee the author, together with an external NTBF, developed a technology intelligence system including business information and on the technical side automatic patent retrieval, capture from external patent databases and integration into the internal database system, filtering for storage, and an assessment sub-system as well as Knowledge Discovery in Text Databases (KDT) facilities (“text mining”).

The filtering relies essentially on human judgment. Incoming patent information is automatically distributed to experts in the particular field. These are notified by e-mail and assess the input. Relevant items are kept and indexed by field-specific technical and commercial keywords for post-processing. Items with high relevance concerning technology and/or competition (threats!) are fully analyzed and the related full-text assessment report is stored in the system. Use of the complex system required, explaining, training and user support [Runge 2006:Part IV].

Software business by technology entrepreneurs may not only address research and technology, but also retail business, specifically marketing, Based on image processing and corresponding software the German NTBF Vitracom AG (B.2) can track and count subjects (people; sports teams) or objects (automobiles; traffic) against a structured background: how many (“frequencies”), where, how long staying, and paths. And through its “Shop Efficiency Monitoring” software it can track people’s behaviors in supermarkets, big retail shops, shopping malls etc. differentiating gender and children versus grown-ups. It can also deal with security issues (airports; sport events, etc.).

Reid Hoffman, an investor-entrepreneur and co-founder of the US professional network LinkedIn, (B.2) sees a shift coming in the Web, with data. This shift, he believes, will be driven by data and its many uses. Hoffman has been investing in companies that are data-driven or starting to work with data in interesting ways (ch. 3.4.2). This is corroborated by Openshaw and Pentland [2012]. But for social data they made the point that “lost from the discussion is that social data is not like other data – it cannot be calibrated, is often ambiguous, and the traditional tools of data analysis may not apply.” “Meaning, not content, matters in social data.”

Regarding data mining US startups like (unprofitable) Splunk, Inc. (founded in 2004 and now traded on NASDAQ) that claim it is solving problems for businesses are seen as a *next wave* of new firms. Splunk intends to help businesses organize and make sense of *all the information they collect*, a trend known as “*Big Data*.” Splunk’s software is essentially a search engine for all the data that servers, network switches and any device such as smartphones with a processor spits out when those devices are in use. Commenting its IPO according to its CEO, "the market appears to be giving us a first-mover advantage on Big Data." [Worthen 2012]

To the author "Big Data" promoted as a "key basis of competition, underpinning new waves of productivity growth, innovation, and consumer surplus" by the big names of consulting firms like McKinsey, KPMC, Accenture or Booz, Allen Hamilton seems to be the most recent hype generated in line with "knowledge management" and then "business intelligence."

Here Runge [2006:835] cites a description of 1998: "But perhaps worst of all, the knowledge management movement is underpinned by a marriage of two of the world's most powerful 'spin' machines – global management consultancy and the IT industry – both dedicated to developing new ways of doing business to keep companies in profit, especially themselves."

> Concerning the function of software for technical systems (or administrative or business processes) software is an *enabling technology* (Table I.12); it is an "embedded software."

There is a wide *perception* that software and data processing and database services (TBS, Table I.1) provide ample opportunities for entrepreneurship. Furthermore, there is a widely spread perception, generated also by the media, that software-related entrepreneurship provides many opportunities for *a short path to wealth*:

It would not require a formal education in computer science (informatics) – having grasped the basics of informatics and then drop out from university or having just heavy interest in the subject, already as a teenager, or using it intensively as a hobby or sideline seems to suffice for successful entrepreneurship in software or TBS.

Almost anyone from any discipline could do it and develop commercial applications – people from hard science (WITec GmbH, B.2) or soft science, particularly economics or business administration. It may even grow out of a hobby (Gameforge AG, B.2).

> The wide view: an appropriate trend, a smart idea and neat execution seem to be everything that is needed to create an Internet firm or software application to make millions.

The development of Internet traffic (Figure I.89) seems to support such views. Furthermore, initial financing needs of a new firm appear to be low in comparison to entrepreneurship in high-tech (TVT or HVT; Table I.1). Generating a marketable service or "product" and huge numbers of copies or uses of the product seem to require little investments.

For instance, Metzger et al. [2010b:46] have shown for Germany that, on average, young or medium-aged entrepreneurs in software or TBS need initial financing of €5,000 - €10,000 compared to €33,000 for TVT/HVT, and additional contributions of non-cash assets for a startup valued €1,000 - €3,000 for software, but €5,000 for TVT/HVT. For producing technical startups it is more in a magnitude of €500,000.

Indeed, software penetrates all our lives and businesses and provides myriad opportunities for entrepreneurs. For instance, in today's cars, software runs the engines, controls safety features, entertains passengers, guides drivers to destinations and connects each car to mobile satellite and GPS networks. Companies in every industry need to assume that a software revolution is coming. In CleanTech, whether it is decentralized power through smart grids or electric or hybrid cars, software will drive the developments.

In this context, recently, Marc Andreessen from the US, a co-founder and general partner of venture capital firm Andreessen-Horowitz, which has invested in Facebook, Skype, Twitter, Zynga, among others and who is also personally an investor in LinkedIn and was a co-founder of Netscape, put forward arguments "why software is eating the world." [Andreessen 2011]

That means, his "theory is that we are in the middle of a dramatic and broad technological and economic shift in which software companies are poised to take over large swathes of the economy." This view reflects the bright side of the role of software. But there is also a dark side (Box I.14).

Box I.14: Is software eating the world? [Andreesen 2011]

Marc Andreessen [2011] argues that more and more major businesses and industries are being run on software and delivered as online services – from movies to agriculture to manufacturing and national defense. "On the back end, *software programming tools and Internet-based services make it easy to launch new global software-powered startups in many industries* – without the need to invest in new infrastructure and train new employees." (Emphasis added). Andreesen rode the 2000 Dot-Com Frenzy to riches at Netscape Communications Corp.

Andreesen [2011] cites "the single most dramatic example of this phenomenon of software eating a traditional business is the suicide of Borders and corresponding rise of Amazon. In 2001, Borders agreed to hand over its online business to Amazon under the theory that online book sales were non-strategic and unimportant."

Today, the world's largest bookseller, Amazon, is a software company – its core capability is its amazing software engine for selling virtually everything online, no retail stores necessary. On top of that, while Borders was thrashing in the throes of impending bankruptcy, Amazon rearranged its web site to promote its Kindle digital books over physical books for the first time. Now even the books themselves are software" and Amazon even emerges as a publisher."

Andreesen refers to Google (ch. 4.3.6; Figure I.159, Figure I.160 ; Box I.24) with its largest direct marketing platform as a software company and views video game makers as the fastest growing entertainment companies – again, software – with the industry growing to $60 billion from $30 billion five years ago.

And as the fastest growing major videogame company Zynga was cited, which delivers its games entirely online (but cf. ch. 3.4.1.1 concerning Zynga's dramatic decline). And following the above line of arguing, traditional videogame powerhouses like Electronic Arts and Nintendo which saw revenues stagnate and fall were presented as "losers'". LinkedIn (ch. 3.4.2.1) was introduced as today's fastest growing recruiting company. On LinkedIn, subscribers can maintain their own resumes for recruiters to search in real time – giving LinkedIn the opportunity to eat the lucrative $400 billion recruiting industry.

Andreessen refers to software to power logistics and distribution capabilities being used by retailers, and he cites Wal-Mart, which has used these to crush its competition. And he also points out that "practically every financial transaction, from someone buying a cup of coffee to someone trading a trillion dollars of credit default derivatives, is done in software."

However, considering how the world, via the US housing bust resulting from an overflood with cheap money to everyone, was pushed into the Great Recession to a considerable extent by the US financial services industry based on "financial innovations," such as CDOs (Collaterized Debt Obligations) the dark side of software appears. CDOs are complicated securities, concerning housing based on pools of mortgages, largely subprime mortgages. CDOs and CDO derivatives as financial investments were often (absurdly) rated very high, AA and AAA, by rating agencies and considered as safe as US Treasuries. But using flawed statistical and probabilistic premises related software predicted considerable reduction of risk loans to less creditworthy home buyers if mortgages are to be re-packaged "appropriately" into "tranches."

"Many of the manufactured tranches are far safer than the average asset in the underlying pool. This ability of structured finance to repackage risks and create "safe" assets from otherwise risky collateral led to a dramatic expansion in the issuance of structured securities, most of which were viewed by investors to be virtually risk-free and certified as such by the rating agencies. At the core of the recent financial market crisis has been the discovery that these securities are actually far riskier than originally advertised." [Coval et al. 2008].

During the Cold War period with its arms race software of the orbital defense system of the Soviet Union (USSR) interpreted a flash of light in the US as the start of US missiles with atomic bombs for a first strike of the US. Soviets had to decide within few minutes to start their "atomic armada" for a counter-strike to destroy the world. A decision of a Soviet officer kept the Soviet missiles on the ground. Furthermore, currently cyberwar initiates a new arms race, hacking and sabotage of firms' software systems and, for instance, a coordinated attack on the US electrical grid is high on list of concerns for defense officials.

Russian intelligence agents are conducting extensive spying to collect US economic data and technology, according to a US intelligence report that concluded China and Russia are “the most aggressive collectors” of US economic information and technology. The bulk of this spying is carried out in cyberspace, where vast volumes of data can be stolen in seconds [Gorman 2011].

Looking also at high-frequency trading at the stock exchange and generally trading at the stock exchange based on super-computers fed with heuristics for buy and sell transactions and introducing extreme volatilabilities of stock values, and adding also Internet crime, hacking and cyber war, one should also consider “why software may be devouring the world.”

And what about the gigantic system PRISM, a clandestine mass electronic Internet and phone surveillance program operated by the United States National Security Agency (NSA) – and additionally NSA’s spying software called XKeyScore. Apart from massive issues of privacy and freedom of the individual and exceeding all imaginations that could be induced by Orwell’s “1984,” many Europeans think it is also heavily involved in industrial espionage for the US economy (cf. Box I.7). Consequently, at least in Europe, this may negatively impact cloud computing.

The very roots of most of issues with software lie in its fundamental basis, “garbage in, garbage out” (GIGO) and the elementary logic that with wrong premises and assumptions you can prove everything and you can react relatedly to everything.

The conclusion of this outline for the context of technology entrepreneurship is that a broad field of opportunties for software will open looking into what computers and software cannot do *per se* and focusing on *designing man-machne systems* with appropriate human interference points in related processes.

The apparently potential of computers to reason is based on gigantic “*manually*” created specifc dictionaries, lexica, taxonomies and ontologies which frame a problem or domain of knowledge (cf. the “computerized innovation and problem-solving” approach TRIZ in ch. 3.3). But the computer cannot frame a problem, cannot find the right questions on its own to frame a problem without human interference.

For instance, Google’s AdSense application is a proprietary search algorithm that was based on word meanings and built upon an underlying lexicon called WordNet, which was developed by researchers at Princeton University (Box I.24).

A discussion of Runge [2006:945-947] of the fundamental issues of Knowledge Discovery in Databases (KDT) and Natural Language Processing (NLP), particularly for the R&D and technical innovation areas, was narrowed down to two conclusions:

> For all these tools, as well as any information or intelligence system, it should be re-emphasized that they are *“prosthetic” aids*: they are crutches for the intelligent mind. They are *no substitutes* for natural intelligence, but enhancers (to serve a desired end).

> Similarly, a pair of glasses is to enhance your eyesight. They are not a substitute for further reading. The glasses do not see instead of you! They are "prosthetic" aids for *interactive*, not interpretive operations and activities.
> *Knowledge discovery* is a complex process, and it fundamentally – for the foreseeable future – *requires human participation*.

When dealing with innovation and entrepreneurship in software and Internet it is important to be aware of national differences in approaching and using programs and software systems. The Americans are much more ready to jump onto new software focusing on *novelty* where the Germans are much more cautious focusing on *functionality*. Americans rely more on the result of software and programs than Germans.

In particular, the *belief in the results of programs and software* is much stronger in the US than in Germany. Re-phrased for another target, the key issue with software, Internet or generally I&CT or computerization is whether to view and take *computer and software tools as a support of human decision-making or a replacement of human decisions*.

This case is extremely dangerous, especially also for innovation, but makes it much easier for people to attribute responsibility for decisions and actions to a "third party" – the software or systems which for "soft" data are often based on premises, quasi-laws, heuristics and "rules of thumb" or statistics unknown to or not understood by the user [Runge 2006: 349-340].

Successful software and TBS entrepreneurs know and understand:

- User demand (markets)
- Training requirements of users or setting up an efficient "New User Starter Guide" (Figure I.29, Table I.11)
- Trends, technology trajectories
- Convergence (Figure I.105)
- Social and technical infrastructure development
- Timing and Window of Opportunity (Figure I.4, Figure I.92).

User demand includes also basic technical requirements for accessing the service, such as computer response time to operations and number of steps ("clicks") to get the requested result.

As a special case for dealing with software startups Google's early phase (ch. 4.3.6; Figure I.159, Figure I.160 ; Box I.24) and PayPal (ch. 4.3.2; A.1.7) will be discussed. Facebook has been mentioned shortly (Box I.9) as well as US LinkedIn and German Xing.

To deal with entrepreneurship in software (and Internet) we shall focus on two (competing) pairs of corresponding firms in the US and Germany. LinkedIn and Xing shall be used as examples of entrepreneurship in the field of "social networks" and

Internet companies (ch. 3.3.2). US Zynga and Gameforge AG are representatives of entrepreneurship in video games (ch. 3.3.1).

Hence, we concentrate on selected “superstars” which formed the above discussed perception of entrepreneurial opportunities in software and TBS to elaborate the specifics compared with technology entrepreneurship in TVT and HWT. Furthermore, particularly the games segment will be used to illustrate a new key component of the revenue model used for social networks – “virtual goods” (ch. 3.4.1.1, Box I.16) – which is totally different from goods traded in the TVT and HVT fields.

The rationale for the choice is that the US “superstars” reflect an entrepreneurship architecture or configuration, respectively, which differs totally from corresponding ones in Germany (and Europe). But even for the US LinkedIn and Zynga foundations are rather special in the way how they refer to PayPal and the “Paypal Mafia” (A.1.7).

Furthermore, especially Zynga is used to illustrate specific entrepreneur-investor relationships which emerged as recent issues in the context of IPO stock prices of Zynga and comparable firms.

> It is to be noted that generally, compared with the situation in the TVT and HVT fields, strategy and plans represent fundamental challenges for new Internet firms as for the Internet a five year horizon is a very large time span.

Social networks have a “cultural flavor.” They operate on many levels, from families up to the level of companies and nations. They play a critical role in socialization into norms and determining the way problems are solved, organizations are run, and the degree to which individuals succeed in achieving their goals.

In its simplest form, a **social network** is a system of specified ties between *individuals* as network *nodes* being observed or studied concerning *relationships and social interactions (*“edges”), such as friendship, kinship, common social values or interest, relationships of beliefs, knowledge or prestige. *Functionally*, it is usually understood as an Internet-based service that allows interacting with others.

The function and purpose of a social networking service means

- Set up contacts
- Find people (with whom you have not communicated for a while or concerning specific purposes; search for other users or content),
- Meet people,
- Share ideas (discussion forums [Runge 2006:933,965]),
- Share activities,
- Share events,
- Share interests,
- Blogging (and microblogging) and discussing your ideas,
- Play games and participate in other activities, such as business activities.

Providers of social network services take the free-of-charge use of the Internet infrastructure for granted.

Providers of social networks may encounter difficulties of internationalizing their social networks. Social networks, due to major effects of local languages, their appearance, acceptance and use, are strongly determined by national culture. Hence, particularly *professional social networks* (ch. 3.4.2) will be affected by *national business culture* and, if interconnections for transnational business are sought, require special considerations and multi-cultural competencies on the side of the provider. Consequently, expanding internationally does not necessarily translate into related (commercial) success.

Social networking technology is catalyzing complete re-inventions of entire industries, such as media, entertainment and music. Social networks are subject to national governmental regulation and other legal obligations related to *privacy and its protection*. Correspondingly, Facebook is heavily criticized in Germany regarding handling of personal data and under continuous scrutiny.

The idea and concept of a "social network" has been used loosely for over a century to connote complex sets of relationships between members of social systems at all scales, from very local regional to international, and for various purposes. "Old boys networks" in policy, management of firms or for career development or the informal "Community of Practice" (CoP) in firms or across firms are quite common [Runge 2006:373, 768]. Wider networks focusing on innovation and entrepreneurship are the "Competence Networks" of the German innovation system (ch. 1.2.6; Figure I.39).

CoPs mean people sharing the same or closely related competencies and acting as self-directing groups – where questions are posed from one practitioner to other practitioners within a *trusted* circle.

> As for CoPs, the key prerequisite for *professional social networks* is trusted relationships among users for searching, reaching and filtering [Hoffman 2007a] which potentially is also opening the way for relationships between corporate and individual users (companies checking prospective employees, but the other way as well).

From a systems point of view for entrepreneurship the study of the "entrepreneurial team" or the "entrepreneur and his/her team" (ch. 2.1.2.5) falls also into the category of social networks as do the firm founder(s) and the startup's Advisory Boards.

Corresponding to the system's approach, studies of social networks include two directions:

- Rather than treating individuals (persons or organizations) as discrete units of analysis, it focuses on how the *structure of ties* (Figure I.68, Figure I.71) affects individuals, their relationships and behavior.

- In addition to analyses that assume that socialization into norms determines behavior (corporate culture; Figure I.120) network analysis looks also to see the extent to which the structure and composition of ties affect norms (core rigidities; Figure I.129).

On the other hand, social networks are not only of interest concerning the change that the related software facilitates in its user community concerning communication and interactions. The knowledge of the extensive demographic and personal data of network users is of particular interest to other parties, such as the *advertising industry.* And new modes of advertisement thus raise issues of protecting data security for individuals. For instance, Facebook encourages users to “friend” brands, potentially opening the way for a more direct relationship between companies and customers. Another interested party is the *recruiting industry* (Box I.14).

According to market research firm IDC, the worldwide markets for *Internet advertising*, television advertising, *video game software* and radio advertising in 2011 were forecasted to be $79 billion, $191 billion, *$50 billion* and $31 billion, respectively [Zynga 2011].

Ad revenue from social networks worldwide was expected to reach $5.54 billion in 2011, according to eMarketer estimates, and will double by 2013. Half of the 2011 ad spent on social networks, $2.74 billion, is coming from the US market. Social networking ads were reported to be worth $2 billion by 2010 (B.2, LinkedIn).

As a *cultural feature* Americans are more ready to speak about their personal situation and pass on personal information about them. Germans are more focused on privacy and confidentiality about personal data and information. Germans separate the private and the public sphere much more than Americans [Böhm 2005]. Correspondingly, input into social networks, use and valuation and perception of the networks may differ by users and services providers in and for the various countries.

Concerning privacy and protecting personal data in Europe Facebook is confronted with an increasing head-wind from policy and movements regarding storing personal data, keeping data deleted by members and providing the data it has stored. Furthermore, information of Facebook resulting from its “*like buttons*,” which are associated with personal preferences, is particularly under criticism.

When, on request for provision of all the data ever stored by Facebook, the initiator of the movement “Europe versus Facebook” Facebook Ireland Ltd. delivered to him 1,200 printed (A4) pages. These included also data that were deleted by the user. On the other hand, data were missing, in particular, those related to Facebook’s face recognition program. Facebook Ireland claimed that these represent trade secrets and intellectual property. But this collides with European data protection law. “Europe versus Facebook” initiated a lawsuit against Facebook Ireland [Wiele 2011].

“Like buttons” lead to “lead generation” in advertising – connecting brands with users that offeres an expressed or implied interest in the product. *Online Lead Generation* is a marketing term that refers to the creation or generation of prospective consumer interest or inquiry into a business’ products or services online.

Concerning knowledge of personal preferences for advertisements “like buttons” in social networks provide related information and, together with personal, demographic data of users, function like “hidden questionnaires.” These allow a very important customer segmentation of high value for the advertisement industry. Hence, as Google has become tremendously successful as a beneficiary of the beginning wave of “contextual advertisements” (Figure I.159, Figure I.160, Box I.24) social networks promise high returns from advertisement and other areas.

Social networks on the basis of the global Internet emerged often from regionally, organizationally or socially restricted domains, such as ConnectU (Box I.9) for a university or implementations of knowledge management sub-systems using the Intranets of large firms (ch. 3.3.1; last paragraph). Social networks running within corporate Intranets which may include interfaces to public social networks on the Internet used by large companies to organize communication and information sharing and probably collaboration are called “enterprise social software.”

Furthermore, the origins of social networks are often mappings of long time existing products or services into the Internet. Additional features and applications made feasible by the Internet are built subsequently during the expansion of the “core offering.”

This is reflected by a Euromonitor International market research report entitled “The Global Rise of Social Networks: Brave New World or the Same Old Thing?” The following discussions will follow this question as a mapping of Andreesen’s “software eating the world” (Box I.14).

For instance, the German Xing AG was named originally Open Business Club GmbH and one of its roots was a map of a conventional business club into the Internet (ch.4.3.2; B.2). A similar situation can be observed for Facebook (Box I.15). Another conceptual model for Xing or LinkedIn has been put forward (ch. 3.3.1, last paragraph) transferring structural and functional features from a *closed* environment of users (“Intranet) to an *open* one (Internet).

In this context it is interesting to note that, according to LinkedIn’s European managing director, LinkedIn may launch an Intranet application for businesses, which would allow staff to collaborate with their colleagues on an internal network in a similar fashion to how they network with their contacts externally. “Clients come to ask and say help us make our intranet better and we work with them on product development.” The problem with many Intranets as viewed by LinkedIn is that Intranets are designed from the “enterprise point of view” rather than the user standpoint. [Marshall 2012].

Box I.15: Social networks as transformations of conventional products or services into the Internet – Facebook's origins [Accel Partners 2005].

In Box I.9 one part of the Facebook story and Mark Zuckerberg is described ending with the sentence "On the other hand, it was Zuckerberg who turned to Silicon Valley and succeeding to catch venture capital to finance and grow the fledgling business of Facebook."

Mark Zuckerberg, a computer-sciences-turned-psychology major, and his two roommates, Dustin Moskovitz and Chris Hughes, started thefacebook.com – now Facebook – in February 2004 as an *online directory of all Harvard's students*, mapping the *photo books of incoming freshmen* the school produced annually onto Internet.

Access to the network was free-of-charge and students wanting to join needed a current ''.edu'' e-mail address to register. They could then supply a digital photo and create a profile of themselves. They could view one another's profiles and, as the site spread to other campuses, those at other schools if they were accepted as a ''friend.'' In this way, thefacebook.com created online interactive college-student networks.

The three friends designed their site, Zuckerberg said, ''in such a way that if it was good, it could be introduced at other schools.'' It was an instant hit, and within one month Columbia, Stanford and Yale students could log on to sites at their schools. By June 2004, sites were available for about 30 campuses and 150,000 students were registered. The colleges and universities themselves did not have any editorial or financial involvement. By mid of 2005 the Web site had attracted 2.8 million registered users on more than 800 campuses since it began in February 2004.

This generated interest of investors, notably Jim Breyer of Accel Partners, one of Silicon Valley's leading venture capitalists. His firm's early $12.7 million 2005 bet on Facebook was worth ca. $5 billion in 2011 (and soaring). That 10 percent stake made Accel Facebook's second largest shareholder (Breyer personally owns an additional 1 percent) [Forbes]. Mark Zuckerberg's stake is estimated to be 24 percent. Accel Partners invested also in German Gameforge AG (ch. 4.3.1; B.2).

Five years after the Internet bubble burst in 2000 Breyer emphasized that his firm backs companies ''like thefacebook, which have built a deep relationship again and again with the customer.'' [Accel Partners 2005]

After having attracted more than 2 million registered users their realization that they were onto something with big potential let the founders of thefacebook.com expose them to Silicon Valley. Zuckerberg and Moskovitz spent the summer of 2004 there, where they had friends working as interns at established companies like Google. Before going back to Harvard to build their network slowly ''because we wanted to create safe communities'' and make sure the system could handle the increased use Zuckerberg arranged a dinner with Sean Parker, the founder of Napster, to talk about his Web site, which had swept through Stanford University in a number of weeks.

Parker began informally advising the company and by the end of the summer he became president. Parker then introduced Zuckerberg to Peter Thiel (A.1.7), a venture capitalist and founder of the online payment service PayPal. Peter Thiel invested $500,000 as seed money, the first major infusion of cash into thefacebook.com. More important, *his connection gave it the imprimatur of an up-and-coming company*.

Also Reid Hoffman invested alongside Thiel in thefacebook.com's very first financing round (LinkedIn Corp., B.2). Soon, other investors came calling. Jim Breyer took a seat on the company's board, joining Mark Zuckerberg, Sean Parker and Peter Thiel. At that time those persons declined to disclose revenue, which came solely from advertising, though they said the company is profitable.

In Germany the social network "StudiVZ" with currently 16 million users can be compared with Facebook in its early phase (thefacebook.com) focusing on students (and now also on pupils - schülerVZ) and generating revenue essentially via advertisements. It was founded by the end of 2005 and is now a subsidiary of the German publishing group Georg von Holtzbrinck. It is concentrating on the German-speaking DACH region in Europe (Germany, Austria, Switzerland).

> One of the key early questions (after The Dot-Com Bubble) was whether software firms and, in particular, social network Internet companies, are building *real values* and how they refer to value in general (ch. 3.4.1.1).

The bottom line: often it is easy to start an Internet business, but difficult to scale and explain what its value concept is and whether it is viable. "Scale" in Internet-speak often means having enough people use a network to make the network actually useful.

Irrespectively, in the US a boom of social media startups promised to unleash a new wave of high-growth businesses in the public markets – referring to number of employees and revenues as indicators of growth. Whether such growth can be turned into profitable and sustainable businesses is a different matter.

On the back of that Internet and the social networking boom the makers of online games, such as German Gameforge AG (B.2) and US Zynga (to which players gain access through Facebook), and German Xing AG and US LinkedIn have built businesses and dollar/euro revenues

Considering these two pairs of NTBFs and also Paypal reveals some significant differences of entrepreneurship between the US and Germany addressing corresponding opportunities. And it also reveals entrepreneurship processes which are different from those observed for other software- or IT-related firms, such as German SAP (A.1.4; Figure I.143, Figure I.147) and US Microsoft (Figure I.144, Figure I.146), Cisco (Figure I.145, Figure I.158), and Google (Figure I.159, Figure I.160, Box I.24).

Furthermore, current US Internet firms in the spotlight, after the Dot-Com Internet bubble, involve sometimes a special breed of (Internet) "*entrepreneur investors*," special approaches to classes of revenues (Box I.16), special constellations, technology speculation and *people networking* for success (A.1.1.7) – "Silicon Valley-style."

A Rise and Fall of US Internet Firms and Ascribed Values

As described above for the "business club" construct fundamental business *ideas for Internet firms* stem rather often from transferring business activities and concepts appropriately to the Internet environment which were common already during the pre-computer and pre-Internet times. Take the functional example of a *cooperative*.

According to Wikipedia a cooperative (also co-operative or co-op) is a business organization owned and operated by a group of individuals for their mutual benefit. Co-operatives may be classified as worker, *consumer*, producer, *purchasing* or housing cooperatives. In particular, acting as a group the cooperative increases the purchasing and bargaining power of the individual members concerning purchasing goods (or services).

Map this to the US firm Groupon (founded in November 2008), which provides purchasing *coupons* to its groups of *members*. As described by Wikipedia, "the company offers one 'Groupon' ("group + coupon") per day in each of the markets it serves. The Groupon works as an assurance contract using The Point's platform: if a certain number of people sign up for the offer, then the deal becomes available to all; if the predetermined minimum is not met, no one gets the deal that day. This reduces risk for retailers, who can treat the coupons as quantity discounts as well as sales promotion tools. Groupon makes money by keeping approximately half the money the customer pays for the coupon."

It took the May 2011 IPO of LinkedIn (B.2), a professional social networking site, to ignite stock market enthusiasm for the latest generation of US Internet listings (ch. 1.2.7.1).

For many of the social Internet companies one can say that *they came up with a new operating metric to show that they are profitable*, elaborated, for instance, concerning Groupon by Waters. "These guys have invented a new way of accounting. The losses are unconscionable." [Waters 2011]. And also LinkedIn's metrics has been critically assessed [Sherman 2011].

In November 2011 Groupon went public and shares rose from their IPO price of $20 at market close to $26.11, up 31 percent. The closing price valued Groupon at $16.6 billion, despite arguments from critics that a much lower value was more realistic [Raice and Smith 2011]. Only three weeks later Groupon's stock dropped 15 percent, partly attributed to e-commerce concerns. Then Groupon shares also became cheaper for short sellers, who sell borrowed shares to bet on a stock's decline.

Moreover, the sudden decline represented "a break in the thinking that the Internet is still a safe "*platform for technology speculation*," and meant investors will be more skeptical of "automatic high-demand IPOs." (Emphases added) [Smith and Raice 2011].

How IPO stock prices in the context of Internet firms may develop are described for the case of Groupon as follows, by "research analysts, {who} usually write rosy reports on companies their firms take public." [Smith and Grocer 2011] In the words of Smith and Grocer [2011] in December 2011 this is:

"Ordinarily, such research by analysts at the underwriters is predominantly bullish – so much that the stocks often rise just before the reports are due to come out. Stock of LinkedIn Corp. rose 20% before a set of uniformly bullish reports by analysts at its lead underwriters, and another 12% on June 28 when the reports were published."

Underwriting means the process by which investment bankers raise investment capital from investors on behalf of corporations (here, for IPOs) and governments that are issuing securities (both equity and debt). According to Investopedia, the word "underwriter" is said to have come from the practice of having each risk-taker write his or her name under the total amount of risk that he or she was willing to accept at a specified premium. In a way, this is still true today, as new issues are usually brought to market by an underwriting syndicate in which each firm takes the responsibility (and risk) of selling its specific allotment."

Indeed, the stock of Groupon, whose IPO was priced at $20 a share on Nov. 3, 2011 had been rising steadily from a post-IPO low of $15.24 to a closing price on Tuesday of $23.32. But when the reports came out, the stock fell by more than $2 in the first hour of trading before recovering to finish down to $22.55 on NASDAQ. Groupon's revenue for the first nine months of 2011 rose more than seven times to $1.12 billion – but, it was unprofitable and the barriers to enter the market remain relatively low for new entrants.

By the end of September 2012 Groupon's stock price reached ca. $4.77 (!), and the swooning share price and stock value of Facebook Inc. (Box I.15) and Zynga Inc. (ch. 3.4.1.1, B.2) have rekindled memories of the Dot-Com Bust in 2000. Unlike many dot-com era startups, the current companies have revenue and in some cases are turning a profit – but their stock values do not match reality.

The cases for the above firms can be seen as exemplary for what differs often in the roles of investors and related firm's stock value for entrepreneurship in the US from those in Germany. This is outlined by Raice and Ovide [2012] and Thurm and Tam [2012].

The Groupon investment flurry (and those of Facebook and Zynga) ended as part of a recent Silicon Valley trend of prominent investors jumping into young companies shortly before their IPOs. Critics say the phenomenon builds unsustainable valuations for those young companies. Well-known venture firms such as Andreessen Horowitz

(Box I.14) and Kleiner Perkins Caufield & Byers (KPCB) popularized these investments and helped propel a boom in valuations for private Internet companies.

“Groupon would never have gotten this big without that late-stage money.” “The guys that backed Groupon early – even at today’s prices – they made lots of money.” [Raice and Ovide 2012]

For instance, “Andreessen was among the investors who helped fuel Groupon’s rapid ascent. His firm, Andreessen Horowitz, was responsible for $40 million of the $950 million investors put into Groupon just months before the company’s IPO. Andreessen Horowitz sold its 5.1 million Groupon shares shortly after restrictions on selling the stock expired June 1, according to people with knowledge of the transaction. Based on the company’s share price when Andreessen Horowitz sold, the firm earned a profit of almost $14 million.” [Raice and Ovide 2012]

Early on, Groupon’s business model raised questions over the sustainability of the daily-deals business which can be easily imitated. Furthermore, concerning its customers, the company was launched as recession-weary consumers were eager for deals.

LivingSocial, an Amazon-backed online marketing (daily-deal) company and founded in 2007 and one of the competitors of Groupon, was suggested to be worth ca. $1.5 billion by the end of 2012. In an earlier round of financing, the company was valued at roughly $4.5 billion or even $6 billion [Tam et al. 2012; MacMillan 2013].

Recently, in a disputed report, the private company research firm PrivCo claimed that LivingSocial’s recent financing round is the “final gasp” of the daily-deal company. PrivCo claimed that the implied valuation of the deal is a startling fraction of the assumed $5.7 billion valuation reported when the company last raised capital in November 2011, actually 94 percent of value is wiped out [Colao 2013].

Zynga went public with its shares priced at $10, a mark that valued the gamemaker at about $7 billion. But since its December 2011 IPO it has lost about 70 percent of its stock value and was at ca. $2.85 by the end of September 2012. But Zynga’s earliest investors (B.2), including entrepreneur Reid Hoffman and five venture firms, still stand to secure profits on shares they bought for less than 50 cents each [Thurm and Tam 2012]. For Zynga, the news was going from bad to worse. Shares dropped to $2.29 on October 4, 2012.

Furthermore, not only early investors, but also founders of Groupon, Zynga and Facebook have sold shares before or during their IPOs. Groupon, Zynga and Facebook have several classes of stock, giving founders and investors before IPO more power (voting rights) than other shareholders. And some investors are voicing qualms about the way some of such companies are run. “The reason public companies have professional management teams is to make decisions for the investor.”

"Right now, investors are saying we're not sure if they're doing the right thing." [Thurm et al. 2012]

Even in Silicon Valley, some veterans were raising eyebrows. "These guys are arrogant," said Arthur Rock, among the valley's first venture capitalists, and an early investor in Intel Corp. and Apple Inc., referring to venture capitalists and entrepreneurs alike. They "today feel like they want to cash out as quickly as possible. … That isn't how I played the game." [Thurm et al. 2012]

Software and TBS entrepreneurship usually rely on types of revenues [Dorf and Byers 2007:358] which are different from those of TVT/HVT ventures (Table I.1, Table I.3). Apart from renting or licensing fees they include the classical revenues of publishers and ecommerce:

- Subscription revenue – access to content of online and/or print media or entertainment offerings for a given period of time
- Advertising revenue – provision of space or time for advertisements
- Transaction fees – providing a transaction source or activity or a feature for a fee (PayPal, eBay).

3.4.1 Entrepreneurship in Video and Computer Games

Within the software industries the computer and video online games segment represents an emerging and growing field. Genres of games may have educational purpose or potential like role or strategy games or serves leisure and entertainment. This can serve to elaborate the specific differences between technology entrepreneurship of software and Internet firms from those active in TVT and HVT fields.

> It is believed that *play* – like search, share and shop – as *general macrotrends* would become one of the core activities on the Internet [Zynga 2011].

The gaming industry and its competitive situation are essentially determined by low entry barriers and pace of new product launches.

Low entry barriers mean that *initial financing* for a firm offering a game may require relatively low investment which means a number of such firms can (are) founded via bootstrapping with own funds, 3F initial financing or own/3F and low level debt financing as an LLC (GmbH). But there is pressure for the firms to develop their techniques for staying in the flow and not flipping out, because this is demanding.

One of the big attractions for developers is how fast they can get a game to market. In the past, a typical videogame made for a console system like PlayStation would take about a year to develop, and then not be improved upon until one or two years later with a sequel.

Mobile-phone developers, by contrast, can make a change, improvement or upgrade to a game and push the code out to consumers within days. As mobile games cannot handle as much data as those played on consoles, development of an iPhone or

Facebook game can take just a few months. You can take your product from idea to launch in four to five months [Walker 2011].

Developing *apps for smartphones and tablets is the latest hype*, a gold-rush, for software developers attracting masses of people to found startups going for wealth. Research firm Gartner reported the mobile app market to have nearly doubled in 2012 with smartphone users worldwide having downloaded more than 45 billion apps that year. Gartner estimates by 2016 300 billion apps will be downloaded.

The hype is enforced by the emergence of some of the *stereotypes* associated with entrepreneurship in software. For instance, in the UK Nick D'Aloisio, a teenager of 17, has sold his free newsreader app which is automatically summarizing news articles to Yahoo with an estimated $30 million for him personally. He began developing the app at age 15, and he taught himself how to create computer programs at age 12, and previously created several apps. In 2011, D'Aloisio founded a company called Trimit and raising funds from investors obviously was straight forward after being mentioned in the media [Efrati 2013; Fröhlich 2013].

A number of teenage entrepreneurs have built companies that later have success, but very few strike it rich so quickly [Efrati 2013]. But considering the myriad developers and millions of apps striving to became a winner their chances can be compared to those of gambling with lotto.

Outlining the Game Industry

For firms, there are *low barriers* to entry in the social game industry, and *competition* is intense. Some Internet game firms organize user access via other social networks; others are independent from other "auxiliary networks." An example for the first type is US Zynga, Inc. which uses *widget applications on social networking websites* such as Facebook.

Competitors that develop social games for social networks vary in size and include publicly-traded companies and privately-held companies. They also differ in diversified set of *revenue sources*. Online game developers and distributors who are primarily focused on *international markets* have to provide their games in a large number of *different languages* (20+) and have to take *cultural differences* into account.

A software widget is a generic type of software application comprising portable code intended for one or more different software platforms. The term often implies that either the application, user interface, or both, are light, meaning relatively simple and easy to use. A "*widget application*" is a third party application developed for an online social network platform, with the user interface or the entire application hosted by the network service. [70]

Concerning *technology* the Internet game providers face competition from developers of games for mobile and other platforms and games for dedicated, standalone boxed consoles (Sony, Microsoft or Nintendo – PlayStation 3, Xbox 360, Nintendo DS), and providers of games on data carriers or download services of games from networks. And one can expect new mobile-game competitors to enter the market and existing competitors to allocate more resources to develop and market competing games and applications.

The market which provides access to games essentially free-of-charge or requires only small fees is *almost independent from economic recessions*. It can be expected that during a crisis people will go for savings regarding many various things, but some few dollars/euros will always be available for games which will (may) stabilize psychological dispositions. The recent recession corroborated this assumption.

Concerning *constraints of operation and risk* all social networks process, store and use personal and other data, which are subject to *national governmental regulation and other legal obligations* related to privacy. Hence, actual or perceived failure to comply with such obligations could harm the business. Software “bugs” is a special category of risk which affects user acceptance of games and retaining users.

In the online games industry, there are three separate categories:

1. Who makes the games? (the “Developers”)
2. Who funds and markets the games? (the “Publishers”)
3. Who supplies the games to the users? (the “Operators”)

Operators, who take none of the up-front risk of a traditional publisher, focus instead on capitalizing on the game once it is made (usually by taking it to countries and languages that the original publisher cannot reach). Operators do not usually enter the scene until the game has already gone to market in at least one country.

The business of the publishers is to take the bulk of the risk by financing the game. If a game is fully developed, and launched, but fails to earn out, the developer makes no profit but also no loss; the publisher, on the other hand, makes a net loss of whatever the development cost was, minus the game’s revenue.

The (online) game industry emphasizes leisure, and in particular, fun and relaxing. Incumbents have to create excitement and emotions of users and correspondingly vision and missions focus on

- We create worlds – every day. We initiate emotion – time and again. We connect people – globally.
  Connect joy of games free of charge, easy accessible at any time and anywhere, easy to get familiar with and high quality and technologically advanced (in German “Wir schaffen Spielwelten, die für alle Menschen leicht zugänglich sind und gleichzeitig großen Spielspaß und hohe Produktionsqualität zusammen bringen”; Gameforge AG).

- Connecting the world through games.
  Play – like search, share and shop - would become one of the core activities on the Internet.
  If we can make games simple, accessible and social the world will start playing (Zynga, Inc.).

These visions/missions including fun express *a player-centric approach*. Based on a study in the US [Burns 2006] *online players* exhibit six distinct groups based on time spent and motivation. Broadly, there are *casual* and *hard-core players*, the first group is often classified as players who play less than 10 hours per week, regardless of the game. The six “customer” segments identified are:

- Power Gamers who represent 11 percent of the gamer market, and 30 cents on the dollar on retail and online games
- Social Gamers play games as a way to interact with friends
- Leisure Gamers spend 58 hours per month playing mainly casual titles
- Dormant Gamers have fewer opportunities to game because of scheduling issues with family, work or school
- Incidental Gamers lack motivation and play out of boredom but spend 20 hours or more a month playing online games
- Occasional Gamers play puzzle, word and board games almost exclusively.

Game users exhibit a gender effect. Typical “core gamers” of MMOG-type games (see below) are male and between 15 and 29 years old. For instance, there are relatively few high-quality games for women and children. The proportion of women as gamers accounts for ca. 30 percent. One reason is that the majority of game developers is men who develop games that they also like to play [Hauger and Kainzl 2010]. Basically, women are more interested in social interactions than competition, and also strategy games. Traditional games are shaped by competitive situations.

Figures issued suggest that 55 percent of all players of social games in the US are female. “More women are playing Zynga’s Farmville than watching soap operas.” Meanwhile, women spent more time playing Zynga games than any other demographic. 53 percent of Zynga players are females aged between 25 and 44. These represent the “core gamers,” [Crossley 2011] contrary, for instance, to German Gameforge which focuses on MMOGs.

The user segmentation and related characteristics will differ for various countries to various extents. Fundamentally, there are differences between North America and Europe and Asia. The US game market is focused essentially on *console games* and games with high optical quality. Games have grown to become the second most popular online activity in the United States by time spent, even surpassing email [Zynga 2011].

The US is the key market for console firms, such as Microsoft, Nintendo or Sony. The US contributes the biggest revenue per country for these firms. In most other countries *browser games* predominate and many countries have not been serviced by the "classical" game industry. These were the interest of European and particularly German game startups providing games in the countries' native languages [Hauger and Kainzl 2010].

Game providers have to carefully track changes in user preferences and, therefore, have to cling to "enforced" innovation persistence (ch. 4.2.3), constantly enhance, expand or upgrade the game with new features that paying players find attractive.

Due to low entry barriers *initial financing* for a firm offering a game may require relatively low investment which means a number of such firms can (are) founded via bootstrapping with own funds, 3F initial financing or own/3F and low level debt financing as an LLC (GmbH). They may originate with the development of a game as a hobby or with an obsession and subsequent firm's foundation (Gameforge AG). However, significant resources may be required for developing or acquiring additional games for firms' survival and growth.

With regard to resources most games will have been developed for less than €0.5 million for a simple game and can be expected to return a huge multiple of that over their lifetime. But for developing (or licensing) sophisticated games expenditures of €10 million are not unusual. Furthermore, to recover development cost as fast as possible expansion of game use in other countries with high growth potential is mandatory.

As for other Internet firms *business revenue streams* of social games firms are usually associated with the product/service offering as well as advertising (ch. 3.4.1.1 and Gameforge and Zynga cases).

If the game is free-of-charge, selected add-ons for gaming may require fees, from a few cents to several dollars/euros for users with premium or super-premium access. This introduces two types of playing, free-to-play (F2P) and pay-to-play (P2P).

> In this context a sort of "80:20 rule" applies: 1) A small percentage of players account for most of the revenue (around 10 percent) and 2) for large firms offering a number of games a small number of games generate the majority of revenues.

Generally, non-advertisement revenues result from subscription, premium accounts and "virtual goods" (Box I.16). For social networks the business model works by offering a product or service free of charge (typically software, content, games or Web services) while charging a premium for advanced features, functionality, or related add-ons. This is called the "*freemium model*" ("free" and "premium"). For instance, revenue stems from selling features that give players an edge, such as virtual magic swords ("virtual goods").

Free-to-play (F2P) [Weidemann 2009] refers to any video game that has the option of allowing its players to play without paying. The model was first popularly used in early massively multiplayer online (MMO) games [69] targeted towards casual gamers, before finding wider adoption. Free-to-play can be related to pay-to-play (P2P) in which payment is required before using a service.

> The key issues are how successful F2P publishers are in converting free users (all their games can be played for free) into P2P or freemium users.

Various forms of F2P games include

- Browser-based games including the Massively Multiplayer Online Games (MMOGs)
- Client-based MMOGs
- Social network-based games, for instance, using Facebook
- Casual games.

Zynga, Inc. covers the last two categories; German Gameforge AG covers browser-based and client-based MMOGs.

A casual game is a video game targeted at or used by a mass audience of casual gamers. Casual games are typically played on a personal computer online in Web browsers. Casual games tend to be those that have simpler game play and engaging game design; they also tend to offer users who come across the game to step in and play a game within minutes. They require no long-term time commitment or special skills to play, and there are comparatively low production and distribution costs for the producer.

The goal with casual games is to appeal to as wide of an audience as possible, including those that have normally fallen outside the traditional “gamer” profile. Casual games tend to be smaller in scope and more limited in terms of game play compared to console or AAA desktop titles, and with that comes lower end-user expectations about the casual game experience [Higgins].

The gaming press tends to use AAA [71] to mean a really high quality game. Marketing folks will use it to refer solely to the advertising budget (which means the actual quality of the game is irrelevant). Producers usually will use it to mean both (high quality and a big marketing budget) – compatible to the “blockbuster model” of the pharmaceutical business [Runge 2006:173,193].

Growth strategies comprise “continuous improvements” of existing games, developing and acquiring new games from others or independent developers, license-in of games, for instance, from Asia and acquisition of game firms and “development studios.” And to finance such capital-intense approaches startups have to turn relatively fast (after 3 -5 years) to *venture capital* or even an *IPO at a stock exchange* – if not having representatives of these sources already on board from the beginning, such as Zynga, Inc. (B.2).

If one accepts social games to represent a new form of entertainment it is notable that social games will compete for attention of players with the other forms of entertainment (movies, books, newspapers, magazines, theater and recorded music) that comprise the global entertainment industry. Entrepreneurship in this whole area would also include a startup like YouTube focusing on videos.

Intellectual property is in the form of software code, patented technology and trade secrets that is used to develop the games and to enable them to run properly on multiple platforms. However, copyright are usually not enforceable if not the entire code, graphics or longer parts of text, but only single ideas or parts are used by others.

Other intellectual properties refer essentially to audio-visual elements, including graphics, music, story lines and interface design. Who later wants to protect the name of a game as a trademark should early think about how to name the game as trademarks are only protectable if they allow distinct differentiation.

Concerning *technology* a lucrative niche, Massively Multiplayer Online Games (MMOG) [69], has emerged, in particular, online and browser-based approaches and using personal computers. Here, German startups were about to exploit the lucrative niche (see below). MMOGs have only recently begun to break also into the mobile phone market.

Industry and market information (magnitude and growth rates) involves a number of commonly well-known assumptions and limitations, but is essential for gross orientations. Whereas in 2009 global sales of computer and console games via retail decreased by 8 percent, the number of browser game providers, their number of employees, products and revenues increased considerably. Market research firm Inside Network reported doubling of revenues with virtual goods in the US to exceed $1 billion and globally from $5 billion to $7 billion [Freundorfer 2010].

The growth of casual gaming on social networking sites and smartphones has transformed online gaming into a mass market. According to UK market-intelligence firm Mintel mobile could be a bigger market than Facebook. In mobile and tablet games alone, the market reached $898 million in 2010, and is expected to almost double to $1.6 billion by 2015.

The rise of the *virtual goods revenue model* (Box I.16, ch. 3.4.1.1), which allows people to play for free and later pay for individual items within the game or the world, has also contributed to the growth of this market. The revenue specifically generated from the sale of virtual goods has increased 245 percent from $2.1 billion in 2007 to $7.3 billion in 2010. In-Stat forecasted total virtual goods revenues will more than double by 2014 [Reportlinker 2011]. The core business, however, remains with sales of data carriers or with downloads of complete games.

Concerning market volume in Germany total sales of computer and video games (PC and console games and licensing of mobile games) amounted to €1.86 billion with the segment “data carriers and downloads” contributing €1.59 billion. Online and browser games accounted for €194 million (subscription and premium accounts), up 24 percent from 2009 (€156 million). Sales of “virtual goods and services” jumped 38 percent from 53 percent in 2009 (€53 million) to €73 million in 2010 [BIU 2011].

For the US it was forecasted that revenue of $510 million from “virtual entities” in 2010 will increase to $792 million by 2012 [Holt 2011].

Market researchers forecast strong growth of games on mobile platforms, such as smartphones, tablet PCs and mobile consoles. In 2010 in Germany 13 million game apps were downloaded [Fehrenbach 2011]. Games are the most popular category of applications on smartphones, representing approximately half of the time spent on smartphone applications in the US [Zynga 2011].

The Opportunity of Massively Multiplayer Online Games (MMOGs)

When at the beginning of the century online games saw their lift off, market research firm Strategy Analytics reported that in 2006 the global online games market was already worth $4 billion with a rapidly expanding Massively Multiplayer Online Games market. It was projected that the market will grow with a compound annual growth rate (CAGR; Equation I.10) of 25.2 percent in the 2007-2011 forecast period to reach $11.8 billion by 2011 [Strategy Analytics 2007].

> The continued uptake of broadband services around the world was viewed as a main driver for sustained growth in the online games market [Strategy Analytics 2007]. And the PC was positioned as the clear leader when it comes to online gaming.

DFC Intelligence’s Online Game Market Forecasts reported estimated that overall worldwide revenue for online games (for both PC and consoles) will grow from $15.7 billion in 2010 to nearly $29 billion in 2016. DFC said this includes revenue from subscriptions, online usage, online in-game advertising and digital downloads. Online game revenue for the PC was expected to be near $23 billion in 2016, buying digital goods would continue to grow at a rapid pace [Brightman 2011].

> Online game revenue for the PC “is being driven in large part by social networks like Facebook, which is also helping to expand the reach of PC games globally.” [Brightman 2011]

A massively multiplayer online game (MMOG) [69] is a multiplayer video game and shares characteristics that make them different from other multiplayer online games. It is capable of supporting hundreds or thousands of players simultaneously around the world. By necessity, they are played on the Internet.

MMOGs host the large number of players in a single persistent *game world*, and all of those players can interact with each other at any given time, for instance, via a chat function. Players can cooperate and compete with each other on a large scale. However, single player game play is quite viable, although this may exhibit some specifics, for instance, the player being unable to experience all content.

To support all those players, MMOGs need large-scale game worlds and servers to connect players to those worlds. Conventionally, a player is connected via a client program with the server. The client covers the data for the content (graphics, objects, music etc.); game mechanics is administered and processed by the server.

The history of modern Massively Multiplayer Online Role-Playing Games (MMORPGs) like World of Warcraft (WoW), and related virtual world genres like the social virtual worlds trace directly back to the MUD genre which emerged at the beginnings of the 1990s. An MUD (originally Multi-User Dungeon, with later variants Multi-User Dimension and Multi-User Domain) is a multiplayer real-time virtual game world, with the term usually referring to text-based instances of these. Text orientation refers to output of the game as well as control with commands issued via a keyboard.

Most MMOGs also share other characteristics that make them different from other types of games. MMOGs create a persistent universe where the game milieu continues regardless of interaction. Since these games emphasize multiplayer gameplay, many have only basic single-player aspects and the artificial intelligence on the server is primarily designed to support group play. Hence, players cannot "finish" MMOGs in the typical sense of single-player games.

In the Western countries German startups were the forerunners of the online and browser MMOG games business, the largest being Gameforge AG (2010 revenues ca. €150 million) and Bigpoint GmbH (2010 revenues ca. €200 million [Lovell 2011]) operating freemium games on the browser or via downloadable clients. Their games run on almost any type of PC; there is no need for a high-performance computer. Concerning the role of console games it should be noted, however, that the newer game consoles, such as PlayStation 3, Xbox 360, Nintendo DS, can access the Internet and may therefore also run MMO games.

In the five years before 2011 Germany as a market has developed its own breed of successful, profitable businesses in a sub-sector of the games industry. "Investors such as Accel, Highland Capital and Doughty Hanson have backed businesses in the browser-based, social and mobile game sectors, betting that the freemium model, with its low barriers to entry for consumers and potentially high average revenue per user, will be a better place for venture capital and private equity than the traditionally hit-driven business of AAA (game) [71] development." [Lovell 2011]

Bigpoint, Gameforge and a number of other German startups began to take European MMO gaming in a different direction to either North America or Asia (where retail or large client MMOG downloads predominate) and provided, in the time of just two to three years, a significant injection of energy and capital into the stuttering indigenous German games development and publishing market. They revolutionized the European MMOG market reaching unheard-of player numbers and generating unprecedented usage which dwarfs anything achieved by any of the more traditional retail-and-subscription MMOGs.

In 2008 Gameforge, founded in 2003, was the seventh most popular worldwide and twice as big as World of Warcraft [Gibson 2008], the last one, an MMORPG, being viewed as the No. 4 of “The 15 Most Influential Games of the Decade” [Tracey 2009].

Recently VC firms (Summit Partners, TA Associates) acquired a majority stake in Bigpoint, founded in 2002, for €350 million, valuing the entire company at over €600 million [Lovell 2011; Rooney 2011]. Bigpoint turned over ca. €20 million in 2008 [Gibson 2008] and ca. €200 million in 2010 [Lovell 2011]. A person familiar with the matter suggested that US social-games giant Zynga might be interested in acquiring the company pre-IPO. The argument was: “Zynga is very aggressive and has the cash. Bigpoint would give them a presence outside of Facebook and a global footprint.” [Rooney 2011].

Bigpoint “makes money selling in-game virtual items, a business model of which it was a pioneer as early as 2003.” [Rooney 2011].

Box I.16: Business with “virtual entities” for gaming.

The freemium model as a revenue model of the games field relies essentially on a source of revenue commonly called “virtual goods” (or called virtual items). That is, providers of social games make real money from the sale of *virtual entities* which may make up the vast majority of its revenues. In the context of this book of entrepreneurship it is therefore of interest how these relate to *intangible entities*, resources and assets (Table I.8).

Intangible resources (assets) are mainly knowledge, experience, communication and coordination and often bound to people and relationships between people (Table I.8). Hence, they may be shared or related ownership rights for their use may be transferred from one environment to a separate other one – and they may disappear immediately or unexpectedly, if humans are carrier of such intangibles.

Virtual goods and additional services have the potential to give players a (competitive) advantage, such as virtual magic swords. Hence, they seem to relate to intangible resources (“sources of aid or support that may be drawn upon when needed,” ch. 1.1.1.1). They are *inherent components of the game*, in-game entities, which are monetarily conditionally accessible by all players of the game and affect efficiency of running the game to its end. But they cannot be transferred to or used in a different environment (game). This makes the comparison with intangible resources incomplete. It should be noted, that online gamers are often ready to buy such extras: to save time.

The virtual entities have meaning for a given environment and are valuated for specific gaming situations depending on the psychological disposition of a person as a player. Furthermore, they have an impact value (in German Wirkwert) like chunks of information, knowledge or intelligence or an invention (Table I.10) or a license (ch. 1.2.5.2). Hence, virtual goods and additional services represent a relation of situational “digital extra content for a game” (in German virtuelle Zusatzinhalte), and thus allow “digital extra business” via monetization.

This “extra content” is no goods: they have no material value, they have no independent life-time; their life-time is associated with the life-time of the game they are part of. And, finally, they can be copied to any extent without any expenditure.

It should be noted that monetary expenditures of players exhibit a “broad” cultural dependence. It is reported [Bidaux 2009] that $ ARPUs (Average Revenue per User) is $12.9 for EMEA (Europe, Middle East, Africa), $8.2 in Asia/Pacific, $11.2 in North America and $6.3 in Latin America (for P2P and F2P games combined).

The question is how the social game provider plans to track income and book real money from the sale of virtual entities”

For instance, Zynga [Zynga 2011; Murphy 2011] adopted an approach to recording the revenue dividing those “virtual goods” into *consumables and durables* and treating them as if they actually existed. That is, Zynga uses a lucid mapping of the real world to the virtual game world (“digital representations of real world goods”) [Zynga 2011], referring to games like CityVille or FarmVille.

Depending on that definition, the company may book the revenue almost immediately or over the course of a couple of years.

Zynga’s primary revenue source is the sale of virtual currency that players use to buy in-game virtual goods. Some forms of virtual currency are earned through game play, while other forms can only be acquired for cash or, in some cases, by accepting promotional offers from advertising partners of Zynga.

For example, a player of Zynga’s CityVille might purchase energy allowing players to build structures and perform other activities more quickly, erect a teeming metropolis, which Zynga classifies as a *consumable* because its full use comes at the election of the player (“consumed” by a specific player action). When the player buys the energy, Zynga records the purchase as “deferred revenue” on the balance sheet, and when that player uses the energy in gameplay, the revenue is recognized on the income statement.

Conversely, a player might buy a tractor on FarmVille to help manage a virtual farm (make players’ virtual fields more productive). It will be accessible to the player over an extended period of time. Similarly, the revenue is immediately classified as deferred, but it is recognized on the income statement ratably over its estimated useful life, just *like a durable good in real life*. Except in Zynga’s case, it is not rust or a broken axle that will determine when the tractor has outlived its usefulness, it is when the player stops playing the game. Revenue from “durable” virtual goods like tractors, which can be used over and over again, is recognized over the estimated average playing period of players for particular Zynga games, a period that ranges between 10 and 25 months, depending on the particular game.

That means, in income statements, for instance, Zynga reports figures in line with Generally Accepted Accounting Principles (GAAP) [72], such as advertising but also bookings including "deferred revenue" as given below. Zynga (B.2) records the sale of virtual goods as deferred revenue and then recognizes that revenue over the estimated average life of the purchased virtual goods or as the virtual goods are consumed. Advertising revenue consisting of certain branded virtual goods and sponsorships is also deferred and recognized over the estimated average life of the branded virtual good, similar to online game revenue.

Year	Booking (mio.)	GAAP Booking (mio.)	Employees
2008	$36	$19	157
2009	$328	$121	576
2010	$839	$597	1,483
2011	$1,155	$1,144	2,846

For instance, "deferred revenue" in 2009 was $207 million and increased to $242 million in 2010.

Such an explosive growth in terms of numbers of employees over the first three to four years of the startup's existence is rarely observed with software- or IT-related firms which later became giants – not with Google (Box I.24), Microsoft (Figure I.146), Cisco (Figure I.145) or SAP (Figure I.147).

3.4.1.1 Gameforge AG and Zynga, Inc.

Gameforge founded in 2003 and Zynga founded in 2007 target different segments of the gaming field. They are no direct competitors. The entrepreneurs of both the firms led and determined the firms' developments (more details in related cases; B.2).

Gameforge AG (B.2) was founded by the *entrepreneurial pair* Klaas Kersting (born 1979) and Alexander Rösner (born 1980) as an LLC (GmbH) with both acting as Managing Directors (in German geschäftsführender Gesellschafter). While Rösner is a serial entrepreneur, Kersting co-founded Gameforge during his study. He graduated later as an "International MBA."

Gameforge offers browser-based and client-based MMOGs (Gameforge AG, B.2).

Essentially the two founders provided the finances for starting the firm and over the first eight years of existence they owned ca. 90 percent of Gameforge. In 2007 the US investment firm Accel Partners, which also invested in Facebook (Box I.15), acquired an "absolute" minority stake in Gameforge AG by estimated no more than €10 million.

Zynga, Inc. (B.2), founded via Presidio Media LLC and a privately held company until its 2011 IPO, develops social games (casual games) played on various social networks including Facebook. Zynga was *growing at record speed* (Box I.16). For Zynga there are a number of founders listed. But undoubtedly, Mark Pincus, then CEO of the firm, is the “lead entrepreneur” and driver. Pincus is a serial entrepreneur and angel investor.

The foundation of Zynga followed a rather rational approach utilizing a network (cf. Figure I.195; A.1.7). Apart from Pincus’ own investments in the first seven months of 2008 Zynga collected around $100 million from various investment firms and friends and notably William “Bing” Gordon, a partner at Kleiner Perkins Caufield & Byers (KPCB) and Reid Hoffmann (ca. $3 million), a key founder of LinkedIn (ch. 3.4.2.1).

By 2011 Zynga “raised hundreds of millions of dollars to maximize its ability to make large investments in teams, games and infrastructure” (over $500 million estimated). However, Pincus succeeded in retaining control over Zynga.

Zynga, founded in 2007, represented the latest in a wave of new Internet companies. It provides *social network-based games based on Facebook*. Indeed, Zynga is *heavily dependent on Facebook and its users* (Zynga, Inc., B.2).

Zynga’s games tend to fall into the category of casual cases. This does not only mean different ways for players to access games. Games and players are different:

- Games’ genres (Gameforge tend to focus, for instance, on strategy, role play, sports and science fiction games. Zynga’s games tend to focus on build-up principles, such as FarmVille or CityVille, or represent types of games played for long without computers, such as poker or “Play on Words”)
- Player demographics, in particular, gender effects; core gamers of Gameforge are male, core gamers for Zynga are female
- Kinds of social interactions while gaming,
- Advertisement as a source of revenue (for Zynga advertisements means 5 percent of revenue; Gameforge’s MMOGs do not have advertisements),
- License businesses (in-licensing of games represent a significant source of revenue for Gameforge),
- Internationalization of games (Gameforge focuses on Europe, Middle East and Africa. Zynga has a strong focus on the US and countries with English as the native language. Localization of games for Gameforge involves 55 different languages, Zynga just started to offer its games in no more than twelve languages)
- Levels of competition with other game companies (Gameforge claims to have none, to be way ahead of others); Zynga recently encountered hefty competition; both will have to position themselves against games on mobile devices.

For MMOGs of German firm Gameforge (B.2), there are guild activities (raids), player-versus-environment (questing), player-versus-player (battle grounds), a wide variety of social interaction (chatting) and more. For Zynga’s games there is usually no direct social interaction (such as, chatting, questing together, fighting each other).

Both share the fact that the essence of their revenues stem from "virtual entities" (Box I.16) according to a "freemium model" and both started to address mobile devices like smartphones for gaming rather than clinging only to PCs. Both involved serial entrepreneurs for firms' foundation.

Concerning exploiting the opportunity both firms strove for continuously expand their portfolios, by number of games and breadth of genres. Furthermore, already during its early period after foundation Zynga needed as many sources of revenue as possible as it prepared for its initial public offering [Zynga 2011].

Both firms showed very high growth rates. For instance, after four years of existence Zynga reached a GAAP booking of ca. $600 million in 2010 (Box I.16). Gameforge was seen as a "most notable example of German companies {that} have unearthed a potential mass-market goldmine rather than a short-term niche" with 2010 revenues of ca. €150 million (Gameforge AG, B.2).

Notable differences for idea generation, revealing opportunity and entrepreneurship between Internet game companies and TVT or HVT firms comprise the following ones.

- Often employees of game companies in creating the video games are also active players. This is also true even for founders. Specifically, the two co-founders of Gameforge started the firm offering two games the co-founders themselves had created as a hobby (Gameforge, B.2).
- Creating games exhibits functional aspects and a creative and imaginative orientation regarding leisure and entertainment.
- Game companies serve exclusively an end-user (consumer) market. For many gamers, video games serve as a temporary respite from reality. The market is related strongly in a much differentiated way to national culture, language, purchasing power and preferred modes of payment.
- Product or service placement in video games is a relatively new and extremely fast growing advertising technique.
- A key problem for business planning is customers tapping in and stepping out of the game, in particular, customers who register, but run just one trial.

And there is the issue of the "churn rate" for the game supplier. The churn rate is one factor that determines the steady-state level of customers a business will support, an important factor for any business with a subscriber-based service model. It is the rate of attrition {customer erosion} over a period of time that subscriber-based customers unsubscribe to the customer base; they "churn out." In other words, of interest is the probability that a Premium Member generating cash flow up to period (t-1) will still be a Premium Member in period t.

The German company Gameforge AG from Karlsruhe (Germany) operating as a holding is a developer and publisher of games. It grasped the opportunity associated with MMOGs. By 2011 it was the largest independent global provider of browser and downloadable client-based Massively Multiplayer Online Games (MMOGs). The revenue model relies on sales of virtual entities and revenue from in-licensed client-based MMOGs.

The key components of Gameforge's business model (ch. 1.1.1.1) differentiated by advantages for the user ("value proposition") – partially as seen by Gameforge – and the firm (Table I.61) emphasizes the business opportunity and how to exploit it.

Table I.61: Key components of the business model of Gameforge (B.2).

Advantages for Players	
Play for free	Gameforge games are basically free of charge. Players pay neither for purchase nor (indefinite) usage. There are no subscriptions or hidden costs. All games can be played to their full extent for an unlimited time
No distractions	No annoying in-game advertisements!
Individual enhancements	Small fees have to be paid only if players want to acquire game add-ons and premium features. Costs will never exceed weekly pocket-money allowances. Fees can be paid conveniently through channels according to personal preference.
Privacy	Gameforge games require just two things: A valid e-mail address and a discretionary password.
Low barriers to game entry	Minimal technical requirements maximize the addressable market of computers and therefore players. Expensive game controllers or always the latest computer model are definitely not necessary. Most of the games are played in a browser using Flash, Java and plain HTML in contrast to the download-oriented Asian and North American MMOGs. This allows the firm to have appeal for frustrated gamers without the money to buy the sort of PCs needed for modern retail PC games.
State of the art	Gameforge always provides the most modern version of its games to all players without exception. New advanced versions of a game or completely new games are accessible by all Gameforge players – again without exception, free of charge, no time limit, guaranteed.

Table I.61, continued.

Advantages for Players	
Broad localization (in-house)	The low minimum hardware specification is particularly appealing to gamers especially in Central and Eastern European countries. This has enabled their services to tap into a vast base of players unable or unwilling to read or communicate in English (the default and, in most cases, the only language used for most traditional MMOGs). In particular, for multiplayer games requiring much communication among players, it is fundamental to use the same, mostly native language. Here, concerning localization, German culture is to view across its own language and culture; US culture is more restricted.
Stable and fast gaming technology	Provide best server technologies and response to incidents; multiple server configuration
Modes of payment	Flexible billing and easy selection of the preferred payment methodology as well as fast and transparent payment processing Gameforge offers a big variety of payment methods such as bank transfer, PaySafe-Card, SMS, phone, credit card or PayPal in more than 50 countries, always giving the player the possibility to pay the way he or she wants to. Any player can pay conveniently via an innovative self-developed payment system. For instance, already in 2007 it partnered with Moneybookers, one of the world's online payment providers, and co-founder Klaas Kersting commented: "Gameforge always aims to offer its customers the best available payment solutions."
Advantages for Gameforge	
Economies of scale	Individual add-ons are affordable for any player, even in economic recessions
Sale: virtual entities	Gaming enhancements and customizations, individual outfits and weapons for players
Multi-premium accounts	Deliver small in-game advantages

For the time until approximately the mid of 2012 Zynga (B.2) developed essentially social network-based games (often casual games) played on various social networks including Facebook, and to a minor extent on mobile devices. For now, Zynga's fate appears inextricably tied to its relationship with Facebook Inc. Zynga said it expects to continue to derive a “substantial portion” of its revenue and players from Facebook for the “foreseeable future.”

Facebook sought to capitalize on Zynga’s popularity, and the social network entered into an addendum with Zynga under which virtual goods purchased on Facebook for use in Zynga games are denominated in Facebook credits. In that way, Facebook received 100 percent of the revenue, and then distributed 70 percent of that to Zynga.

In the US Zynga is under heavy attack by giant Electronic Arts (EA) known for console games (Zynga, B.2). EA’s goal was to win not just also in the market for Facebook games, but across all digital platforms, including mobile devices. According to Electronic Arts Zynga has a bit of a reputation for cloning other game developers’ ideas. For instance, Zynga’s early big success was FarmVille which was derived from “Happy Farm,” developed in China and released in 2008. Happy Farm was cited as No. 14 among the “The 15 Most Influential Games of the Decade.”

The fundamental entrepreneurial/innovation-related approaches of Zynga’s key founder Pincus (B.2) are firstly to *be better than others*.

> “FarmVille wasn’t the first farm game. It wasn’t even the first farm-set social game. The reality is that he did it better than everyone else.”

Secondly, Zynga follows *a quasi “structural platform” approach*. Zynga’s pattern of success in *similar games*, FarmVille, CityVille, CastleVille, FrontierVille etc., is keeping the basic structural formula for new games and changing the components, their interactions and additions. This can be viewed as a kind of *component innovation* (ch. 3.1) which entails changes to one or more components of a product system without significantly affecting the overall design. From a gamer’s perspective this may lead to disinterest – knowing one (game) is knowing all.

In 2012, Zynga was being sued by EA for “infringing EA’s copyrights to its Facebook game, The Sims Social.” EA said Zynga’s The Ville “copied the original and distinctive expressive elements of The Sims Social in a clear violation of US copyright laws.” The degree to which Zynga copied The Sims, said Electronic Arts, “was so comprehensive that the two games are, to an uninitiated observer, largely indistinguishable.” (Zynga, B.2)

The key components and structural features of Zynga’s’s business model differentiated by advantages for the user (“value propositiob”, essentially seen by Zynga) and the firm (Table I.62.) emphasize the business opportunity and how to exploit it.

Table I.62: Key components of the business model of Zynga (B.2).

Advantages for Players [Zynga 2011] – and Disadvantages	
Play for free	Zynga provides the players with the opportunity to purchase “virtual goods” that enhance their game-playing experience. Zynga believes players choose to pay for “virtual goods” for the same reasons they are willing to pay for other forms of entertainment. Zynga believes players are more likely to purchase “virtual goods” when they are connected to and playing with their (Facebook) friends, whether those friends play for free or also purchase “virtual goods.”
Accessibility, low barriers to game entry	“Accessible by Everyone, Anywhere, Any Time; games easy to learn, playable in short sessions,” and there is geographical and demographical diversity of players
Individual enhancements	Benefits received by players from the purchase of “virtual goods.” Players can earn “virtual goods” through game play, receive them as gifts or purchase them. Within these games, players can purchase virtual currency to obtain virtual goods to enhance their game-playing experience and extend the duration of the game session. Through virtual goods players are able to extend their play sessions, enhance or personalize their game environments, accelerate their progress in the games and share and trade with friends. A player may purchase decorative and functional items to personalize their game environment and express his/her individual taste or style
Fun	Zynga strives for keeping the games fun and engaging by regularly delivering new content, features, quests, challenges and “virtual goods” that enhance the experience for the players. As a result, the games are perceived as a perpetual source of play, evolving with the community of players over time. Players express their personalities by designing and customizing the appearances of their characters and building and decorating their own virtual city, farm, homestead or restaurant. In CityVille, players can personalize the names of their store franchises: for example, friends can shop for virtual shoes at “City Soles.”

	Friends can also visit and admire each other's creations.
Supportive of Social Good; contributions to charitable causes	The players are able to enjoy fun social games while also contributing to charitable causes. Through the philanthropic initiative, Zynga.org, launched in October 2009, players are enabled to contribute to charitable causes by purchasing specially created virtual goods in the games. For example, the players were able to buy Sweet Seeds in FarmVille, the proceeds of which were used to build a school for children in Haiti. Zynga have raised more than $10 million for donations to non-profit organizations from payments made by the players.
Social aspects	Social interactions, around trading goods, sending people trains and all kinds of things that one can do to play with each other, for instance, to friends to grow his/her city in CityVille. But there is also "social pressure," exemplified for FrontierVille: "To encourage you to find more friends to play the game, Zynga may limit access to specific resources such as animals, trees or buildings. Without a certain number of friends playing the game, you cannot access these resources. Even when a specific mission requires you to interact with the resource that you do not have access to, it will stay restricted."
State of the art technology	Provides the most modern version of its games to all players
Advantages for Players [Zynga 2011] – and Disadvantages	
Distractions and disturbances	In-game advertisements are often seen as a distraction (cf. Gameforge AG – B.2). There is game mechanism when playing on Facebook which is a constant reminder that you "need more friends" to play the same game, so that you may advance. This may be seen as social pressure.
Little localization	Users from many countries. However, little location of games in terms of languages (cf. Gameforge AG with games in 55 languages (B.2) with Zynga offering, for instance, 5 languages for CityVille.
Privacy	Related to Facebook's management of personal data which is partly questioned in Europe (ch.3.4)
Modes of payment	In May 2010, Zynga entered into an addendum to Facebook's standard terms and conditions requiring the transition of the

	payment method to Facebook Credits, Facebook's proprietary payment method, as the primary means of payment within the games played through Facebook. By April 2011, Zynga had migrated all the games on Facebook to Facebook Credits. On platforms other than Facebook, players purchase the virtual goods through various widely accepted payment methods offered in the games, including credit cards or PayPal. For instance, an estimated 2 to 3 percent of "FarmVille" users – 5 to 10 million people – do use their credit cards to buy virtual goods [Kaplan et al. 2010]
Advantages for Zynga	
Economies of scale and almost free from recession effects	Generating new games along structural lines, like FarmVille, CityVille, CastleVille or "Words with Friends" and "Hanging with Friends." Individual add-ons are affordable for any player, even in economic recessions But the related incremental and expectable changes in a commodity-like series of games may lead to disinterest of gamers.
Sales of virtual entities	The primary revenue source (ca. 95 percent) is the sale of virtual currency that players use to buy in-game "virtual goods." Some forms of virtual currency are earned through game play, while other forms can only be acquired for cash or, in some cases, by accepting promotional offers from advertising partners. Zynga says its *paying players* are a "small percentage of its total players." [Zynga 2011] For accounting and reporting purposes Zynga adopts an approach to recording the revenue dividing those "virtual goods" into *consumables* and *durables* and treating them as if they actually existed (Box I.16). In its filing Zynga said that future player behavior could change, thereby changing the period during which it recognizes revenue for its durable virtual goods. Players can primarily pay for virtual currency using Facebook Credits when playing games through the Facebook platform, and can use other payment methods such as credit cards or PayPal on other platforms.
Advertisements	Advertising revenue (ca. 5 percent of revenue) primarily includes branded virtual goods, sponsorships and en-

	gagement ads. Zynga generally reports its advertising revenue net of amounts due to advertising agencies and brokers.
Scalable technology and data.	Zynga processes and serves volume of content for its players every day, which it believes is unmatched in the social game industry.

Finally, Zynga was very critically assessed in the media and it is not just only issues of stock pricing for its IPO and the dramatic decline of stock value (ch.3.4).

In the context of entrepreneurship it is the leadership style of its key founder and CEO Mark Pincus. Its corporate culture got a very bad press. Zynga was not only characterized to have a "tough culture," it was called "an oppressive {tyrannical, repressive, unfair} corporate culture leading to losses of talents, executive and deals and a serious loss of reputation."

Concerning entrepreneurship one reads: "{Instead} it's going to be a Harvard Business School case study on founder overreach – this will be a cautionary tale." (Zynga, B.2).

3.4.2 Special Entrepreneurship in Professional Social Networks

As described (at the end of ch. 3.3.1, 3.4) concepts of professional social networks interconnecting professionals were practiced already in large firms using their corporate Intranets. The current conceptual approach is just a shift from a private restricted domain to the public domain using the Internet and targeting a mass market of a special consumer segment with high purchasing power. The other conceptual model for professional social networks is the (classical, face-to-face) business club (ch. 3.4).

Technically, such systems rely on a storage and search system with input about and by professionals (or also profiles of firms) augmented by communication and other interaction facilities for business transactions. Ideally, people present themselves the "right way." The glue for interactions is create attention, trusted relationships, searching, reaching, and filtering leading to main revenue stream of job postings, advertising, and online (freemium) subscriptions

People can recommend their connections to other people as they see fit and provide an online means for doing what people have historically done offline. When one person approaches another for a job or deal a *trusted intermediary* recommends them.

3.4.2.1 Xing AG and LinkedIn Corp.

As a case the stories of the two professional social networks, the German Xing AG (B.2) and American LinkedIn Corp. (B.2), and their comparison are interesting to reveal differences between approaches to company foundation and developments in

Germany and the US as well as the roles of private venture capital and the stock market.

Both were officially founded at almost the same time in 2003 and both became publicly traded firms. Both received rather early significant venture capital, but remained largely under control of the founder (Xing) or co-founder (Reid Hoffman), respectively.

In December 2006 Xing had a successful IPO as the first company of the “Web 2.0” category in the world.

For LinkedIn (and its key co-founder Reid Hoffman) the accelerating change of the world around us and the Internet were seen as an opportunity the way *individuals* would interact with each others and do business.

Hence, LinkedIn’s initial focus was how each of us as an *individual professional* on the Internet can respond to the changes the way we do business, our careers, our brand identity and influence the perception by others online via “written self-presentations” etc. Building the professional social network meant adding necessary features that allow individuals to truly present their credentials and backgrounds.

Such a concept would not only help employers to reference check prospective employees, but the other way as well. As a corollary, to achieve fast growth LinkedIn’s development was about scaling by utilizing network effects.

Xing, founded by Lars Hinrichs, followed essentially the lines of a “classical business club.” Correspondingly, its name for the first years after foundation was openBC – “Open Business Club” (B.2, Xing). It used essentially a mapping of a business club into the Internet. But Xing’s business club targets not only the online world, but addresses even face-to-face contacts as a basis of trust.

A “business club,” often associated with a membership fee, provides physical proximity of members to have *face-to-face interconnections*. One of its objectives is to *educate* members about being successful in the world of business, including but not limited to finance, marketing and consulting – and presenting oneself. A goal to develop new ideas, new skills and profitable processes means that business people overcome their own experience – “we don’t know what we don’t know!”

The club will accomplish this goal by *organizing and sponsoring events* pertaining to the business world, for instance, conducting mock interviews and inviting speakers to discuss their experiences. The second objective concerns “*networking*,” *facilitating interconnections of various types of people with commercial orientations* and *facilitating various commercial activities*.

By 2010 the revenue models of LinkedIn and Xing comprised essentially three components.

Members – Professional Networks. Membership on the Web site is available at no cost. But to get full functionality of the offerings for online professional networking solutions members must pay a fee; they are "premium members," subscribers.

Enterprises Professional Organizations – Recruiting. There are hiring solutions, comparable with what established online recruiting companies, such as Monster-Hot Jobs, or talent management companies or traditional recruiting firms do.

Enterprises Professional Organizations – Advertising and Marketing. With respect to marketing solutions the professional social network must attract and retain advertisers by giving them access to relevant and targeted audiences for their products or services.

The relevance of each of the components of the networks has different origins and, according to the quantity of the contribution to the overall revenue, will lead to different dependencies of the two firms upon external effects. For instance, as mobile ads cost less than online ads viewed on desktop computers, declining prices for the ads by a shift of advertisers toward mobile ads may affect LinkedIn more than Xing. Both are increasingly accessed via mobile devices.

While subscribers account for three quarters of Xing's income LinkedIn relies on advertisement and hiring by an extent of three quarters. Sources of 2010 revenues of both the firms demonstrate the situation (B.2, LinkedIn).

LinkedIn	**Xing**
$61.9 mio. (25%) Premium (paying) members	€42.4 mio. (78%) Premium (paying) members
$79.3 mio. (33%) Advertisements, marketing	€3.9 mio. (7%) Advertisements, marketing
$101.8 mio. (42%) E-recruiting, hiring solutions	€7.1 mio. (13%) E-recruiting, hiring solutions

Through acquisition in 2010 Xing opened "events" as a further source of revenue by an event management unit and ticket service providing the registration for events and tickets. In 2011 revenues from Events, which were reported for the first time in Xing's history, totaled €2.5 million (3.8 percent of total revenue).

Xing, hence, has "hybrid features" and facilitates (and further develops) *online as well as face-to-face interconnections* of individual users (as is found with a classical business club). On the other hand, LinkedIn as a professional social network has "hybrid features" in that it acquires *revenue distinctly by online and offline approaches* to non-individual users by a massive field sales unit.

Furthermore, Xing focuses on the way *how a first contact occurs*. That means getting to know *by whom one is addressed* is assumed to facilitate the first contact. Hence, while the main driver for Xing users is the ability to check who visits his/her page (a passive approach), LinkedIn users typically pay to see profiles and get search results (a proactive approach).

Equipped with $103 million investment capital LinkedIn pursued and achieved massive growth in terms of number of employees, from ca. 45 in 2005 to 990 in 2010. Employees' numbers grew by hiring and a non-organic approach (acquisitions), nearly doubling every year since 2006. Correspondingly revenue increased from $32.5 million in 2007 to $243 million in 2010, also roughly doubling per year.

Similar effects are observed for Xing, but on a much lower level. Xing had ca. 30 employees in 2005 and 306 in 2010. Revenue climbed from €4.6 million in 2005 (ca. $5.8 million) to €54.3 million in 2010 (ca. $73.3 million).

A significant difference, however, is seen if profits of the two firms are taken into consideration. In relation to net income Xing's performance is much better than that of LinkedIn's performance.

LinkedIn	**Xing**	**Proportion**
990 employees	306	3.24
Revenue $243 mio.	€54.3 ($73.3) mio.	3.32 (regarding revenue in dollars)
Net Income $15.4 mio.	€7.2 ($9.7) mio.	1.59
Net income/Revenue = 6.3%	13.3%	Though LinkedIn is larger by factor of ca. 3.3 than XING in terms of employees and revenue, in relation to profit Xing's performance is twice that of LinkedIn's performance.

Generally p*rofessional* social networks will be affected by national cultural differences and particularly by the "business culture" (ch. 3.4.2). Another cultural effect that has to be considered for comparisons between LinkedIn and Xing refers to the frequency of changing jobs or "job hopping," respectively, in the US and Germany. This will affect "hiring solutions" (e-recruiting) as an offering.

According to an online-survey of the career-portal Monster in Germany obviously the number of people who want to accelerate their career by frequent job changes, increase their salary or change jobs because of dissatisfaction are rather low. According to Davide Villa, CEO of Monster Worldwide Deutschland GmbH, "what is normal in the

US, is still viewed with skepticism in this country." Frequent job changes are seen still as critical by HR (personnel) managers.

Furthermore, concerning payment and premium subscriptions, the readiness to pay for Internet services exhibits a relationship to culture. For instance, most of the developing countries (for instance, in Asia) still have a use-for-free culture when it comes to the Internet.

Concerning influence on other sources of revenue (particularly, advertising) data on customers and their access to the networks become important. A detailed metrics of users and usage of Internet services is given in both the case documents (B.2) and include,

- Number of registered members,
- Number of paying members (premium members, subscribers),
- Unique visitors,
- Page impressions (for instance, being relevant for revenues by advertisements via the "click-per-pay" (CPM) mode).

Related 2010 data are listed below.

LinkedIn	**Xing**	**Proportion**
90 million registered members	10 million	9
52 million unique visitors	2.1 million	24.8
ca. 200,000 premium subscribers	718,000 (first half of 2010); premium members do not see ads	Premium subscribers/ registered members = 0.3% for LinkedIn, 7.2% for Xing

Furthermore, putting the emphasis of valuing the offerings on *individual users* the proportion of paying users of Xing is far ahead that of LinkedIn. LinkedIn's value is seen more by firms which are interested in the demographics of the individuals for advertisement or hiring.

While both firms are having an international orientation LinkedIn is globally present; it is the world's largest professional network on the Internet. But, 80 percent of all members of LinkedIn are in the top 10 countries. Both firms reflect a strong focus which is related to the language and culture of their customers – English-speaking versus German-speaking countries. Correspondingly the potential user-base for LinkedIn is approximately four times that of Xing, disregarding India (!).

Both firms obtained 70-80 percent of their revenues in their home countries (in 2010).

<table>
<tr><th>LinkedIn</th><th colspan="2">Market Focus by Country</th><th>Xing</th></tr>
<tr><td colspan="2">US (ca. 68% of revenues), India, UK, Brazil, Canada, France, Australia</td><td colspan="2">DACH region (ca. 80% of revenue), Turkey, Spain, South America and Latin America *)</td></tr>
<tr><td colspan="2">Ca. 40 mio. members in the US</td><td colspan="2">Ca. 3 mio. members in Germany</td></tr>
<tr><td colspan="2">2 mio. registered members in the DACH region, ca. 1.5 mio. in Germany</td><td colspan="2">4.1 mio. in the DACH region, ca. 1.4 mio. in Turkey</td></tr>
</table>

*) DACH region = Germany, Austria, Switzerland (German-speaking countries); in Germany ca. 3 million people of Turkish origin live and Germany is the biggest trading partner of Turkey.

Emphasizing competition between the two firms LinkedIn is more of a competitor for Xing than Xing is for LinkedIn.

The most perplexing difference between LinkedIn and Xing and the situation of related entrepreneurship in Germany and the US concerns the valuations of the firms, particularly after Xing's IPO in December 2006 after three years of existence and LinkedIn's lofty $8.9 billion IPO valuation in 2011.

The concern is not much with regard to the $2 billion in 2010, but with the jump to the $8.9 billion IPO valuation in the next year. In an interview, LinkedIn Chief Executive Jeff Weiner played down the significance of the IPO's surge. "This isn't necessarily indicative of anything," he said. "The market will do what it will do." More discussions on that are given in the LinkedIn case document (B.2).

<table>
<tr><th>LinkedIn</th><th colspan="2">Market Capitalization</th><th>Xing</th></tr>
<tr><td colspan="2">$8.9 billion (IPO May 2011),
is 578 times 2010 profit;

$1 billion in 2008 in a private market
$2 billion in 2010 in a private market</td><td colspan="2">€157 million (IPO, Dec. 2006),
is 22 times 2010 profit;

ca. €210 million (2010; ca. $270 mio.)</td></tr>
<tr><td colspan="2">Raised $352.8 million capital with the IPO</td><td colspan="2">Raised €35.7 million capital with the IPO</td></tr>
</table>

A final question of this chapter on entrepreneurship in software and Internet firms is in how far the status of the dollar as global *reserve currency* and the current availability of "cheap money" in the US by the Federal Reserve System, "The Fed," (the central bank of the US) which is printing masses of money and floods the US financial system with money at negligible interest rates (ch. 1.2.7) facilitates entrepreneurship and particularly entrepreneurship with skyrocketing valuations, for LinkedIn and other firms (Groupon, LivingSocial, Zynga and more).

4. ENTREPRENEURIAL SUCCESS AND VENTURE GROWTH

The day is committed to error and floundering; the time series commands success and achievement.
(Der Tag gehört dem Irrtum und dem Fehler, die Zeitreihe dem Erfolg und dem Gelingen.)
Johann Wolfgang von Goethe

Fueled by selected stereotypical and simplistic profiles of entrepreneurs in the media, public perception is understandably focused on the least common – and usually most successful – entrepreneurial efforts. And policy usually also follows that track. "Success" is attributed to an entrepreneur who made a fortune or tremendous growth of a new firm is translated by policy into large numbers of jobs created .

> However, most businesses (and NTBF) start small and stay small [Bhidé 2000:207].

"**Entrepreneurial growth companies**" (EGCs) make up only a minute portion of all new firms. In the US, for instance, their share is estimated to be ca. 4 percent [Russo 2001]. An EGC has *sustainable high growth* and *high profitability* as its primary objectives. Regarding profitability by the end of 2010 LinkedIn was not an EGC.

Young firms that continue to *grow rapidly* over several years *into large and globally dominant firms* (startup "superstars") are usually also called "*gazelles*."

> On the basis of an NTBF sample from Germany and the UK collected 1997 – 2003 Cowling et al. [2007] reported: "Employment by 2003 in the median firm in its 12th year was 12 persons in Germany and 10 in the UK."

This finding reflects quantitatively potential discrepancies between perceptions of various stakeholders in technology entrepreneurship. In particular, it requires being aware of the various perspectives of the stakeholders what "success" in this context means to them.

For instance, the *Inc.* Magazine in the US asked founders (of privately held firms) that made its "500 list" from 1982 to 1989 about their *original intentions for growth of their firms*. And a recent Finnish study on "growth orientation" reflects the special situation of firms in an incubator, which means essentially RBSUs.

Results are presented in Table I.63. A minority planned to grow fast or considerably, respectively. Bordt et al. [2004] found: "Whether this was to avoid formalization, 'playing in the big leagues' or shunning a more competitive environment, some companies did not seek opportunities for further growth." It is to be noted for later discussions that Mäki and Hytti present an essially European view when internationalization of NTBFs is taken into consideration.

Table I.63: Intentions of entrepreneurs concerning growth of their firms.

Original Intentions of Firm's Foundation Study by *Inc.* Magazine (1982-1989) in the US [Bhidé 2000:264]	**"Does Your Firm Aim To Grow?"** Study of Incubator Firms (RBSUs), Finland 2004-2007 [Mäki and Hytti 2008]
33% planned to grow as fast as possible	Yes, considerably – 46%
27% had planned to grow slowly	Yes, reasonably – 16%
12% had planned to stay small	Yes, to some extent – 26%
The rest (28%) did not plan at all	Not that much – 11%
	Not at all – 2%

Our focus on *intended success* of the founder(s) as a driver of NTBF development (Figure I.97) will use growth as an indicator roughly differentiating

- Non-growth (including low growth) firms
- Good growth (including medium- or average-growth) firms
- High-growth firms (including EGCs).

The immediate consequence of this distinction is the differences in necessary tangible assets and resources, particularly finances, and intangible assets (intention, human resources, execution and control).

On the other hand, one can assume that the small firms need to grow in order to be able to take full advantage of existing resources and capabilities [Bhidé 2000:230-233]. In particular, financial backers like venture capitalists or government, will put their emphasis on growth or high-growth firms. And even the firms of the category ”non-growth” firms need growth; to survive they have to grow, at least, in line with the national inflation rates.

Growth patterns of technology-based firms (NTBFs) may be differentiated according to various growth phenotypes of structurally quasi linear or curved patterns (Figure I.107). High-growth firms (and also entrepreneurial growth companies, EGCs) typically exhibit exponential growth. However, over a 3-5 years time horizon of observation, it may become difficult to differentiate exponential growth from early phases of typical linear growth or even delayed growth (cf. Figure I.144).

Growth patterns with setbacks exhibit a decrease after linear increase and open three options for further development, back to growth, plateauing or decline. Such setbacks may result from company-internal effects, such as organizational problems, or external effects like an economic recession (ch. 4.3.1, 4.3.5).

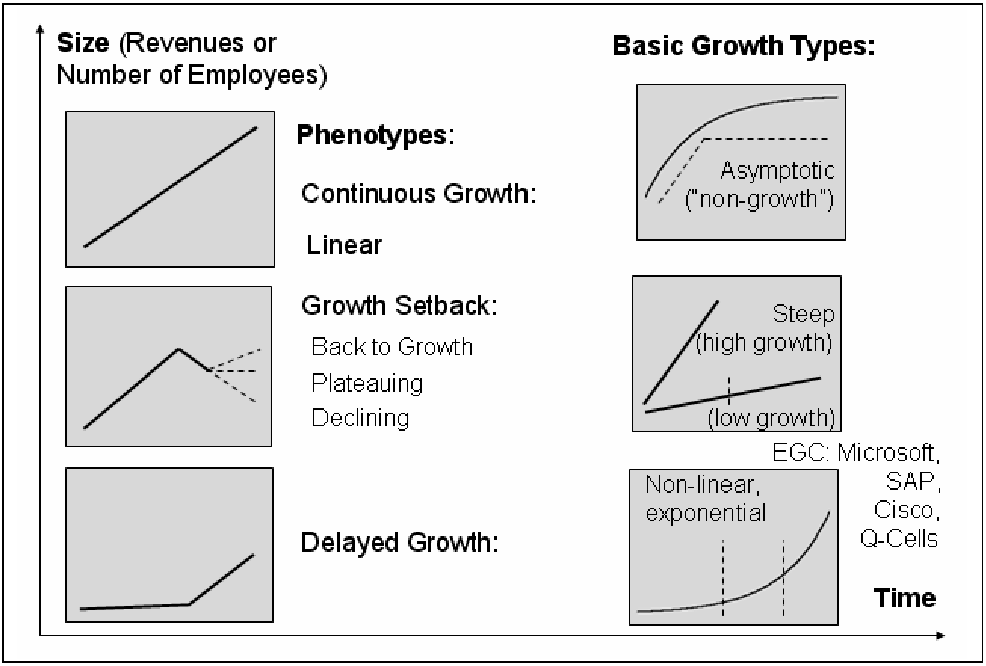


Figure I.107: Growth phenotypes of new firms (modification of charts from Stam and Garnsey [2007]).

4.1 Perspectives of Success of Entrepreneurship

Intention, aspiration and expectation (Figure I.78, Figure I.97) of the entrepreneur(s) drive essentially the further development of NTBFs, for instance, as "**growth orientation"** – but there are also *expectations of stakeholders*, particularly financial backers and policy (Table I.64). Growth orientation defines the perceptions of what entrepreneurs regard as success – related specifically to their aspiration. The level of aspiration represents the *expected level of achievement* or *expectation in the satisfaction of needs* [Van Gigch 1974:59].

Even though in the literature growth orientation has been associated with growth of a firm, it does not ensure that the firm actually grows (Table I.63). Growth orientation does not alone lead to growth. For instance, the acceptance of new offerings in the market might fall below expectations, and expected growth may not take place. However, Mäki and Hytti [2008] have shown that *without a growth orientation it seems unlikely that the firm will grow at all*. Growth orientations have also been demonstrated to remain relatively stable over time [Mäki and Hytti 2008].

> In most cases, entrepreneur(s) make intentionally the fundamental decision the firm to grow or (essentially) not to grow.

Following Mäki and Hytti [2008] *non-growth is seen as a combination of the actual non-growth and lack of growth orientation*. The group of non-growth firms is considered to include the firms that just have not grown in the past but also do not intend to grow in the future either, resulting in a more plausible dependent variable. Among NTBFs there are different kinds of business logics that are associated with growth or non-growth in different ways.

The author is close to a corresponding example. He is personally and professionally interrelated with the German firm "G. E. I. Kramer & Hofmann mbH" [Runge 2006:950] and particularly one of its founders for more than twelve years. "G.E.I." is engaged in electronic storage, retrieval and processing of scientific and technical information (text and graphics) emphasizing innovation, research and patent systems. Over the last ten years the firm worked continuously with two founders, two employees plus one external contractor and survives with "sufficient" growth adding at least two new customers per year. Recently G.E.I. added the wives of the two founders as employees.

For these founders entrepreneurship appears as a substitute for employment and, furthermore, their behavior directs the view to their attitude that "entrepreneurship isn't just about business, it's a way of life" [Gangemi 2007] or as H. Opolka, together with his identical twin brother and co-founder of Zweibrüder Optoelectronics GmbH (B.2), said "entrepreneurship is one facet of life."

Hence, intentionally looking for low growth founders must be aware of the minimum requirements to achieve fitting their goals and standards for their overall lives. This means in that case entrepreneurship may be seen essentially as self-actualization with self-employment and an "*income substitute*" as just one aspect. Non-growth as intentionally "growing in line with inflation" may not suffice as a target, as it is not clear whether the firm can get related price increases of their offerings accepted by its current customers.

Growth orientation may change over time. It may well be that an entrepreneur with an excellent idea/opportunity and growth orientation does follow that track when the firm was founded (Figure I.97). The entrepreneur may have had corresponding aspirations, but exploiting the opportunity fully may later require much capital which can only be collected from VCs. An entrepreneur being "VC-averse" may give up or suspend the growth option and may restrict the growth level to a median or low level.

The behavior to found a firm for which success is perceived as "satisfying" or low growth for the founders is related to the principle of "satisficing," a term redundantly melding "satisfy" and "suffice," but distinctly different.

Accordingly, the **Principle of Satisficing** is a principle which identifies the decision-making process whereby one chooses an option that is, while perhaps not the best, good enough. More specifically, the term selected by Herbert Simon [1955; 1956] refers to a mode of decision-making that is viewed as more realistic than "maximizing" ordinarily postulated in economic theory and related areas of social science.

A “non-growth orientation” is an *intentional* restriction to a level fitting the balance of the overall life-style and this level could be below what, according to knowledge, information, capability and acceptable risk, would be possible.

A *decision maker* is said to exhibit satisficing behavior when he or she chooses an alternative that meets one or more specified criteria, but that need not be optimal with respect to any particular set of preferences or objectives.

Maximizers are individuals who aspire to find and accept only the “best.” They want the best job, the best car – found the “most successful” and most appreciated new firm! *Satisficers* are those who settle for something that is “good enough.” That does not mean generally that they settle for mediocrity; their standards can be very high, but as soon as they meet *their* criteria they select that option and are satisfied. They make decisions based on the information at hand.

The primary goal for the following discussions is not to provide an explanation of or insights into non-growth firms. The emphasis will be on the characteristics which enable to differentiate between non-growth firms and other firms in the context of NTBFs. Furthermore, we shall inquire into conditions and/or events that let growth firms become high-growth firms.

Operationally, for non-growth firms results of Mäki and Hytti [2008] show strong associations with lack of innovations, lack of previous growth orientation and modest internationalization orientation. But, innovations might in the short term represent more investments than growth and the growth might take place only later. The same might be the case with internationalization. Thus the association between innovations and internationalization and growth are not very easily detected during the first years of the new firm’s activities. However, their results suggest that growth is very unlikely for NTBFs that operate without innovations and in geographically narrow markets.

Due to tremendously differences in potential market magnitudes US entrepreneurs apparently do no feel the same pressure to internationalize as their European counterparts. However, disregarding internationalization in a global economy increases the risk that a business idea is imitated elsewhere and thus competition to emerge. In line with this and the historical approach of the German industry a large proportion of German NTBFs exhibit internationalization very soon after their start.

A study of German (and British) NTBFs found that 60 percent of the sample started international business already in their first year. A large proportion of these can be viewed as “born global” which means they internationalize from the beginning.

Typically, these international young firms have regular R&D activities and search for advantage in the market by technology-based differentiation of products. Moreover, their founders more often have work experience abroad or experience from working for large international companies. Drivers are primarily goals for growth or expansion and secondarily the limited potential of the home market [Fier and Fryges 1999].

The growth of NTBFs and small firms has continued to intrigue researchers for a great deal of time (ch. 4.3). Research centers on definitions of NTBFs, periods of investigation as well as indicators to be used to reflect growth. Most studies focus on *economic indicators* as measures of growth, such as the relative or absolute growth in turnover or employment, rather than growth in socio-economic value for the firm founders and stakeholders.

Analyzing absolute growth is rare and there are no criteria what kind of increases in absolute turnover or in employment could be considered as important growth, for instance, due to differences of developments between the industries.

The ideal measurement would use profit (cf. Nanophase Technologies Figure I.140 or Google Figure I.160) instead of revenue and payroll instead of employee headcount. But those are numbers tougher to find for obvious reasons. Concerning profits it has been found that SMEs exhibit similar characteristics across sectors and that “they tend to be associated with growth in output and employment, but not necessarily profit” [Tidd et al. 2001:364]. This will probably also apply to NTBFs.

Relative growth is easier to achieve in smaller firms whereas substantial absolute growth figures favor larger firms. The number of employees alone is not a sufficient indicator of growth because the firms may also grow significantly by turnover without an important increase in employment (when becoming more efficient by learning and increased professionalism).

But for NTBFs there is another issue referring to reported sales versus revenues. For NTBFs it is not unusual to incorporate money received through public research grants and similar public financial contributions into revenues without indicating this to be a source of revenue separate from sales to the market. And, furthermore, public money is received for a particular period or time and, correspondingly, when having used for hiring it may result in firing when streams of public money dry up.

There are suggested several measures to characterize **high-growth firms**. In the analysis of relative growth aiming at identifying high-growth firms and so-called gazelles, Mäki and Hytti [2008] referred to *annual growth* of 30 percent in employment and 30 percent in revenue *over three consecutive years*; often 50 percent in turnover are applied.

For the European Union enterprises are considered high-growth enterprises if the turnover has increased by 60 percent or more *within three years*, the number of employees has increased by 60 percent or more within three years or the turnover and the number of employees have both increased by 60 percent or more *within three years* [EMI 2009]. Furthermore, Bhidé [2000:3-4,18,20-21,25-28] uses a related concept of “*promising start-ups*” through the occurrence of the firm in the “*Inc.* 500” list (which narrows the view towards privately held firms).

Shifting the measurable growth perspective by indicators for new firms to the *measurable perspective of the founders* the Global Entrepreneurship Monitor (GEM) introduced the notion "**high-growth expectation firms**" (or "***high expectation firms"***) driven by *entrepreneurial aspiration* and expressed through *entrepreneurial activity* [Bosma et al. 2008; Autio 2005; Autio 2007].

Product and process innovation, internationalization, and ambition for high growth (growth orientation) are regarded as hallmarks of ambitious or high-aspiration entrepreneurship. And GEM has created measures to capture such aspirations (Figure I.14) [Bosma et al. 2008; Autio 2005; Autio 2007] and introduced two characteristics of *high-growth expectation*:

> Either *a nascent entrepreneur or owner-manager of a new business* (Figure I.15) *expects* to create at least 10 jobs and at least double current employment in 5 years time or expects to create at least 20 jobs in 5 years time.

However, entrepreneurs' expectations with regard to self-assessing their firms' capabilities and developments is often biased by overoptimism and there is a fine line between expectation and hope.

Observing high-expectation activity empirically can be prohibitively difficult. Most studies of this phenomenon are *ex-post* meaning they look at entrepreneurial activity after the results of the activity are known. High-expectation entrepreneurial activity varies significantly between industrial sectors. And high-expectation and high-growth entrepreneurs are generally overrepresented in the manufacturing and business services sectors, transportation, communication, and utilities sectors, but underrepresented in agriculture and consumer services [Autio 2005, 2007].

Ex post means analysis and explanation usually 5-8 years after the firms have been founded. This approach is basically associated with a "survival bias" and "hindsight bias." Special emphases of this kind are represented by reference to promising or fast growing startups like *Inc.* 500 or "Fast Company" lists established by various magazines or consulting firms (ch. B.1).

The job-oriented measure is just paraphrasing "number of employees" and using absolute figures in line with thinking of policy in terms of jobs. It raises, however, some questions concerning such a relationship.

- Will high-growth companies guarantee the creation of sustainable firms and sustainable job creation? Five or more years later the business may fail and the jobs disappear.
- Does the high-growth expectation is met, if a startup with 13 jobs after 4 years acquires another startup (or micro firm) with 8 jobs in its fifth year? Concerning the national economy there is no addition of jobs; it relates to non-organic growth of NTBFs (Figure I.127).

- What about a startup with 15 jobs after 5 years (with R&D and Administration in Germany), but having a joint venture for production in China and having extraordinary growth rates for revenues and profit (for instance, BlueBiotec GmbH – B.2)?
- What about an NTBF with several years of existence, then changing its *business* almost totally, not meeting the job criteria for high-growth, but utilizing a wholly owned subsidiary for production in China showing extraordinary growth rates for revenues and profit and employees in China (for instance, Zweibrüder Optoelectronics GmbH – B.2)?

There are not only entrepreneurs and policy having interests in entrepreneurship. This raises more views of success the corresponding "players" may have. Given the relevance of systems for technology entrepreneurship (Figure I.13.), the objectives and related perceptions of success of the key systems' components are given in Table I.64.

The table reflects "success" in the context of entrepreneurship (which is related to aspiration) to be an individual expression, a small group's expression or expression of many other relevant components of the entrepreneurs' environment. This means, a confrontation of individuals (the entrepreneur or the founder team) with different expectations they may interfere with and which may affect their own (original) intentions, opinions and courses of decisions and actions.

Table I.64: Goals and objectives and related perceptions of success of the components of systems relevant for technology entrepreneurship.

Systems and Active Components	**Success Orientations and Key Indicators of Success**
The Political System (involving also the Higher Education and S&T Systems)	Strategically oriented: growth of national economy, regional developments; wealth creation by innovation and entrepreneurship; high-growth firms and jobs
The Financial Subsystem (venture capital investors, angel investors): Firm owners with majority stakes (equity)	Financially and strategically controlling: high-growth firms, high profit, big financial reward, "easy "exits" (ch. 1.2.4.1), e.g. by IPO or selling stake or firm; generally, development of IPOs for a particular industry segment (Figure I.89)

The Industrial System: (corporations, corporate venturing)	Strategically and financially oriented: developing a new business, acquisition of various (innovative) competencies, acquiring the firm invested in and running it as a separate unit or integrate into a relevant division of the firm
Organizational and Financial stakeholders (not investors, corporations, policy; co-founders, other owners, other lenders)	Consensually or not controlling goal setting: banks (interests and security of loans), shareholders (continuous stream to income; dividends, share of profit); other backers, like "silent partnerships" (share of profit)
Entrepreneur	Goal setting, strategically independent: IPO, selling firm – high growth – high profit (wealth); many other facets of expectation (Figure I.65, Figure I.66, Table I.39, Table I.40)

The interest of policy (but also some founders) in "*gazelles*" would require concepts, models and theories of (technology) entrepreneurship which will allow *reasonable "predictions" on the basis of NTBF development over the first three to five years*. Such general theories and related "measurements," however, do not exist. Based on empirical evidence, at best, high probabilities of success may be discussed for certain types of NTBF with particular configurations. The models/theories may "predict" what happens or will likely happen, but not generally why.

Moreover, the time span of observing 3-5 years of an NTBF's development as the basis to infer characteristics the NTBF to be a gazelle is often too short if the firm is involved in larger scale production. NTBFs looking for production have a need for large amounts of capital envisioning primarily venture capital organization as the source for financing and will have long lasting scale-up processes (A.1.1).

NTBFs with production often encounter "*asymmetry of expectation*." This exists when entrepreneurs expect that they can make a profit, but investors do not. The entrepreneurs often do not have any observable innovation, experience or record of past achievement. They do not have reasonable information about their ability to make a profit. Investors can only find out after the fact who has the ability to succeed. "If the average entrepreneur cannot earn a profit, investors will not back any of them." [Bhidé 2000:39].

Observing high-expectation activity empirically is usually fundamentally difficult. Most studies targeting this phenomenon are *ex-post*.. And there is also very little empirical research on *ex-ante* growth aspirations to help us understand who aspires for and expects rapid growth, and what factors are associated with such expectations [Autio 2005].

Ex ante statements of observers or stakeholders on a startup base their expectations usually on more or less rational arguments which follow a line of “reason for thinking that” rather than a “reason why” (Figure I.2, Box I.17; ch. 4.3.6).

Considering technology and non-technology entrepreneurship according to GEM [Autio 2005] high-expectation entrepreneurial activity represents only a small proportion of all entrepreneurial activity. Accordingly, on average, 9.8 percent of *startups and newly formed businesses expect* to employ 20 or more employees within five years (this varies from 3-17 percent depending on country and world region).

Bosma et al. [2008] reported that only 8 percent of all startup attempts expected to create 20 or more jobs. Similarly, only 4.9 percent of startups and newly formed businesses expect to employ 50 or more employees within five years (varying from 1 to 7 percent depending on country and world region).

Though rare, high-expectation entrepreneurial activity explains a bulk of expected new jobs by startups and newly formed businesses; its potential economic impact is significant. In the GEM study between 2000 and 2006 only 6.5 percent of new entrepreneurs (owner-managers of entrepreneurial firms less than 42 months old) expected to have 20 or more jobs in five years’ time. Nascent and new entrepreneurs expecting to create more than 100 jobs in five years represent only 1.7 percent, yet they expect to create nearly 50 percent of all expected jobs. Almost 90 percent of all expected new jobs are foreseen by less than one-quarter of nascent and new entrepreneurs [Autio 2007].

> The fact that high-expectation entrepreneurship is elusive has consequences for policy-makers. In order to design effective measures that support job creation through the entrepreneurial process, *empirical data (and information) is needed from both before and after the marked growth of the firm*. The shortage of this information, particularly on growth expectations, constrains the development of effective job creation policies.

To identify the small group of high-expectation NTBFs and to support them as good as possible is one of the key challenges of political economy (and entrepreneurship research).

By related promises (for instance, in business plans) expectation of job creation by ministers, majors, agents etc. of cities, municipalities, counties, federal states and federal government has become a key card played by more and more entrepreneurs to become beneficiaries of the various initiatives and programs to financially and otherwise support firm's foundation. And, furthermore, they learned to play these off against each other for their advantage (A.1.1).

From a psychological point of view expectations of individuals are attitudes towards more or less clear goals. It is the imaginative anticipation of events, states or developments or just steps of development, goals of thinking and of acting that will happen in the future. Expectations are anticipating reactions to actions that are waited for, wanted, desired, hoped or supposed.

Following role models or historical analogy may reflect expectations. Expectations may also quantify the time horizon for success. In particular, entrepreneurs may expect that reaching their ultimate goals may take rather long, for instance, more than 10 years. In this case, patience and perseverance will be the basement of entrepreneurial decision-making and action (ch. 4.1.1).

A questionnaire or interview with entrepreneurs – as GEM does – can directly collect expectations of entrepreneurs. But this does not provide insights about the characteristics of "real high-growth firms." The author is not aware of any study in technology entrepreneurship which investigated a sample of firms whose founders states to have high expectations and which after 3-5 years indeed have turned out to be high growth firms.

As another approach to reflecting the growth expectation of the NTBF's founder(s) or leaders, respectively, one can use an indicator which refers to outspoken planned or observed executed expansion in terms of the NTBF's area of facilities (office, laboratory and probably production space) in square meters (m2) or feet (sqft) occupied by the firm in a given building or the overall space of a planned new (own?) building (cf. ChemCon GmbH, WITec GmbH, Nanion Technologies GmbH – B.2). For production-oriented startups expansion of production capacity or increasing number of devices or pieces to be sold (Figure I.150, Figure I.154), can reflect expectation.

The research issue remains how an "observer," for instance, from policy or venture capital, attains a position to identify "pearls" *ex ante*, or, at least, find them with a high probability. The prerequisite is to assess the founders' intention to grow, knowing their growth orientation. And the subsequent question is: what, in in the context of the entrepreneurial architecture and configuration, are the critical success factors (CSFs) for the early development phase to turn into high growth. As emphasized again the entrepreneurial configuration (by GEM called Entrepreneurial Framework Conditions – EFCs) will have a significant impact on the entrepreneurial area (Figure I.13, Figure I.14, Figure I.16). Finally, there is the issue of expectation transformed into execution (Figure I.87).

For the case of venture capital-based startups one can assume growth orientation of entrepreneurs to exist and that great businesses (creating a very large number of jobs) often take 7-10 years or more to reach fruition (cf. German SAP AG – Figure I.143 or Microsoft – Figure I.144).

VCs generate their expectations accepting that it is almost impossible to make *ex ante* statements about future success of startups. They actually follow a three steps approach starting with sorting out those firms that may be successful on the basis of the startups' business plans (Figure I.106). Additionally, they assess the personality of the to-be founder(s) by face-to-face contacts. And then, VCs accept that it will take two to three years to sort out "promising firms" which may become "pearls":

- "Lemons" ("losers") ripen in about 2 1/2 years.
- "Pearls" ("winners") take seven to eight years.

We shall use a notion **promising firm** for NTBFs (to be differentiated from Bhidé's "*promising start-ups*") referring to an observer's assessment of having a potential for good or high growth after ca. three years of operation or even immediately after a start due to extraordinary initial conditions. The related time period after foundation will later be called the "*startup thrust phase*" (ch. 4.3.2, Figure I.125). The observation of firm's operation during this phase may implicitly reveal the founders' intention to grow.

There are some examples which may fall into the category of "promising firms" due to a *favorable starting condition*. The German startups (cases in B.2) WITec GmbH (Figure I.123), Solvent Innovation GmbH, IoLiTec GmbH (both in A.1.5), ChemCon GmbH and Attocube AG all had already customers and sales when the startup was founded and later showed good/high growth. A corresponding example for the US is Cambridge Nanotech (cf. Table I.80).

"Promising" is seen as a projection onto the firm – showing promise of favorable development or future success (promising in German "vielversprechend"; sense of promise – grounds for feeling hopeful about the future – *origin of expectation*). This, admittedly, does not lift the problem of identifying high-growth firms *a priori*. It just concedes that there is a possibility of a transition from a good growth firm into a high-growth firm. We shall also make use of the notion "*high-potential firm*," if the related idea or business opportunity, respectively, is assumed to be exploitable by the particular entrepreneur(s) according to an observer's assessment.

It is notable that Forbes (online) Magazine's award "America's Most Promising Companies" refers to a scoring algorithm based on a vast range of variables that determine a company's potential. It is developed by The Venture Alliance (TVA) and targets *fundability of startups by investors* – and, ultimately, its worth to investors (Box I.17, Figure I.162).

Usually, growth is not a deterministic cause of certain prerequisites. In a study cited by Wadhwa [2009] it was found, contrary to opinions, that there is no correlation between raising money and success of startups. What appears likely to matter more for these ventures is the creative transformation and use of resources at hand and a disciplined approach to cash management."

To generate “reasonable” expectations about a new firm’s chances of success *ex ante* requires including assessment of overcoming critical phases of the firm like a recession (cf. WITec GmbH). That means capabilities have to be evaluated not only to run successfully in “growth mode,” but also running in “survival mode.” This may be necessary already during the start phase, but also later during the firm’s development. Economic recessions, though to be expected, but not predictable exactly when, will occur at least once during the first twelve years of the NTBFs.

An arguable approach to expectations and, hence, statements about the future by an outside observer on a startup is one way to address – not solve – the *ex ante* problem of entrepreneurship (Box I.17). Predictions in the sense of natural science including extrapolations would only be possible if the subject and the time period under consideration can be viewed approximately as a closed system or for a restricted time period are representing a quasi-equilibrium of an open system.

Box I.17: Futuring and Measuring Expectations.

Promising (successful) firms reach the *expected level of achievement* or *expectation in the satisfaction of needs* [Van Gigch 1974:59]. Dealing with human-activity systems and related manifestations, such as expectation and high-growth firms, one must take into account the following.

1. Informal reasoning processes, such as judgment and intuition; a line of “reason for thinking that” rather than a “reason why” (Figure I.2),
2. The weight of evidence stemming from few observations and small chance of replication (and irreproducibility),
3. More domain discontinuities, relevance of the single (unique or recurring) event,
4. “Prediction” on weaker evidence than explanation or confined to restricted domains or time periods, respectively (in German Voraussage – ahead – with a spatial and temporal component) and forecast (in German Vorhersage, Vorhersehen – beforehand – with a stronger temporal association, ahead of time).

In the context of entrepreneurship this translates into statements about the future and the roles of experts. According to Webster’s **intuition** is “the power or faculty of attaining to direct knowledge or cognition without evident rational thought and inference.” Measures of *confidence for behavioral and social systems* are based on relative frequencies of observable events (“objective probability”), but also on subjective judgments on the probable occurrence of events (“subjective probabilities”) which makes experts to fill an important role with respect to generating information about the future. Experts are needed to ascertain the “evidential weight to be accorded various pieces of … information” and to provide unsystematized background in the formulation of predictive conclusions and to provide intuitive appraisal of intangible factors.” [Van Gigch 1974:149]

Judgment may be associated with a single person, but can also be related to “*group opinion*.” “Judgment is group belief.” The essence of this concept of judgment is the establishment of agreement in the context of disagreement [Van Gigch 1974:10]. It leads to *foreknowledge*. A typical example of interest for "predicting the future" ("*futuring*") based on opinion convergence which will cover the triad vision – success – expectation (Figure I.78, Figure I.77) is the Delphi method [Van Gigch 1974:324-326].

Delphi processes follow an approach whose objective is to *obtain the most reliable consensus of opinion of a group of experts*. The Delphi method is actually designed *aiming at the best use of the information available in the group*. This makes the selection of the group and the required general characteristics of an expert with regard to the inquiry critical [Van Gigch 1974:331-332], in particular, for the areas of forecasting or "prediction," that is, looking into the future. For technology entrepreneurship, furthermore, expertise requires additional knowledge (and experience) in the scientific and technical area under consideration, its applications, markets and industries.

The best known of the various Delphi methods are the Lockean Delphi and the Kantian Delphi hinting at the philosophers John Locke and Emmanuel Kant. The Lockean Delphi relies on agreement as the sole major principle for producing information ("consensual Delphi"). The Kantian Delphi has the explicit purpose to elicit alternatives on which to base a comprehensive overview of the issue. Technology forecasting (TF) is a typical example of Kantian inquiry.

The essential structure of the Lockean Delphi corresponds to an iterative procedure by which a panel of experts is requested to provide several rounds of answers to a series of questions. The members of the panel answer the questions without confronting each other, or even knowing each other. After each round of questions the answers are tabulated and a probability distribution of the answers is prepared. Before the next round the participants can evaluate the results of the preceding round including the reasons given for each answer. It is felt that the respondents are influenced to a certain degree by reading the answers of their unknown peers. And after several iterations of the process agreement is improved (Figure I.77).

An illustration of the various approaches to "futuring" is given by Griesar [2008:20-22].

One of the central questions of "predicting the future" is the occurrence of the "*single event*." Generally, to infer the proceeding of a process, one must make many observations before being in the position to hypothesize the pattern of the relationship among the variables observed. In particular for human-activity (social) systems one cannot rely on replication and reproducibility. This means a *unique event* will never take place again, and also the *recurring event* will never take place with the same quantitative impact and in an identical (political, economic, social etc.) constellation – an identical form of economic recession will never take place again.

At least with regard to recurring events somehow a pattern emerges in the similarity among those. Hence, assessment of "historical analogy" in terms of key variables and environmental parameters allow experts to deal with recurring events on the basis of "subjective probabilities" for an event's occurrence and effects. Here, probability turns out to be the expectation founded upon subjective partial knowledge.

A typical example of events amenable to analysis in terms of historical analogy (over several or few decades) is biofuels (A.1.1).

Futuring based on historical analogy must not be confused with *extrapolation* which is based on past trends and changes in trends. Extrapolation methods can only be applied for short- and medium-term stability of the situation under consideration. This means only small fluctuations and no discontinuities (events). And it requires sound knowledge of current and past developments.

Expectation is what people assume about the future, especially when they make decisions. And, measurement is "a decision-making activity … designed to accomplish an objective" [Van Gigch 1974:141]. Economists debate whether people have basically irrational or rational expectations, or adaptive expectations (ch. 4.3.4).

Adaptive expectations (as contrasted with rational expectations) model expectations' formation in which expectations adjust gradually towards observed values of the variable concerned or change to reflect learning from past mistakes. In this regard Lockean Delphi or Delphi-like approaches relate to adaptive expectations and are assumed to provide "acceptable" expectations concerning high-growth firms and gazelles.

A corresponding special approach has been used in this book (and the previous one [Runge 2006]) when selecting NTBFs for case studies (B.1, B.2). It is assumed that the group of people performing NTBF assessments for very renowned prizes or awards to be provided by various organizations to entrepreneurs on the national and international levels (in Germany and the US) can be viewed as an expert panel dealing appropriately with promising firms. One can make use of several organizations and more details are given in the Appendix (B.1).

The essentials of measuring "promising firms" are summarized below. Selected aspects of the related assessment criteria will enter the discussions of growth of NTBFs (ch. 4.3.6). It should be noted, however, that the below approaches usually do not differ between technical and non-technical NTBFs.

On the international level the present emphasis is on *The World Economic Forum* and the *Red Herring* magazine.

The World Economic Forum publishes yearly under the heading "The World Economic Forum's Technology Pioneers" assessments of new firms. Wholly-owned subsidiaries of large firms are not eligible. Its criteria include

- *Innovation*; should be recent – not more than two years old and the company should invest significantly in R&D.

- *Potential Impact*; must have the potential to have a substantial long-term impact on business and society in the future.
- *Growth and Sustainability*; should have all the signs of being a long-term market leader and should have well-formulated plans for future development and growth.
- *Proof of Concept*; have a product on the market or have proven practical applications of the technology.
- *Leadership*; must have visionary leadership that plays a critical role in driving the company towards reaching its goals.

For *Red Herring*, a weekly (online) magazine focuses on the business of funding, building, and taking new technologies to market. Own research (business analysts and technology writers) provides its “100 Awards” after assessing nominated promising startups (differentiated by global regions, such as Europe or North America).

Editors will assess nominees on both *quantitative and qualitative criteria*, such as financial performance, technology innovation, quality of management, execution of strategy, and integration into their ecosystem. This unique assessment of potential is complemented by a review of the actual track record and standing of the company.

Assessment criteria include the business model. Each company is subjected to a rigorous (structured) analysis to arrive at the 100 finalists. The selection criteria for the firms are as follows (apart from the location criterion):

1. Must be a private company, preferably not elder than 3 years.
2. Must have a technology, CleanTech or life sciences focus.
3. Must possess a disruptive technology (process) with significant market potential.
4. Privately held and not listed on any exchanges anywhere in the world.

At the national level there are particularly The German National Founders’ Award (“Deutscher Gründerpreis”) and, for instance, “America’s Most Promising Companies” by the Forbes Magazine.

The German National Founders’ Award (“Deutscher Gründerpreis”), an initiative of the magazine “Stern,” German Saving Banks, TV station ZDF and Porsche Cars and supported by the German policy (BMWi), provides its nation-wide prize to entrepreneurs in various categories nominated by ca. 250 experts. The experts consider any awards (winning) of business plan contests, but these and similar contests will be used only as additional evidence for startup success.

The category *StartUp* awards entrepreneurs, whose firm are *no more than 3 years old,* for a business idea founded in the market. And the entrepreneurs must have implemented their business plan particularly successfully. Awardees must have:

- Convincing business plan
- Successful entry into the market and good development
- Complete and competent management team
- Assured financing.

The category "*Climber*" (in German Aufsteiger) awards entrepreneurs, whose firm are 3 – 7 years old and within short time could achieve extraordinary growth of revenues and have the potential to become a market leader via

- Convincing, robust business model
- Strong growth of revenues (probably started international expansion)
- Complete and competent management team
- Proof of renowned reference customers
- Assured financing.

Forbes (online) Magazine's award "America's Most Promising Companies" (AMPC) uses a call for *self assessment* for application providing information about the firm answering questions of a standardized questionnaire. The pool of candidates includes companies launched within the last 10 years and that had not passed $25 million in annual sales. Pre-revenue companies were allowed [Forbes 2009].

Forbes.com has teamed up with The Venture Alliance (TVA), an investment adviser to early-stage companies, to reveal the most promising companies. TVA has a consistent methodology to evaluate how a company might rate with professional investors.

It developed a scoring algorithm based on a vast range of variables that determine a company's potential – ultimately, its worth to investors defined by the fundability of a company. TVA has devised a comparative rating system for young companies in order to determine how fundable they are. Aggregation of measurements provides reduction to one "Fundability Score" and to twelve categories for macro interpretations to be visualized in the "TVA Radar Graph" (ch. 4.3.6; Figure I.162) [Forbes 2009; Nelson 2009; TVA].

Prospects are scored, for instance, on the size of the markets they serve, the strength of their intellectual property, the extent to which founders put their own capital at risk, the experience of their management and of their directors (or advisory boards), and their record in hitting product-development benchmarks promised to equity investors. Finally, Forbes reporters interview all the finalists. The 20 highest scorers are assumed to have a better shot at raising capital – and thus are considered more scintillating than their peers.

In essence, the assessment of "promising firms" is the attribution of "high-potential" (for achievement) to the entrepreneur(s) as well as to the opportunity and the fit of both.

Summarizing the preceding discussions the essence may be threefold:

- Mäki and Hytti [2008] take the position that "among NTBFs identifying growth firms and predicting growth is a very difficult task."
- Moreover, Cowling et al. [2007] even present "the improbability of spotting winners."
- Bhidé [2000:251] cites Nelson and Winter who argue that in a typical competitive situation, "luck is the principal factor that finally distinguishes winners from near-winners – although vast differentials of skills and competence may separate contenders from non-contenders."

According to Mäki and Hytti [2008], "the firms that do not look promising seldom turn out to be growth firms by chance or even by active development." Since "predicting" growth is difficult among NTBFs it must be even more difficult among incubator applicants (they studied). It is important to re-emphasize that non-growth does not necessarily imply lack of opportunities or resources among NTBFs but it might be more a question of low level of ambitiousness (Figure I.97).

With regard to policy aspects and expectations Cowling et al. [2007], who studied the UK and Germany, point at Europe's dilemma, the absence of significant numbers of "gazelles" (which also become globally dominant firms). And they ask "Why does the USA appear so much better than Europe in creating successive generations of global businesses from new technology opportunities?" like Microsoft, Oracle, Genentech and Amgen, Intel and Cisco, eBay, Amazon, Google or Facebook. One rational to deal with that situation may be due to appreciation of spectacular successes in terms of magnitudes of firms and wealth achieved by the extremely ambitious founders which just reflects the American Dream.

But Cowling et al. [2007] make another point: The *real* value of European NTBFs lies in their total aggregate impact on their host economies. In particular, in Germany, the greatest economic value has been created by the cumulative impact of several thousand more "normally" growing firms complemented by some high-growth firms with sales between 1 and 12 billion euros, such as SAP (Figure I.143, Figure I.147; A.1.4), Würth GmbH [Runge 2006:241], Enercon GmbH (wind turbines; Figure I.150, Figure I.151) or Q-Cells AG (solar cells) (Figure I.152, Figure I.153) and the special class of very successful firms, the "Hidden Champions."

> Finally, the "1:100" rule-of-thumb for commercialization of R&D projects indicates that *entrepreneurship* and *innovation in the industry continues to be a numbers game* – the more tries, the more likely there will be hits – and more spectacular hits. The US has considerably more tries (ch. 1.2.4).

4.1.1 Hidden Champions – a German Business Success Configuration

The class of European, particularly German, firms called Hidden Champions provide a number of interrelated critical success factors which may guide generating expectations concerning the initial configuration of new technology ventures (chi. 4.3.2) to enter a path of good or high growth.

The German Hidden Champions are *medium-sized and medium-large companies* and represent a class of firms that share basically *comparable structures and strategies*. The vast majority have annual revenues of less than €3 billion, on average €100 million [Runge 2006:239-241]. As going for success often needs a rather long time, fifteen years and more, the founders or leaders/managers do not only exhibit perseverance and persistence (Table I.31), but share also the expectation of final success as well as patience and the conviction to win.

The *class of excellence* by virtue of their superior growth, sustained superior profits over very long periods of time, financial strength, global reach and consistent innovation was named "H*idden Champions*" by German consultant Prof. Hermann Simon (Bonn) [Simon 1996; 2007; 2008] and entered European business lingo.

Their class term is derived from the fact that they *lead their world markets*, but *can develop in the clandestine*, not observed and tracked by the public. These firms that we seldom hear of, however, are well known to two important groups: their customers and their competitors. The class of Hidden Champions covers all kinds of technical and non-technical businesses. Of about 100,000 mid-size industrial companies in Germany, an estimated 8-10 percent is "Hidden Champions."

Leadership in these companies means, family-owned and family management by 57 percent and family owned with non-family management by 15 percent, 15 percent are corporation, 7 percent are public and 6 percent have a private equity ownership [Schedl and Vola 2007]. Their average equity ratio (in German Eigenkapitalquote) is 42 percent. Financing is predominantly via own resources and cash flow [Runge 2006:239-241].

The cluster of Hidden Champions represents a **strategic group**, defined by M. Porter as "*a group of firms pursuing similar strategies along strategic dimensions*" [Runge 2006:221]. They provide a means to classify firms within industries into defined groupings based upon the strategies which *they choose to execute*.

Firms within a strategic group are assumed to be sensitive to their dependencies and are therefore likely to respond similarly to external events or competitive changes. Hidden champions have turned out to be robust: About 30 percent of them survived serious crises with new strengths.

According to Hermann Simon [2008] Hidden Champions do almost everything different from

- What management-gurus teach,
- Fashions of the day suggest,
- Large firms practice.

To become a Hidden Champion is not the result of short-term actions; it must be built on a cognitive and behavioral basis. It involves achieving *a smooth transition from entrepreneurship to SME (and large firm) management* and in this way can serve as a *model for many German NTBFs*. They exhibit the following seven characteristics.

1. *Extremely ambitious aspirations and goals* – Market leadership and growth; consequently *executing* towards achievement of the goals.

These companies always aim to be No. 1; they do not mean No. 1 in home markets, but in the world. Specifically that means No. 1 in Europe and at least No. 3 globally. Many of these Hidden Champions were truly global long before the term "globalization" was coined.

A prototypical expression for Hidden Champions is presented by the firm "3B Scientific GmbH" (Hamburg), which is an internationally operating group by its vision, motto and slogan.

- We want to be and remain the number 1 worldwide (in German "Wir wollen weltweit die Nummer 1 sein und bleiben").
- Best Quality, Best Value, Best Service!
- "...going one step further".

Sometimes, Hidden Champions may exhibit delayed growth (Figure I.107) and after some solid growth phase (of ca. 15 years) become big champions (SAP AG, Figure I.143, Figure I.147) or large firms (Enercon GmbH; Figure I.150, Figure I.151). Over many years they increase their yearly revenues by 5 – 10 percent. Structurally similar transitions are observed for growth patterns of small Hidden Champions.

2. *Leadership and Employees*

Hidden Champions have been founded and led often by personalities with determination, risk taking, persistence and inspiring abilities, who "walk as they talk," have high credibility and act as examples.

Organizationally, they often appear to be managed by hands-on CEOs whose knowledge of the key technologies is equal to their knowledge of the customers that they personally work with ("*technical entrepreneurs*"). CEOs of Hidden Champions often have an engineering background. There is continuity of leadership; CEOs often lead the firms over 20 years.

Their CEO's key *leadership qualities* when building and maintaining the firm's culture are to be great communicators and great listeners and they are usually the first to recognize problems. Finally, they are great recruiters.

For them, a European economic model – based *on a highly skilled, well-paid workforce* – works pretty well. The educational level of the workforce is very high. Employees work in a *high-performance-oriented corporate culture*. The *fluctuation rate* of Hidden Champions' employees is only ca. 2.7 percent as compared with Germany's average rate of ca. 7.3 percent and that of the US of ca. 30 percent [Simon 2008].

But a highly educated workforce is not only typical for Hidden Champions; it is a characteristic of the German industrial system including big, publicly traded firms like Siemens, Volkswagen, Daimler, BMW, Bosch, BASF etc.

Recently, the US became aware that Germany's transplant-factories, like the sprawling Volkswagen AG complex in Chattanooga (Tenn.), are not just cranking out cars, machinery and chemicals. They are also bringing a German training system to the US that could help narrow America's skilled labor gap.

Volkswagen, whose auto factory will graduate its first class of US apprentices in 2013, is one of dozens of companies introducing training that combine German-style apprenticeships and vocational schooling. These worker training programs are winning US adherents as manufacturers grapple with a paradox: Though unemployment remains close to 8 percent, companies cannot find enough machinists, robotics specialists and other highly skilled workers to maintain their factory floors [Fuhrmans 2012].

Even Jeffrey Immelt of the all-American company General Electric admits: "We need to be more like Germany." And US President Barack Obama asked a consultant when planning its economic policy: "How does it Germany to be so successful, despite the high cost of labor in the industry?" [Ross Range 2012].

3. *Offerings are characterized by focus and "deepness"*

Hidden Chamions often will be doing just one or few things, but that with extraordinary competency, professionalism and quality. Their success and survival relies on doing one area of competence extremely well.

Rather than positioning towards various customer segments (wideness) they concentrate on deepness for one particular segment, which is often a whole value added *process chain* covering products, services and consulting (example [Simon 2008], cf. also, Figure I.11, Figure I.12 for illustration and see below ProMinent example). They tend to have *a unique offering*. Deepness is in terms of a *total solution* customers seek (Figure I.94), preferentially if that takes the company beyond its industry's traditional offerings and positioning.

Deepness implies some particular features, 1) no outsourcing of core competencies, 2) R&D in the clandestine and skepticism with regard to strategic alliances. To guarantee top quality of their offerings Hidden Champions keep production almost entirely in the country – industrial jobs in Germany.

For instance, the German engineering firm BOKELA (Ingenieurgesellschaft für Mechanische Verfahrenstechnik mbH, Karlsruhe, Germany) is focused not just on separation processes, but focuses on various filtering and centrifugation processes to separate solid components from liquids ("suspensions"). Its business process and offering to the customer is conceiving and analyzing the particular type of suspension, providing a customized economical process solution and a reliable filter plant (the apparatus solutions). It serves users of solid/liquid separation technologies in many different industries.

BOKELA belongs to the technology leaders in the field of mechanical separation worldwide. It sees itself as the global leader. For instance, BOKELA technology allows separation in just one step compared to the common four-stage process associated with considerable cost savings for the customer, apart from high quality of the offering [Karlsruhe 2001; Econo Editor WST 2007]

It was founded in 1986 by two chemical engineers with a doctorate (Reinhard Bott and Thomas Langeloh) of the University of Karlsruhe and was awarded in 1999 by the German President as one of the thirty most successful "Science-Spin-off"-firms in Germany. BOKELA had 25 employees in 2001 and 40 in 2006. Revenues according to orders were between six and ten million DM (€3-5 million) in 2001, in 2005 there were €10 million and €12 million in 2006 [Karlsruhe 2001; Econo Editor WST 2007]. Estimated revenue for 2008 was ca. €10 mio. [Wirth 2009]

In 2009 BOKELA GmbH signed a contract valued at €8 million with one of the biggest Chinese producers of PTA (pure terephthalic acid) for supply of BOKELA filters to their new pure terephthalic acid plant. The PTA plant with technology from a Chinese process licensor has a nameplate capacity of 600 kta. PTA is for PET (polyethylene terephthalate), the major material for plastic bottles. According to BOKELA worldwide demand for PTA amounts to 43 million metric tons [Wasch 2010].

However, the typical (non-technical) Hidden Champion is a one market company with a functional organization. If they diversify, they follow an orientation towards strict decentralization and target groups. They proceed with "*soft diversification*," in which companies *use specific technological know-how as a platform* to set up new operations.

While diversification, not putting all eggs into one basket, is viewed as risk reduction, it has a notable disadvantage: Distributing attention and efforts among various fields increases the risk to not overcome the competition or retaining competitive advantage in individual fields.

4. *Internationalization*

Globalization is the root for growth of Hidden Champions. Specialization of products and know how is associated with worldwide marketing and distribution. This means a continuous multiplication of market magnitude: a €2-5 million niche market in Germany translates into a €20-50 million "super-niche" worldwide market.

Serving the markets (in various countries) is by an increasing number of subsidiaries for the important target markets or otherwise offices or, in case that no direct contact to customers can be set up, by distributors. Though still rooted in Western Europe for export the current trend is a shift from transatlantic operations to Eurasian orientations (Asia, Russia and other Eastern European countries at the expense of the US).

Internationalization for Hidden Champions tackles also socio-cultural attitudes and behavior with regard to foreign customers. This covers not only languages but also multicultural business aspects – which means "intercultural competence" which on average is more pronounced with German than US firms [Runge 2006:392-394].

Internationalization preferentially starts early on in the firms.

5. *Innovation*

Approximately one third of the Hidden Champions have *R&D intensities* exceeding 9 percent, which means for technology-based firms to belong to the class with top value technology (TVT). Their *patent intensity* (patents per 1,000 employees) is higher than that of typical large or giant German firms by a factor of ca. five [Simon 2008].

In particular, in two thirds of the cases innovation is driven simultaneously by market and technology, whereas for large firm ca 50 percent on their innovation originates with the market, ca. 30 percent with technology and ca. 20 percent with market and technology (cf. Figure I.44 for technical/commercial competencies of startups).

Hidden Champions show "*innovation persistence*" (ch. 4.2.3). Often the products are unique and can rarely be substituted.

6. *Customers and Competition*
"It takes two to tango" (in German "Es gehören immer zwei dazu")

To become or remain a global market leader is associated with a *focus on top customers worldwide*. Customer relationships abroad are usually held by own subsidiaries, affiliates or representatives in the particularly important countries. Often 20-25 percent of the employees of Hidden Champions visit customers regularly, whereas for large companies the proportion is 5-10 percent.

They follow their top customers to anywhere in the world and top customers are origins of innovation and partners. These firms use their knowledge of the customer and their command of the key technologies to develop products that the customer will want to buy, which reflects "*the customer as innovator*." The very narrowly focused niche strategy with a *deep understanding of business and customer problems* is associated with consistent top service worldwide. Furthermore, the process of innovation has to be continuous.

Hidden Champions have significant competitive advantages and they continuously drive up entry barriers into their turfs through increasing technical value, the level of complexity of their offerings.

7. *Value against Price*

The strategy is *value-oriented* rather than price-oriented. The firms compete on the basis of performance.

The overall competitive advantage of Hidden Champions is visualized in Figure I.108. Hidden Champions have the key attributes assumed to provide competitive advantage (VRIO; Table I.75).

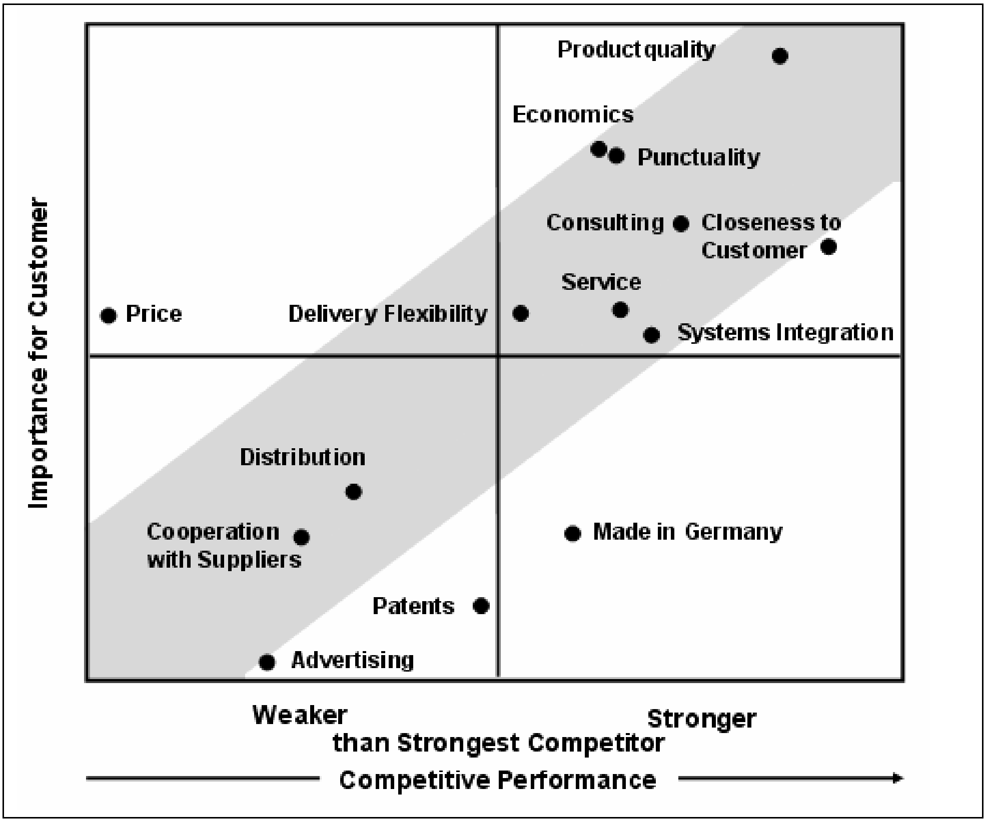


Figure I.108: Competitive advantages of Hidden Champions [Simon 2008]; courtesy of Professor H. Simon..

Concerning new product development, 1) their new products are almost always first-to-market, and 2) their new products must be good ones because they strive to continue to dominate markets for long, long periods of time. These outcomes are obtained by *focusing energy on the long-term development of a global market niche*. Such firms have to know their customers. Furthermore, their customers must trust them because they need them for their own long-term survival.

These champions do not engage largely in price competition; they prefer developing high-quality, high-technical-feature and high-performance products with superior gross margins (a price premium of 10-15 percent).

The mapping of the strategic approach of Hidden Champions outlined above is exemplified in Box I.18.

Box I.18: Wideness as well as deepness in steps of the German ProMinent Group.

For instance, the German Hidden Champion ProMinent Group [Runge 2006:74-75] including its wholly owned subsidiary ProMaqua GmbH generated in 2009 a turnover of €309.5 million with 2,079 employees (2005: €239 million sales, 1,500 employees; 2000: €150 million (DM 310 million), 1,400 employees; more than 50 percent of sales abroad). Fifty-five own sales and service companies and representations in 60 countries guarantee worldwide service and availability.

In 2010 ProMinent celebrated its 50th anniversary. It began in 1960 with an emphasis on an innovative pump and an emphasis on drinking water (ProMInent GmbH). In 1968 the founder Viktor Dulger achieved a decisive breakthrough by the innovative development and marketing of the first electronic and magnetically driven membrane dosage pump ("ProMinent electronic").

At first, it became a global market leader in the segment of "*standard membrane dosage pumps*." With the next step based on high-performance dosage pumps it became a "total supplier" for the segment "*dosage pumps*." And finally it grew from a component producer to a *worldwide operating system provider* for fluid dosage technology, water treatment and water disinfection. It became a solutions partner for water treatment and a manufacturer of components and systems for chemical fluid handling, measurement and control and polymer preparation systems.

Under the motto: "Reliability is our main virtue," the subsidiary ProMaqua offers worldwide complete system solutions making use of all current methods to treat water for various industries. It is focused currently on the following sectors and applications: food and beverage industry, drinking water supply, swimming pool and wellness industry, hotels as well as cooling water disinfection and combating legionella, oil and gas industry, paper and pulp, engineering and plant construction and envisions almost any industry – where fluid chemicals are applied.

For instance, it provides water treatment for hotels and resorts from planning to commission based on the following offering.

A. Drinking water supply

- Desalination of seawater and brackish water
- Oxidation and disinfection of ground water and surface water
- Disinfection of well water
- Dosing of additives for pipe protection

B. Protection against legionella

- Degradation of biofilm in piping with chlorine dioxide
- Disinfection of cooling water with chlorine dioxide or ozone

C. Water treatment for kitchen and laundry

- Demineralized water for dishwashers and washing machines
- Dosing of corrosion inhibitors and other additives

D. Water treatment for pool and wellness area

- Oxidation and disinfection with chlorine electrolysis and ozone
- Chloramine degradation with UV radiation
- Measurement, controlling, and dosing of treatment chemicals

E. Waste water treatment and reuse

- Biological waste water treatment
- Effluent disinfection with UV or chlorine dioxide

Contrary to common approaches, rather than focusing on water treatment for various facilities (kitchen and laundry, pool and wellness), applications or types of water (drinking water, cooling water, waste water) and water treatment additives ProMinent shows up as an effective global “one-for-all” supplier.

Providing a total system solution requires not only adjust and fine-tune all components and their inter-linking to produce the best solution possible. To guarantee the best solution possible, all involved components have to be connected, adjusted and fine-tuned, with each other and, if necessary, with a superordinated control unit.

Furthermore, possible parasitic drags from the surrounding have to be taken into consideration. This is why ProMinent’s specialists are experts not only on the products but also have the necessary knowledge in hydro-chemistry, hydraulics, measuring and control technology, microbiology and other areas required to solve the application problems.

4.2 Entrepreneurial Risk-Taking and Decision-Making

All is needed in this world
is a smart idea and a firm decision.
Johann Wolfgang von Goethe

Alles was es braucht auf dieser Welt
ist ein gescheiter Einfall und ein fester Entschluss.

In the context of revealing an opportunity making appropriate decisions and risk-taking represents a central constellation for (technology) entrepreneurship (Figure I.87). The meaning and the use of the word risk can be confusing. Sometimes people use it interchangeably with hazard or relate it to uncertainty [Dorf & Byers 2007:134-142]. There are many definitions of risk that vary by specific application and situational context. The widely inconsistent and ambiguous use of the word is one of several current criticisms of the methods to manage risk.

Previously in this book risk and uncertainty has been introduced in the context of a *decision-maker's information* referring to systems' states and their probabilities. Furthermore, it is implicitly assumed that the decision-maker personally, as an entrepreneur, as a representative of an organization, as an intrapreneur or manager, has a stake in the value of the outcomes/results of his/her decision.

Risks concern people as they think that they or the group of people they are responsible for will suffer a negative effect on their future. And risk concerns the deviation of one or more outcomes or results or one or more future events from their expected value.

Hazard may be associated with an *immediate (reactive) effect* or with *a development of activities over time* with a *potential (negative) end*. For instance, running out of cash may be the end of a firm. Hazards may relate to a single outcome or a limited or wide range of outcomes. That means the entrepreneur is usually confronted with a variability of outcomes and making decisions based on a spectrum of alternatives to avoid or mitigate related risks.

We shall use the following terminology:

- A **hazard** is any source of, or any event that could cause, potential material (physical) or immaterial (mental and social) damage, harm or adverse effects on something or someone under certain conditions of activity. Specifically, a hazard is a situation that poses a level of threat to life, (physical and mental) health, property or environment.
- **Risk** is the probability or likelihood that something or someone will be harmed or experience an adverse effect *if exposed* to a hazard. It may apply to situations, for instance, with loss of property, equipment or market share or refer to information states in decision-making situations.
- If the probability of risk is unknown or hazard is associated with occurrence by chance we speak of **uncertainty**.

Concerning informational states and decision-making two conditions can be differentiated. **Ambiguity** is a condition where information (or a pattern) can be understood or interpreted in more than one way. It is distinct from *vagueness*, which is a statement about the lack of precision contained or obtainable in data or information. Context may play a role in resolving ambiguity. For example the same piece of information may be ambiguous in one context and unambiguous in another. [73]

Attitudes toward risk and ambiguity are uncorrelated [Bhidé 2000:97].

For a formalized approach we propose attributing hazard with a "*factorial*" relation to risk and exposure (Equation I.8; cf. also equation (6.3) in Dorf and Byers [2007:13]):

The symbol ⊗ denotes a *systemic "factorial" relation* meaning more than a number-based multiplicative or divisional relation. Compare, for instance, 4∗3 = 12 with a special factorial notation, such as 3! = 3∗2∗1 = 6; 4!∗3! = 144.

Accordingly, no risk or no exposure means no hazard.

Exposure may change over time (t) and in this way hazard becomes time-dependent. Risk is implicitly time-dependent via the development of the constellation defining the risk. Risk may be related to statistical probability, estimated likelihood or personal perception (Equation I.8). The biggest challenge is assessing risk realistically.

Perception is central for risk-taking of entrepreneur(s). Human beings generally have problems to assess probabilities and, hence, risks. A risk of one to thousand may be compared with a risk of one to one million. For instance, many people perceive the risk of flying as being much higher than the risk in ordinary road traffic, though fatalities of road traffic are much higher than fatalities of flying. Personal perception let us associate a higher risk to air traffic than to road traffic.

Additionally, there is a component that human beings associate higher risk to situations we cannot control in comparison to those we assume to be in control like smoking or overtaking maneuvers.

The issue of perceiving a too low risk in relation to control one has may have an adverse effect to internal locus of control which is an important trait favoring entrepreneurship (Table I.31). Overoptimism may be the result.

Consequently, entrepreneurs often underestimate particular risks and often the total risk of founding a new venture. For instance, in Box I.11 it is described that the founders of Concept Sciences, Inc. (CSI) had to weigh essentially risk of large-scale production (high) of the semiconductor-grade chemical hydroxylamine (HA) in the form of "hydroxylamine free base" (HAFB) versus market risk (low) and high reward when deciding whether to go ahead. Hydroxylamine is generally known to be highly explosive on the small as well as the large scale.

The founders obviously totally underestimated that danger in that they overestimated their capability to control the reaction (as BASF can). When starting production an explosion killed and injured people and destroyed a large area and also ended the existence of CSI.

In statistics, risk is often mapped to the probability of some event which is seen as undesirable. Usually, the probability of that event and some assessment of its potential harm must be combined into a believable setting (an outcome), which combines the set of risk, regret and reward probabilities into an expected value for that outcome. Regret is operationalized as the amount of loss a person can tolerate.

Statistical evaluation often relates to repeated events whose relative frequency is known from past experience. On the other hand, there is no information for *recurring events* (repeated occurrence, but no way to forecast the time of occurrence and the level of impact) and *unique events* (ch. 3.2.1). "Statistical evaluation of risk" can often only be assessed semi-quantitatively on a three- or five level scale referring to the severity of the outcome that will be experienced, for instance, large severity (replaces $0.6 \le \text{Risk} \le 1.0$), medium ($0.2 \le \text{Risk} < 0.6$) and small severity (replaces $R < 0.2$).

An event may exert its impact on different time scales:

- The *immediate effect* will be felt or recognized immediately by the target.
- The *delayed effect* will be felt or recognized by the target only after some time.

Values of the outcomes may be tangible or intangible; they may be known for some outcomes, but not all. Uncertainty specifically means that risk, though known to exist, is not attributable or the values of the outcomes are not attributable.

Equation I.8:

For defined constellations including constraints,
usually qualified by some statement of the severity of the hazard:

$$\text{Hazard} = \text{Risk} \otimes \text{Exposure}$$
$$(\text{e.g. } 0 \le \text{Risk} \le 1 \text{ and } 0 \le \text{Exposure} \le 1)$$

$$\text{Risk} = \text{Risk}(\text{Statistical Probability, Personal Perception});$$
$$\text{Exposure} = \text{Exposure}(t)$$

We relate hazard to endangerment (in German Gefährdung) and define a **threat** as the possibility that *vulnerability* may be exploited to cause harm to a system, environment, a firm or its personnel, an alarming indication of something hazardous. Threat is usually associated with "weakness." Reaction against exploitation is achieved by "guards" minimizing or avoiding exploitation. We tentatively propose Equation I.9:

Equation I.9:

Threat = Vulnerability ⊗ Exposure (Subject to Exploitation)

In the context of entrepreneurship, the notion exposure is used to comprise several dimensions linked to a harmed person or the environment, outcomes of a person's activities and executing technical and business processes involving material or technical means or executing technical and business processes as a consequence of decision-making based on various immaterial categories (Figure I.109). In the simplest case of a technical situation, exposure means the spatial (physical) distance to the origin of potential harm or executing dangerous operations without safety gloves and safety glasses.

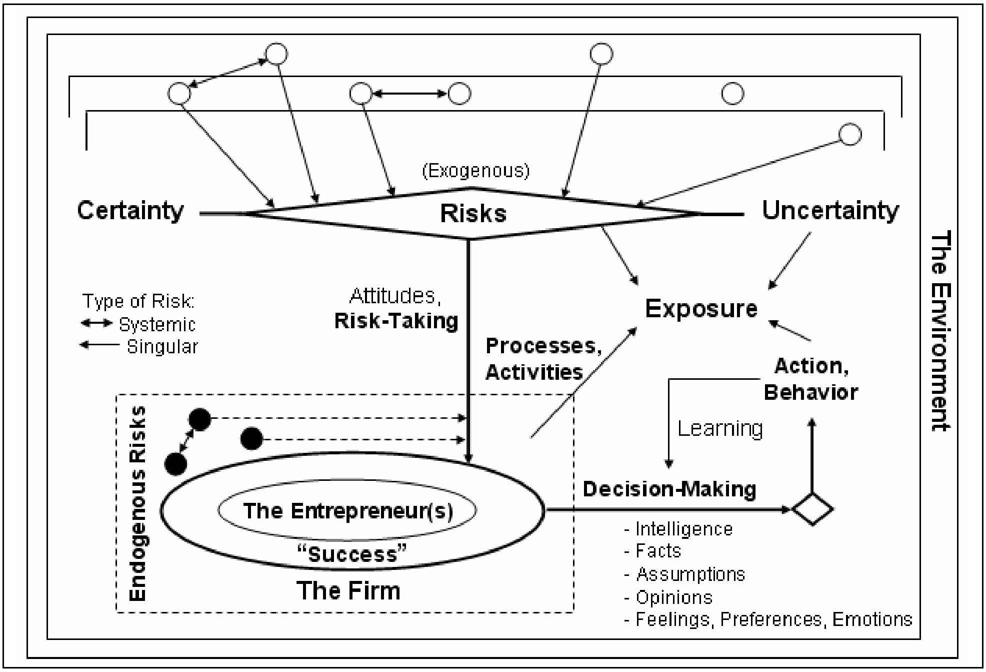
For technical firms hazards result often from mistakes, erroneous behavior, operational failures, breakdowns, damages or loss of apparatuses, equipment or plants, disturbances and interruptions of processes, incidents, harm to others etc. which is always associated with a loss – money or personal harm and, worst, fatality. On the other hand, there is the spectrum of business decisions and actions including investment in people, projects and technology. Here damage is associated with profit or loss of monetary value, often according to human decisions.

Basically, we distinguish *endogenous risks* associated with hazards from inside a system under consideration (here the firm) and *exogenous risks* induced from outside the system of interest, the environment.

For a systemic approach, furthermore, one can distinguish, whether the target of hazard originates with an isolated factor associated with a "*singular risk*" or whether a hazardous factor is interacting with another, probably not identified one which influences the one of primary interest. This leads to the class of "*systemic risks*" (Figure I.109). We cannot look at risks independently of each other. Effects of endogenous hazards are assumed to be (largely) controllable, whereas exogenous ones are uncontrollable *per se*.

Systemic risks may involve sources of potential harm from the same system or from different systems. For instance, for biofuels the societal system may expose a to-be founder of a biofuel startup to a small risk due to the societal "green wave" of fighting climate change and dependence on mineral oil, but if the startup will use biotechnology and genetically modified objects (GMOs) to produce biofuels certain societies reject GMOs (A.1.1).

Hazard can be viewed in many cases as a class feature. For instance, "*market risk*" relates hazards (threats), for instance, to current competitors, future competitors (entrants), customers' level of adoption of the offering etc. Similarly, "*technology risks*" of a firm operating on the basis of an enhancing technology refer, for instance, to societal acceptance of technology (cf. GMOs), to underlying technologies (of incumbents), generic (substitutive) and emerging technologies (Table I.12). Furthermore, products derived from the technologies may encounter different difficulties or risks concerning the scale-up process for production.



Decision-making under **certainty**	know the values of the outcomes {of actions} completely	know occurrences of the states (of the system)
Decision-making under **uncertainty**	values of the outcomes may be known	no information on the probability of (occurring) events affecting states
Decision-making under **risk**	know the values of the outcomes (of actions)	relative probabilities of the states (of the system) given

Figure I.109: Types of risk and their interconnections with the entrepreneurs' attitudes and risk taking, decision-making, behavior and processes.

A very severe, but for the founder(s) not necessarily the severest hazard, is firm failure. According to Dorf and Byers [2007:6] "only about one-third or fewer new ventures survive their first three years." If this would be the case for the US or specifically technology entrepreneurship (NTBFs) it would represent a situation for technology ventures that is fundamentally different from the situation observed in Europe and, in particular, in Germany.

There are a number of studies including technical and non-technical ventures dealing with firm failure (cf. for Germany Egeln et al. [2010]), but not specifically for technology ventures.

Tidd et al. [2001:350] report an estimate of the proportion of startups, particularly NTBFs that will survive and grow and ultimately will show up as a medium to large-sized company.

- The *mortality rate* of NTBFs is lower than that of most other types of new firms, around 20 – 30 percent in 10 years, compared to more than 80 percent of most types of new businesses.
- If one looks into the *survival rates* of NTBFs until the corresponding market consolidates into a stable state 50 – 60 years after the foundations of the first firms in the particular area, the "survival of the fittest," is around 20 – 30 percent.

Corresponding *survival rates of NTBFs* are cited by Runge [2006:274-275] for the global dye industry (period 1854-1914) and automobile industry in the UK (period 1895-1960). A recent dedicated study [Cowling et al. 2007] documents over a twelve year period (1991-2003) the continued fortunes of 600 independent NTBFs which were founded in Germany or the UK between 1987 and 1996.

> The recent study on the survival and growth of NTBFs in Germany and the UK [Cowling et al. 2007] found that once an NTBF has survived to its 5th year, there is an approximately 80 percent chance that the firm will still be trading in its 12th year. The Cowling study is remarkable in that the observed sample included survival progressing through economic cycles, including the recession of "1990/1991" and the "2001/2002 Dot-Com Bubble."

There is a notable corroboration of this finding for RBSUs [Issig 2006]. In the state of Bavaria in Germany there was a program called "Flügge" ("Förderprogramm zum leichteren Übergang in eine Existenzgründung") to support spin-outs from universities. Over eight years 94 spin-outs directly out of the university were supported and funded – and for five RBSUs funding was still active. Out of these 89 startups 70 firms were still running (and four were sold).

However, this situation of survival of NTBFs may be quite different, if "hyped fields," such as special area Internet firms or developing apps for mobile devices (ch. 3.4) or NTBFs targeting large-scale or mass-scale production are considered, for instance in biofuels (A.1.1). In the last case the failure rate is often due to issues of scale-up (Figure I.8, Figure I.9). The situation may also be different, if specifically VC-based NTBFs are considered. Including technical and non-technical VC-based startups a recent study shows that 3 out of 4 startups fail [Gage 2012].

Reformulating these findings in terms of Equation I.8 means that the hazard of (total) failure (severity of the hazard) of founding an NTBF and running it for five years in Germany or the UK (the total exposure to the hazard with a value of almost 1) has a risk of ca. 25 percent of not running the firm also in its twelfth years. Correspondingly, there is a rough *indicator to regard a firm's foundation as "successful" ("surviving")* if the firm survives *operations in the market* for five years.

> Moreover, Egeln et al. [2010] have shown (their Fig. 4-3) that the *probability of exit from the market of a young technology venture in Germany* increases after foundation until the firm is about three years old, but then the probalility decreases again. This means, after foundation *the first three to four years are the most dangerous ones for the firms* (the "*startup thrust phase*" (ch. 4.3.2, Figure I.125).

Their sample covers market exits of NTBFs closed in 2006-2008 which means in an economically favorable situation before the Great Recession. During an economic recession or shortly after one would make things even worse.

An issue of such statements usually is that firms do not only *close their doors for insolvency but also for positive reasons:* they are acquired by larger firms, get sold at a profit or merge with another company.

This above study also does not differentiate

- Firms following a regulated process for insolvency, such as Chapter 11 in the US,
- Closing without going for a regulated process for insolvency due to economic or financial reasons,
- Closing due to personal reasons.

Cowling et al. [2007] furthermore found that the *creation and maintenance of managerial skills* in small high-tech firms continue to be of *profound importance for both survival and growth*. For example, persistent and unresolved *weaknesses in management* (Germany) and in effective *financial controls* (UK) both increase the long-run risk of firm failure.

> Very important reasons for failure of startups during their early years is *leadership's or management's failure to act, or leadership's/management's failure to react, or leadership's/management's failure to plan.*

Egeln et al. [2010] have shown that there is *no single reason for firm failure*. Usually there is a cluster of reasons which combine interactively and build upon each other and which ultimately lead to a "disaster" (ch. 4.2.3, Figure I.114).

Specifically, for RBSUs (particularly university spin-outs) Fyfe and Townsend [2005] reported that in the UK only a small number of spin-outs had been outright failures. The general consensus, however, was that they are more likely to show limited growth and hence, become the '*living dead*' rather than disappear completely.

Finally, there are particular factors which are generally assumed to decrease risks of (technology) entrepreneurs:

- *Motivation and commitment* of the founder(s);
- *Experiences* including leadership experiences and skills, as is found with serial entrepreneurs or people who have industry experience and left a company to found their own firm;
  when it comes to *execution*, there is no substitute for experience. Assessing the potential of execution can use level of experience as an indicator.
- A *founding team* is associated with a higher probability of survival; *combining technical and commercial competencies* of other people in a founder team;
- A common response to reduce risk is to *build a new venture in steps*, as is also found in large firms with innovation projects according to a Stage-Gate® process (Figure I.79, Figure I.180) or observed for venture capitalists relying on milestones for development and financing stages (Figure I.52, Table I.27).
  These *sequential* processes contain decision points ("gates") to check whether intermediate goals have been achieved and whether to proceed or not or whether to change direction.
- Finally, there is risk which is insurable. Property & Casualty insurance can mitigate losses from fire, theft, and natural disasters; liability insurance can mitigate lawsuits resulting from product defects or on-site injuries to visitors.

4.2.1 Risk Taking

Innovation, entrepreneurship and firm's foundation are associated with risk and uncertainty. Risk-taking by key players in the context of entrepreneurship occurs on two levels:

- *The individual risk level*:
  The entrepreneur and the private (individual) investor or backer
- *The systemic (group or organizational) level*:
  The founder team, the intrapreneur (corporate entrepreneur), bankers and venture capitalists and, if not one-to-one trading is considered, the customers.

The individual level is related to the entrepreneur's personality and the "near" environment in terms of uncertainty avoidance or risk aversion, respectively, induced by the *national culture* (Table I.37, Table I.38). Furthermore, national culture is an important factor how to perceive personal failure. This is particularly striking comparing Germany and the US (ch. 2.1.2.3). Furthermore, the family and role models of parents seem to be important, in particular, whether parents motivate their children to take risks autonomously.

> Considering different levels of risk aversion due to the national culture one can hypothesize that Germans follow opportunistic adaptability for technology entrepreneurship to a notably lower extent than do Americans.

Similar to cases described (ch. 1.2.5.1, Figure I.25) one encounters different perspectives of risk for a given situation in the course of entrepreneurship. Different perspectives are often active, for instance, looking at perceived risk of an innovator or an entrepreneur versus that of the customer ("asymmetry of risk perception"). The entrepreneur may assume that the customer will not adopt the offering for technical reasons. But the customer, probably even appreciating the offer, does perceive the risk that the entrepreneur's firm is too young and weak and may go bust or will not be able to provide technical service (ch. 4.2.1.1).

> Risk-taking on the group level for an entrepreneurial team means, for instance, that the members have to take risk collectively thus reducing overall risk of the individual member.

For intrapreneurship risk-taking can be seen as a "group's decision." The level of accepting risk is mostly ingrained in corporate culture. And risk-taking appears mostly directly through a more or less structured corporate process of risk management with defined criteria and measures. Furthermore, risk-taking of a (corporate) project selection team is based on this framework and usually additional constraints by considerations of fit with corporate or business, respectively, strategy.

For a particular business and strategic fit of an innovation project of a large firm with considerable risk and a corporate culture it is not unusual that the members of a selection team share the personal risk: *People make projects*. If a corresponding selection team likes the idea or project (and like each other) and is willing to take the risk they "let the project fly" [Runge 2006:786].

Risks for technology-based firms are found for the following areas of exposure (cf. also ch. 4.2.3):

- The states of the cultural, societal, economic and political environment
- Scientific/technical area and industry
- Getting, utilizing and exploiting resources
- Company structures, activities, work and conversion processes
- Executing technical and business processes (targeting markets and industries)
- Supply of offerings/products (production and distribution).

Associated risk classes for decision-making for firm's foundation and early development stages organized according to factors and forces of related systems (Figure I.109) are given in Table I.65.

Table I.65: Selected risk classes according to involved systems for technology entrepreneurship and technology ventures.

Risk Class According to System	Examples and Remarks
Gross National Economy; Society; The (National and States) Political System	
Gross Economic, Societal and Political Risks	Economic cycles (recession); societal attitudes towards technology; effects of legislation, taxes, subsidies and other direct or indirect political programs affecting new firms
The Economic (incl. Financial & Legal) System	
Legal, Regulatory and Industry Standardization Risks	The choice of legal entity or state of incorporation of the startup; regulations; patent infringement and litigation (for standardization issues cf. Smart Fuel Cell [Runge 2006:332-335])
Financial Risks	Access to capital/financing; undercapitalization for startup; managing finances (Figure I.114); exchange rates for export businesses (ChemCon GmbH (B.2); First Solar, ch. 4.3.5.2; Figure I.154)
The Industrial System	
Market Risks	Adoption issues (e.g. novelty of offering, ch. 4.2.1.1); competition, customers (and suppliers) including customer (supplier) concentration on just one or very few customers (cf. Encapsulated Six Forces Model); distribution – Figure I.33, Figure I.115
Offering Risks (Product Risks)	Missing product requirements or specifications; insufficient product or service quality; overshooting (Figure I.88); malfunctions, side-effects; risks of cost over-runs, jobs taking too long

Technological, Research and Development Risks	Technology *per se*, novelty of technology; any firm running R&D projects is intrinsically associated with many risks; technical failures; ways to protection or non-protection of technology and related offerings against competitors; appearances of generic or emerging technology; the major source of technical risk is uncertainty about the technical feasibility of new technology; and originates not only in the technology itself, but also with regards to its compatibility with other technologies; scale-up issues (Figure I.8, Figure I.9)
The Firm	
People Risks	Dependency on employees in key positions; key people leaving the organization; failure to recruit, motivate, and retain the right employees, partners can spell doom; founder team tensions – new company fall apart when it develops major rifts: when one faction wants to move one way, others seek a different result (ch. 4.2.3, [Egeln et al. 2010], Cambridge Nanotech – B.2)
Organizational Risks	Competencies; leadership or managerial capabilities; issues of coordination; productivity of employees
Operational Risks	Production process, harm to employees etc. cost of raw material/input – dependence on one supplier (cf. Figure I.33, Figure I.115); security of the firm's I&CT system and, for software and TBS firms, computer viruses and computer hacking attacks could harm the business and results of operations

Table I.65, continued.

Identifiable Systemic Risks	Company image induced by product risk issues, loss of business partner or employee confidence, or damage to reputation in the market; people risk may induce financial risks if due to founder team tensions a founder leaves the firm and there are not enough monetary reserves to provide the share of the founder
	The *worst systemic risks* are those that threaten the viability of entire markets, industries or even countries (as is *seen for the US financial system, the resulting Great Recession and spread around the globe*)

Recession involves a typical systemic risk. It may or will affect the number of customers and the level of orders and purchasing by a firm which in turn may send the supplier into financial troubles.

Related harm may be *reversible* like financial risks or *irreversible* like the explosion in a chemical plant. Financial risks are essentially not risks of permanent damage (like an explosion), but instead are constantly changing values of assets that can and must be recognized from time to time for accounting and managing purposes.

Financial risk is often viewed as the unexpected variability or volatility of returns and thus includes both potential worse-than-expected as well as better-than-expected returns.

Entrepreneurs with a tendency to set challenging, but realistic personal goals do not gamble, but tend to take *calculated risks* in controlled ways (Table I.31). That means they follow certain more or less structured ways of assessing risks versus potential hazard and hazard versus their view of success; they *manage risk*. If such a process is structured in a corporate environment as a company management process we deal with risk management.

Typical examples of risk areas or threats for technology entrepreneurship or innovation of large firms are given in Table I.66, partially also reflected by Figure I.47. A detailed overview, for instance, of the risks of the US NTBF Amyris Biotechnologies (Table I.99) in the biofuels area is given in the Appendix (A.1.1).

Table I.66: Typical risk areas or threats for technology ventures.

Risk Areas	Comments and Examples
The entrepreneurs' personal decisions and activities	Personal financial, psychological and social damage
Production processes	Scale-up failure (German Zoxy Energy Systems AG (B.2); cf. also biofuels in A.1.1); dangerous chemicals leading to explosion or fire (Concept Sciences, Inc. (CSI), Box I.11); faulty or low quality input (raw material, technical components) from supplier; environmental damage by spills
Product properties and liabilities	For pharmaceutical/biotechnology firms side-effects of drugs, such as Bayer's Lipobay/Baycol and Merck's Vioxx cases and the US tort system [Runge 2006:52-54]; malfunctions of devices or instruments or vehicles; post-processing mistakes in the supply chain (Nanopool GmbH (B.2) [Runge 2010])
Corporate image	Perceptions of (pharmaceutical and chemical) firms through special incidents with customers/consumers (Nanopool GmbH [Runge 2010]); "*issue management*" (Lipobay/Baycol, Vioxx and other cases [Runge 2006:52-54])
Product "pipeline," product portfolio	Loosing patent protection of pharmaceuticals, generics entering the market (cf. 2.1.4.2); missed "protection hedges" through absent "defensive patents"; focusing on the "wrong" technologies
Intellectual properties (IP)	Insufficient protection of technology – by IP, but also theft and industrial espionage (Box I.7); "loosing the race" (time-to-patent target not met); unintentional patent infringements through unawareness of existing technology protection through competitors' patents

Table I.66, continued.

Laws and regulations	Loosing markets through missing compliance ; missing opportunities; issues with permits for (technical) operations; occupational safety and health issues in a plant or with technologies, such as: nanotubes showing toxic effects "similar to asbestos," under scrutiny; for software (Internet) firms: storing and using personal information and other data, subjected to governmental regulation and other legal obligations related to privacy; actual or perceived failure to comply with such obligations could harm the business.
Missing approval by related agencies (FDA in the US, EMEA in Europe for public use)	Biomedical or health-related research studies in human beings and animals, "clinical trials" in Phase I – IV *)
Market and technology competition	Current and future threats through known competitors, threats of new entrants (from anywhere in the world); "loosing the race" (time-to-market target not met); threats of appearances of generic or emerging technology; entering markets abroad
Managing finances for founding a firm and running a firm	Undercapitalization for financing firm's foundation; undercapitalization when the startup begins business activities, related to difficulties to build sufficient retained earnings to overcome temporary setbacks; may be related to financial controlling, for issues with accounts receivable if customers pay late (cash flow!) or a major customer purchases less or stops purchasing at all (Figure I.114, Figure I.115; Figure I.140).

*) Staged clinical trials are generally considered to be biomedical or health-related research studies in human beings that follow a pre-defined protocol. They are associated with sizable cost for a full series of clinical trials. Negative impacts may occur for each of the stages.

Barriers and potentially related risks of NTNFs' foundation and early phase situations are reported by Metzger et al. [2010a], mainly

- Securing financings
- Market entry and positioning of the startup's offerings in the market (ch. 4.2.1.1)
- Capturing orders and establishing a set of customers (ch. 4.2.1.1)
- Lack of business and market-specific knowledge.

Risk management [Runge 2006:873] focuses on the subjects and objects which cause, contain or transfer risks. As risks always relate to “ends,” managing risks means who (and/or what) is affected to which extent. This may be the company itself, its economic situation and stakeholders (employees, investors, firm neighbors etc.). Risk may cover tangible or intangible categories. It deals with mitigation of the risk *per se* or mitigating the hazard.

Basics of *risk management as a (“standardized”) corporate process* of large firms include the following steps which provide also guidelines for entrepreneurship.

- Risk identification,
  elements for risks, types of risk, balance controllable/uncontrollable risks;
- Risk assessment including assessing risk and exposure,
  level of impact, likelihood of occurrence;
- Risk analysis,
  understand and quantify risk so it can be managed;
- Risk controlling,
  early warning and controls; risk thresholds; limitations and options for action and monitoring (to mitigate risk);
- Risk reporting,
  presenting real and potential risks and opportunities.

Risk management is “*reactive*” (after-the-fact; “root-cause-analysis” as a risk avoidance or minimization strategy) or “*pro-active*” emphasizing identified risk and strategies to avoid or minimize these. Strategies to act include immediate responses or responses based on impact, resources, cost or affected stakeholders.

Decision strategies for managing risks include

- Risk avoidance;
- Risk retention (“toleration”):
  “Mitigation” through reduction of severity and/or probability of impact;
- Risk transfer:
  Acting on contractual terms (change time and money or deliverable specifications, if not in conflict with strategy;
- Alternative options:
  Leaving the risky area (no or negligible exposure!).

Risk management as a corporate process assumes that we can find attribution, that we can attribute failure to key events or circumstances based on rational lines of arguments. However, one has to accept the fact that businesses and entrepreneurship represent largely behavior, actions and events in *human-activity systems*.

Despite myriad studies of organizational efforts in business pretending to be a science and widespread assumptions that this science can be practiced based on its results and prescriptions (for instance, via business administration) human behavior is often unpredictable and counterintuitive.

We tend to look for ways to control business and project outcomes that sometimes simply cannot be controlled. We seek answers for failures to fix them, yet often we do not know what factors were important. If a system fails we want to find out why it failed.

> *Managing risk is invariably associated with issues of information and intelligence and decision-making in a systemic environment!*

Given the *extreme complexity* of the spectrum of sources of hazards for technology entrepreneurship or startups and the scarcity of financial resources "risk management" is practiced largely as an art rather than science of thinking and using common sense about what could go wrong, and what should be done to mitigate related risks in a cost-effective manner. Furthermore, it has to be accepted to act under uncertainty in many situations that must not hinder decision-making.

General Systems Theory directs thinking that risk can be stewarded and managed by good planning and analysis to the position that in the end it is often the gut feeling of the entrepreneur, the entrepreneurial team or the project manager that turns the firm or project into the right direction and overcomes risk.

The first and most serious obstacle for an entrepreneur to manage risk for firm's foundation and early phases of the firm is:

> When You Don't Know What You Don't Know.

An important aspect here concerns the *risk that the entrepreneur him-/herself may represent particular weaknesses of the firm*. This means, the basic risk assessment for firm's foundation for the entrepreneur is:

> Know Thyself!
>
> Do I have what it takes (aspirations, personal traits, operational competencies, commitment, persistence, etc.)?

And this assessment is performed advantageously by oneself ("self-perception") *and* by the family, friends and other people who provide honestly, frankly and directly their perceptions of the to-be entrepreneur followed by checking self-perception and revealing matches and discrepancies of the perceptions.

Furthermore, there may be issues of life style and balancing family and firm which means, apart from financial risks, burden and stress during the firm's foundation and early development processes [Metzger et al. 2010a].

Then, the pursuit of the entrepreneur should always be to remove as far as possible the unknown of the constellation of the business. Once one has an estimate of the severity and likelihood of a given hazard and the level of exposure, one can answer the question: Does the benefit of mitigating a risk outweigh the cost of doing so? Anticipating every possible risk factor is neither possible nor practical. Entrepreneurs will have to *manage risk pragmatically*.

- Engaging *common sense* to *identify* the most obvious hazards, the level of exposure and related risk and *mitigate* in a cost effective manner;
- **Contingency planning**, a systematic approach to identifying what can go wrong in a situation of exposure, anticipating contingency events and be prepared with strategies, plans and approaches for avoiding, coping or even exploiting risks;
- *Early warning*, risk reporting and creating awareness (in the firm);
- Developing a *culture of responding* to unanticipated developments as a reaction to uncertainties.

Contingency planning can rely essentially on scenarios (Box I.19) and developing a "*Plan B*." Having Plan A and Plan B can be viewed as "minimal scenario planning." People are often poorly motivated to develop a strong "Plan B" as they have too much of an emotional investment in the "'Plan A" they want to execute. Plan B should be properly thought-through when laying out risk reporting.

An entrepreneur should assume always two things, good luck and bad luck. Good luck is not as simple as "it works out." Rather, good luck is when you suddenly reveal a great opportunity and can quickly shift to go after it. Bad luck is what happens when the business idea does not work out. It does not mean instant failure, but may mean to go to plan B.

Using a formalized approach to managing risk the entrepreneur(s) firstly will start with "*identification*" and creating a list with the following categories:

No.	Constellation	Hazard	Risk	Exposure	Control, Insure?
	Statement	1)	1)	1)	yes/no

1) Categories: small – medium - large – or related numbers as well as uncertain (U) or "P" if not "rationally estimated" but otherwise "perceived" (or even by feeling).

For instance, the entrepreneur may run through considering Table I.65 and Table I.66, Table I.18, Figure I.33 to see if any apply.

Secondly," *risk assessment*" has to think through the people, systems, organizations, structures and processes that are active, analyze hazards and threats to any part of those. Advantageously, one asks other people, who might have different perspectives.

Thirdly ("risk *analysis*"), *understanding risk and exposure* and attributing "measures" to them form a basis for decision-making on how to tackle the hazards. To estimate risk and exposure one approach is to make the best estimate of the probability (numerical or through three-level scale) of the event occurring following also "*educated guess-work.*"

Guessing is when logic and information do not provide sufficient insight to answer a question completely. An *intelligent guess* (contrasted to a" blind guess'" without any clue whatsoever as to what the question is all about) means analyzing the question, and achieve inferences through a process of intelligent deduction, coherent lines of arguing and elimination of the wrong choices, eventually narrowing down the choice to just one. The approach is using "related" information, using an analogous question or case and making extrapolation from historical data or facts or any other evidence.

It is advantageous to start with an "assumption" – any assumption like the worst one – as it is easier to refine this understanding than to create the refined analysis in one step. Whenever you have a statement, you should automatically think: Does this level of magnitude, attribute or number seems reasonable? Is it far too small, or far too large? You can correct the gross "misses" after you have got a feeling for the problem, and have learned which assumptions are most critical.The essence of such a process is to strip away a vast proportion of facts, assumptions and opinions and what you are left with usually supplies the answer for decision-making (Figure I.109).

Fourth, *managing hazards* means responses to the issues raised. Once you have worked out the impact levels of hazards you face (Figure I.110), you can start to look at ways of managing risk (and exposure) and balancing risk and exposure.

Prioritization of the hazards make sure to get "all" of the really important stuff done which is timely task accomplishment in advance of actual need. When you are doing this, it is important to choose cost effective approaches. Often, it may be better to accept the risk than to use excessive resources to eliminate it.

One way to approach the combined effects of risk and exposure, hazard, is to relate identified risks associated with a three-level impact (low-medium-high) to hazard by attributing perceived exposure (small-medium-large) to these as done in Figure I.110.

When the semi-quantitative measures are mapped to a numerical scale (like 0.2, 0.6, 1.0) a multiplication table suffices to assess hazard semi-quantitatively. And the original chart can illustrate overall hazards as a bubble chart.

Risk-taking by academic entrepreneurs (founders of RBSUs) passing a transition phase in an incubator often disregard risks associated with firm's foundation. Usually they have completed the study with a diploma or master degree or even a doctoral or PhD degree. And being novice entrepreneurs they perceive their risks of firm's foundation as rather low.

The line of rationale is that RBSU foundation in an incubator usually means personal income (assumed to be "sufficient") via special grants, scholarships or funded research projects and operational support via dedicated micro-grants and utilizing rooms, equipment or other infrastructure free-of-charge or for a rather low fee (ch. 1.2.6.2).

And this is seen often to be similar to a "post doc" experience. In this case another kind of experience is gathered. And if failed with the firm there are still all other options for employment – it is not wasted time, it is not irrelevant for a job in an industrial or commercial environment. This is a kind of rational decision-making concerning risk.

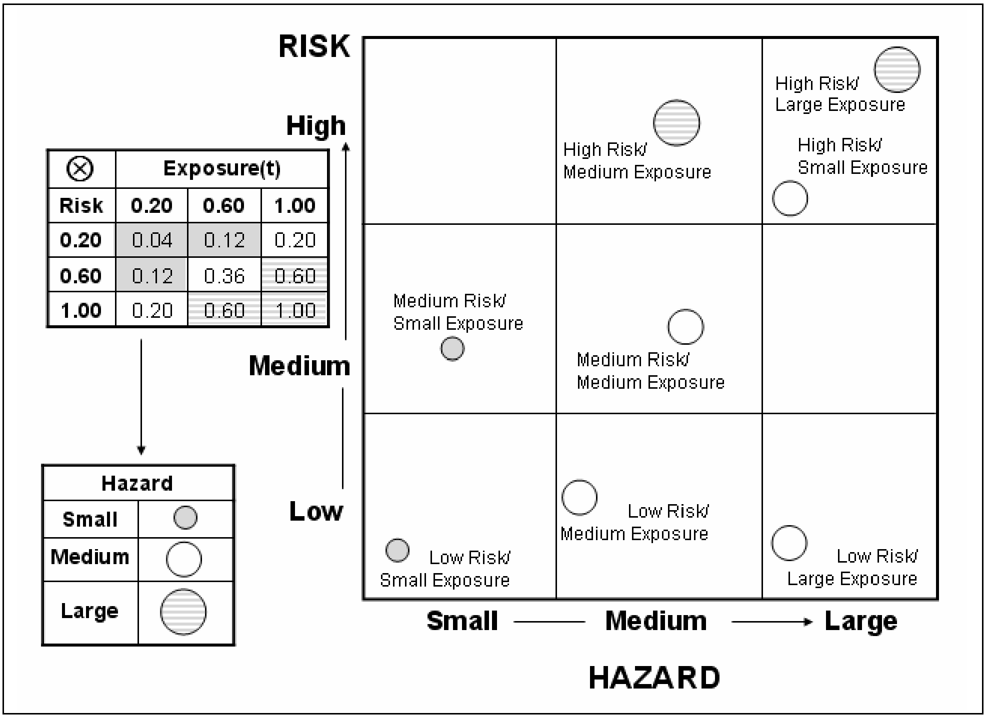


Figure I.110: Approaching a three level hazard reporting based on risk and exposure assessments.

Concerning entrepreneurial proceeding in this particular environment one meets Bhidé's concept of *opportunistic adaptability* (ch. 1.2) which refers to a style of reasoning and behavior in the context of Systems Thinking and the Environment-Modification Principle of General Systems Theory (ch. 1.2) and dealing with the future in line with the old saying of Peter Drucker (1909-2005) and Dennis Gabor (1900-1979) (motto of ch. 1.2).

There is a goal and the availability of tangible and intangible resources. After having revealed a new opportunity or a different route to the originally targeted goal or how to change the environment by an innovation consideration of the situation and reasoning how to enlarge one's existing resource base and accessing other supporting resources a decision is made how to proceed.

Such an approach in the special context of an incubator or a startup location in a cluster (for instance, a science park) in close vicinity to a university exhibits some relation to "effectuation" and "effectual reasoning" [Burkeman 2012], a concept put forward recently by Saras Sarasvathy of University of Virginia's Darden School of Business [Effectuation.org] with currently a community of scholars involved in its exploration [Mauer and Brettel 2008].

Effectuation is introduced as *an idea with a sense of purpose* – a desire to improve the state of the world and the lives of individuals by enabling the creation of firms, products, markets, services and ideas. Essentially, the notion Effectual Reasoning involves being given the means and choices and defining what the goal is (A.1.7).

Effectual Reasoning follows the logic, "*To the extent that we can control the future, we do not need to predict it*. How do you control the future? By inventing it yourself – marshalling scarce resources, understanding that surprises are to be expected rather than avoided, reacting to them fast." [Taylor 2009] This seems conceptually to be close to opportunistic adaptability and Drucker and Gabor.

4.2.1.1 Risk-Taking by Customers and Suppliers

Capturing orders and establishing solid customer relationships is often a major problem for startups. Additionally, young firms often do not have enough experience to reveal customers' wishes and make their products or services fit their expectations. [Metzger et al. 2010a].

In most cases also the customers appear to face a great risk dealing with startups [Bhidé 2000:69, 70-75, 80-86]. If the startup becomes bankrupt or go out of business and could no longer provide support for their offerings, customers would face significant losses in substituting the offerings they had committed to by another offering or system, respectively.

Hence, one can assume customers, like potential investors and suppliers to the startup, to assess the chances of survival of the startup and reliable delivery of the offering and, if applies, related technical service before they make an almost irreversible commitment in time and money, or close off other options. Essentially switching cost including search cost for alternatives and sunk cost may show up.

Suppliers, for instance, those providing raw materials or intermediates for material-oriented startups or technical components to devices or instrument producing startups, may fear to continuously run after payment of bills by a new firm or even encounter a financial loss if the startup becomes insolvent. Such assessments based on realistic concerns about the survival and solvency of a new firm may get reinforced by a general "risk aversion" of the customer or supplier, respectively.

If cautious customers are attracted by the startup's offering(s), uncertainties can only be lifted by inquiries to credit bureaus or by conducting own test and make investments. The more rational approach of the customer would be to let someone else go first and have access to corresponding information.

> Consequently, customers or suppliers who are comfortable and satisfied with their current arrangements have no incentives to look farther afield. The minimum in overcoming the "business credibility barrier" startups should do is to

provide a list of reference customers on their Web site, unless the existing customers prohibit that.

For the new firm it means, find and bind customers who are so innovative that they accept to become early adopters (Figure I.29) or have a problem that needs to be solved such that the risk of dealing with the startup is small compared to the risk of not solving the problem.

In relation to customers entrepreneurs without much business experience and who do not have deep prior relationships or reputations need reassurance about their capabilities. They need a perception (or expectation) of “performance persistence” (defined by Gompers et al. [2008] in a context and way different from here).

The above description is a general expression of *reflexive behavior* of resource providers to startups, such as financial backers, customers, suppliers and even to-be employees, to rely on “social proofs”: To do what others are doing; to be consistent with what has already been done [Bhidé 2000:72]. The typical response to such behavior, for instance, concerning investors would be to get a “lead investor” or corporate venturing as a start to attract more investors for NTBFs (ch. 1.2.7.2).

4.2.2 Decision-Making

No man who has not sat in the assemblies of men can know
the light, odd and uncertain ways in which decisions are often arrived at.
Sir Arthur Helps

So far, concerning decision-making and behavior entrepreneurship has turned out to be *facultative*. It means there is no obligation or reliable guidance for decision-making by a choice of adapting to the environment or the possibility to adapt to different conditions or states, or being able to exist under more than one set of conditions opening different paths for further development.

There are typical situations for technology entrepreneurs to make decision, such as

- Business ideas and opportunities (ch. 3.2)
  (Figure I.87, Figure I.91, Figure I.92, Figure I.96, Equation I.7)
- Ideation (ch. 3.3),
  (ch. 3.3.1; Table I.60; fuzzy front-end of ideas or idea generation (ch. 3.3.2))
- Technology – variabilities; for instance, different inputs (biomass) for conversions into biofuels via different technologies
  (Figure I.174, Figure I.175, Figure I.181, Figure I.184)
- Entrepreneur plus team and networking; leadership/management team of startup
  (ch. 2.1.2.5; advisory board (ch. 2.1.2.4, 4.3.5.1))
- Location selection
  (ch. 1.2.2, 1.2.6.2; Figure I.49)
- Financial sources (Figure I.59), financing (Figure I.52; Table I.30, ch. 1.2.7.2) and financial structure (Figure I.54)

- Risk-taking (Figure I.109, Figure I.110, Equation I.8, Equation I.9)
- Markets and industry – market segment selection and entry, overcoming entry barriers (Figure I.98)
- Types of market (Table I.15, Table I.16):
  An "economic market" is essentially what economists or MBAs tell us a market to be. But the taxonomy in Table I.15 which is not taught by economics focuses on players, drivers and functions that will affect decisions and actions for technology entrepreneurship and innovation.
- Competition (Figure I.33), competitive performance (Figure I.108)
- Stage-Gate® process for innovation (Figure I.79, Figure I.180)
- Value chain positioning (Figure I.7, Figure I.11, Figure I.12); output value for given input (Figure I.176, Figure I.185)
- Revenue model; types of offerings
  (Figure I.94, Figure I.95; Table I.3)
- Profit model, value system position (Figure I.7, Figure I.11, Figure I.12)
- Business model varieties (Figure I.183).

Basically, decisions in the context of technology entrepreneurship are made compromising between long-term (ultimate) goals and short-term, current necessities.

The decision-making situations of primary importance to entrepreneurs refer to opportunities. Accordingly, there are several kinds of decisions with regard to the number of alternatives, selections and choices.

- Binary Decisions – Whether:
  This is the yes/no, either/or decision that must be made before we proceed with the selection of an alternative. Decisions "whether" are made by weighing reasons pro and con and weighing trade-offs.
  It is important to be aware of having made a decision "whether," since too often we assume that decision-making begins with the identification of alternatives, assuming that the decision to choose one has already been made.
- Selective Decisions: – Which/What/Where/When:
  These decisions involve a choice of one or more alternatives from among a set of possibilities, the choice being based on how well each alternative measures up to a set of predefined criteria.
- Conditional Decisions – If, Unless, While:
  Decisions that have been made but put on hold until some condition is met; including conditions with branching into two alternatives or decisions with "fall-back options" or a "safety net" ("what – if") or use of scenarios (Box I.19).

The decision for a choice means a commitment to some idea or an immediate or postponed course of action. In many cases decisions are made under risk or uncertainty (ch. 4.2.1). Using a sequential phased process with several "decision gates" including branching (what – if) usually reduces risk (Figure I.52, Figure I.79).

With regard to the process of business decisions and related behavior one can differentiate [Runge 2006:341-342]:

- Programmed Decisions and
- Non-Programmable Decisions.

Decisions as the answer to problems can be programmed to the extent that they are repetitive and routine. They will follow a pattern or procedure developed in the past. In such cases little cognitive processing is necessary; identification of a gap tends to evoke a programmed response instantaneously. This means, a definite procedure including controls has been worked out for handling them. This includes a set of given criteria.

Decisions are non-programmed to the extent they are novel, unstructured and consequential – or refer to a "wicked problem" (ch. 3.1). With re-occurrence and emergence of structures over time some of them may became programmable. However, if problems are ill-structured and non-recurrent or extremely complex related decisions continue to be non-programmable. Basically, the above notions make no explicit reference to "computer programs." Decisions which are called "programmed" do not necessarily have to be suitable for computer programming.

The strict and formalized Stage-Gate (PhaseGate) process for NPD and essentially incremental innovation in large firms (Figure I.79) can be viewed as largely programmed. It is conceptualized to have "decision points" ("gates") after the end of each stage and defines after review (usually by a dedicated group) whether and how to proceed in the process. Assessment is usually by *given* criteria, explicit "milestones" or control points ("*judgment in the process*"), but rarely "tacitly" by group consensus ("*judgment by the people*"). A stage review requires that all activities be finished up for review before the next phase can start ("synchronization").

In the corporate environment non-programmable decisions are usually in the realm of middle and upper management who deal with non-programmable decisions by using a great deal of judgment, intuition, "gut feeling" and creativity. Ironically, it is often these kind of people who deny researchers and innovators to apply intuition, inspiration or "gut feeling" as a support of their ideas and projects.

Judgment refers to decision-making when the range of possible future outcomes, let alone the likelihood of individual outcomes, is generally unknown (Table I.31, Box I.17). For entrepreneurship judgment usually means the process of forming estimates of future events in which the relevant probability distributions are unknown.

Key for programmed decisions is the notions of "*algorithm*" and "*heuristic*." An algorithm can be defined as a step-by-step procedure which insures that, in a finite number of steps, the optimum solution is reached. A heuristic can be defined as a step-by-step procedure, which in a finite number of steps insures that *a satisfactory solution* to the problem is reached. Heuristics are methods to reduce search. *Algorithms can be* *developed only in the context of a model* that applies preferentially to programmed decisions. Therefore, an algorithm is any well-defined procedure for solving a given class of problems.

In contrast to heuristics a "*rule-of-thumb*" has usually no analytical foundation and has been developed on the basis of long-time experience and intuition. Algorithms or heuristics are typically constructed on a case-by-case basis, being adapted to the problem at hand. Current computer-based decision-making, as in financial analysis, risk management or options analysis, makes use of all the three above approaches.

Programmed decision-making specifically by software programs is rather common for buying and selling at the stock exchange where transactions without any interference of human beings are made on the basis of a large number of heuristics and rules-of thumbs rather than algorithms.

Particularly, the Systems Approach is a decision-making process which is used to design systems. Decision-making is also fundamental for researchers to design an experiment or engineers to run a project. It is therefore important to deal with this process, before tackling the issue of designing systems – founding a technology-based firm (ch. 5.1) and further decision-making during the early phase of the startup and transition into growth mode when entrepreneurship becomes overlaid by SME management.

The current GST approach is in contrast to the notion that economic decisions are based entirely on rational motives. Behavioral factors, such as social preference (social or altruistic motives), bounded rationality (limited insight or cognitive ability) and behavioral bias (interpretive errors) also play important roles.

Decision-making [Van Gigch 1974:55-63] is required when we have needs to satisfy or a problem to solve. Related to *purposeful human activities* it is a thinking process which pervades all problem-solving activity. The step of defining the problem can be viewed as a subproblem of the main problem; that is, it is a "*loop-within-a-loop*" in the *decision-making cycle* (Figure I.113).

The decision maker is usually endowed with a certain *fund of knowledge and experience* from which he draws information or *intelligence*, respectively, to outline a set of *alternatives*. And *decision-making reveals itself by related observable behavior;* the output of decision-making may be action(s).

Alternatives are different strategies by which the *objectives* can be met (whose definition must imply methods by which they can be measured). Each alternative leads to one or several anticipated outcomes. Before the decision maker can make a choice among the alternatives and their corresponding outcomes, each must be evaluated in terms of the extent to which they satisfy the objective(s).

For the purpose of choice, a value is attached to each outcome on the basis of consistent criteria, the formulation of which is usually embodied in a *rational decision model*.

Often non-commensurability of the attributes of the various alternatives may raise issues of quantification and measurement.

In terms of Systems Thinking (ch. 5.1) evaluation of outcomes means:

- The envisioned outcomes of a decision are evaluated for fit with the objectives, but also revealing more possible positive and negative consequences.
- The decisive actions are taken, and additional actions may be taken to prevent any adverse consequences from becoming problems and starting both problem analysis and decision-making all over again.

Furthermore, decision-making has to consider *short-term impacts* of the actions and also *long-term impacts*.

Decision-making does not proceed only through *conscious* processes, but also *unconscious processes* comprising *non-rational aspects*, such as emotions and passion; it can be based on *explicit assumptions* or *tacit assumptions*. Hence, decision-making relies on intelligence, facts, assumptions, opinions, feelings and (personal) preferences (Figure I.109). For instance, it was found [Hills and Shrader 1998] that entrepreneurs consider intuitive judgment or “gut feel” sometimes to be an important part of judging market potential.

Good decisions require “trained” thinking mechanisms. The brain usually refers to learned decision patterns which provide a framework for decision-making. Consequences of decisions together with the decision path are stored in the brain. But, there is a downside of this mechanism. The human “thinking apparatus” tends to monocausal prescriptions which can only be overcome feeding the brain continuously with new aspects.

Thinking prescriptions relate to the “status quo bias” which is defined as the tendency to select a previously chosen alternative disproportionately often [Burmeister and Schade 2007] or “confirmation bias” seeking evidence to confirm own hypotheses or convictions and to avoid information that might refute them (“confirmation of one’s own prejudices”).

Studies on decision-making have repeatedly demonstrated that entrepreneurs make extensive use of simplifying heuristics and thus often exhibit cognitive biases. Based on the literature on experience effects, Shepherd et al. [2003] argued that more experience will most probably lead to a higher susceptibility to the status quo bias because thoughts may become increasingly channeled by past experience.

Apart from the already mentioned “inertia” (keeping thought patterns that were used in the past even in the face of new circumstances) some commonly debated biases entering decision-making processes will comprise the following ones (cf. also Bhidé [2000:73]).

- Selective search for evidence:
  We tend to be willing to gather facts that support certain conclusions but disregard other facts that support different conclusions.
- Wishful thinking or (over)optimism bias:
  We tend to want to see things in a positive light and this can distort our perception and thinking.
- Choice-supportive bias:
  We distort our memories of chosen and rejected options to make the chosen options seem more attractive.
- Information recency:
  We tend to place more attention on more recent information and either ignore or forget more distant information.
- Source credibility bias:
  We reject something if we have a bias against a person, organization, or group to which the person belongs: We are inclined to accept a statement by someone we like.
- Underestimating uncertainty and the illusion of control:
  We tend to underestimate future uncertainty because we tend to believe we have more control over events than we really do.
- Group thinking:
  Peer pressure to conform to the opinions held by the group.

The *non-linear, recursive process of decision-making* means that most decisions are made by moving back and forth between the choice of criteria (the characteristics one wants the choice to meet) and the identification of alternatives. The alternatives available influence the criteria we apply to them, and the similarity of the criteria we establish influences the alternatives we will consider.

The decision-making cycle is usually activated by the urge to satisfy *needs*. Needs can be ranked in a hierarchy and we cannot expect to satisfy all our needs. Therefore, a *choice* is made to select a subset which we define as *wants*. Another subroutine is needed to establish the *level of aspiration*, which represents the expected level of achievement or *expectation in the satisfaction of needs* (ch. 4.1).

It is sufficient to say that an individual's level of aspiration depends, to a large extent, upon what success he/she has met in previous attempts at satisfying his/her goals. Faced with conflicting objectives, the decision-maker will resort to substitutions and trade-offs. The hierarchy of needs constitutes a list of *priorities*. Needs, expectations, and trade-offs converge toward goals and objectives as depicted in Figure I.111 [Van Gigch 1974:59].

Measurement in our context, as a test of a hypothesis, refers to the output (and outcomes) of "soft" systems and methods to evaluate complex alternatives. Therefore, "a decision-making activity … designed to accomplish an objective" is a measurement [Van Gigch 1974:141].

Individual decision-making is influenced by cognition. Cognitive processes relate largely to the manner in which knowledge is selected, organized, stored and utilized and they are related to "cognitive frameworks" (ch. 3.2). These are influenced by *information propensity* of the individual which is decision-making based upon sparse (even halfhearted or dubious) information versus insisting on as sound an information base as possible. Content and organization of knowledge provide knowledge structures of the individual.

Cognition science suggests that there are differences among individuals with regard to their cognition. These differences have been partly explained by variations in the level and nature of individual's experience, which itself is viewed as a key contributor to the development of cognition, a "self-reinforcing mechanisms."

The decision-making process is influenced by interactions with a relevant environment. Every decision is made in the context of a time-dependent "**decision environment**" (Figure I.111). For technology entrepreneurship or a corporate (innovation) environment it reflects the decision-makers personality (including status within the firm) and current psychological and cognitive dispositions as the core which is surrounded by two relevant super-systems ("shells") influencing decision-making.

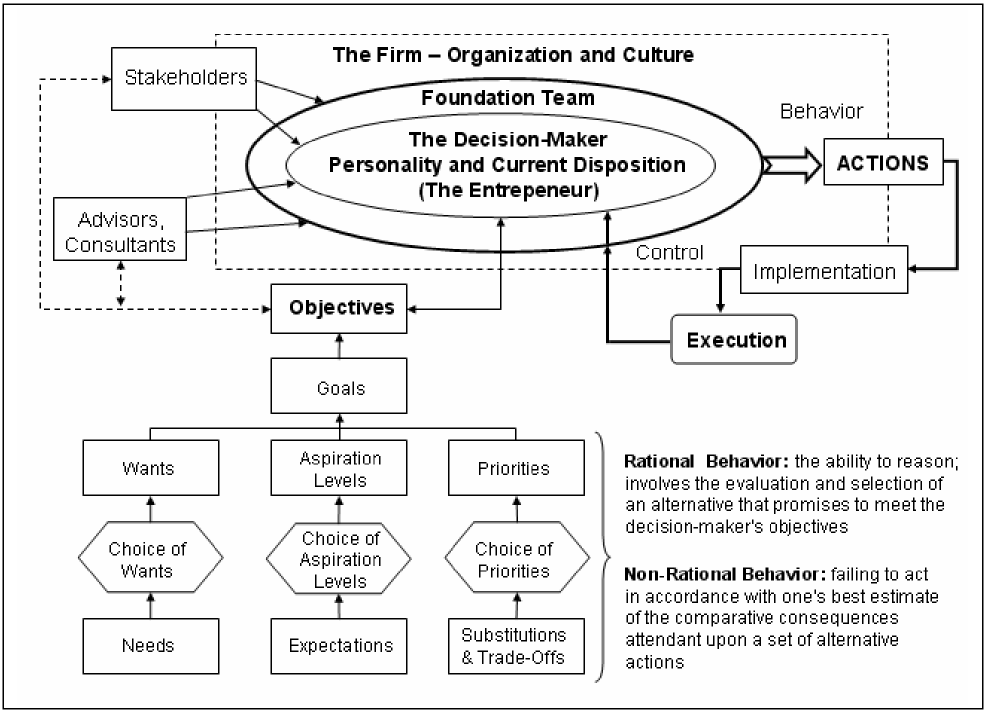


Figure I.111: A systemic model of the decision environment and the decision-making process for entrepreneurship (utilizing partly [Van Gigch 1974:59]).

In Figure I.111 the nearest shell refers to the question whether decision-making is achieved by a single person on his/her own, as, for instance, by the single entrepreneur and firm owner or sometimes the CEO of a large firm by status and power, or whether decision-making is by a "participative" process to achieve a consensual decision involving a leadership/management team or sometimes the founder team of an NTBF together with employees.

The decision environment of an NTBF includes additionally influences of external advisors or consultants, for instance, an Advisory Board and it takes into account that decisions may also be affected by considerations of consequences of a decision for stakeholders of the firm.

For the actual decision to found a firm there is no corporate environment and the group of advisors comprises usually the entrepreneurs' near social environment, such as parents, family, relatives and friends. For decision-making environments of established VC-based NTBFs or large existing firms CEOs in firms always have to consider ownership (Figure I.19).

In large mature firms the existing assets and norms limit the options that the top management (or intrapreneurs) can manipulate. The need to match new initiatives with these – and corporate strategy – limits technology and product market choices [Bhidé 2000:289]. They cannot easily change the firm's basic purpose or its organizational culture and climate.

Furthermore, related to corporate culture, organizational memory and core rigidities (ch. 2.2.1) Bhidé [2000:249-250] emphasized *"routinized" decision-making*. Firms can be expected to behave in the future according to the routines they have employed in the past; internal routines of a firm drive their behavior. This implies that it is inappropriate to conceive of firm behavior in terms of deliberate choice from a broad menu of alternatives some external observer considers to be available for the organization. "The menu is not broad, but narrow and idiosyncratic; it is built into the firm's routines, and most of the "choosing" is also accomplished automatically by those routines."

An *ideal* decision environment would include all possible information and knowledge, all of it accurate, and every possible alternative. However, both information and alternatives are constrained because the *time and effort* to gain information or identify alternatives are limited. The *time constraint* simply means that a decision must be made by a certain time ("*urgency of decision*") utilizing accessible resources. The related *effort constraint* reflects the limits of manpower, money and priorities. Furthermore, there is the issue of the "*information dilemma*" (ch. 1.2.1).

The time factor for decision-making appears in its structure and impact similar to the Window of Opportunity (Figure I.4): It can be made too early or too late. The aim to simplify a complex situation may induce a premature decision which is mostly a mistake. Making a decision only when all the data and information are available may be too late to be effective. The questions are: Is this the right time for decision-making; is there a need for decision-making now? Correspondingly, it has been suggested that "the prudent and rational executive make final commitments *as last as* possible with the information *available*" [Bhidé 2000:257].

But there are more constraints. Fundamentally, a strategy of a firm reduces the number of choices among alternatives. Furthermore, decisions are made in a context of other decisions and decision-making appears to be *path-dependent* unless decisions include "fall-back" options.

This means previous decisions may define decision threads for the future: A decision 1) follows from previous decisions, 2) enables many future decisions and 3) prevents certain other future decisions. Hence, as making a decision precludes other decisions the "space of alternatives" might be restricted and cause a loss of freedom of choices or decision-making. This is illustrated for a simplified situation of binary decisions in Figure I.112.

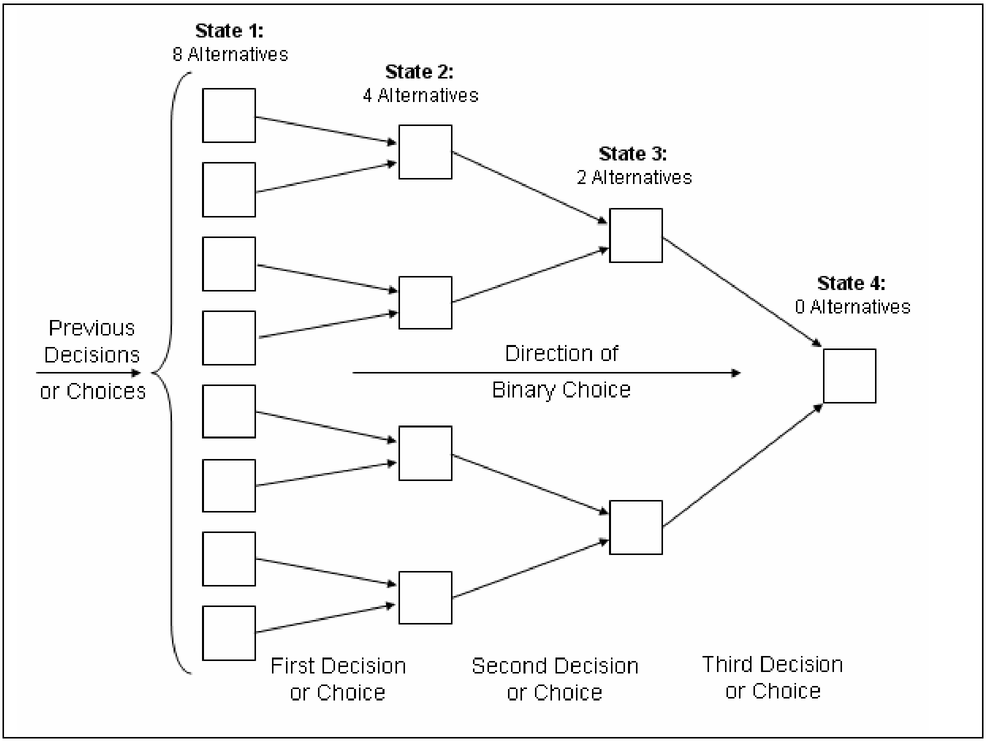


Figure I.112: How successive binary choice decisions reduce freedom.

The *search process* by which the mind generates alternatives is only partially understood. However, it is obvious that the process of generating and searching for alternatives is central and crucial to the successful achievement of objectives.

An *abstract* description of an organizational decision process is show in Figure I.113. It refers to explaining the behavior of established firms within an environment of well-defined markets, stakeholder relationships, technologies, etc. and in so far may model the situation of existing large firms, VC-based NTBFs or very advanced NTBFs in growth mode. It may become an iterative process (thick lines) starting with revealing a *need* which stimulates a definition of the related *problem*.

The *process of choice* consists of selecting the "best" alternative among those available. Underlying *criteria for choice* may be (socio-economic) benefit or cost in nature. Then the problem might be to *rank these alternatives* in terms of how attractive they are to the decision-maker(s) when all the criteria are considered simultaneously.

If the alternative is implemented and executed it leads to *outputs and results* (outcomes) which should satisfy the original needs. An evaluation round takes place to assess the extent to which the chosen alternative satisfies the objectives. The comparison between anticipated and achieved results may lead to a modified approach to the original problem and to a new round of the cycle (thin lines).

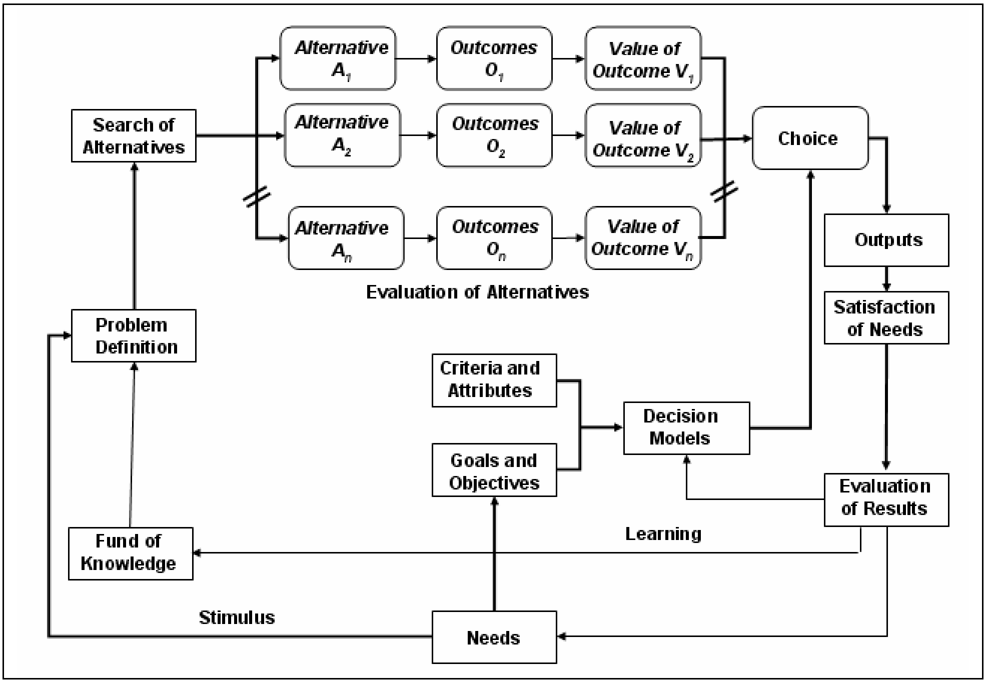


Figure I.113: Generics of an organizational rational decision-making process [Cyert and March 1963:127].

To express the idea that human decision-making is limited by available information, range and scope of the alternatives, available time, the information-processing ability of the mind and also environmental influences J. G. March and H. Simon coined the phrase “*bounds of rationality”* [Van Gigch 1974:60-61]. The notion particularly refers to the limitations in the individual’s inherent capabilities of comprehending and comparing more than a few alternatives at a time.

Comparison becomes more difficult as the number of variables bearing on the alternatives increases. For most decisions considering three alternatives – for example, a spectrum of two extremes and the point in the middle – may be sufficient. However, this cannot be said of important decisions. Here, one should consider as many alternatives as possible in order to cover all possibilities. Alternatives can then be weeded out, as the constraints of the problem are taken into account.

Though the concept of bounded rationality refers to consciously made decisions it comprises also unconscious judgment which is influenced by *attention-directing factors*. Human beings usually have several goals which, however, are not weighed against each other. They form expectations concerning the goals and make them fit to a higher expectation if an improvement appears to be possible and correct them to a lower level if needed.

For instance, a firm may pursue profit and market share. Both goals, however, are rarely offset against each other. The firm will seek primarily that neither profit nor market share will decrease. The firm will rarely take into account to replace a one percent decrease of market share by increase of profit by some x percent.

Apart from bounded rationality there is another directing factor, the *Principle of Satisficing,* which characterizes a decision-making process whereby one chooses an option that is, while perhaps not the best, good enough (ch. 4.1).

A decision maker is said to exhibit satisficing behavior when he or she chooses an alternative that meets one or more specified criteria, but that need not be optimal with respect to any particular set of preferences or objectives. “Human beings satisfice because they have not the wits to maximize.” [Van Gigch 1974:80] It appears that firms often follow “satisficing” behavior [Bhidé 2000:249].

The “satisfier” seldom evaluates the existing alternatives, because the first acceptable alternative is considered to be as good as all others. To satisfice is often in line with the “principle of least effort.”

As a note concerning experienced serial entrepreneurs Sarasvathy cited by Buchanan [2011] concluded that “*master entrepreneurs*” (essentially serial entrepreneurs) rely for decision-making on what she calls *effectual reasoning.* Brilliant improvisers, these entrepreneurs do not start out with concrete goals. Instead, they constantly assess how to use their personal strengths and whatever resources they have at hand to develop goals on the fly, while creatively reacting to contingencies (cf. discussion in ch. 4.2.1, A.1.7). By contrast, *corporate executives* who in a study group were also enormously successful in their chosen field – use *causal reasoning*. They set a goal and diligently seek the best ways to achieve it [Buchanan 2011].

Concerning *“heuristics” as the basis of decision-making*, especially in complex situations where less complete information or uncertainty is available, Alvarez and Busenitz [2001] reported that entrepreneurs use heuristics more extensively than managers in larger organizations. Correspondingly, they introduced the notion “entrepreneurial cognition” defined as the extensive use of individual heuristics and beliefs that impact decision-making.

This is contrasted with “managerial cognition” which refers to more systematic decision-making where managers use accountability and compensation schemes, the structural coordination of business activities across various units and justification of future developments using quantifiable budgets. Hence, it is suggested that managerial cognition is more factual-based while entrepreneurial cognition builds from limited or key experiences and beliefs.

Given the high ambiguity and uncertainty that entrepreneurs typically face in the pursuit of a new venture, the willingness and confidence to readily rely on heuristics to piece together limited information to make convincing decisions may be virtually the only way to progress forward.

The use of a more factual-based logic in the pursuit of new opportunities becomes too overwhelming and very costly if not impossible for entrepreneurs. Their decision-making contexts also tend to be more complex. This is comparable with the characterization of intrapreneurs (entrepreneurs) and managers in terms of the psychometric MBTI indicator (ch. 2.1.2.1; Table I.35).

The heuristic-based logic can have a great deal of utility in enabling entrepreneurs to make decisions that exploit brief Windows of Opportunity whereas the elaborate policies, procedural routines and structural mechanisms common to those with more of a managerial cognition (managers in large organizations) are likely to erect barriers in the pursuit of innovative activities [Alvarez and Busenitz 2001]. This heuristic-based logic *enables entrepreneurs to more quickly* make sense out of uncertain and complex situations. Such decision approaches can lead to forward-looking approaches.

For decision-making in the context of financing the startup or further developments of NTBFs (Figure I.52) one is led to the “Pecking Order Theory” of Myers und Majluf [1984] or its modifications. This theory suggests a rather rational approach for selecting financial sources using monetary criteria (interests and fees) and, if possible, preference of firm-internal financing.

In case of a need for external financing, a private firm will probably prefer debt (credits and bank loans) over equity if the equity is associated with a loss of control over the firm. That is, if the internal sources of financing are depleted, the firm will raise capital according to a “pecking order” that ranks different sources of financing and different implications for levels of ownership and control (Table I.74) and interference with strategy directions. Individuals looking for wealth as the primary reason for becoming an entrepreneur (Table I.39, Table I.40) are indifferent, but more apt to accept VCs and probably also CV (ch. 1.2.7.3).

Furthermore, it was shown that the entrepreneurs' *attitudes* toward financial sources (Box I.20) and their motivations and aspirations (Table I.28, Table I.29, Table I.39, Table I.40) enter the decision process as important criteria.

Finally, it has been suggested that concerning decision-making for financing one should additionally consider opportunity costs [Metzger et al. 2010b].

As a summary, depending upon the situation there is *prevalently rational* decision-making versus *mixed rational and non-rational* decision-making. In situations with higher time pressure, higher stakes or increased ambiguities, people will rely on instinct, intuition and gut-feeling for decision-making rather than rational structured approaches. Researchers suggest making oneself aware of non-rational patterns of evaluation and decision-making to avoid risky errors.

According to the MBTI psychometric approach these two ways to make decisions is related to personality according to the prevalence of personality type – particularly regarding the "T-F Thinking or Feeling" and "J-P Judgment or Perceptive" dichotomies (ch. 2.1.2.1, Table I.34) and entrepreneurs showing prevalence of the ENTP type.

A **decision situation** represents perceived circumstances by which a person or group of persons, respectively, perceive the necessity to make a decision. Decision-making and (re)actions in such an environment of systems with interactions may be compared with communication between systems or persons, respectively.

> Referring to the fundamental principle of communication "one cannot not communicate" [Watzlawick et al. 1967] *no decision and (re)action* with regard to an event or option *is a system's (firm's, firm's leadership) response* to the event or option!
>
> *Decision-making* and *execution* are often *facultative* (take/do X out of Ys) including the "NULL" option (no decision or deed).

However, one should always be aware of one of Murphy's Laws:

> "Left to themselves, things tend to go from bad to worse."

An important tool, more in use by large firms rather than small ones, to deal with upcoming decision-making is **scenarios** (Box I.19). Scenarios help linking the uncertainties about the future to the decisions that must be made today (alternatives and options); they allow working today with the uncertainties of tomorrow.

Box I.19: Scenarios and Decision-Making.

According to Wikipedia [74] a scenario is a synthetic description of an event or series of actions and events. The term scenario is also used for an account or synopsis of a projected course of action, events or situations.

Scenarios [Runge 2006:528-531] can help an organization identify which factors need to be monitored closely in its business environment and when a strategy must be updated to meet a shift in the industry, market or technology. Hence, scenarios deal with the future. For corporate innovations scenarios focus often on technologies, their impact, degree of change, opportunities and threats and timing or on applications. However, any business quality or quantity may be the subject of scenarios, for instance, the cost of a product or price of raw materials (cf. [Runge 2006:531]).

Scenarios' creation usually stems from Systems Thinking, where a systems approach considers direct and indirect effects of current or future change in any element within a system or external to a system that has the potential to affect any element or process within the system. Systems Thinking requires seeing four simultaneously operating levels within a system: events, patterns, other systems, and mental models.

Pragmatically scenarios are carefully crafted plausible stories how the future may develop, based on corresponding information using a coherent and internally consistent set of assumptions about key relationships, driving forces (for instance, technology changes, prices) and constraints and integrating them in a way that is *communicatable and useful* (understandable options; "victory conditions" or specific rules).

Unlike traditional forecasting or market research, *scenarios present alternative images* instead of extrapolating current trends. Scenarios also embrace qualitative perspectives and potentials for sharp discontinuities that econometric models exclude.

The practice of scenarios depends on the capability of "story-telling." "Stories," not anecdotes, may refer to cases and historical examples and events for "case-based reasoning," and scenarios may use all the other methods or results of forecasting to create a story These must identify upcoming opportunities and threats very early and aim at acquiring multiple views. Generating scenarios will benefit from entirely different perspectives and thought processes.

Scenarios help *linking the uncertainties about the future to the decisions that must be made today* (alternatives and options); they allow working today with the uncertainties of tomorrow. Hence, the key role of scenarios is not to answer the question

"What will happen?"

Instead the focus will be on

"What will we do if it happens?"

Accordingly, the question is not "What will happen in the future?" but "What future events do we have to factor into our present thinking and actions?"

Scenarios are *neither predictions nor forecasts*. According to the Forecasting Dictionary, a scenario is "*a story about what happened in the future.*" [74]

Scenarios also provide a way to *trigger institutional learning*, if from a set of scenarios a clear signal emerges which requires action or starting to change behavior.

The importance of the role of scenarios as anticipation of future decision-making and enforcing action is not shared by all. For instance, while prognoses are regarded as reducing uncertainty ("What will be the future?"), scenarios might appear as contributing to an increase of uncertainty ("What might be the future, if events A, B or C will happen?"). But, we suggest following the alternatives, decision-making and action emphasis, to use scenarios for corporate planning and strategy. And, therefore, leadership also means doing the right things without knowing how the future may be.

The presented alternatives of scenarios can be viewed as a "dynamic model" and, hence, help also to discover sets of trigger points for an event under consideration. Operationally scenarios may explore the effect of changing several given industry-specific parameters and company-specific variables leading to uncertainty at once with objective analysis and subjective interpretations.

It should be noted that scenarios may also serve as *models for behavior*, for instance, for software or systems developers in describing one or several persons' interactions with a (technical) system. Scenarios help focus design efforts on the user's requirements.

Scenarios may be related to "use cases," which describe interactions at a technical level. Unlike use cases, however, scenarios can be understood by people who do not have any technical background. They are therefore suitable for use during participatory design activities.

> Considering the complexity and difficulty of entrepreneurial decision-making, after all, we speculate that without the use of biases and heuristics, many entrepreneurial decisions would never have been made.

Entrepreneurs, especially in the formative stages of their organizations, do not have the luxury of becoming expert decision-makers in a specific area. If entrepreneurs wait until all the "facts" are in to start convincing others that their venture is indeed legitimate, the opportunity they are seeking to exploit will most likely be gone by the time all the data becomes available.

4.2.3 The System of Failures and the Pitfalls for the Start-Up and Early Growth Phase

When entrepreneurs found a firm after risk assessment and having conceived how to mitigate risk, failure is not what they expect. Statistics, however, show that failure is part of the game (ch. 4.2).

In line with the GST approach problems of young firms are related to external factors and firm-internal factors over which the firm's leaders or managers have (largely) control and those they do not control or only have little control over. Specifically, there will be firm failures which are basically related to decision-making and corresponding actions and execution.

To some extent, failures of firms ending in bankruptcy are part of the creative destruction phenomena (ch. 1.1.1.1) that contribute to the dynamics of innovation and economic renewal. Egeln et al. [2010] have shown that generally there is no single reason for failure of young firms. Usually there is *a systemic complex set of reasons* which combine interactively and recursively and build upon each other and which ultimately leads to a “disaster.” Despite the complexity of the variability of reasons and their interdependencies one can reveal certain patterns inducing a young firm to exit a market due to insolvency.

Failure here is seen as the antonym of success and, hence, any discussion of failures looking into barriers of and interferences with founding and developing a new NTBF and identifying pitfalls will simultaneously disclose aspects of success, in particular, “*critical success factors*” (CSFs).

Identifying and measuring business failure can be difficult for several reasons. Inquiry into firm failures leading to an exit of the market is largely a matter of definition [Carter and van Auken 2006]. The definitions in the literature include, for instance, 1) discontinuance for any reason; 2) bankruptcy/loss to creditors or 3) business liquidation to prevent further losses.

For young firms we shall consider business discontinuance as failure (when the business ceases to exist) and use the results of a German study. The investigation of Egeln et al. [2010] covers German firms which were closed or insolvent in the period 2006 – 2008 and which were founded during the period 2002 – 2008. Hence, on exit these firms were six years old at the highest.

For the investigation the sample was restricted to selected branches covering as the largest block firms from the chemical industry, machinery and automotive, medical, measuring and control technology, textile and food and nutrition industry and technology-based services like data processing and R&D services and thus may reflect also the situation for most NTBFs as sufficient guidance.

A number of reasons for failures represent “generic” causes applicable to technical and non-technical young firms. The financial structure of the last set of closed firms does not differ significantly from that observed for NTBFs (Figure I.54). This means that the sample of Egeln et al. [2010] does not exhibit a systematic problem of their financing structure as the cause of failure.

In addition to the study of Egeln et al. [2010] an investigation in the US on “Small Firm Bankruptcy” will be considered [Carter and van Auken 2006]. Here, characteristics of the firms concerning primary activity of business include retail, services, manufacturing, agriculture, and others, with a large emphasis on retail and services, but small contribution of manufacturing.

Though not directly related to only technology ventures and to the education level found in NTBFs' founders and leadership/management teams, the US study adds indications of and guidance for generic factors of firm failure.

Apart from situations enforcing market exit due to economic reasons there are also firms which have been closed voluntarily though the respective firms were not endangered by economic factors. Egeln et al. [2010] mention four major reasons,

- missing expected financial reward (which is the main reason),
- family problems,
- health problems and
- stress.

Obviously financial reward through entrepreneurship did not meet expectations of the firm's founder(s). This indicates that many entrepreneurs overestimate the potential and amount of financial gain by self-employment – at least, during the first few years of the firm.

Time constraints and personal burdens, particularly during the foundation process and the early phases of the firm may result in incompatibility with the private and social life and family as well as stress are further reasons of giving up. Additionally, health problems also showed up as a cause of exit. This factor, however, is not specific to entrepreneurship as it may also be encountered for ending other human activities.

Apart from the special factors associated with the founders' personalities and personal causes, failure can also originate with leadership/management issues, in particular, with the team of founders. A team is usually associated with reducing the probability of firm failure. Compared with a solo entrepreneur a team has more resources in two ways: 1) knowledge, qualifications, skills and bents of the team members may be complementary (ch. ch. 1.2.6.1, 2.1.2.5; Table I.41) which contribute generally to survival and success and 2) endowment with capital is usually larger in team-led young firms than in those run by solo-entrepreneurs.

On the other hand, Egeln et al. [2010] found that 14 percent of young German firms went bankrupt due to *disagreements and tensions within the leadership team* without any economic reason (Table I.65). Heavy tensions among an entrepreneurial pair and the separation of the founders are described for Cambridge Nanotech, Inc. [Yang and Kiron 2010] A general discussion of co-founder conflicts is provided by Shah [2007] presenting the structures and behavior for "five corrosive co-founder conflicts."

Any shut down of a young firm can ultimately be related to running out of cash. Securing financing for the startup phase as well as the early growth phase represents a key barrier or pitfall, respectively, for many new firms [Metzger et al. 2010]. And a major part of closed young firms encountered problems of considerable *undercapitalization* [Egeln et al. 2010].

Starting with *undercapitalization* and considering the role of cash flow as an important contribution to the financing structure of NTBF (Table I.24, Table I.25, Table I.30, Figure I.54, Figure I.55, Figure I.59) Figure I.114 exhibits the *build up of a vicious circle* for the startup. The *downward spiral is triggered by events from the market*, over which the startup may or may not have control. These start a sequence of effects *reinforcing* themselves through a feedback loop which continues to make the financial situation worse.

For NTBFs *losing the far biggest customer* out of a set of few customers (Figure I.140) may trigger a downward cycle and then may invoke declined innovation persistence etc. (Figure I.115). For NTBFs with ambitions to produce the *scale-up* (Figure I.8, Figure I.9) may turn out to be an obvious reason to enter the route to failure. This is described for the German NTBFs Zoxy Energy Systems AG and the German firm mNemoscience GmbH which was a spin-out of MIT involving serial entrepreneur Prof. Robert Langer (B.2).

Carter and van Auken [2006] report nine related problem areas as origins of bankrupt firms: availability of business loans, availability of equity capital for business, availability of personal loans for business, high cost of borrowing, high operating expenses, inadequate sales, lack of money, personal guarantees for business loans, and poor cash flow which are primarily related to the cash-flow solvency of the firm. When asked to indicate those potential problem areas that had *the greatest impact on the viability of their firms*, issues related to *cash flow* and *financing* were among the most important for firms in general.

The question of viability of a venture, whether new or established, is ultimately determined by the markets. Therefore, it appears obvious that young firms may encounter serious problems when *markets lead to survival-threatening crises*, in particular, if these problems arise as a surprise or with a large impact.

For instance, there may be bad debts, decreasing orders and demand by customers or price increases by suppliers, underestimating competition, targeting non-attractive markets and insufficient management of accounts receivable which affect cash flow and prevent keeping sufficient monetary reserves. This may induce the need for more loans and increasing debts and, in the course of further developments, rejections of applications for further loans or denunciation of loans. The consequence would be further financial problems necessary to respond to the market situation and the competition (Figure I.114).

Figure I.114 illustrates "*connectedness*" which means how one action can affect other elements of a system or interconnected systems. Connectedness comes from at least two sources: the web of *counterparties and common exposures*. Exacerbating all of these is the speed with which decisions must be made.

Figure I.114 exhibits that almost 60 percent of closed (German) young firms view reductions in orders or demand as a serious cause for the firm's crisis. On the other hand, more than 50 percent of the young firms cited bad debts as an important reason for closing the firm. It is not clear whether this result includes issues of insufficient cash flow management concerning accounts receivable.

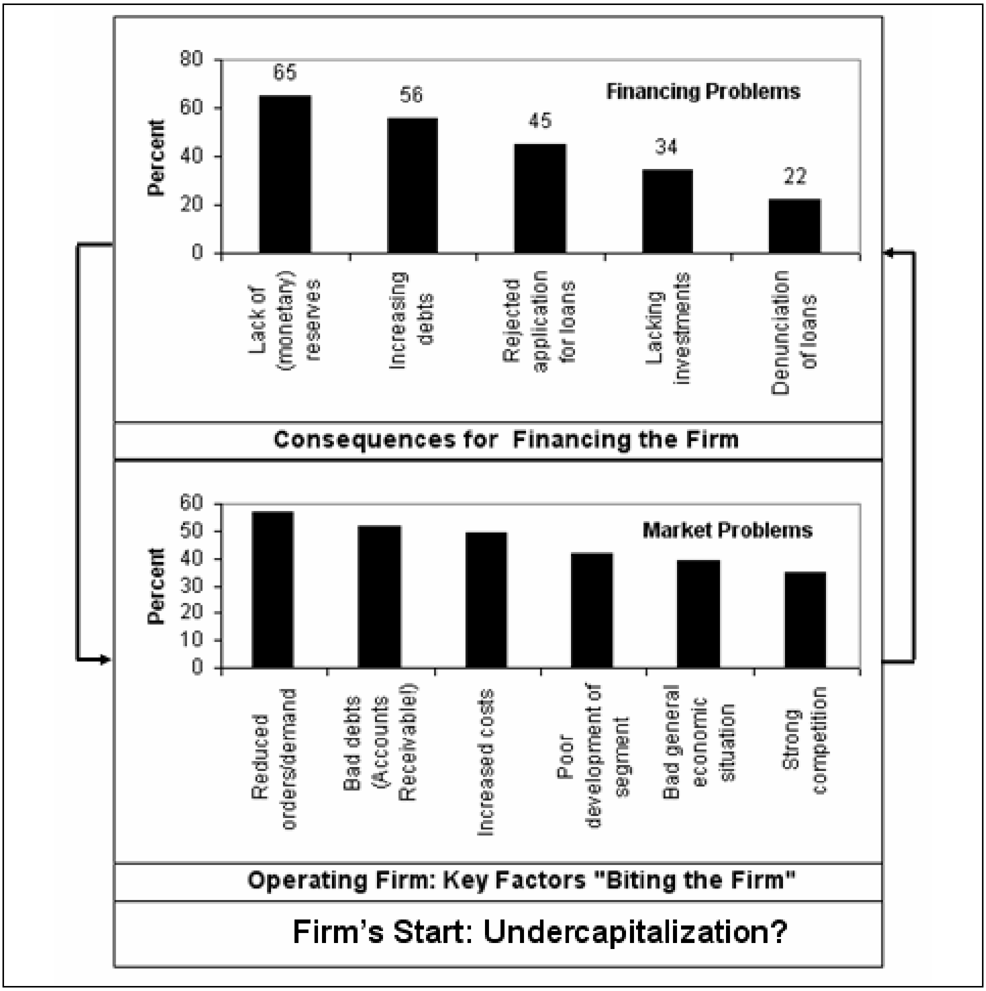


Figure I.114: Systemic route to financial collapse and NTBF failure by reinforcing factors (using data from Egeln et al. [2010]).

Also *factor markets and factor costs* play an important role for firms' failure. Approximate 50 percent of young firms attribute price increases, for instance, for raw material or technical components, as a problem. For such reasons of failure, however, the firm bears only restricted responsibility.

Similarly, other factors are cited over which the firms have no or little control. Both with around 40 percent, reduced revenues have been attributed to bad economic conditions and poor market development. However, Egeln et al. [2010] argue that this finding represents a “euphemistic view” of the firms’ sales problem. The “boom period” 2006 – 2008 during which the firms failed did not allow to understand such a rationale.

On the other hand, sales problems may also arise from the *intensity of competition* and, indeed, competition is cited as an important reason for failure (Figure I.114). Egeln et al. [2010] also report sales problems of failing firms in the context of issues to keep customers or to gain ones.

As a conclusion the financial state or deterioration of the financial state, respectively, of an NTBF is susceptible to self-reinforcing processes leading to firm failure. Here *interrelated firm internal factors and processes* with *customer market, factor market* and *financing* effects are operative.

Reversing the above outline one can expect a list of critical success factors for survival and viability of a new firm:

- The years of *work experience* in the industry segment the NTBF is primarily active in will reduce the probability of market exit (in relation to staying in the market).
- *Initial endowment with resources* should help survival of a startup. That is, avoiding undercapitalization, if possible. It is easier to get more money up front than later have to ask for more!
- Even the *legal form of a startup* may have an effect on survival (Box I.20).
- *Location of a startup*, for instance, in a cluster or technology or science park (ch. 1.2.6.2), of the startup may provide access to resources, operational support and execution of strategy logics (Table I.33).

From the situation depicted in Figure I.114 an important consequence concerning financing NTBFs can be deduced.

> If it is known that the firm will need further financing it is always advisable to go for the needed capital as long as the firm is in good shape – and view it as a reserve. It is much more difficult to get financing, if the firm is in trouble.

More than for established large companies weal and woe of young firms depend on decisions, skills and competencies of the entrepreneur(s) or leadership team. Their knowledge, capabilities and judgments as well as advisory resources (Figure I.111) are the basis for all important decisions and planning for the firm and their quality of leadership determines whether the decisions are put appropriately into actions and executed according to plans meeting the goals (cf. Hidden Champions, ch. 4.1.1).

A set of interrelated strategic decisions has been cited by “failed entrepreneurs” as the most significant reasons for insolvency or market exit [Egeln et al. 2010]. In particular, *strategic decisions during the early phase of young firms* to set the “directions” for entry and further developments in the market often turned out to be wrong decisions that lead the company into the offside. Related topics are referred to in Figure I.115:

- Selecting the customers (by segment and target group or geography)
- The planning horizon which is often too short with the consequence that even small delays will induce not manageable problems
- An unrealistic (or bad) investment strategy
- An unrealistic growth strategy.

Egeln et al. [2010] also emphasize that a typical management and execution error of young firms is due to certain inactivity: after two rather good years they missed to capture and exploit new, potential customers. The obviously comfortable position focusing on only existing customers did not meet the gradual changes of the market. The emergence of the related sales decline actually originates as a secondary effect of a poor or missing marketing plan.

Continuously broadening the customer base requires three actions (Figure I.117):

- Find them
  (or advantageously, *have them* already for firm's foundation (as WITec GmbH, Attocube AG and ChemCon GmbH (B.2), IoLiTec GmbH and Solvent Innovation GmbH (A.1.5) and Cambridge Nanotech, Inc. did),
- Attract them,
- Bind them.

For NTBFs, particularly in the high-tech sector, a fundamental problem to find and attract customers is the level of novelty of products or services or technology which is generally high above average (ch. 4.2.1.1).

Figure I.115 shows that the critical task concerning getting customers or selecting the field of operation (region) is actually meeting the target, the focus of the variety. This issue can be paraphrased by an "80:20 Rule" as a good rule-of-thumb:

> 20 percent of your customers will consume 80 percent of your business's products or services.
>
> It is your job as an entrepreneur to identify your "20 percent" and (initially) market toward them.

Moreover, to be successful NTBFs need to exhibit **innovation persistence** (ch. 4.1.1). For German young technology-based firms founded between 2005 and 2008 its has been found [Creditreform - KfW - ZEW 2009] that of the firms which launched a *product innovation* into the market in 2007 ca. 40 percent again had a product innovation. Of those firms which did not offered a product innovation in 2007 more than 80 percent also did not launch a product innovation in 2008.

And for *process innovation* a similar situation over the underlying period was observed. In this context McCann [1991] found: "The highest-performing ventures were found to be pursuing internal innovation through R & D for product breakthroughs."

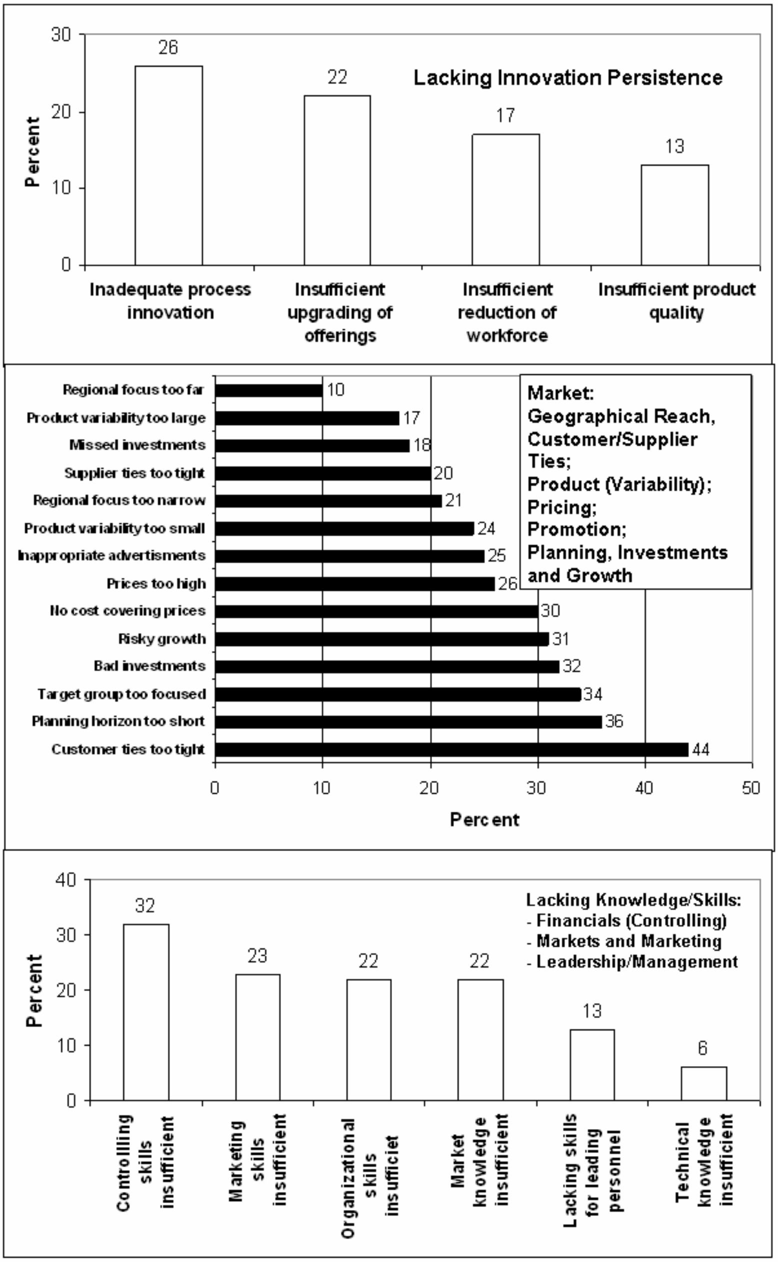


Figure I.115: Origins of NTBF failure emphasizing lacking innovation persistence and knowledge or skills and specifics of product and market factors (using data from Egeln et al. [2010]).

Typical cases of German NTBFs showing innovation persistence include WITec GmbH (Figure I.123, Figure I.156), JPK Instruments AG (Figure I.141), Nano-X GmbH (Figure I.137, Table I.77), Q-Cells AG (Figure I.152, Figure I.153), Enercon GmbH (Figure I.150, Figure I.151) and Novaled AG (Figure I.148, Figure I.149); for the US Cambridge Nanotech, Inc. (Figure I.163) is a lucid example.

Correspondingly, also **investment persistence** can be viewed as a success factor for NTBFs. Three quarters (79 percent) of new firms which issued investments during the foundation year also invested during the second year. Moreover, these firms did investments also in the third (75 percent) and in its fourth year (71 percent) [Creditreform - KfW - ZEW 2009].

> Lacking innovation persistence (Figure I.115) and also lacking investment persistence or bad investments (Figure I.114), hence, represent typical reasons for firm failure.
> The other way round, innovation and investment persistences including "continuous improvement" form a basis for firm success and for identifying promising NTBFs.

Innovation persistence and associated investment persistence for entrepreneurial success has already been emphasized by Thomas Edison who once said:

> "I always invented to obtain money to go on inventing."

Results of Carter and van Auken [2006] indicate that, apart from inaccessibility to debt and economic climate, very serious problems of bankrupt of small firms can be related to *lack of knowledge*, such as lack of *management skills*, particularly for rapid growth, poor financial records (*controlling*), problems with planning and lack of knowledge about pricing which require processing and availability of information and intelligence. This is also reflected in Figure I.115.

The availability of information is critically important for good decisions in all aspects of business operations. The lack of information or poor information would lead to ineffective and costly decisions that result in financial hardships, at the least, and bankruptcy, at the worse. Also this is reflected by the recent results of Egeln et al. [2010] for young German firms (Figure I.115). And these results additionally show that lack of technical knowledge is not a significant factor for firm failure, and reveals that deficiencies in leadership/management concerning organization and leading personnel are so.

It is important to note that many of the knowledge deficiencies given in Figure I.115 represent *skills which can be taught*. On the other hand, experience cannot be taught as it is related to an individual's learning process. In the current context experience is expressed by a person's alertness to relevant new information, actually intelligence (ch. 1.2.3), and may generate a changing sequence of decisions.

Lacking market knowledge or generally business knowledge can be mitigated by setting up an Advisory Board whose members may be selected to lift lacking special knowledge or experience. However, for RBSUs members are typically academics (professors) with related reputation, but often not with commercial knowledge let alone experience. Generally, the composition of the Advisory Board may also add to visibility and credibility of a startup.

Many problems leading to firm disappearance (Figure I.114, Figure I.115) are related to Porter's five forces (ch. 1.2.5.3; Figure I.33, Table I.16, Table I.18), such as rivalry (competition) among firms, bargaining power of suppliers and customers. In particular, the dependencies of young firms on a single or one to three customers of only few existing customers represent a great hazard for a small firm (cf. Figure I.140). The same applies to dependency on one supplier.

On the other hand, NTBFs operating internationally, or specially across only two countries like the US and Germany (for instance, US firm First Solar (Figure I.154) and ChemCon GmbH (B.2)), may also be endangered. Here the currency exchange rate and currency volatility play the key roles.

For instance, ChemCon (founded in January 1997 as ChemCon GbR, since 1999 a GmbH) had an 80 percent proportion of revenues from sales in the US. After the dollar exceeded the $/€ = 1.2 threshold (2004; Figure I.116) ChemCon's leaders felt the pain in Germany and worked on shifting their customer base to the euro zone. In 2007 revenues from Europe were 55 percent and targets were 70 percent for 2008.

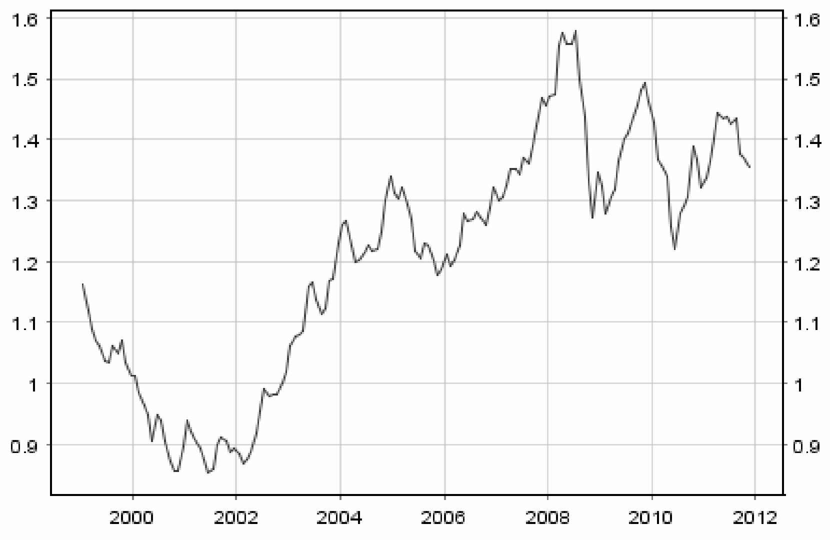


Figure I.116: ECB reference exchange rate, US dollar versus Euro (Source: European Central Bank [75]).

A study of Canadian NTBFs [Bordt et al. 2004] concerning the US-Canadian dollar exchange rate found that this affects input prices, product prices and relative salaries.

There was no preferred exchange rate (a high Canadian dollar benefited those who mainly purchased US goods, a low Canadian dollar benefited those whose main market was the US) but large fluctuations in the rate seemed to impact everyone.

Aggregating the essentials concerning a firm's failure and success the basis for foundation and operation of NTBFs (Table I.65, Table I.66, Figure I.114, Figure I.115) are leadership and company culture as well as endowment with adequate tangible and intangible resources. Strategy (or strategy logics), decision-making, actions and execution (ch. 4.3.2) are at the center of driving two interwoven, one another reinforcing loops for early and further development of the new firm.

Endowed with adequate finances (Figure I.117) viewed as the "real" start the firm will have to go for the market, go for customers, and sales which will feed the financial resources – always being aware about competition. Using profit and cash flow from the sales cycle decision-making and action in line with a strategy transform into investment persistence to execute innovation persistence to keep and respectively enlarge the customer base.

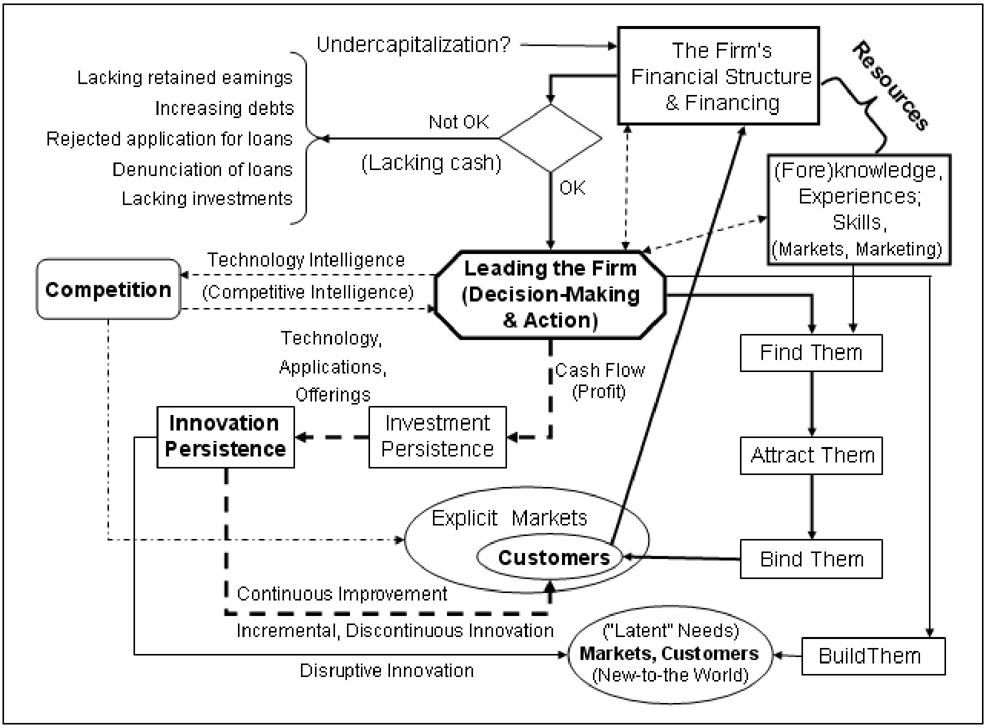


Figure I.117: Leading a new technology-based firm to survival and growth relying on tangible and intangible resources and interwoven customer-orientation and innovation persistence.

Innovation persistence covers any type of innovation referring to existing (explicit) market needs, but also “latent” (tacit) needs and markets. In the first case (incremental and discontinuous innovation) there is a largely established approach to keep and get customers. In the last case (disruptive innovation; new-to-the-world offerings) the task is to *develop a market and build the related customer base* (“Build them”, Figure I.117).

Apart from blunt faults according to Drucker [2002] there some typical *pitfalls* or mistakes, respectively, entrepreneurs make in four situations. All four are foreseeable and avoidable.

They have a large *empirical* basis. According to Drucker: “You know, *I’ve worked with entrepreneurs for fifty years* and can say that *there is a fairly normal curve; 80 percent fall within it*.” Drucker’s pitfalls refer by the large proportion to privately held NTBFs and also those which do not have a professional management team during the first three to four years of their existence (the “startup thrust phase”), that is non-VC-based NTBFs. The pitfalls are cited almost completely below.

The **first pitfall** comes when the entrepreneur has to face the fact that the new product or service is not successful where the founder-entrepreneur thought it would be but is successful in a totally different market. Many businesses disappear because he or she insists that he or she knows better than the market.

This situation is worse than the one that the entrepreneur often is actually succeeding but does not realize it. According to Drucker he or she rejects success. And he argues that the majority of successful new inventions or products do not succeed in the market for which they were originally designed. Rejecting unexpected success results largely because it is not what the entrepreneur had planned.

Pitfall number two refers to the fact that entrepreneurs often believe that profit is what matters most in a new enterprise. But profit is secondary. *Cash flow (ch. 1.2.1) matters most*. Growing bodies need to be fed, and a business that grows fast devours cash. You have to make constant investments just to keep even. This is totally predictable, so is totally unnecessary.

The **third pitfall** looming on the horizon is *when the business grows* – and there is no “professional management” team in the early phase of the NTBF as show up in many VC-based startups (cf. the biofuels field, A.1.1). The person who founded the firm is incredibly busy. *Rapid growth puts an enormous strain on a business*. You outgrow your production facilities. You outgrow your management capabilities.

Your company may have outgrown you. Some entrepreneurs are quick with creative ideas, and even excellent at managing the chaos of initial implementation. That is not the same as instilling order and discipline in a larger organization, where mostly the *challenge is people*.

The entrepreneur begins running around like the proverbial one-armed paperhanger. {in German der einarmige Tapezierer}. He sees the sales figures, and he sees profit forecasts. Those make him believe that in another year he can sell out and get $10 million. And he does not see that he is outgrowing his management base.

Even if your business is growing at a normal rate – not tripling in size every six months, but growing at a good, solid, sustainable rate – the "*management crunch"* (Figure I.118) hits you at the end of the fourth year. You outgrow your *management* base. Suddenly everything goes wrong. The quality falls out of bed. Customers do not pay. Deliveries are missed.

Necessary re-organization represents a challenge for growth. It is a challenge for the leaders and the employees. With growth flat hierarchies may soon become inefficient. Leaders lose personal contacts to employees; employees are confronted with new structures of decision-making. As a consequence, the leader or leadership team, respectively, must recognize early the problems and find solutions together with the employees – or, at least, clearly communicate their new approach.

The "management crunch" may be viewed as an "empirically founded reproducible observation" and represents an issue of organization, specialization and coordination, management and employees' productivity and the transformation step when leadership of entrepreneurship has to be complemented noticeably by SME management.

This means, startups which are still owned and controlled by the founder(s) like an LLC (GmbH) will encounter this issue unless the founder or one member of the founder team takes over the management role (Figure I.118). Correspondingly, installing a manager side-by-side to the founder(s) is a particular specialization of the executive level of the firm.

Entrepreneurs are often unable to make the transition to the growth mode by becoming executives of a high growth firm – or meeting executive qualities expected to grow the firm venture capitalists have invested in. One consequence could be replacing the original founder(s) of the firm by "professional managers" (A.1.1). But there are also "stage-oriented entrepreneurs" founding and leading a new firm to a particular state of development and then handing over to professional management (ch. 2.1.2.6).

It is an oft-told, oft-expected story that the high-flying entrepreneur steps aside when he or she succeeds at building a company big enough to need an experienced CEO.

In essence the "management crunch" represents *an internal transition state of the system*, the firm, which requires, for instance, change of behavior and organizational structure achievable over a certain period of time to respond to external requirements or demands. Initiation of need to change within the firm, for instance, may be peak-like, such as a sudden capture of a very huge order, or may evolve over a longer period by increasing customer orders or numbers of customers until a certain threshold is achieved which makes the change unavoidable.

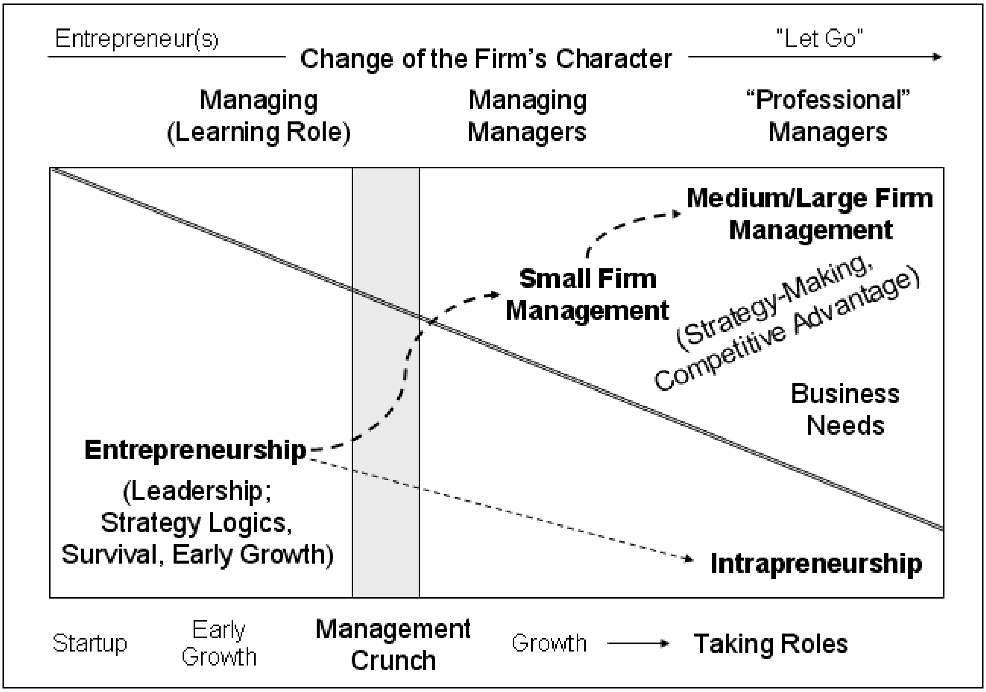


Figure I.118: Illustrating Drucker's pitfalls.

Overcoming the "management crunch" barrier can be achieved through learning-by-doing, essentially focusing on a "need to know" level whose scope can be roughly identified with the "PocketTM" approach by Luggen and Tschirky [2003, 2004]. PockeTM (Pocket Technology Management) represents a holistic technology and innovation management system, which integrates NTBFs' internal and external aspects on the normative, strategic and operational management level.

In this context of growth there is a complementary pitfall related to the increase of number of employees. That is, hiring people that the founder(s) like or "hiring your own image" rather than people whom they need.

The **fourth** pitfall is the most difficult one. It is when the business is a success, and the entrepreneur begins to put him-/herself before the business. Here is a person who has worked eighteen hours a day for fourteen years and has a $60-million business and a management team that works. Now he asks him-/herself, "What do I want to do? What's my role?" Those are the wrong questions. If you start out with them, you invariably end up killing yourself and the business.

The right question should be: "What does the business need at this stage?" The next question is "Do I have those qualities?" You have to start with what the business needs [Drucker 2002].

Over the years and related growth a firm changes continuously. The entrepreneur may have been a good leader for the early growth of the startup, but not for a successful $60-million business.

The entrepreneur needs to know when to let go (Figure I.118) – even with no serious crisis of the firm. And that requires an honest self-assessment of his/her strengths and weaknesses, likes and dislikes. *Founders must let go*; they should have or recruit people who manage or sell for him/her, if this is a weakness or dislike. They should set up an organizational framework that makes the firm less and less independent from their own persons [Drucker 2002]. This is described below for R. Stanton Avery and the US firm Avery Dennison.

The fourth pitfall associated with the special case of approximate revenues of $60 (€50) million – what the business needs – leads to a *general issue of a firm's growth* which may emerge by an *overproportionate growth* of the number of employees (ch. 4.3.1).

Consider, for instance, growth of German SAP AG (A.1.4) and Microsoft and take productivity (Table I.67). It has turned out generally that decreasing productivity while revenues grow to be an appropriate indicator of *a firm's organizational issues* (SAP (Figure I.143, Figure I.147) and Microsoft (Figure I.144, Figure I.146)).

Table I.67: Exemplifying productivity as an indicator of organizational issues for growing firms.

SAP AG (Germany; founded 1972)			
Year	**Revenues (mio.)**	**Number of Employees**	**Productivity *)**
1986	€54.2	290	€187,000
1987	€77.2	468	€166,000
1988	€91.6	940	€97,000
Microsoft Corp. (US; founded 1975)			
1981	$16.0	128	$125,000
1982	$25.5	220	$111,000
1983	$50.1	476	$105,000

*) Productivity: revenues per employee.

Finally, Kaplan [2003a] mentioned another *pitfall*. That is, if the entrepreneur wants to proof to be smart and is building a company for ego gratification. But, if you do not share credit with other people for building the company; you will not get help and support from others which often leads to firm failure.

The extreme example of NTBF failure due to the ego of the entrepreneur is William Shockley [76], a co-winner of the Nobel Prize for Physics in 1956 for work on the transistor. In February 1956, with financing from Beckman Instruments Inc., he founded Shockley Semiconductor Laboratory with the goal of developing and producing a silicon transistor. He recruited twelve young scientists dedicated to the use of germanium and silicon for transistors – his "Ph.D. production line." [78] He founded the Shockley Transistor Corporation to turn his work to commercial advantage.

"Working for Shockley proved to be a particular challenge. He extended his competitive nature even to his working relationships with the young physicists he supervised. Beyond that, he developed traits that we came to view as paranoid." [Moore 1999] According to Wikipedia Shockley's firm (later incorporated into Beckman Instruments, Inc.) was run "his way," which could be generally summarized as "domineering and increasingly paranoid."

In 1957 eight employees, the "Traitorous Eight," left Shockley Semiconductor and used $3,500 of their own money to *develop a method of mass-producing silicon transistors*. Previously, transistors could only be manufactured one at a time. The potential for the new "mesa process" was enormous, but the inventors needed financial backing. Fairchild Camera and Instrument Corporation invested $1.5 million in return for an option to buy the company within eight years. On October 1, 1957, Fairchild Semiconductor was born and developed further. [78]

Some of the "Traitorous Eight" later (in 1968) played a key role in the foundation of Intel [77], Gordon E. Moore (of "Moore's Law" fame, a chemist and physicist), Robert Noyce (a physicist and co-inventor of the integrated circuit), and Arthur Rock (investor and venture capitalist).

The "*knowledge walk out*" of six or more persons leaving an existing firm to generate a new independent business based primarily on a scientific and technical knowledge and experience base is structurally similar to a management buy-out (MBO) to found a new firm, which takes a business with a large number of people (15+) out of an existing firm, often also associated with business and leadership/management experience (ch. 1.1.1.1, 2.1.2.4).

Avoiding (most) failures and pitfalls of NTBFs discussed above and taking differences in starting a promising firm/business, running a promising firm/business and building a (very) large firm/business into account will likely lead to a firm characterized by *longevity*. In particular with an entrepreneurial aspect of founding or building a large firm associated with *longevity* Bhidé [2000:208] emphasized the significance of *ambition* and especially *audacious ambition* as the drivers.

Entrepreneurship and Longevity

In the context of entrepreneurship it is argued that ambition can target a firm as a means to an end, such as getting wealth or providing firm longevity, to "leave a legacy" or feeling a "breeze of immortality." (ch. 2.1.2). The vision or idea of longevity of founding a firm may implicitly include business succession by children, mainly, but not only, sons, as observed for: Henkel ([Runge 2006:473], Figure I.138, Figure I.139) Prominent Group (Box I.18), AluPlast GmbH (B.2), and in the US Wal-Mart (Sam Walton's sons Rob Walton succeeded his father as the Chairman of the Board of Wal-Mart, and John Walton was a director until his death in a 2005 plane crash) [41].

The transition from "managing managers" to "professional managers," from small firm to medium and large firm management and the "let go" requirement (Figure I.118), is associated with the development and implementation of a formalized strategy approach to build a firm. However, McCann [1991] cites research which has pointed out that young entrepreneurial ventures typically do not utilize highly formalized strategic planning processes. At best, technology entrepreneurs follow "strategy logics" (ch. 2.1.2; Table I.33). Strategy formation in young firms tends to be informal and episodic.

It might seem optimal for the many individuals who only have the abilities to start a business to transfer control to individuals who have the capacity to build a firm but not the capacity to start a firm (cf. stage-oriented entrepreneurs, ch. 2.1.2.6). But this does not occur often – not in the US and not in Germany.

Bhidé [2000:305] cites famous examples, such as HP, Microsoft, Oracle and Wal-Mart, and the situation of his sample of *Inc.* 500 firms as evidence that long-lived firms are built, over several decades, by the individuals who started them. And the same CEO, the founder or one member of the founder team, was still involved in management. The German Hidden Champions (ch. 4.1.1) add further evidence, particularly the Prominent Group (Box I.18), Enercon GmbH (Box I.7, Figure I.150, Figure I.151) and Würth Group (Box I.23). This shows that longevity under the leadership of individuals require personalities who have an exceptional capacity and willingness to broaden their skills and roles (Figure I.118).

In some cases, such as IBM, 3M or Cisco in the US or Bayer AG in Germany where the founders bowed out early or withdrew, we find a similar continuity of leadership provided by individuals who took control when the firm was still in a formative state or the to-be leader added totally new businesses [Bhidé 2000:305].

When Thomas J. Watson Sr. was hired he transformed The Computing-Tabulating-Recording Company founded in 1911. Thomas. Watson's personal rise started when, on May 1, 1914, he assumed the presidency of the Company. "The company is the creature of the man who commanded it for forty-two years." He had "grandiose visions" and renamed the firm to IBM [Bhidé 2000:253; Obituary 1956].

William McKnight being revered to this day as the "spiritual father of the company" [Runge 2006:446] served as the president of 3M and then chairman between 1929 and 1969. And he built 3M's corporate culture insisting "…Management that is destructively critical when mistakes are made kills initiative, and it is essential that we have many people with initiative if we are to continue to grow." [Runge 2006:721]

John Morgridge “built the management structure” after he was in 1988 recruited to run Cisco (Figure I.145, Figure I.158). A key empasis was hiring of “professional and experienced people in all the main functional areas.” [Bhidé 2000:285]

In Germany Carl Duisberg did not only shape the future of Bayer. Duisberg was named to Bayer’s Board of Management in 1900 and served as the company’s Management Board Chairman from 1912 to 1925. Together with Carl Bosch Duisberg was one of the founding fathers of I.G. Farben. The German “Farben cartel” dated from 1925 when a super-giant chemical enterprise out of six already giant German chemical companies was created. Between 1927 and the beginning of World War II, I.G. Farben doubled in size. By 1939 I.G. Farben acquired a participation and managerial influence in some 380 other German firms and over 500 foreign firms [Runge 2006:478-479].

When Duisberg died in 1935 The Times of London summed up Carl Duisberg’s achievements in its obituary: “His country loses a man who, all things considered, I believe may be regarded as the greatest industrialist the world has yet had.”

Bhidé [2000:305] discusses “the value of continuity” emphasizing that the goals and incentives of a company’s founder limit the frequency of top management changes. But Bhidé also looked at exceptions, that the individuals who start businesses are often unwilling to relinquish control. For instance, venture capitalists more or less forced out the founders Lerner and Bosack (Figure I.145, Figure I.158) from Cisco’s management team.

Such entrepreneurs lack the ability or personal characteristics to build a large firm. To overcome such a situation is exemplified by the case of the US firm Avery Dennison [Runge 2006:474]. In July 1935, R. Stanton Avery, with a reputation as a tinkerer, introduced the first pressure sensitive labels mounted by their own adhesive on a continuous backing. These labels could be removed either manually or by automatic means, and applied simply by touch.

With this process, Avery founded not only his own company but started an entire new industry. After World War II Avery self-assessed his capacities, interests and bents and weaknesses and, as a consequence, in 1946 he hired Russ Smith as general manager. Smith had a varied background in finance and marketing and became the architect of the company’s organizational evolution. Avery gave the new leadership team wide latitude in managing the business. Avery himself continued to devote most of his attention to technical issues.

For entrepreneurs this provides an insight about learning when to ask for help from others, and then standing aside to let them teach you (“tailored mentorship”) or let them take a role to build a real business and grow because they have the competencies and know what is needed and to be done.

4.3 Approaches to New Technology Venture Growth

Venture growth is currently an issue of strategic management or entrepreneurship – and of particular interest to policy. For the field of strategy the emphasis was and is on existing firms and business growth, but this makes insights to be transferred to firm's foundation and early growth of new (technology) ventures problematic.

Understanding the origins of new venture growth and why and how startups grow and become successful or even very successful firms ("promising startups") is still one of the least understood aspects of entrepreneurship research.

> It is our conviction, in line with Bhidé [2000:11],
> "We cannot expect to derive a fool-proof formula or a 'complete' description for starting a profitable business."

Furthermore, entrepreneurs or the leadership team of young technology-based ventures are being presented with a much larger "menu" or array of choices for decision-making (opportunities, financing, etc.), at many points in time, than established firms.

From a choice-taking perspective the critical questions become the following: a) Are there identifiable patterns of growth, technology, and financial choices for a particular industry or even industry segment? b) What factors shape or determine which choices are taken? c) Are these patterns related to venture productivity and performance (Equation I.2)?

Furthermore, are the above questions to be differentiated for the various types of NTBF – RBSUs, academic NTBFs, EBSUs (ch. 1.2.6.1)? Do they differ with regard to initial (startup) financing, such as financing by bootstrapping, mixed private/loan financing, financing by private investors or venture capital investors? What is the role of the different types of markets for NTBFs (ch. 1.2.5.3; "economic markets" "policy-driven markets", etc. – Table I.15)?

Under which circumstances do we have a transition of a growing young firm from "strategy logics" to formal "strategy-making"? How is the evolvement of strategy bound to the change of entrepreneurial leadership to management, if at all?

> Following Drucker's third pitfall (4.2.3) one can say: *Growth creates problems*!

There is evidence that the young firms' growth dynamics, as a teleological process targeted at a given vision, mission and goal, may not be governed by a random process and this has stimulated scholars to investigate factors and put forward a large number of growth models.

Each of these theories focus on explaining different aspects. There is no commonly agreed framework or theory for growth of startups. The frameworks are not mutually compatible or consistent. They do not agree on which (endogenous and/or exogenous) variables are the essential drivers of startup growth. Bhidé [2000:210] suggested, for instance, that “the transition to a large enterprise requires greater heterogeneity of assets and functions and investment in administrative infrastructure.”

Most of the literature on the theory of the firm assumes a firm to be already in operation, but “mainstream economics has little to tell us about how and why some firms survive and grow and others do not.” [Bhidé 2000:242]

What is needed is a conceptually grounded *explanatory model* allowing making sense of the extremely broad spectrum of findings in the technology entrepreneurship area. Such an approach to tackle the developmental processes found among new technology firms as they generate and increase revenues and build their employees’ base can only be fully illuminated by *micro-data from case histories*.

In this line it is important to find out how the overall GST framework for technology entrepreneurship as the conceptual basis of this book can make use of gross aspects of common venture growth models and add insights on the structural and processual levels – and raise further research questions.

Teleological, future-oriented GST models would imply that it is the purpose or final goal of the founder(s) and their views of “success” that guides the development process of a new firm. Hence, the developing entity *is purposeful and adaptive* to internal and external forces and events, and the process can be seen as a repetitive sequence of goal formulation, implementation, execution, evaluation and modification of intermediate goals or milestones or even distinct changes of goals (*purposeful enactment*).

For our context, the *explicit consideration of economic recession for firms’ growth* will illustrate important broader conceptual implications for reasoning and exemplify the general paths followed to generate statements like hypotheses, proposals, propositions or explanations.

Figure I.2 and surrounding text has outlined that for statements with conditionals there is a need for care in making clear whether “reason why” or “reason for thinking that” relations illustrated in terms of antecedents and consequents are being stated. For instance, “prediction” in chemistry refers often to properties and reactivities of molecular classes and *exceptions* (“single events,” “single data points”) explained *a posteriori* by a particular condition.

In a related way, our growth models targeting expectations are often statements of that kind, for instance: the particular startup configuration let expect strong growth (> 25 percent) over the next 4-5 years unless an economic recession prevents that. Or, the startup can be expected to show good growth (around 10 percent) provided the oil price will not fall significantly below $80 per barrel.

Discussing NTBF growth we shall focus essentially on the time periods surrounding firm birth (Figure I.122) and its first eight to ten years of existence. The entrepreneurs’ reasons and motivations to found a firm (ch. 2.1.2.5) and the ideas and opportunities they pursue (ch. 3) have been discussed in previous sub-chapters.

However, growth of a new firm is not only a matter of the drive for achieving the goal, but also of the pace of development (Figure I.122) and attitudes toward resources. “But founders, not outside investors, should determine the proper pace of growth for a company. And a founder who is about to lose his or her life savings is far more likely to drive a company towards profitability.” “Landing equity money early on quickly leads to bad habits” and “bringing in outside money usually creates expectations of very rapid growth.” In the end, creating a culture that emphasizes long-term profitability over rapid growth is critical for success.” [Wadhwa 2009]

The author encountered the description of the above situation several times with founders as guest lecturers for his Technology Entrepreneurship curriculum (Box I.20). All the cited firms were LLCs and for the first ten years of existence under full control of the founder-owners who had invested much of their private money.

Box I.20: How founders of NTBF with preferences for financial sources determine the pace of their firms’ developments.

As Wadhwa [2009] says “Hungry companies figure out ways to keep eating because they don’t know whether there will ever be another meal.”

We hear the same from WITec GmbH (B.2). WITec was funded with private money, which is not necessarily a bad thing, one of the founders (Klaus Weishaupt) said, because it creates pressure to make profits as soon as possible. “If the fridge is empty, the pressure is greater to make money than when you have millions from an investor to spend,” he said, adding that he does not want the company to get listed on the stock exchange anytime soon. “We don’t want to sell. It’s better when the profits go into your own pocket.”

Corresponding statements are heard from one of the founders of Nano-X GmbH (B.2), Reimund Krechan. “Permanently, I have been addressed by venture capital firms, but so far I have rejected their offers,” Krechan said. “Money makes only lazy” (in German “Das Geld macht nur bequem”).

“In hindsight, this scarce funding had also a positive impact as we had to focus on the essentials,” said Niels Fertig (founder of German Nanion Technologies GmbH), “we have learned how important it is to orient ourselves toward the market and not toward the investors.”
(“Im Nachhinein hatte diese äußerst knappe Finanzierung auch positive Folgen, weil wir uns auf das Wesentliche fokussieren mussten,” erläutert Fertig. „Dabei haben wir gelernt, wie wichtig es ist, sich am Markt zu orientieren und nicht an den Investoren.”)

And ChemCon GmbH (B.2) follows a strict strategy that growth (in terms of employees and office/laboratory space) follows cash/profit development; positive growth *allowed* expansion. (in German: Das sehr positive Wachstum erlaubte eine Erweiterung des

Teams um 10 Mitarbeiter bis zum Ende des Jahres). ChemCon's principle from the beginning: continue to invest only if a new order was caught ("…weil immer erst dann investiert wurde, wenn auch ein neuer Auftrag vorlag.)

A graphical reflection of this attitude is also seen for German Nano-X GmbH (B.2) after having bought a building in 2001. After having caught a big order for its products, Nano-X additionally bought the adjacent area for a new production hall and office. At first Nano-X increased the number of employees to then later execute the request (Figure I.137).

Looking at growth of young firms is associated with perspective (Table I.64). For instance, the policy perspective (and expectation) is related to job creation (and growth). We shall take primarily a perspective of the firm and its founder(s) (and probably stakeholders).

Indicators of Growth

Development of a new firm can be tackled along several dimensions which characterize "input," internal structures, events and processes in a (new) firm or relate to performance and output, for instance, growth in terms of revenues or number of employees over time or interrelate both of these aspects (productivity, Figure I.130).

Garnsey et al. [2006] have critically discussed the various indicators that can be used for observing and measuring growth according to relation to input, value and output. The most common ones are absolute figures of revenues and numbers of employees (ch. 4.1). Each is subjected to limitations. Employment figures are the most commonly used measure because they seem to offer standardized, comparable data on the rate and direction in which a firm has been expanding. But, developments of revenues (disregarding inflation effects over time) and numbers of employees are not necessarily correlated.

Absolute figures of revenues and numbers of employees, particularly with regard to NTBFs, may have special issues. To a certain degree it has become common practice of NTBFs to incorporate money (funds or grants) from public sources for R&D into reported revenues. But, reliance on public grants or funds must be viewed as time-delimited projects. If this money is used for temporarily hiring personnel and without knowing about this may easily lead to misinterpretations of an effect of the decrease in the number of employees.

Depending on the situation the following discussions of NTBF developments will usually focus on "*absolute years*" for a time period or a sequence of individual years (for instance, 1997-2006 or 2003, 2004, 2006, 2008) rather than years of existence. Furthermore, we shall usually consider

- Absolute figures of revenues *and* numbers of employees *and*
- Productivity (revenues per employee),
- For production-oriented firms also output-oriented indicators, such as pieces of items (devices, instruments) sold or produced, volume of material (pounds or kg, barrels or liters) or overall performance of items sold, such as producible power (cf. Figure I.150, Figure I.154).

Getting data on revenues and numbers of employees is rather difficult, particularly for privately held firms. Except for public firms which are required to publish such data by law and according to standard accounting rules one has to rely on data collected by special for-profit firms, data reported to and published by the media or published by firm founders (in interviews).

Hence, one is plagued with issues of missing data for timelines and reliability and quality of the data. And even official data, for instance, in annual reports sometimes vary – and it is well known that such data for a year to year may be distorted in the framework of accounting rules to fit corporate policy.

Concerning growth rates we shall sometimes refer to the "Compound Annual Growth Rate." **Compound Annual Growth Rate (**CAGR) is a widely used mathematical formula that provides a "smoothed" growth rate. CAGR is often used to describe the growth over a period of time of some element of the business, for example revenues.

The compound annual growth rate is calculated by taking the nth root of the total percentage growth rate, where n is the number of years in the period being considered (Equation I.10).

Equation I.10:

$$\mathbf{CAGR}(t_0, t_n) = \left(\frac{\mathbf{V}(t_n)}{\mathbf{V}(t_0)}\right)^{\frac{1}{t_n - t_0}} - \mathbf{1}$$

$V(t_0)$: start value, $V(t_n)$: finish value, $t_n - t_0$: number of years

In any case, specifically for a GST approach, understanding a new firm's development requires taking firm-internal and external factors into account. Following the axiom that at any point in time, metrics of *firm size change* will show the firm undergoing growth, stability or decline and transition points between these expressions of development will indicate change of the firm from one state to another one, one may encounter problems of interpretation over a time period if economic recession is not taken into account. Its effect may show up in one or the other indicator or, worst, it may show up as growth in one (in revenues), but decline in the other (employees) as is observed, for instance, for Novaled (Figure I.148).

Growth discussions are especially critical if a sample of firms is considered using growth indicators based on “year of existence” (year = 1, 2, 3, …) of NTBFs. Any observation and related comparisons referring to “year of existence” may cut off any external effect with a relevant impact for growth a startup may be subjected to and compares or group together “apples and pears” and other fruit.

Referring again to recession this could mean to group together startups with lacking necessary (external) financing during foundation, startups in their third year and almost no chance to catch customers due to the recessions and struggle for survival and “stable” NTBFs in their sixth year which just encounter a manageable reduction of revenue due to reduced orders of customer with conviction to overcome the recession and will be back to growth.

Generally, recessions may lead to difficulties in interpreting just growth curves (revenues or employees) which show setbacks (back to growth, plateauing; Figure I.107) in terms of firm internal problems or recessions or both. Additionally, revealing firms with delayed growth require careful examination of whether this is a reflection of slow firm growth in the early development phase or whether the situation reflects structurally effects of the firm, a characteristic of good or high growth hindered by recession and a rather long time for catching up to structurally appropriate characteristics – or just a favorable event that leads from a state with a medium or low growth to an “explosion of growth.”

In addition to recession, there is a further environmental factor for (technology) entrepreneurship one must be aware of, the situation of industry genesis which may show up in waves of segments, such as the chemical industry and particularly the synthetic dye industry or automotive industry [Runge 2006:266-269, 274-275]. Currently such waves occur in the I&CT industry and here particularly the hard- and software industry and the “Internet industry” – and also in CleanTech with the biofuels segment (A.1.1)

Entrepreneurship in a segment of industry genesis usually has a special constellation concerning attracting entrepreneurs and financial backers as well as the government. This may induce a “push” for founding and funding affecting the early state of new firms compared to startups in other industry segments.

Finally, to understand growth of new technology venture it is important to be aware of factors and their interrelations (Figure I.114, Figure I.115) which led to decline and ultimately closure of the firm.

To proceed selected aspects of common growth models and their key fundamentals shall be discussed to reveal how to integrate them or, at least, put them into the context of an embracing GST framework.

4.3.1 Life-Cycle Models and Stage-Based Views

Life-cycle models [Bhidé 2000:244-259; Dorf and Byers 2007:459-465] similar to those of technologies and industries (Figure I.32) reflect stage-based views and suggest that organizations evolve in a consistent and "predictable" manner.

One widely-cited conceptual life-cycle work was published by Larry Greiner in 1972 and 1998. His emphasis is on five *continuous phases of growth* ("stages of evolution") interrupted by "stages of revolution." A growth phase (evolution) is characterized by a *particular style of management* (Figure I.118). Each "revolution" is specified by a *management crisis* and the solutions that lead to the next phase of growth. *The same organizational practices are not maintained throughout a long life span* (Table I.68).

The model's phases cover explicitly the development of firms till maturity. However, in the context of entrepreneurship the main emphasis will be only on foundation, early and later growth phases which are the "S-part" of a development curve (Figure I.32). Greiner tackles key issues that are relevant for entrepreneurship as *effects and organizational processes*.

Table I.68: Larry Greiner's Five Phases of Business Growth [Greiner 1998].

<table>
<tr><td>Size: From Small to Large ↓</td><td colspan="2">Life-Cycle (Age): From Start Up to Maturity</td></tr>
<tr><td rowspan="6">Revolution: stages of crisis
Practices become outdated.
Companies that do not change will fold or cease to grow.
Often solutions for one crisis become a major problem in the next crisis.</td><td>Growth through</td><td>Crisis of</td></tr>
<tr><td>Creativity</td><td>Leadership</td></tr>
<tr><td>Direction</td><td>Autonomy</td></tr>
<tr><td>Delegation</td><td>Control</td></tr>
<tr><td>Coordination</td><td>Red Tape</td></tr>
<tr><td>Collaboration</td><td></td></tr>
</table>

Generally, a stage-based view may be viewed as a "*stimulus-response" mechanism*. Stage-based models presume that development is achieved by firm-internal change initiated by controllable or even uncontrollable events or processes or intentionally initiated change by entrepreneurs/managers or responding to external effects (cf. US Osmonics [Runge 2006:91]; German Zweibrüder Optoelectronics (B.2); Google (Figure I.160, Figure I.163; Box I.24).

An internal "event" could be the detection that the productivity of employees has decreased or grasping an opportunity and pushing a firm into a new direction. Fundamentally, in staged-based models new firm growth will be described in terms of some *prototypical triggers* affecting a stage and responses to initiate a new stage.

Mostly related to entrepreneurs starting in niche businesses who initially do not face obvious growth opportunities an emphasis can be that by intention – and dissatisfaction with the status quo – entrepreneurs decide consciously to go for larger opportunities or change development direction and invest in broadening the offering line or become active in another area of the value system [Bhidé 2000:252].

Drucker's pitfall number three – outgrow your production (deliverables) capabilities, management capabilities (Figure I.118) – seems to provide a good rule of thumb for entrepreneurship for growing private firms and associated effects on the organization of the startup. Furthermore, its empirically founded occurrence after four to five years shows up when the early period of risk of failure of the startup has passed the maximum and decreases (ch. 4.2).

But the new firm enters a first growth crisis. We look at the period of the new firm's ca. four years of existence simultaneously as the "*startup thrust phase*" for "lift-off" (ch. 4.3.2, Figure I.125) into potential growth of the startup. This shifts the focus to special *organizational life-cycle* (OLC) models for NTBFs.

The "startup thrust phase" coincides temporarily largely with a definition of "*early-stage entrepreneurship activities*" (Figure I.15) that covers a time span which begins with the initial communication of startup intentions, continues with the transition into active business as defined by the actual start of business activities (first sales revenues), and includes the ensuing survival or failure of the new venture. Thus the period covers the subject of nascent entrepreneurship as well as that of new venture survival/failure matching recent work [Keßler et al. 2010].

The paper of Keßler et al. [2010] based on a model (not specifically for NTBFs) consisting of the *person, resource/environment and founding process* forwards the basic assumption that *characteristics of nascent entrepreneurship* have significant explanatory power for founding success and new venture survival.

Growth of a firm is associated with *development of organization*. **Organization** refers to *structure* (order of components/parts) and *function* (order of processes/activities) and *coordination* for the pursuit of a goal.

Organization in firms is seen essentially as being determined by lines of *communication* and *influence*, *authority or power* as well as data and information flows through these lines of communication. Lines of influence/authority/power to structural components of the entity will be superimposed by *coordination* among the structural and functional components.

C*orporate culture* is usually seen as the basement of communication and coordination. Treating organizational development is often reduced to a special "one-dimensional" aspect in terms of the organizational structure and management complexity.

Malone [1988] defines **coordination** operationally "as the *additional information processing performed* when multiple, *connected actors* pursue goals that a single actor pursuing the same goals would not perform." (Emphases added) Coordination means extra organizing activities related to achieving a goal.

Boiled down to entrepreneurship and micro- or small firms this definition of coordination implies the following components: 1) a set of (two or more) actors, 2) who perform tasks, 3) in order to achieve goals.

The common problems that have to do with coordination are [Malone 1988]:

- How can overall goals be subdivided into tasks?
- How can tasks be assigned to groups or to individual actors?
- How can resources be allocated among different actors?
- How can information be shared among different actors to help achieve the overall goals?
- How can the different knowledge, education and professionalism and professional (special) languages be overcome and conflicting preferences of different actors be combined to arrive at overall goals?
- How can we track and measure the level of overall goal achievement referring to a system of activities and sub-processes? (added by the author)

These problems have been tackled partly in the discussion of the single entrepreneur (A.1.2) versus team constellations (ch. 2.1.2.5) and specifically entrepreneurial teams (Table I.41; Figure I.72, Figure I.73), but shall get more attention for entrepreneurship.

A paper by Hanks et al. [1993] presents an effort toward an empirical taxonomy of life-cycle organization-related stages in young high-technology organizations. In GST language, however, one would speak about navigation through a series of (system) "*states*" rather than "stages" each of which can be induced by a significant change or development challenge.

Two aspects of particular importance for organizational change (the internal dynamics of growth) are "specialization" and "centralization." *Organizational specialization* means how many functional areas exist in the firm so that at least one full-time employee fills the function. It should be noted, however, that specialization may be present already by functional roles at the start and in the very early phase of a young firm (Table I.41, Figure I.72). It may appear as a path from personal operational competencies to corporate functions (and establishing the value chain).

Formalization has been introduced as a further division of functional areas according to particular activities and professionalization, such as finances as financing versus controlling versus accounting.

Organizational centralization was measured by Hanks et al. [1993] referring to a list of five decision issues and finding out the level of management that must approve the decision (authority/power) before legitimate actions may be taken.

Cluster analysis has been used by Hanks et al. [1993] to derive empirically a taxonomy of growth stage/state architectures (originally called configurations) in a 1988 sample of high-technology organizations (R&D intensity on average 3.1 percent) reflecting a situation in 1987/1986. The derived architectures were interpreted as a sequence of four growth stages.

The notion architecture in the context of a firm may represent various expressions of organizational structures (Table I.69) [79]. It was proposed in this study that life-cycle stages could be defined and operationalized as unique architectures of organization context and strategy.

However, one has to note that in the sample firms which are seven years in existence could be affected by two recessions and those of sixteen years even three recessions in the US (Nov 1973–Mar 1975; Jan–July 1980; July 1981–Nov 1982), if sales and growth rates are considered. Suffering from a severe recession may require up to two years to catch up to the growth level before the recession.

Our interpretation of State I in Table I.69 is that it represents early growth until the “management crunch” after four to five years of existence (Figure I.118) reaching 6-7 employees with organizational settings probably close to the startup architecture. The NTBF is still a “micro enterprise” (Table I.4). State II has emerged after having crossed the “management crunch” and having adopted a functional basis of the organization and further differentiation toward less centralization but more formalization (a small enterprise; Table I.4).

State III having an average age of seven years similar to State II seems to represent a quite rapidly growing firm in terms of number of employees and sales with an operationally functioning *manufacturing* orientation and related necessary functional specialization, such as customer/product service, production planning and scheduling and quality control.

State II and State III show comparable original productivity which is on average $59,200 sales per employee for State II and $59,000/employee for State III. And the proportion of number of employees per special functions is 7.0 (State II) versus 6.2 (State III). However, the clusters differ markedly by level of centralization.

Hanks et al. [1993] view their State III as a fast expansion stage of development and this may tentatively assumed to be associated with a transition from the stage of Direction in State II to Delegation in III in the sense of Greiner (Table I.68).

The increase of number of employees above “25” would reflect a change of the firm’s organization in terms of communication including reporting lines and coordination following the “10 - 25 - 150” rule of thumb (Table I.72).

Table I.69: Growth states and related organizational features for young technology-based firms [Hanks et al. 1993].

State I – Average growth in sales				
Relatively young, small, highly centralized and informal firm, focusing on the development and early commercialization of their technology-based product(s)				
Age (Years)	**Average Sales ($)**	**Number of Employees**	**Employee Growth**	**Special Functions**
4+x	271,000 (404,000) [1)]	6.46	29%	1.5 (mainly R&D)
	Organization Structure	**Organization Level**	**Centralization**	**Formalization**
	Simple	Little (2.2)	High	Quite informal
State II – Average to low growth in sales				
Appears to represent an expansion state of development; in addition to research and development, specialized functions present in at least 50 percent of firms; include sales and accounting, indicating that these firms are actively involved in the commercialization				
Age (Years)	**Average Sales ($)**	**Number of Employees**	**Employee Growth**	**Special Function**
7.36	1.4 million (2.0 million) [1)]	23.64	94% [2)]	3.4
	Organization Structure	**Organization Level**	**Centralization**	**Formalization**
	Adopted generally a functional basis of organization	Compared to State I firms an additional organization level (3.18)	Still very centralized, but less so than in State I	Little more formal than in State I

Table I.69, continued.

State III – Good-growth in sales				
Firms are still growing quite rapidly. In addition to research and development specialized functions are present in at least 50 percent of the firms and include sales and accounting; include functionally also shipping and receiving, finance, purchasing, customer and product service, production planning and scheduling, quality control and payroll. This appears to indicate expansion and increased professionalization, particularly in the *manufacturing* arm.				
Age (Years)	**Average Sales ($)**	**Number of Employees**	**Employee Growth**	**Specialized Function**
6.6	3.7 million (5.5 million)[1]	62.76	28%	10.17
	Organization Structure	**Organization Level**	**Centralization**	**Formalization**
	Employ a functional organization structure	Average four levels of management	Have the lowest centralization mean of all the clusters	The second highest level of formalization
State IV				
Specialized functions present in this architecture, over and above those present in the other states; include personnel, building maintenance, advertising, market research and inventory control. Presence of these specialists may suggest greater formalization of human resource programs and policies, cost control, and market expansion; a divisional structure has emerged in several firms. They have overcome obstacles, such as a recession, and via healthy growth have achieved the status of a medium-sized firm. They have achieved the characteristics of Drucker's forth pitfall (ca. $60 million with 300-500 employees after 8–14 years of existence (ch. 4.2.3; Table I.67; Figure I.143, Figure I.144).				
Age (Years)	**Average Sales ($)**	**Number of Employees**	**Employee Growth**	**Specialized Function**
16.2	46 millions (69 million)[1]	495	57%[2]	15.3
	Organization Structure	**Organization Level**	**Centralization**	**Formalization**
			Centralization is low	Formalization is the highest of all the clusters

1) To make monetary values from 1986/1987 comparable with those observed for 2006/2007 we assumed an average inflation rate of 2 percent, which is multiplying the original figures by 1.49. 2) Not clear; due to the way of measuring growth, our emphasis will be more on absolute employee numbers.

State IV is characterized by a productivity (sales per employee) of $93,000. Hanks et al. [1993] put forward several limitations which hinders clear interpretation of State IV. But it may be tentatively associated with a further development of the high growth State III. The nearest comparable example to the situation of State IV could be the German SAP AG which after fifteen year of growth in 1987 had 468 employees and sales of €77.7 million (Table I.67).

Other clusters revealed by Hanks et al. [1993] are notable characterizing essentially *non-growth firms*:

> While similar in size to Clusters A (State I) and B (State II), respectively, they are significantly older than their counterparts. Companies average 18.7 years of age, yet employ a mean of only seven employees. Employee growth is non-existent, actually declining slightly. These firms have virtually no specialization, less than two organization levels (1.71) and employ a simple organization structure. Centralization is the highest of all the cluster groups and formalization is lowest. These are old small firms. They are presently not growing, and appear to have their product(s) fairly well developed.

This is in line with the discussion of "non-growth" NTBFs (ch. 4, Table I.63). For these firms entrepreneurs or owners, respectively, have consciously chosen to keep their firms small with a size of five to nine employees. The phenotype growth pattern corresponds to that of the "Growth Setback – Plateauing" phenotype or "Continuous Growth – Asymptotic" (Figure I.107).

Specialization in terms of developing functions of startups may appear by more or less fast hiring of appropriately targeted personnel of an otherwise unsystematic hiring process during the startup's development so far.

For instance, Cisco System's founders relied on improvised staffing for its first four years, but obviously ran into a "management crunch" (Figure I.118). John Morgridge "built the management structure" after he was recruited as President and CEO of Cisco in 1988 (Figure I.145, Figure I.158). He concentrated on hiring of "professional and experienced people in all the main functional areas – a Chief Financial Officer, a Vice President of Engineering, a Vice President of Manufacturing, and a marketing person" and recruited a professional sales staff. [Bhidé 2000:285].

Organizational development of NTBFs concerning specialization may follow a path from personal competencies and roles and activities of founders' functions outlined in Figure I.72 and Table I.41.

An illustrative development of internal and external organizational structures through specialization, leadership structure and networking during ca. nine years is given for the German NTBF IoLiTec GmbH (A.1.5; B.2). Furthermore, by the end of 2011 IoLiTec achieved a status concerning the level of progression from R&D via piloting to commercialization of offerings. One can also see how IoLiTec's *technology strategy* is implemented in the firm's state reflecting *executing the strategy*.

Disregarding the environment, for instance, that business growth is determined by technology and market environment of its industry, as a summary of internal effects for the firms' early growth one finds:

- Problems tend to change with increased number of employees and sales revenue.
- New functions emerge (specialization).
- Structural hierarchy increases.
- Formalized processes are established – for control (formalization).
- Jobs become more interrelated.
- Coordination and communication become more difficult.
- Organizations that do not grow can maintain the same structure for longer periods of time.
- Prior to change being possible the owner-managers need to develop skills and competencies in leadership, coaching and management before effective delegation and team building could take place.

A growing firm needs "feeding" (ch. 5.2); it must draw in new resources to support growth, but it may face coordination and delivery problems and planning delays as it is very difficult to synchronize resources to requirements in a dynamic system.The need for internal coordination and resource allocation sets a brake on the rate at which business opportunities can be pursued.

Start-up and early growth of NTBFs encounter several organizational challenges for growth. Parallel to increasing the number of hierarchies (organizational levels) relevant changes include

- The way of communication and the flow of information,
- Individual working processes and their coordination,
- The scope of tasks for employees,
- Employee development (Figure I.121),
- The felt extent of responsibility of the individual employee for the firm (commitment).

However, revisiting development of specialization in new firms requires lifting the assumption that the new firm builds functions or functional activities only internally to get results of particular activities. In contrast to the notion "outsourcing" meaning transfer of existing activities or whole functions of a firm to external service providers we look into "*outcontracting*." This will be understood here as an NTBF buying in "contract services" for functional activities or a "whole function" that are needed for the business, but do not exist so far in the NTBF and will not be established in due course. Concerning the necessary activities of the startup a decision must be made between “do-it-yourself” or “let others do it.” “Outcontracting functional activities” means additional and other kinds of coordination efforts.

Gottschalk et al. [2007] found that ca. 87 percent of young firm of research-intense industry sectors “outcontract” functional activities in Germany. They found the following levels of totally or partially utilizing contract services:

- Accounting (74 percent)
- Payroll (57 percent)
- IT Infrastructure (26 percent)
- Production (24 percent)
- PR/Marketing (18 percent)
- R&D (15 percent)
- Distribution/Sales (12 percent).

The vast majority of these contract services are done by domestic firms. The highest costs for outcontracting have been observed for outside manufacturing.

Young German firms have various reasons for outcontracting functional activities [Gottschalk et al. 2007]. Only 47 percent of the firms put forward cost as an argument. The major line of arguments followed a longer term strategic decision to outcontract functional activities to concentrate on core competencies and activities.

The insufficient endowment with personnel, technology and laboratory or pilot plant facilities, but also lack of experience in the context of application-oriented R&D projects imply that necessary scientific resources and research services, such as chemical or technical testing or engineering activities, must be purchased from external firms or research institutes to push the own R&D projects or to produce own products.

For young high-tech firms it is important to gain or complement, respectively, the lacking or insufficient technical and administrative infrastructure by external providers. Reasons for outcontracting are as follows [Gottschalk et al. 2007].

- Data security (16 percent)
- Reduce risk (28 percent)
- Lack of special personnel (33 percent)
- Lack of personnel (44 percent)
- Reduce cost (47 percent)
- Get better quality (55 percent)
- Gain flexibility (61 percent)
- Access to technology and know-how (65 percent)
- Focus on core competencies (97 percent).

A particular interesting case of outcontracting is the German firm Xing AG (ch. 3.4.2; B.2). For starting his Internet company the founder who perceived the opportunity implemented his business idea essentially by outcontracting a very large proportion of needed functionality from the beginning, in particular, software development.

Effects similar to directions of outcontracting in the US have been observed by Ardichvili et al. [1998] who looked into timing and sequence of startup teams' delegation of business functions in growing entrepreneurial ventures.

In 1986/87 their related study surveyed startups founded in the period 1979-84; and they repeated the survey in 1992/93. They found that there was no difference in the patterns of delegation of functions between manufacturing and service firms. Irrespective of the sales level and timing top level delegated functions included Accounting, Warehousing and Shipping, Production, Computer Systems, Purchasing and Personnel.

Currently, for NTBFs with larger production facilities also "*Quality Management*" has become a very important formalization (cf. IoLiTec (A.1.5, B.2), Nano-X GmbH (Figure I.137; B.2), Novaled AG (Figure I.148; B.2), Heppe Medical Chitosan GmbH (B.2)).

For NTBFs, also other kinds of specialization show up rather early – according to applications (IoLiTec (A.1.5, B.2), products or product groups and business lines (for instance (all described in B.2), WITec GmbH, Novaled AG; Zynga, Inc. (online games as products; ch. 3.4.1.1).

Finally some facts with regard to resources and organizational development of startups and NTBFs are to be noted.

- Startups, particularly RBSUs, often need internal and also a *distinct external organization* in terms of networking and cooperation with universities and public research institutes (as exemplified by the IoLiTec GmbH case (B.2)).
- VC-based startups and NTBFs usually get organizational structures of medium to large firms imposed by the investors which may occur rather early (Novaled AG (Figure I.148), biofuels NTBFs – A.1.1);
  NTBFs with management and organizational structures closely related to those of large firms are characterized by Bhidé [2000:4, 21] as "*transitional firms*" to indicate their way to become large firms.
- Founders with industry experience in (very) large firms tend to set up early an organizational structure for the NTBFs that mirrors business and organizational processes they encountered with their previous employer (ATMgroup AG, Polymaterials AG; B.2).

To inquire further into the details of NTBF growth complementing the sales and number of employees figures from Table I.69 one can refer to the study of Gottschalk et al. [2007] which provides averages of related indicators for German NTBFs (Table I.70). The data differentiate the high-tech area according to Table I.1, but do not differentiate initial funding and ownership (Table I.74). The data cover the 2001 dot-com recession.

According to the study, only ca. 7 percent of the high-tech firms in Germany did not achieve any revenues in the first year after foundation. In the first year of business all firms of the sample had average revenue of €190,000 which increased to €840,000 after ca. six years in 2006. The extents of growth of revenues and employees depend on the industry segment of the NTBF. On average the firms started with three to four persons.

Concerning employee growth after ca. seven years the firms had on average nine employees with five employees having a university degree; after ca. five years the firms had seven employees (see next page) roughly comparable with State I in Table I.69.

Young technology firms' growth during the first few years is rather strong with the growth rate decreasing significantly after four years. However, one must be aware of the fact that for startups high growth rates are often due to the low level they have started from. More realistic impressions would consider growth rate calculations to start with year four of the firm's existence. This would be after the "*startup thrust*" phase (Figure I.125).

The data of Cowling et al. [2007] reported for an NTBF sample from Germany and the UK collected 1997-2003 fit these findings: in the median firm in its 12th year there were 12 persons in Germany and 10 in the UK.

Furthermore, for the NTBFs growth in sales is consistently larger than growth by employee numbers. That indicates the productivity (sales per employee) has continuously increased over the time period under consideration, probably due to learning effects.

The data in Table I.70 show that after foundation on average revenues for NTBFs from the industrial high-tech areas TVT and HVT are considerably larger than those from the software and TBS areas. The yearly averages across the Dot-Com Recession shed some light on an recession's impact and the issue of sampling for statistical descriptions of NTBFs, such as that of Hanks et al. [1993] [79] (Table I.69).

Table I.70: Sales, number of employees and average growth rates of German NTBFs [Gottschalk et al. 2007].

Averages	**Sales Year 1 1) ; 1,000 €**	**Sales 2006; 1,000 €**	**People Year 1 2)**	**People 2006 3)**	**Growth, Employees**	**Growth, Sales 4)**
All 5)	190	840	3	7 (3)	24%	34%
TVT	260	1,130	4	8 (3)	25%	34%
HVT	350	1,530	4	10 (2)	29%	39%
Software	140	480	3	6 (3)	25%	37%
Other TBS	160	670	3	7 (4)	22%	32%

Table I.70, continued.

Year Started						
1998-2000	210	1,270	4	9 (5)	13%	28%
2001	170	740	3	7 (4)	17%	34%
2002	190	690.	3	6 (4)	18%	40%
2003	220	760	3	6 (3)	23%	50%
2004	170	650	3	6 (3)	39%	–
2005-2006	150	260	3	5 (2)	60%	–

Growth rates are actually calculated in terms of a CAGR formula (Equation I.10).
1) Sales in first year of business; 2) Number of full-time employees;
3) Total employee number and employees with university degree in parentheses;
4) Foundation years 1998 - 2003; 5). For acronyms cf. Table I.1.

In addition to the above outline on NTBFs' growths the following observations were made for German NTBFs. With regard to the foundation dynamics *NTBFs differ already during their early years by their development paths* [Creditreform - KfW - ZEW 2009]:

> *Most young technology ventures exhibit only little economic activities.* Except for the founding persons there are rarely additional employees. Except for the year of foundation there are no further investments and neither a product nor process innovation is launched.
> They probably represent largely RBSUs characterized (for the UK) as a "spin-out becoming one of the 'living deads' with little prospect of success." They have limited growth and hence, become the 'living deads' rather than disappear completely [Fyfe and Townsend 2005] – They are "*non-growth NTBFs*."
>
> For a *second* group of NTBFs' foundation indicators for development reflect *a build-up process which, after some time, comes to an end* (cf. Clusters A (State I) and B (State II) text below Table I.69): Growth in terms of number of employees and volume of investments slows down and the NTBF does not launch additional new products or processes.
> Technical developments concentrate on updates or improvements (phenotype: growth setback – plateauing, back to (low) growth or asymptotic growth (Figure I.107) – they are "*marginal NTBFs*."

> *The third group of NTBFs comprises firms which in their core domain exhibit high activities.* Over several subsequent years they show high growth rates in terms of number of employees, they launch new products or processes or issue high investments (innovation and investment persistence; ch. 4.2.3, Figure I.117) in expansions or renewal of their capacities. The related phenotype could be assigned to "continuous growth or growth setback – back to growth" or even non-linear exponential growth (Figure I.107) – they are "*promising NTBFs*."

This grouping is in line with data in Table I.63 and associated text, which is: most NTBFs start small and stay small, having roughly between twelve and fifty employees (Table I.69). A general analytical description of the developments is displayed in Figure I.155.

The above grouping is also reflected by a study of German *NTBFs founded in incubators with entrepreneurial teams*, the survey's population being from 2007 [Zolin et al. 2008]. Accordingly, all firms with an entrepreneurial team are rather small. On average they have twelve employees, 80 percent of them achieved less than €2 million in revenues and 82 percent report a balance sheet total of less than €2 million. Since no firm in the sample exceeds €50 million in sales or a balance sheet total of €43 million, according to Table I.4 the sample can be classified as reflecing a sample of small and medium-sized enterprises mainly consisting of micro firms.

Though not strictly related to technology ventures, a rough "80:20" rule seems to be also applicable for mid-sized firms. An investigation of 1,300 German mid-sized, usually family-controlled firms [Fröndhoff 2008] and comparisons with the 180 firms (14 percent) showing the strongest growth revealed that the top firms have growth rates of 10 – 39 percent, far exceeding the others (ch. 4.3.6).

Concerning the proportion of NTBFs with growth or fast growth characteristics, in line with general results from GEM (ch. 4.1), a recent US study [Stangler 2011] found for new (technical and non-technical) firms, for instance, that about two-thirds of job creation came from young firms, many of which were small and never got much bigger. Only a small number of firms creates a disproportionate share of such additional jobs; these are the top-performing firms. According to the study

- Measured by employment growth, in any given year, the top-performing 1 percent of firms generates roughly 40 percent of new jobs.
- The top 5 percent of companies (measured by employment growth) creates two-thirds of new jobs in any given year.
- The fastest-growing young firms (between the ages of three and five years) account for less than 1 percent of all companies in the economy, yet generate 10 percent of new jobs each year.

The "average" firm in the top 1 percent contributes eighty-eight jobs per year. The large majority of these companies end up with somewhere between twenty and 249 employees. On average, fast-growing young companies create about twenty-seven jobs per year, with most growing to a size of about twenty to ninety-nine employees. The average firm in the economy as a whole adds two or three net new jobs per year [Stangler 2011]. This has also been described for NTBFs in Germany (ch. 4.3.1).

Importantly to note, however, many of the jobs created by these fast-growing firms will disappear. Most of the companies in the top 5 percent and top 1 percent are young and so susceptible to failure even if they have been creating jobs. That means promoting fast developing, high-growth companies will not guarantee the creation of sustainable firms. Three or four years later the business may fail and the jobs disappear.

Specifically, controlling for industry sector and ranking on the *Inc.* 500 lists, it was found [Markman and Gartner 2002] that extraordinary *high growth – in terms of sales and number of employees – was not related to firm profitability* (cf. also LinkedIn Corp., ch. 3.4.2.1, B.2).

Venture capital and large private investment are viewed in the US to be important for the development and growth of certain firms. However, it does not appear to be universally important for creating high-growth companies.

Of several hundred fast-growing companies on the *Inc.* list over the last decade, only sixteen percent ever received a venture capital investment (cf. also the German situation, Table I.24, Table I.25, Figure I.54, Figure I.55). *Venture capital, moreover, is highly concentrated in just a few sectors*, but high growth companies can be found in nearly every sector of the economy [Stangler 2011].

We assume that foundations of technology-based firms are roughly a quarter of all foundations (Table I.2). But young, *high tech firms create a greater percentage increase of net new jobs than do the other categories of young firms* [Kirchhoff and Spencer 2008]. Hence, we propose that job creation by NTBFs can be approximately related to a kind of “80:20” pyramid displayed in Figure I.119.

From a point of view targeting practice providing *rules of thumb*, similar to Drucker’s pitfall No. 3 (ch. 4.2.3), and in a context of a stage-based view of firms’ growth one is led to search for approximate time lines with development-related “markers” for NTBFs, keeping Bhidé’s [2000:247] basic approach into account that “does not try to force empirical regularities into a recurring temporal sequence.”

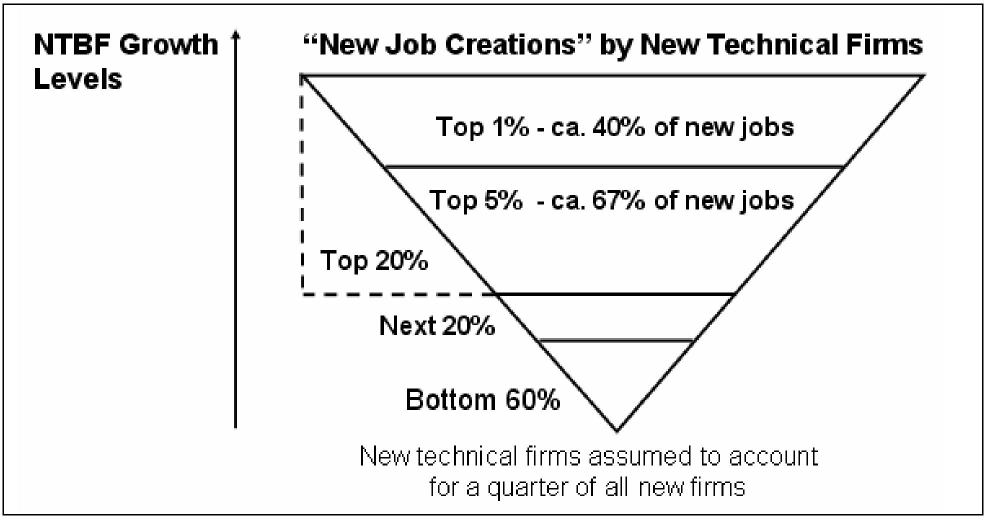


Figure I.119: The inverted pyramid of growing NTBFs related to employment contributions according to a rough 80:20 rule.

For instance, all the previously described observations suggest the following tentative time-related markers (Table I.71) concerning revenues for NTBFs with founders having full or majority ownership and full control of the venture (Table I.74) – unless significant firm-internal or external events interfere strongly with the development. The attribution also takes productivity (revenues per employee) into account.

Table I.71: Approximate time-markers for NTBFs with above average growth (non-VC-controlled startups).

Years of Existence	Revenue	Number of Employees	Average Growth Rates *)
4 - 5	$400,000; €300,000	7 - 8	Year 2: 60%
5 - 6	$1.6 mio.; €1.2 mio.	9	Year 3: 50%
7	$5.5 mio.; €4.1 mio.	30-60	Year 4: 40 %
15 - 17	$50 – 70 mio. €37 -52 mio.	500	Year 6: 30%

*) Estimations using data from Table I.70.

Other time markers for such kinds of NTBFs can refer to three rules of thumb reflecting organizational issues of young firms (Table I.72).

Table I.72: Approximate time-markers for development phases of NTBFs without VC participation and control via an implemented management.

- Drucker's third pitfall, the management crunch after 4-5 years (Figure I.118) for startups without a professional management team – and the NTBF having 9-11 employees;
- Fourth pitfall, the "Let go" issue (Figure I.118) after 10-15 years and ca. $60 million revenues (Table I.67, Table I.71);
- The "10 - 25 - 150" rule of thumb relating the number of employees to organizational issues, particularly related to leadership/management, specialization, communication, coordination and delegation.

The "10 - 25 - 150" rule of thumb, covering essentially the ranges 8-12 or 20-30, relates to the approximate number of employees of a growing firm or an overall range of 8 to 30 employees without discrimination. It has emerged from various discussions with entrepreneurs and confirmed by several of those who contributed to the author's Technology Entrepreneurship curriculum. For instance, in the time table of Attocube AG (B.2) one reads: "2005 >10 employees, introducing new organizational structures."

The situation inducing new firm structures was characterized by P. Klausmann [2011] by relating to communication and coordination issues: "You can gather up to ten people at one table to have a productive meeting." And N. Fertig, founder of Nanion Technologies, explained: "Sticking points for organizational problems occur with ten to fifteen employees. Then, internal communications becomes the decisive factor for the future development." (in German "Knackpunkte für Organizationsprobleme treten bei zehn bis fünfzehn Mitarbeitern auf. Dann wird die interne Kommunikation zum entscheidenden Faktor für die weitere Entwicklung." [Fertig 2012:Slide 42].

The rule relates to typical thresholds associated with necessary adaptation of the organization and its infrastructure to changed conditions of growth. The "10-threshold" is in line with Drucker's "management crunch" in year four to five of a new firm having on average seven to nine employees and Greiner's "revolutions" (Table I.68).

Overcoming these thresholds requires time, energy and money (including conflicts with employees and partners or stakeholders). According to Weber [2002] the *ability of large groups or organizations to coordinate* 12 people successfully (ch. 4.3.2) represents a certain threshold of efficient coordination *per se*.

The "10 - 25 - 150" rule of thumb is corroborated also considering growth of a startup in terms of the number of employees and associated expansion of building facilities. This means relating "communication intensity" (probability of communicating at least once per week) of the firm's employees in relation to separation distance in meters between the employees. Accordingly, communication intensity is ca. 30 percent, decreasing to 15 percent for a distance of 5 meters and converging to 12 – 10 percent if

10 meters are exceeded. The last measured distance was 80 meters [Ulrich and Eppinger 2000:Exhibit 14-12].

Concerning the “25 threshold” we hear from Niels Fertig (Nanion Technologies GmbH, B.2) when the firm founded in 2002 after seven years had 30 employees: “We now have reached a size which requires new structures (in German “Wir haben jetzt eine Größe erreicht, bei der man neue Strukturen braucht.”; cf. also Table I.90).

Lars Hinrichs, the founder of German Xing AG (ch. 3.4.2.1; B.2), pointed to another relevance of the number 30 for firm development. During the early phase of Xing he held regularly meetings with his employees every Friday. Every employee was motivated to speak out, what went well and what went wrong – and to make suggestions for betterments. This worked until the group reached the number of thirty as a threshold because with more people no longer everyone could or would speak up. For more people in the firm corresponding meetings were organized by department in a face-to-face manner or for distributed departments via video conferences.

> According to the above view one can assume that the “30 marker” more or less ends a startup’s state of *organizational success as an outcome of a dynamic organization-wide and all employees embracing process*.

It is notable that, for instance, Autio [2005] interconnects the “25 threshold” to “high-expectation activity” which is attributed to “all startups and newly formed businesses which expect to employ at least 20 employees within five years’ time.” His rationale: achieving the size of 20 employees is not simple (cf. also Solazyme – Table I.90). Firms of this size, typically, will have a developed internal specialization, identifiable management roles and some separation of ownership and employees, in the sense that not all employees are also owners of the company.

Several entrepreneurs the author spoke to mentioned that the “twenty-five employees threshold” has shown up as a dip in the firm’s productivity chart (revenue per employee). Crossing successfully the “twenty-five employees threshold” has been identified as inducing a period with a rather long lasting organizational stability – unless other factors like recessions interfere.

> An economic recession may show up every 5-10 years (with predictable occurrence, but ignorance when it will occur and with what intensity). Furthermore, *a recession requires usually other qualities of leadership/management than a “normal” growth phase*. In particular, it may turn an NTBF’s state into “survival mode.”
>
> Hence, a recession does not only affect the financial state of the organization, but also the organization in terms of management, control and execution.

The “150 rule” has been put forward, for instance, by Sonnete [2011] through a social hypothesis, which covers also the “10 - 25” part: The brain size constrains the size of social networking (by group size) which requires memory on relationships and social skills. And the human brain can only remember 150 meaningful relationships.

Indeed, evolutionary anthropology suggests a hierarchy of social networking according to the number of sub-group members [Sonnete 2011]: Support Clique (ca. 3-5 members), Sympathy Group (ca. 10-15), Camp (ca. 25-30), Village (ca. 130-180) and Tribes (ca. 500-1,000). This fits also with the organizational hierarchy of the army with Sections (squads) (10-12 soldiers), Platoons (of 3 sections, ≈ 35 soldiers), Companies (3-4 platoons, ≈ 120-150 soldiers) and Battalions (3-4 companies plus support units, ≈ 550-800).

The “150 threshold” is also seen in Microsoft’s (Table I.67) and Xing’s (B.2; Figure 8) productivity data.

Gladwell [2000] also remarks upon the unusual properties tied to the size of social groups. Accordingly, groups of less than 150 members usually display a level of intimacy, interdependency and efficiency that begins to dissipate markedly as soon as the group’s size increases over 150. This concept has been exploited by a number of corporations that use it as the foundation of their organizational structures and marketing campaigns.

Staged models mostly emphasize the fit between the design of the organization and growth stage. Growth is considered to distort the balance between the design of the organization and the stage of growth, and the task of leadership/management is to restore a balance. In this sense, the models are also *metamorphosis* models, as the organizational architecture of the firm needs to be changed for each stage.

The above patterns do not generally apply to VC-based NTBFs and NTBFs striving for large scale productions. Here, the following rules of thumb may be useful (Table I.73).

Table I.73: Approximate time-markers for developments of VC-based and production-oriented NTBFs.

- Venture capitalists assume that “lemons” ripen in two or three years, but the “pearls” take seven or eight.
  A new business rarely establishes itself in less than three or four years.
- Developing a company of sufficient size out of a new business development (NBD) initiative of a large firm will take five to eight years [Runge 2006:464].
- A seven-eight years requirements is also often observed in non-technical areas, e.g. it took FedEx eight years from idea to become operational [Bhidé 2000:168-185].
- For (existing) companies observed for a period of almost a century it took 6-11 years to transform laboratory results into *mass production* [Runge 2006:654-655].
  This seems also to be the case for NTBFs (cf. Nanophase Technology (Figure I.140) and biofuels startups – A.1.1). The related phenotype of growth corresponds *often* to that of “delayed growth” (Figure I.107).
  However, delayed growth may also be associated with an “unexpected event,” such as a political interference as in the case of US firm First Solar (Figure I.154) and the German firm Enercon GmbH (Figure I.150; B.2) or due to firm-specific development issues, as observed for US Closure Medical [Runge 2006:98-103].

As a summary, staged approaches do have the merit of making observations of firms' dynamics with regard to revenues and number of employees as growth indicators – and combining both into productivity. However, without observations at the firm level, the mechanisms and processes of growth remain obscure.

Disregarding VC-based startups with their stage ("series") approach (Table I.27), "life-cycle and staged models" fail to adequately account for the great variety in the manner in which new technology-based firms grow. Moreover, comparing developments of "Ford versus General Motors" there appeared "great differences in how the two competitors developed their assets and routines, and in the role of their founders." [Bhidé 2000:245-247]

VC-based NTBFs follow often the VC-staged process (Table I.27) for (anticipated) growth which is structurally related to the Stage-Gate® (PhaseGate) process for innovation in large firms (ch. 1.2.7.2 Figure I.76, Figure I.180). In large firms intrapreneurship is often following strict phased processes with decision points and a restricted number of progression paths for innovation, NPD or NBD processes. Here, the prototype is the Stage-Gate® process (Figure I.79, Figure I.180).

Moreover, the early phases of a new product development project (which is concept generation and product planning) are commonly acknowledged to play a central role in the success of product innovation of large firms. Early decisions are unlikely to be changed during downstream phases, unless high costs and time are experienced. They have therefore the highest influence on project performance.

However, early analysis and problem-solving is also a difficult task, because the necessary information and insights are not available until one gets into detailed design. Most companies are locked in this dilemma between anticipation (anticipating decisions in the early phases of product development, where influence on performance is substantial) and reaction (delaying decisions to downstream phases, where information and opportunities are manifest).

A structurally similar situation is also found for startups. Though for a large part of new technology ventures developments seem to evolve in a phased manner following "stimulus-response" mechanisms and representing particular states of the firm the absence of prototypical *initial startup constellations and conditions* in stage-based models and the *absence of predetermined development paths* precludes so far some common features in the growth of NTBFs.

4.3.2 The Initial Architecture and Initial Configuration

The startup constellation represents a key for entrepreneurship as the basis for further development of the firm and its assessment by others ("observers," particularly financial backers). It will generate expectations concerning the development or even generate expected values for the firm (,for instance, financial projections of VCs).

In line with the GEM model (Figure I.15) we assume this constellation to be preceded often by a "pre-startup" phase comprising linking idea generation and revealing opportunity and conceptualizing the firm (Figure I.125). In the GEM-approach (Figure I.15) the pre-startup phase covers activities of the "potential entrepreneur" and the "nascent entrepreneur."

The diaries of the German firm Suncoal Industries GmbH (B.2) provides a lucid insight into the pre-start phase of an NTBF.

Basically, one must differentiate the *founding success* and the *survival* of the new firm. We shall denote the *one to four years period* after firm's foundation as the "*startup thrust phase*" (Figure I.125). Our discussion will follow an approach focusing on the founder person(s), resources and environment as well as the founding process. Here the vision and mission of the founder(s) (ch. 2.1.2.7) are important for building the firm and expectations.

Previous research suggests that the *initial choices of the entrepreneur or the team have a lasting impact on the way the company evolves*. In particular, they may facilitate *self-reinforcing* mechanisms (ch. 2.1.2.5), positive feedback mechanisms, by which a system's conversion processes and output (Figure I.5) or states are enhanced or brought into a more favorable situation.

For instance, group formation is often associated with processes of system's development by self-reinforcement and self-enforcement (ch. 2.1.2.5). Early decisions referring to intangible and tangible resources (Table I.8) will be important (ch. 4.2.2).

The discussions so far emphasized the fact that startup and NTBF development will be affected not only just by financing, but also by associated issues of ownership and control of the new firm. Correspondingly, initial architectures of NTBFs must be differentiated – by one of several classes of *taxonomy* given later in Table I.74 and Figure I.128 – to discuss the various NTBF developments adequately (cf. also A.1.1.6).

Initial *resource endowments* – the stocks of resources including the founders' experiences (ch. 2.1.2.4) that entrepreneurs contribute to their new firms at the time of founding – may explain the different life chances of new firms during start-up (cf. [Bhidé 2000; Klepper 2001]). In that way certain firms, such as spin-outs of industrial firms or serial entrepreneurs already control a relatively large productive base and some financial reserves at start.

Initial financing and very early development will often rely on own resources and resources of family and friends (3F) and significant cash flow (Table I.23, Table I.24, Table I.25).

And there is a number of NTBFs which were started because the founders had already customers (notable cases cited in this book are ChemCon GmbH (B.2) and PURPLAN GmbH (Box I.21) whose founders started as consultants or engineering planners, IoLiTec GmbH and Solvent Innovations GmbH (A.1.5), WITec GmbH (Table

I.41, Figure I.123; B.2) and US Cambridge Nanotech ([Yang and Kiron 2010], Table I.80; B.2) , SAP AG (A.1.4) and Concept Sciences, Inc. (CSI; Box I.11).

Furthermore, family and family members may not only provide financial resources (3F, ch. 1.2.7) or buildings/land to the entrepreneur, but also other business-related support and advice or other commitments as observed for William Henry Perkin in Britain, the "father" of the synthetic organic dye industry (A.1.2.), ChemCon GmbH (B.2) and Nanopool GmbH [Runge 2010].

Additionally, the Family & Friends System (ch. 1.2.2, Figure I.16, Figure I.17) may provide emotional support and role modeling. For instance, spouses with similar or complementary talents, skills or education (for instance, commercial rather than technical orientation) may enter the startup of the entrepreneur full- or part-time, as described for the role of spouses of the US firms Osmonics, Inc. and Avery Dennison [Runge 2006:91-94, 474-477]. Spouses also founded Cisco Systems in the US (both with IT competence; Figure I.145) or in Germany ATM Group AG (B.2), CeGaT GmbH ([CeGat 2011], B.2) and OHB AG (end of ch. 2.1.2.4).

Hence, many entrepreneurs owe much of their success to parental education or inherited or won family contacts. WITec GmbH could take advantage from two factors. One of the founders, J. Koenen, got a loan from his father-in-law who also served as a role for being self-employed (Table I.41).

Special family-related cases occur if entrepreneurial activities sprout out of existing firms of the family. One case concerns business succession. Another case is "branching" or "specialization" of a family-owned firm. For instance, the German startup "Heppe Medical Chitosan GmbH" providing nano-chitosan as well as high-quality and high-purity chitosan and chitosan derivatives for medical and cosmetics applications is run by Katja Heppe (now Katja Richter), whose parents run the company Heppe GmbH. The parents' firm produces among other things chitosan for industrial paper and textile applications.

Chitosan is a natural product, a linear polysaccharide, which is produced for commercial use from the shells of shrimps and other sea crustaceans. It is one of the most important renewable raw materials of the world, cellulosics being the most important one.

At the startup phase the founders' aspirations, ambitions, experiences, competencies and skills are crucial to the company's growth, as are financial and business resources. But, potentially interconnected to financing aspects, the initial startup setting is influenced by the fact whether the startup will strive for *large-scale production* or whether the characteristics of the opportunity requires *fast* development for entering the market.

Large-scale production requires tremendous amounts of capital. To be successful a rule-of thumb says: For markets with short product cycles the time till market entry is important, for longer product cycles cost of production is critical.

For the startup the environment of the NTBF is relevant, for instance, statuses and developments of technology, existing or emerging functionally equivalent technologies and industry (segments, markets and competition, and other relevant systemic influences). Therefore, the entity of inquiry will be the *initial configuration* which covers the startup's *initial architecture* (ch. 1.1.2; Table I.5).

> Technology entrepreneurship may be compared with an across country auto racing with a starting point and various initial conditions, but with a given finish. At the start there are cars with various technical and design features having a driver or driver team with various capabilities and experiences. But to reach the finish (goal) there are several courses with various hindrances, barriers, ups and downs as well as bumpy or smooth roads and an environment affecting the course, for instance, wind and rain making the course slippery.
>
> And there will be gas stations to get needed power and cross-roads requiring a decision to follow the planned route or changing direction. The "starting constellation" of the entity determines the momentum for "lift-off" and then decisions will have to be made which route to follow initially (the "expected path to success") and in which manner ("action and execution and speed").

A complementary metaphor can focus on the start of an aircraft: A runway is used for preparation and then there is a needed thrust for the departure of the aircraft (lift-off). All that is in the aircraft's "potential"; and sometimes there may be an additional momentum, for instance, wind from behind (for instance, reflecting a startup having already customers on foundation, as described above).

The metaphor concerns the "*startup thrust phase*" (Figure I.125) which may cover a *one to four years period* with the startup and the founder(s) having their new firm steam up (Figure I.122).

For those NTBFs which started with having customers the thrust phase will be very short, probably one or two years. The startup thrust phase of NTBFs will be associated mostly with characteristic "average" growth rate patterns (Table I.70, Table I.71) reflecting "acceleration" to lift-off. The startup thrust phase must be differentiated from the "*scale-up period*" of new firms with large-scale production which usually takes six to eleven years until product launch into the relevant market (Table I.73).

> If vision is where the entrepreneur wants to arrive at (ch. 2.1.2.7), culture is the foundation he/she can get there (cf. also Table I.43).

In this context of direction, execution and control Reid Hoffman, co-founder of LinkedIn (ch. 3.4.2; B.2), made some recommendations for entrepreneurship [Kaiser 2004]:

"Smart people tend to think that they can execute on a complex plan. Executing on a complex plan is generally a recipe for failure. If you can't make a startup work on a simple plan then your chances of success are very low.

Another lesson is that as an entrepreneur you want to choose a project that is far enough away from what others are doing. You want as much distance from other players so that you have the opportunity to create something.
The last thing I would add is that you want to measure your endeavor as soon as possible. You want to be able to gauge the viability at the earliest possible moment, so that you can change and adapt your model as needed.
Entrepreneurs tend to want to launch only when their product or service is perfect. The problem is that waiting undermines the ability to evaluate whether the idea works as quickly as possible, so that you can correct course. Correcting course frequently is key to success." (cf. overshooting, Figure I.88)

Creating Firm Culture and Developing Employees

In Silicon Valley, it is often said that the founder is the startup.

One of the components of initial resource endowments of NTBFs, being also a differentiator, is corporate culture which plays an important – though generally hidden – role. It emerges in the first few years of the startup. Particularly as an *intangible asset* a unique culture offers an advantage over competitors. It will affect product design, prototyping and realization, hiring practices and the values empowering employees to live the mission [Lowry 2011].

Usually it is assumed that the entrepreneurs play the key role in shaping corporate culture which is "intrinsic" to the initial architecture. Focusing on the founders we put forward a model of corporate culture to be formed essentially by a *self-replicating* process. Figure I.120 illustrates this for "*behavioral patterns*" as the important and observable expression of culture.

Self-replication is any process by which an entity will make a copy of itself – usually by distinct steps increasing the number of entities by one or more. The important ingredients to such a step comprise entrepreneurial *leadership by example*, *influence and employee development* (Figure I.141). Establishing behavior and "how things are done here" through "leading by example" ("walk as you talk") is a characteristic of many CEOs of Hidden Champions (ch. 4.1.1).

Metaphorically, assuming the founder(s) to determine the DNA for behavioral patterns can be compared with *gene expression*, which is the process by which information from a gene is used in the synthesis of a functional gene product.

An NTBF usually starts with up to five persons. That means shaping culture starts almost from scratch with the entrepreneurs/owners driving its direction. There is mostly one "leader" who has the greatest influence – usually the founder or the "primus inter pares" of a team. Disregarding situations were only two persons form the new firm, the model of a self-replicating system can start with a three-person constellation.

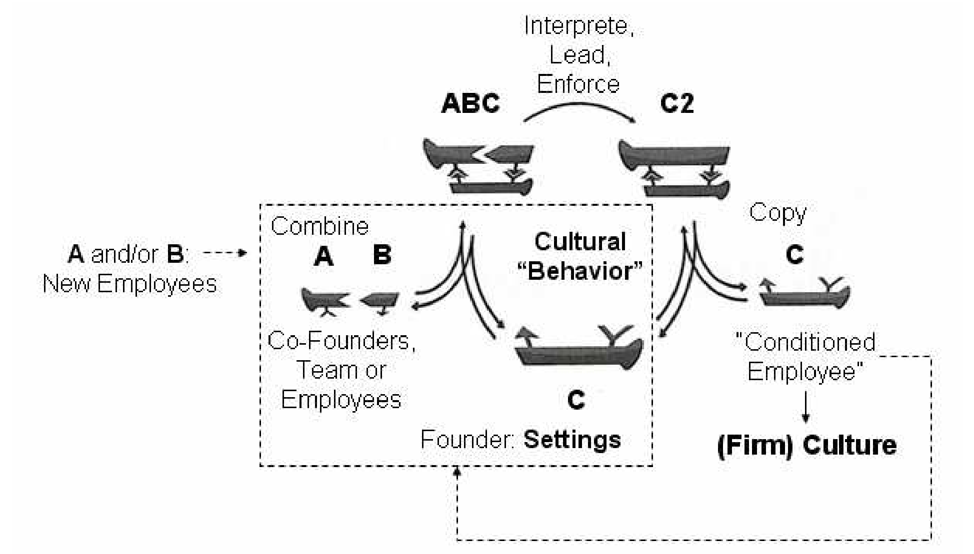


Figure I.120: Development of firm culture expressed by behavior of a firm's leader or founder by a self-replicating system.

Whereas Figure I.120 refers to a pattern-related process of firm culture evolution an interpretation of this process takes the following route. A small group, such as the founding members of a firm, does not face substantial difficulties in coordinating efficiently. Once they have done so, they can *establish a set of self-reinforcing rules or norms either tacit or formalized governing what actions and behavior are appropriate*. These norms allow the group or organization to continue to successfully coordinate activities.

As the group grows, new entrants' exposure to these norms allows the entrants to be aware of the appropriate behavior and creating an expectation for everyone in the group of what everyone else (including the new entrants) will do. Therefore, relatively slow growth and exposure of new entrants to the group's previously established norms can overcome large coordination failure.

The missing part of this interpretation is the "new employee" ("entrant") of the firm, which is associated with the firm's hiring process. A complement to the interpretation could tentatively refer to a "*targeted selection*" process which is ubiquitously applied by large firms for hiring activities focusing on a primary facility (a technical, commercial or administrative/managing specification) and a secondary facility of importance and additionally "needed to have" or "nice to have" competencies or personal traits and overall fitting with the corporate culture. [80]

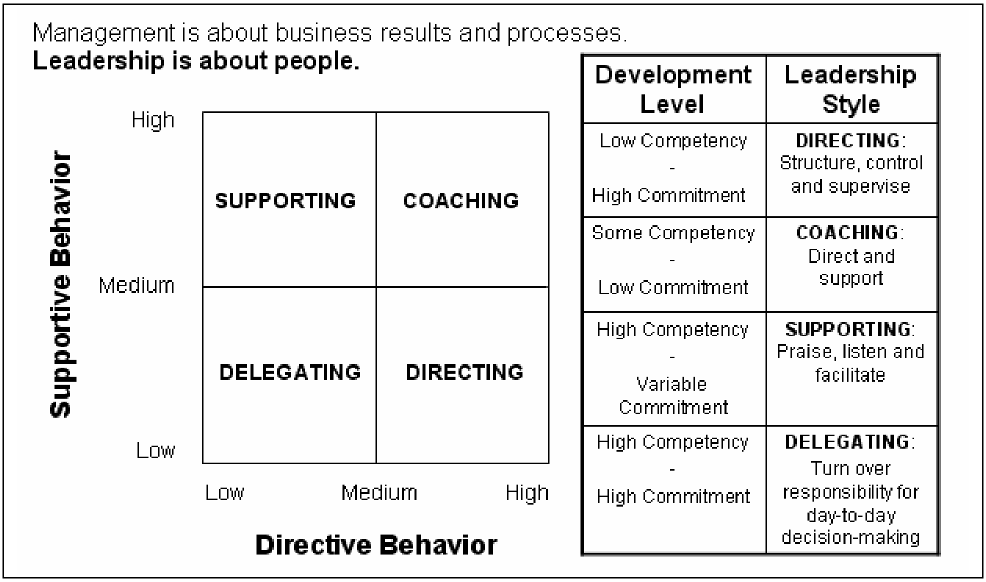
Creating NTBF culture is the leader's responsibility to drive *employee development* by a directing or supporting style according to the employee's status of competence and commitment (Figure I.121). Leadership focusing on people in startups will emphasize influence rather than power as a means of assertiveness and execution (influence > attitudes > behavior; ch. 1.1.2).

Delegation and transfer of responsibility to the individual employee increases the level of identification with the firm. The leader's goal must be:

Keep the corporate culture across growth processes.

The human resources philosophy of 3M made in 1948 can serve as prerequisite of the interconnection of employee development and firm growth: "*As our business grows, it becomes increasingly necessary to delegate responsibility and to encourage men and women to exercise their initiative. This requires considerable tolerance. Those men and women to whom we delegate authority and responsibility, if they are good people, are going to want to do their jobs in their own way.*" [McLeod and Winsor 2003]

It is interesting to note that Greiner's staged model of firm growth and associated style of management (Table I.68) for growth of the firm also emphasizes directing and delegating as emphasized for leadership style for (individual) employee development in Figure I.121.



Development Level	Leadership Style
Low Competency - High Commitment	**DIRECTING**: Structure, control and supervise
Some Competency - Low Commitment	**COACHING**: Direct and support
High Competency - Variable Commitment	**SUPPORTING**: Praise, listen and facilitate
High Competency - High Commitment	**DELEGATING**: Turn over responsibility for day-to-day decision-making

Figure I.121: Leadership styles for employee development referring to employees' development levels.

Self-reinforcing mechanisms as described above occur specifically in the context of *coordination* (ch. 1.2.1, 2.1.2.5; Table I.8, Figure I.73). There is ample evidence in experiments on coordination games that what a team did previously is likely to become a self-reinforcing norm about what to expect in the future. Game theorists have also recognized that organizational culture is one way in which a precedent helps select an equilibrium by reinforcement.

> Based on game-theoretical experimental settings with group sizes of 2 – 16 persons it was shown [Weber 2002] that the *ability of large groups or organizations to coordinate* successfully is *critically affected by the group's growth process itself*. Consistent with previous experimental research, coordination is much easier in small groups. It was shown that, even though coordination does not occur in groups that start off large, efficiently coordinated groups can be "grown." This corroborates also the interpretation of self-replication.

The experiments, indeed, indicated that efficient coordination in large groups is possible when groups start small and then grow slowly (coupled with the exposure of new entrants to the group's history). Moreover, the early failure of groups in the growth sessions of Weber's experiments appeared to produce an instance of the common view in the business world that firms can "grow too fast."

Following Kaplan [2003b] skills related to building the firm's culture comprise

- Leadership (ch. 1.1.2; Equation I.1): ability to build consensus in the face of uncertainty
- Communication: ability to keep a clear and consistent message
- Being a good team player: knowing when to trust and when to delegate
- Decision-making: knowing when to make a decision.

Trust, competencies and commitment will always be the foundation of success through leading decision-making and related courses of actions and execution (Figure I.111, Figure I.117). However, the starting point is always beginning with *communication* to ensure understanding of the vision and mission (ch. 2.1.2.7) and agreeing on common priorities.

Hence, 1) the leader must share his/her goals and objectives with the staff. And, after having a concept of activities and operations and specification of tasks in place he or she must 2) clarify coordinating instructions and 3) explain control and how to measure level of achieving objectives – having success (ch. 4.1).

Building consensus means *achieving agreements among a set of possibly very diverse people*. Building consensus is in the context of risk and uncertainty (ch. 4.2.1) and *making decisions* (ch. 4.2.2) at the right time. The expected result is that *everyone of the new firm is aware what his/her role and job is and what he/she contributes to success*. This implies to continuously check whether the firm's operations (Figure

I.5) have generated value and, moreover, whether value creation has been achieved efficiently.

Communication based on explaining *what is* and *why what to do* is a key capacity to *influence* someone else's behavior as compared with one's own behavior. In the context of entrepreneurship and building consensus among all the people of a startup it is advantageous to refer to operational facets related to *each individual's decision problem in the context of objectives* introduced by R. Ackoff.

Ackoff's suggestion as cited by Runge [2006:341] is concerned with the valuation of the objectives, the possible courses of action and the efficiency of each course of action in achieving each objective and the individual's probability of choice for each course of action. Accordingly, there are three *effects of communication* with a related basis, options and results referring to individual behavior and actions:

Motivation:	Values of the objectives
Information:	Possibilities of choice of the available courses of action
Instruction:	Efficiencies of the available courses of action.

Information usually affects a person's mental state of cognition. Instruction refers to a finite number of actions to achieve a result which, as the simplest case, may proceed sequentially, but will become complicated through conditional branching options or loops. An everyday example of an instruction is the "cooking recipe." Motivation is the major effect leaders should focus on.

Concerning operations, behavior and social interactions corporate culture in large firms develops for new employees usually quite differently. Here one often observes three paths:

- Official and Codified:
  "Manuals"; for instance, Operations Manual, Office Manual etc. (on paper or the firm's Intranet); spelled out by supervisors
- Official and Not-Codified:
  Expected behavior; "tacit," rarely spelled out
- Unofficial & Not Codified:
  Do's and Don'ts; individual leaders' approaches to coaching and supporting.

This means, it takes rather long (and is costy) before a new employee has learned not only about the firm's offerings and strategies, but also the culture.

Initial Architecture and Initial Configuration with Corporate Culture Given

The notions *architecture* and *particularly configuration* for (technology) entrepreneurship (ch. 1.1.2; Figure I.16, Figure I.72, Figure I.73) are fundamental if we are looking for that “*footprint of a firm*” which may be sufficient to understand, explain and make statements about what can be expected from a firm’s development.

According to GST the architecture is always related teleologically to the founder’s goals interconnected with his/her aspirations and expectations. But there are various routes for the firm founder to reach the goals (Figure I.122). Accepting bounded rationality (ch. 4.2.2) the founder may not necessarily be aware of all the paths that are possible. As a reflection of competitive situations for startups striving to reach the “same goal” the systems view implies that there may be, for instance,

- (Almost) identical architectures having different initial configurations (think of startups in different countries, think of different input material as is observed for the biofuels industry – A.1.1).
- Initial architectures that may differ, for instance, just using generic technologies.
- Different architectures which will usually follow different paths (such as various conversion processes);
  however, at a particular “cross-roads” (Figure I.122), one architecture may switch to a path of another one; think of the many processes in biofuels when an initially thermochemical route switches over to a bioengineering process, becoming a hybrid process (A.1.1.3; Figure I.175).
- But, different architectures can generate the same value for firms and thus would not provide competitive advantage.

The initial configuration (Figure I.122), structurally initial architecture plus environment, depends essentially

- on the industry’s or economy’s situations like a recession or a “bubble” or the start of a new industry and
- on the market level and type, whether foundation is oriented toward a megatrend, a niche, requires building a market (disruptive innovation strived for) or start in a policy-driven market or mediatorial market (Table I.15).

Entrepreneurship in an area of *industry genesis* represents a special initial configuration for an NTBF (ch. 4.3.5; Figure I.143, Figure I.144, Figure I.145) and is often associated with the phenotype of “exponential” growth (Figure I.107).

Financing is a key component of a startup’s architecture. Initial financing of technology-based startups often begins before the formal incorporation of the new firm. It begins during the *pre-startup phase* (Figure I.52, Figure I.125).

The “pre-startup phase” covers a time span which begins with the initial communication and discussions of startup intentions, driving forward related specific scientific or technical inquiries and continues until the formal foundation as a legal entity that has been authorized to operate by a state or other political authority (“incorporation”).

After firm's foundation there is the startup thrust phase which coincides essentially with the phase of "early stage entrepreneurial activities" covering the first 3.5 years after formal firm's foundation according to the GEM model (Figure I.15).

Incubation of RBSUs (ch. 1.2.6.2; Figure I.) represents a particularly illustrative example of financing toward formal firm's foundation. Concerning availability or gathering of resources the pre-startup phase may overlap partially or totally with an incubation phase, which, on the other hand, may also extend into the startup thrust phase (Figure I.125; ch. 1.2.6.2; Figure I.).

Independently from sources of financing (Figure I.52, Figure I.59, Table I.30) one should take the statement given by a "bioentrepreneur" as a general recommendation:

> "The key thing I have learned over the past six-to-seven years is the importance of having enough cash in the bank. ... I have learned that it is a good strategy to raise money, even when it is not needed, so that there is always a sufficient cash cushion for when the market is uncertain." [DeFrancesco 2004]

Initial financing as one basis of pursuing the business opportunity is a key component of the startup's (initial) architecture and configuration (ch. 1.2.7). As founders' attitudes (and goals) toward financing in relation to control/ownership of the new firm differ the initial financing structure is an important factor and issue when addressing a firm's development and growth.

For proper discussion we shall introduce a taxonomy for financing of NTBFs (including initial financing) according to ownership and control by founders as given in Table I.74 (cf. also Table I.30). Control affects essentially leadership/management and strategy or strategy logics, respectively, and, hence, decision-making concerning the firm's development or growth path and pace. Initial NTBF configurations may show initial financing according to all these types. For instance, a large number of biofuel startups started with venture capital (A.1.1). They are "*VC-based startups*."

Obtaining massive amounts of venture capital or capital from an IPO does not necessarily mean loss of control. For instance, due to a dual class structure of common stock, a Class A share may be accompanied by five voting rights, while a Class B share may be accompanied by only one right to vote, or *vice versa*. Also dissection into three classes is observed.

A detailed description of a company's different classes of stock is included in the company's by-laws and charter. In this way the founders of the US firms Google (Box I.24), Groupon, Zynga, LinkedIn and Facebook (ch. 3.4) retained control over their firms.

Table I.74: Taxonomies of financial structures of technical startups' initial architectures in terms of ownership and control by founders and related typical sources for financing.

(Almost) Full Ownership, Full Control	Majority Ownership, Almost Full Control	Minority Ownership, Little (almost no) Control
Examples (any combinations or left out of one or more of the given components)		
Bootstrap; Cash flow; 3F + Bank loans; 3F + bank loans + "angels" + public R&D projects	3F, cash flow; bank loans + public R&D organizations (e.g. universities', research institutes' ownership in exchange for IP) + CVC + angels + silent partnerships of (public) investors or even VC	3F + VC +CVC + private large-scale investors ("*VC-backed startups*")

The vast majority of NTBFs fall into the two groups in which the founders' control over the firm is retained (over the first ten to twelve years of their existence). *VC-based NTBFs* account for no more than 5 percent of all the NTBFs (Table I.23, Table I.24, Table I.25). Their economic significance results particularly from the number of jobs they generate for the national economies (ch. 1.2.7).

We shall consider *VC-based startups* always as a class of NTBFs where venture capital firms or corporate venturing companies exert control over the firm. Sometimes there are firms which may have venture capital from investors or companies, but control remains with the founder(s), such as the above mentioned companies (Google etc.) or in Germany CeGaT GmbH (B.2) or Gameforge AG (ch. 3.4.1.1, B.2).

The transition from of a fledgling business or NTBF to a well-established medium-sized or large company is associated with fundamental transformations. If a startup becomes a VC-based NTBF the associated change from leadership and management roles of the founders does not only mean a change to professional management (Figure I.118), but usually also a switch to approaches of Management Science and Technology and Innovation Management (TIM, Figure I.1) with formalized structures and work processes, such as New Product Development (NPD), New Business Development, PhaseGate innovation processes (Figure I.79, Figure I.134, Figure I.180) etc.

Particularly, approaches, visions and leadership/management style of a CEO established by VCs – usually persons with one or two decades of experience in relevant positions in large firms – may clash with that of a founder taking a CTO or CSO position as observed for Amyris Technologies (Table I.99; A.1.1.5).

In line with phased models we assume that the paths of the startup to reach its goal are interrupted by "transitions of one into another state" with a certain period of duration (ch. 4.3.4), the "*transition states*." These are depicted as squares in Figure I.122

and occur as "crises" in Greiner's model (Table I.68) or "adaptations" in Bhidé's [2000:22] view. Transition states will "relax" to new states which will be "dynamically stable" characterized by a new configuration until the next "interruption" occurs. Additionally, it is assumed that

> the "transitions" and associated development phases are distributed uneven and *usually not foreseeable* for the whole path to sustainable growth.

"Interruptions" of a firm's development are initiated by events, happenings or "perturbations." And we regard a "firm event" (or "firm happening") as any effect from inside or outside of a purposeful system with a positive or negative impact on reaching the organization's goal(s) or keeping the organization's current state.

If these events or happenings become aware to the organization's control system (for instance, the firm's leadership or management team) they will require to make decisions how to proceed to reach the goal(s). Here, it is to be noted that for purposeful systems the principle "one cannot not decide" applies. This means, even no decision will have an effect on the firm's further development (ch. 4.3.5.1).

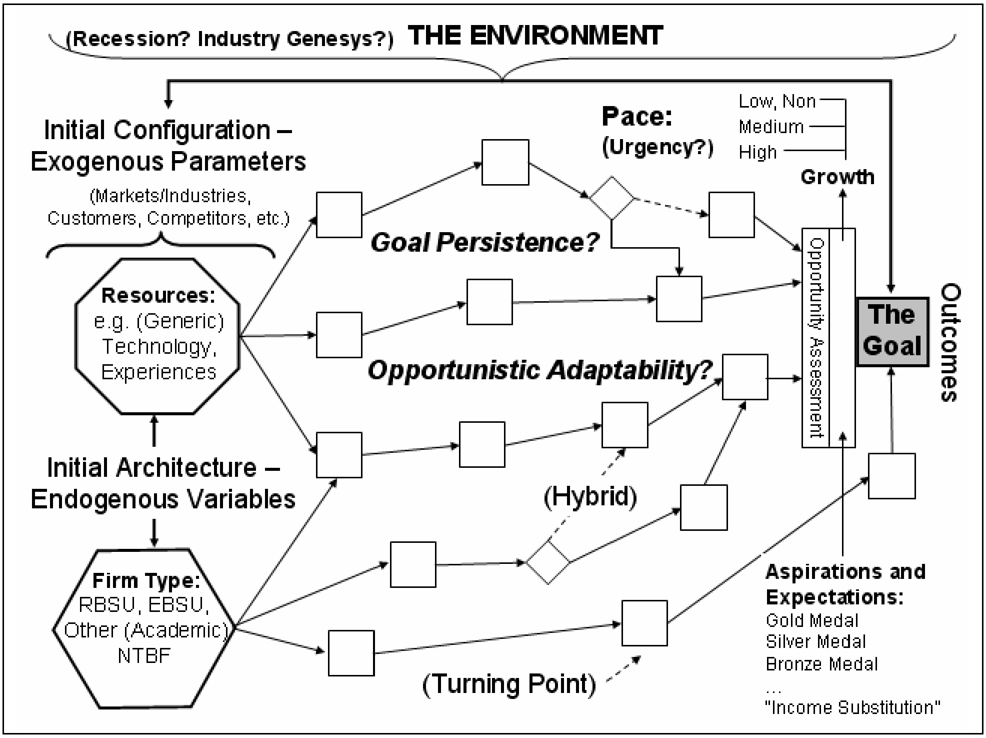


Figure I.122: Relating initial configuration with associated architecture and variability of paths to goal achievement for NTBFs.

Usually *unpredictability of specific growth paths* is assumed to be due to the increasing complexity of the firm as it grows. But, moreover, a purposive system like a firm must always exhibit choice of alternative courses of action (Table I.6), a choice of paths. The mix of tangible and intangible resources required for growth is rather precise, but shortages of any one resource, for instance, by a recession, can create bottlenecks with knock-on effects.

Apart from consideration of goals there may be requirements of *pace* for the growth of a startup. Pace can be defined by the entrepreneurs themselves (Box I.20). But in case of external financings there may be pushes for pace (or urgency) by investors or lenders. Another criterion for pace and speed up will be a conscious decision to compete against another large or small firm on pace if the entrepreneur knows that the particular competitor has a slowly moving organization, for instance, a bank [Hoffman 2007b].

Hence, pace or urgency as a driver of development may have an influence on the decision concerning the path to be followed to reach the goal.

On the other hand, Bhidé [2000:61] pointed out that there may be a number of startups which have no clearly defined goals, but follow an approach of adaptation to emerging or revealed opportunity: One third of the *Inc.* 500 sample entrepreneurs changed their initial concept.

Additionally (ca twenty years ago) 41 percent of the *Inc.* 500 entrepreneurs had *no business plan* at all and 26 percent had just a rudimentary plan [Bhidé 2000:54].

For technology ventures, however, one can assume that the situation has drastically changed. One can assume that currently the vast majority of the related technical startups have clear goals and plans (and will use a business plan). But there continue to be successful foundations without explicit and formal planning documents and are based essentially only on purposeful action (German PURPLAN GmbH, Box I.21).

Box I.21: Jump starting a company by finding, attracting and binding customers rather than writing an explicit business plan or doing detailed planning [Wintzenburg 2009; PresseBox 2012].

The German NTBF PURPLAN GmbH was founded in 2003. It had revenue of €14.2 million, 114 employees and 15 apprentices in 2011 and had revenue of ca. €18 million with ca. 120 employees in 2010 and an export rate of ca 50 percent (in 2009 €10.6 million and 120 employees; 2008 data: ca. €16 million and 103 employees; 2007 data: 80 employees, 2006 data: ca. €7 million and 65 employees). Since the year of foundation revenues have increased by a factor of ca. eight.

PURPLAN plans and constructs complex plants for storing and refining liquid substances – many of which are water-contaminating or inflammable, such as MDI and TDI and polyols for polyurethanes, hardeners, binding agents, pentane, solvents or glues. PURPLAN with a distinct focus and targeting consequently a niche in established markets has been recognized by the German National Founders' Award as one of the Top-Climbers (Box I.17).

PURPLAN carries out demanding tasks combining high-tech-planning and precise workmanship and executing its contract jobs through project teams in which engineering competence and practical project-handling skills complement each other successfully. Running successfully the interfaces between engineers, master craftsmen and craftsmen is PURPLAN's *core competency*.

Usually, there are firms which are good with planning or good with fast and cost-efficient construction, but only few can combine both areas. The interface is very difficult to manage. Characteristic features of all PURPLAN plants are holistic system solutions, high user comfort, quality and pronounced safety systems. In the area of automation programming is performed and software-solutions are compiled which meet the most sophisticated requirements.

PURPLAN has two mid-aged (ca. 45 years old) engineers as founders and firm's foundation resulted from frustration. One of the founders, Andreas Sandmann, was an employee and engaged considerably for fifteen years in building a machinery firm. However, in the end his boss rejected to delegate more responsibility to him. Sandmann wanted to shape more, wanted more decision-making authority and more reward.

Fully upset by this situation he decided to leave the firm and founded together with a colleague, Oliver Schawe, the firm PURPLAN – without a business plan, credit and starting capital. Their major "capital" was experience and contacts and networking. The team just called potential customers by phone ("cold call") and caught the first orders for selling a plant for production of polyurethane foams – via sub-contractors.

At the beginning they just wanted to plan the plants. But with an increasing number of orders growth started and customers suggested that they themselves build the plants – and they started PURPLAN. In retrospect Sandmann's conclusion was: "I now reap the fruits of several years of employment. This would not have been possible immediately after leaving the university."

This path of experience-based entrepreneurship starting with not much planning to change over to production compares with starting with consulting (ChemCon GmbH, B.2) and focusing directly on customers without much explicit planning; and it is similar to the path the founders of SAP AG (A.1.4) followed.

PURPLAN followed "*opportunistic adaptation*" [Bhidé 2000:18] which means without much effort to prior planning and research or only sketchy planning and rather high risk entrepreneurs adapt to unexpected circumstances in an "opportunistic" fashion.

PURPLAN GmbH is one of the above mentioned NTBFs which almost from the start are involved in commercial activities and production-oriented firm's foundation occurred through initiatives of customers. Some key components of the initial architecture include the founders having industrial experience in the startups activities, the firm type being “other (academic) NTBF” (Figure I.122; Table I.2) and relying on unique core competencies (Box I.21). Firm developments followed an exponential growth until 2008, when the Great Recession began.

As market entry by catching customers represent a key step and event for a startup and having already customers at the foundation provides simultaneously an emergence of an initial configuration out of the initial architecture.

> Having orders and/or customers already at firm’s foundation is a special *favorable initial configuration* as it does not only provides revenues (and positive cash flow) from the beginning, but makes further planning of penetration into a largely known market rather reliable.
> Correspondingly, it will be much easier to attract external financing, if needed.

The below Figure I.123 illustrates this situation for the case of WITec GmbH, which was founded as a university spin-out (firm type RBSU) by an entrepreneurial triple (Table I.41). Similar to PURPLAN growth of WITec in terms of revenues exhibits a dip when a recession (here Dot-Com Recession) occurred. Otherwise growth follows roughly a linear pattern. Though revenue data are still missing, WITec does not seem to exhibit a decrease of revenue in 2010 as most firms do during the Great Recession. A “full” description of WITec’s entrepreneurial configuration is given in Table I.80.

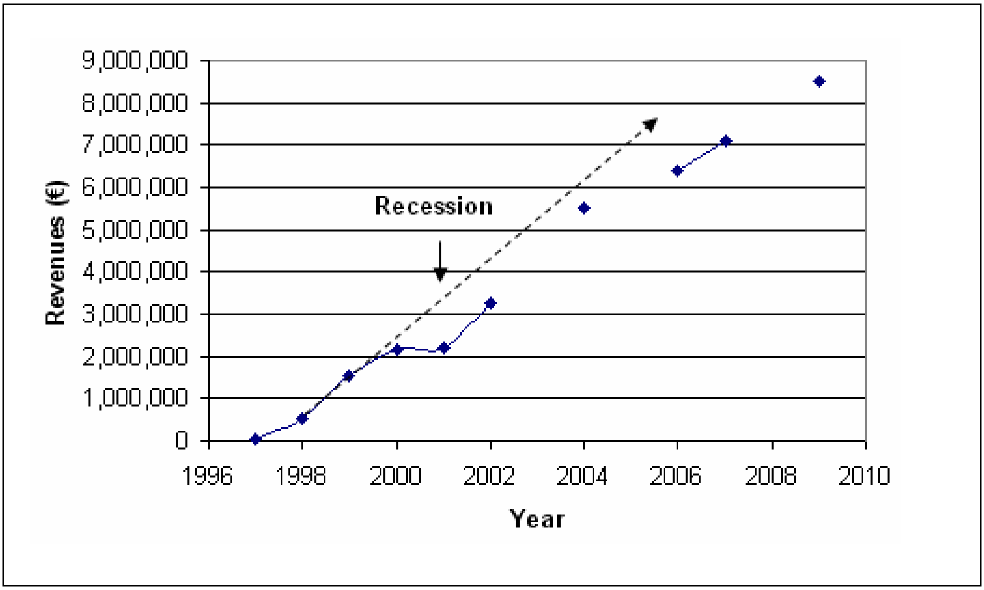


Figure I.123, continued.

German WITec GmbH (from Ulm in Germany; B.2) started 1997 with a real customer and some more customers with purchasing intentions and provided reliable expected values of profit data for 1998 [Koenen 2010]. This opened options to choose among three banks which offered needed loans for expansion (financial resource base). WITec's initial architecture is additionally characterized by a favorable leadership team (Table I.41, Figure I.73) and resource building.

Since 1998 revenues of WITec exhibited strong linear growth (squares represent real data, the dashed arrow extrapolates early revenue data). CAGR (Equation I.10) between 1998 and 2009 is ca. 29 percent. Since 2000 productivity of WITec is extraordinary and consistently around €271,000 per employee (configuration in Table I.80). WITec shows both innovation and investment persistence.

WITec could finance its growth essentially from generated cash-flow ("organic growth"; Figure I.127). In 2010, however, it added non-organic growth to its strategy. It acquired a majority stake of the Ulm company omt optische messtechnik GmbH which focuses on industrial process control.

Figure I.123: Revenue development of German WITec GmbH.

Similar situations of initial configurations (Figure I.124) when entrepreneurs start with customers with foundation of the new firm are the management buyout (MBO) and business succession (as described for Aluplast GmbH and KWO, B.2). A key differentiator here is the architecture with regard to education and/or experience of the entrepreneur(s). Admittedly, business succession is rarely a "new firm." It could be one, if the successor(s) reduces activities in the old business considerably and adds a new one or changes over to a totally new business model for the firm.

If there is an *a priori* strong interconnection of the founders' intentions and an explicit goal, there may be situations happening inside or outside the company that require changing the path. Furthermore, if the founders evaluate particular paths to be equivalent so that they cannot decide which path to follow they find themselves in a situation of "experimenting" – probably by trial and error.

The theme remains, but the way of implementation and execution changes. Then, it is of extreme importance to stick persistently to the vision and the essence of the goal – there must be *goal persistence* (Figure I.122). Take, for instance, the US company PayPal (A.1.7) that provides people the opportunity to pay online. Recently, payment by PayPal became also available for smartphones and PC-tablets.

According to Wikipedia, PayPal, founded in 2000 as a merger of two startups, is an e-commerce business allowing payments and money transfers to be made through the Internet ("e-payment"). Online money transfers serve as electronic alternatives to traditional paper methods such as checks and money orders. A PayPal account can be funded with an electronic debit from a bank account or by a credit card. The recipient of a PayPal transfer can either request a check from PayPal, establish his/her own

PayPal deposit account or request a transfer to their bank account. In October 2002, PayPal was acquired by eBay for $1.5 billion (ch. A.1.7). PayPal dominates e-payment globally.

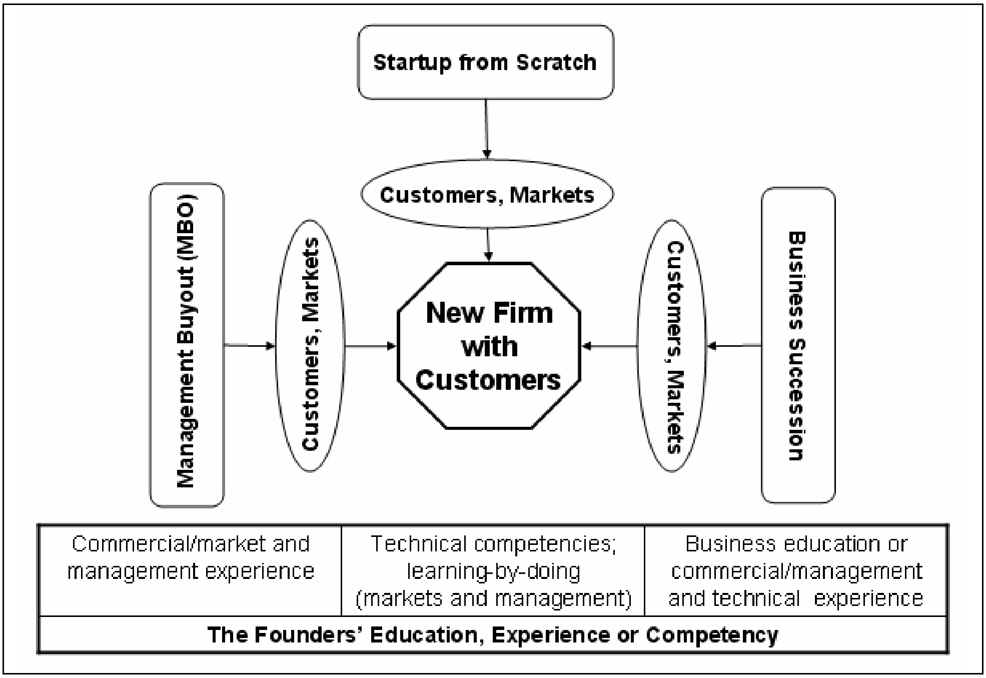


Figure I.124: Initial configurations for new firms having customers with foundation extended to management buyout (MBO) and business succession as an aspect of entrepreneurship.

According to Reid Hoffman who is also a co-founder of LinkedIn (ch. 3.4.2.1; B.2), over the years PayPal has made *multiple significant pivots*. The company started as a mobile encryption platform. Then it was a mobile payments company. Next PayPal was a combination of mobile and Web site payments company. Finally PayPal became an email payments company.

Each pivot over the life of the company was the result of *rethinking the business but maintaining the vision.* The focus was always to become a *payments operating system*; but the nature of the operating system changed multiple times [Hoffman 2010]. Such *goal persistence* can show up when it is operationally possible to accept long-term duration of developments to reach the goal (versus short-termism).

Goal persistence will be intimately related to the reason why to become an entrepreneur (Table I.39, Table I.40, Figure I.66), for instance, if the entrepreneur follows a vision or dream or wants to transfer science or technology into applications. In this case there is a directional relation to addressees, customers and markets.

On the other hand, if the driver of *firm's foundation is reflexive to the entrepreneur*, such as wealth generation, having self-determined work or seeking challenges, rather than goal persistence entrepreneurship may follow a path of *opportunistic adaptability* (ch. 2.1.2.4) indicated as an option in Figure I.122. However, focusing on self-determined work and independence without a clear direction following *opportunistic adaptability* may end up in a situation to be one's boss for a business one is able to manage, but does not like or is not convinced of.

Furthermore, goal persistence does not make sense, if the founders of a new technology venture recognize during the very early ("thrust") phase of their startup that their business idea will not materialize. Such a *false start* requires an immediate change of business direction and redefinition of the business goal ("failing fast" principle [Runge 2006:787]).

A corresponding situation is described for the 3M Corporation (ch. 1.2) or more recently observed for the German startup NanoScape AG which appears currently as a provider of porous, nanocrystalline materials (particularly nanocrystalline zeolites) and a developer of tailored application solutions for the CleanTech markets. Customer orientation of NanoScape means modification of NanoScape's materials to suit the needs of each individual application or adaptation of NanoScape technology to fit its customers' processes.

The road to the current orientation, however, was rather illustrating. NanoScape AG, founded in 2001, is a spin-out of Ludwig-Maximilians University in Munich (Germany) and the Fritz-Haber Institute of Max-Planck Society in Berlin. It was highly awarded in a business plan competition and got much publicity in the media through its catalytic (nanotubes-based) process of producing styrene, a fundamental raw material for the chemical industry (with the prospect that the technology could halve the cost of making styrene, targeting bulk chemical producers such as BASF, Dow and RoyalDutch Shell as customers) [NanoScape 2002; NanoScape 2005; Marsh 2003].

However, the original business orientation on catalysis and high-throughput technologies did not materialize which the founders realized soon. Due to the (dot-com) recession the founders encountered additional problems of financing. Hence, they ceased activities in the area of carbon nanotube catalyst development and some other activeties and repositioned their business model. NanoScape has so far survived on equity investments totaling less than €1 million. With 13 employees, it has built sales up to about €1 million in 2008 [Marsh 2008].

The NanoScape founders characterized their false start in the following way:

> "After an exciting jump start in the wrong direction NanoScape has now the right position to start toward a successful future."
> (in German: "Nach einem begeisternden Frühstart in die falsche Richtung ist nun die NanoScape in der richtigen Position, um einer erfolgreichen Zukunft entgegenzustarten.") [NanoScape 2005]

The additional lesson learned here is: Even being perceived as a high potential start-up on the basis of a business plan assessment and gaining general recognition and much attention in the public are no secure basis and guide to establish a successful NTBF.

The same can appear even to large firms. For instance, Dow Chemical won an R&D 100 Award regarded by The Chicago Tribune as “the Oscars of Invention” for developing a new plastic material, ethylene styrene interpolymers introduced as INDEX® Interpolymers, which was a novel family of plastics. However, this “new-to-the-world plastics flopped” terribly [Runge 2006:280].

Expanding the Resource Base by Networking

Finally, the role of *networking providing resources for startups*, not necessarily only for their initial architecture or configuration, has been described for the national innovation systems in terms of the concept of a “networked economy” (ch. 1.2.6, A.1.3; Figure I.39, Figure I.51). In its function to provide tangible (financial) and intangible resources to startups, such as access to analytical, testing or information services, corporate venturing (CV) arms of large firms (ch. 1.2.7.2; Figure I.125) are special. Corporate venturing, for instance, is not amenable to all kinds of NTBFs as CV follows either a strategic intent or specific interest in a particular technology and market(s).

CV may appear as the lead investor who then increases credibility of a startup to catch also other investors. Additionally, access to resources like those of the investing firm, for instance, to analytical or testing services and consulting, is also possible by networking with universities or public research institutes, as described for IoLiTec GmbH (A.1.5) and in many other case studies (B.2).

Variability of resources in a networked environment promises that there is scope for NTBFs to obtain leverage from financial resources (“smart money”) affecting access to other resources (ch. 5.2) and tackling different aspects of resource requirements of the NTBF. But there are also pitfalls. The startup’s leaders may not be aware of the gain of knowledge and experience of their (human) resources cooperatively involved with partners of the investing firm and, hence, may not fully leverage the (CV) resource from a strategic point of view.

The other situation concerns the situation if the firm investing in the startup will be simultaneously a customer, which may look for customized products. This apparent advantage may turn to serious problems when the initially favorable configuration of having a customer (and also money) becomes flawed.

For instance, as part of the business model of the US NTBF Nanophase Technologies (Figure I.140), the company expected its market partners to fund equipment that is primarily dedicated to produce their partners’ products – not just only providing equity and consulting and services with the characters of an alliance.

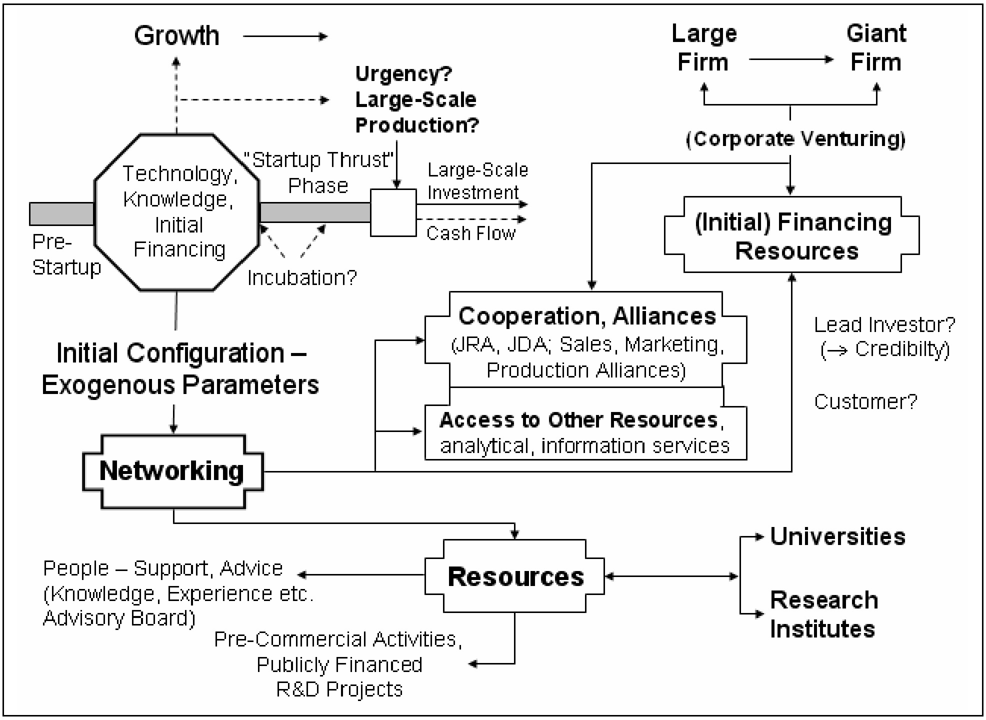


Figure I.125: Example of leveraged startup resources by networking with corporate venturing and academia.

German specialty chemicals firm Altana uses Nanophase's nanomaterial products as ingredients and additives for paints, coatings, polymers, plastics, inks and sealants under its NanoBYK brand. Altana made a $10 million equity investment in Nanophase during 2004. Altana also lent Nanophase $1.6 million to purchase and install nanomaterials production equipment during 2006 to support capacity requirements related to volume growth.

Early, during 2000, also German chemical giant BASF loaned Nanophase $1.3 million to purchase and install production equipment to produce nanomaterial products for its Z-Cote brand (zinc oxide into sunscreen applications). In particular, the role of BASF as a customer of Nanophase turned out to be highly critical (Figure I.140).

Apart from acquisition of an NTBF after corporate venturing into an NTBF (for instance, hte AG, B.2) also a marketing and sales agreement with a large firm may ultimately lead to acquisition, if the alliance was viewed as a strategic partnership with the NTBF (Closure Medical [Runge 2006:99-101] or Solvent Innovation GmbH; A.1.5).

More "Interruptions" for NTBFs' Developments

What was widely observed in the past and also in the present for a startup's initial architecture (for instance, in biofuels; A.1.1) is that its need of large investments often means a change of ownership to venture capital or similar investment firms with additional significant changes in leadership/management, fast increasing number of employees, organization and imposing urgency of development.

Figure I.126 illustrates these situations, often for startups aiming at large-scale production, referring explicitly to a VC case (cf. also Equation I.11). In this case not just the strategy of the firm to reach the firm's goal may be changed, but even the original goal may be changed.

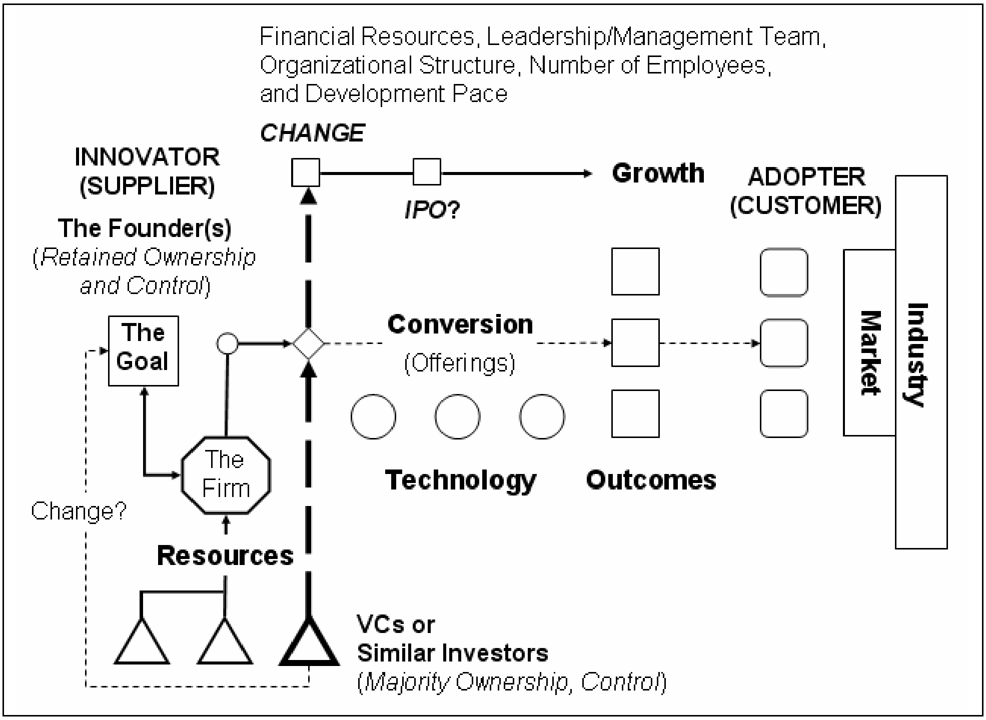


Figure I.126: Leadership/management change and equity ownership/control changes inducing organizational implications.

On the other hand, also changes of a startup's leadership/management to professional management or persons with profound leadership/management experience in industry or large research institutes without affecting ownership and control may be associated with a notable change of organizational (and probably strategic) settings.

Both effects can be expected to significantly influence development (and growth) of young firms, as does the "management crunch" (Figure I.118) for privately held

NTBFs (with full or majority ownership and control). We regard all such effects as relevant “interruptions” for new firm development.

A further related notable effect of cash influx for the young firm’s development is a rather early IPO issuing public stocks which may or may not affect the majority stake situation. Going public of startups sometimes occur very fast, three to five years after foundation. Examples are the US Internet firms Groupon (founded 2008, IPO 2011; ch. 3.4), Zynga, Inc. (foundation 2007, IPO 2011; ch. 3.4.1.1; B.2) and Google (founded 1998, IPO 2004; Box I.24, Figure I.159) and German Xing AG (founded 2003, IPO 2006; ch. 3.4.2.1; B.2).

Basically, after initial financing and early commercial activities growth of NTBF may proceed along two different processes (Figure I.127):

- Organic growth:
  Growth essentially by own resources of the firm (cash flow or ownership and control keeping financial options)
- Non-organic growth:
  Growth through investment in other (micro or small) firms or acquisitions of or mergers with other (micro or small) firms.

While developing organic growth resembles the same entity to wind up by persistent innovation and investment cycles to reach the goal(s). Non-organic growth resembles an independent loop initiated by investment in a different entity – a new asset. The value results from financial contributions and – hopefully – also particular synergies of resources. Both kinds of processes may contribute to the overall observable growth. In case of a merger or acquisition to generate a new firm issues relate essentially to leadership structure, creating a generally accepted (new?) mission and fit versus clashes of firms’ cultures.

> Due to the amount of money involved investment at any level in another company may represent an “interruption” of a firm’s development path in the sense of Figure I.122.

Non-organic growth by acquisitions is often associated with a change to a group (“holding”) structure of several firms at different locations. Legally, the “holding” covers controlling the individual “subsidiaries.” The other option is integrating the acquired firm at the location of the acquiring firm. Very fast growth of startups is often achieved by non-organic growth (LinkedIn and Zynga; ch. 3.4).

Basically, both modes of growth will (have to) be linked to innovation and investment persistence.

In the context of entrepreneurship non-organic growth has notable consequences. When observing numbers of employees (or revenues) a jump in the figures may lead to erroneous conclusions concerning the firm. And concerning the embracing economic system, the total number of jobs created by firm merger or acquisition may not have increased. On the contrary, firms' mergers and acquisitions are often associated with job losses.

A central issue of investment decisions and activities (illustrated by Figure I.154) is associated with the firm's deciding on

- invest following demand or
- invest anticipating (before) demand.

For instance, private firms relying much on generated cash flow for development tend to invest after demand (Box I.20).

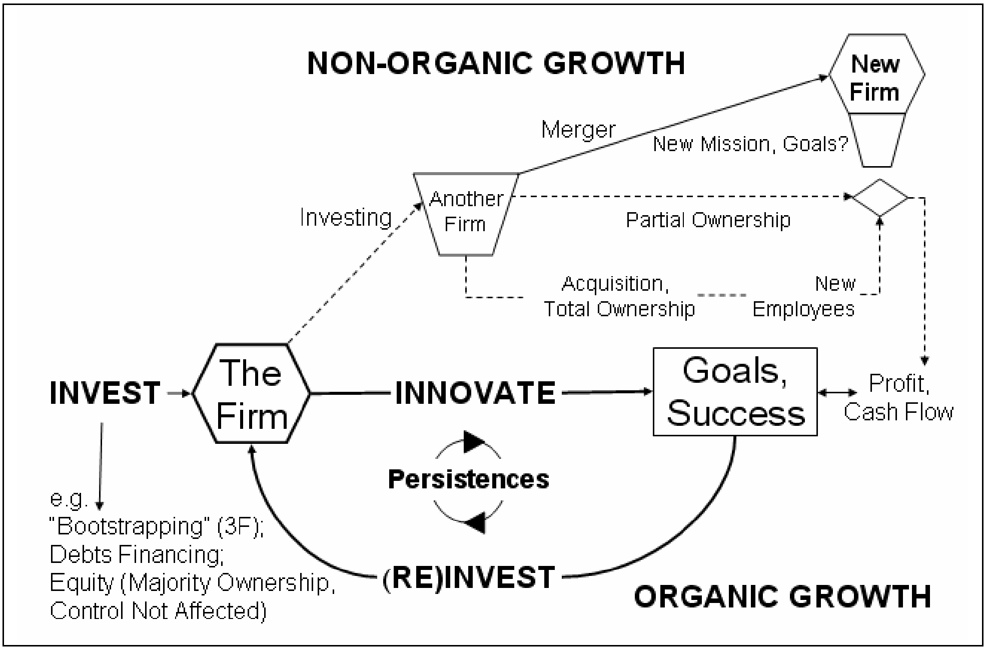


Figure I.127: Differentiating organic and non-organic growth of (new) firms.

The most prominent example of organic growth versus non-organic growth of NTBFs is the "Ford versus General Motors" case [Bhidé 2000:246]. The Ford Motor Company (FMC; started in 1903) evolved in line with Henry Ford's engineering and manufacturing interest and was build essentially using initially raised capital from friends. He turned his vision of large-scale production to manufacture cars that everyone could afford through raising capital without losing majority control.

General Motors (GM), founded by William Durant, followed a different route. In its early years it grew through acquisitions of smaller companies then in the automobile production rather than building its own plants, for instance, in 1904 the Buick Motor Company etc. GM as a holding company for further acquisitions was formed in 1908.

Organic growth and non-organic growth may occur very early during the development of the NTBFs, already during the startup thrust phase. And there is no way to differentiate these processes referring to the typical growth indicators – revenues or number of employees.

A striking example is the Nanogate AG [81] / Nano-X GmbH (B.2) cases in Germany. Here, both NTBFs where spun out at almost the same time from the same research institute, both having a person with high leadership/management experiences in the foundation team and both targeted markets for surface coatings on the basis of chemical nanotechnology. Both firms had different initial financing sources and very different growth strategies, in particular, non-organic growth versus organic (Figure I.137, Figure I.141).

Furthermore, it seems that firm's foundation by persons with deep and broad experience in technology, markets, management and simultaneous responsibilities for several subsidiaries of a large firm are more ready to build their grow strategy on non-organic growth (ATMgroup AG, B.2).

Finally, on their road to SMEs based on organic growth, ten or more years after start-up, NTBFs may also select non-organic growth as an additional path to growth. This is observed, for instance, for the German optical instruments ("nano-tools") firm WITec GmbH (Figure I.123). On the other hand, the German optical instruments firm JPK Instruments AG, which addresses similar markets as WITec with a related technology followed non-organic growth rather soon after foundation (Figure I.141). Also Google followed a non-organic growth path (Box I.24).

Features of new firms' development described so far in terms of a general systems view, using teleology and specific effects from inside and outside the firm influencing further development, suggest evolutionary models to contribute to additional insights into growth of new firms.

Evolutionary models [Bhidé 2000:249-254; Runge 2006:7-8] essentially map startup and firm developments to Darwinian Theory of hereditary factors as the origins of change variations and "natural selection." Accordingly, history (of the initial architecture) matters – and firm development would be largely "path-dependent" unless a "mutation" induced by external factors gives rise to spontaneous and permanent change in the DNA of a "gene" of the firm.

In Darwinian Theory hereditary factors are determined by the principle of homology. Hereditary factors will only be transformed in small steps and the degrees of freedom of these hereditary factors will be retained (under negligible or slowly changing external conditions) and will only change according to certain patterns. In social systems, for instance, one has processes of homologation for values and behavior of persons, layers of groups and larger organizational units.

The related Darwinian natural selection according to reproductive fitness, however, cannot explain all the shaping. Functionality has to be differentiated from "pattern formation." *Structural evolutionary theory* is concerned with pattern formation and works to explain why Nature favors relatively few structural archetypes. It limits the choices available for selection and explains formation of similar patterns as "*Variations on a Theme*." Some aspects of this theory can be used for a GST approach to development of firms (A.1.6).

4.3.3 Resource-Based Views

Entrepreneurs who are involved in the early stages of business creation are unlikely to become preoccupied with life-cycle issues of decline and dissolution. Inspection of major factors for decline of young firms refers often to lack of resources (Figure I.114, Figure I.115) – often already at the start of a new venture.

"What an organization knows at its birth will determine what it searches for, what it experiences, and how it interprets what it encounters" [Huber 1991:91]. One implication is that a new firm's learning and capability accumulation may influence its decision-making and paths of development markedly (cf. Figure I.129 and below text).

When dealing with startup architectures and configurations and their significance for the development of young firms the previous discussions have emphasized a number of *tangible and intangible resources* (Table I.8). Some of them are sufficient, some being necessary and some fulfilling both requirements to expect viability and growth of a technical startup of a particular type (RBSU, Other academic NTBF, EBSU).

Apart from country-specific factors, we dealt, for instance, with a variety of resources of the entrepreneur(s) or the startups, respectively. Personality (ch. 2.1), cognitive abilities, creativity and revealing opportunities, education and experience (ch. 2.1.2; 3.2, 3.3), personal competencies (Figure I.72), a team for firm's foundation (ch. 2.1.2.4; Table I.41, Figure I.72, Figure I.73) and team extensions (including an Advisory Board), communication and coordination (ch. 2.1.2.4), networking and cooperation issues (ch. 4.3.2), financial endowment (ch. 1.2.7) etc. were emphasized.

We also dealt with macro-economic events like recessions, markets, industries, competitors and national legislations etc. and interconnected endogenous factors of a firm's internalities with exogenous factors from external analysis (Figure I.114, Figure I.115). Finally we observed a "strategic group" in Germany with very similar architectures to exhibit from the start good to high growth patterns to become mid-sized or large firms (Hidden Champions, ch. 4.1.1).

Concerning viability and growth of startups all this directs special attention toward *resources* (ch. 1.2.5.2) *and sustainable competitive advantage*. Hence, it is important to inquire into the role the economics-oriented resource-based theory or the resource-based view (RBV) [82] of firms [Bhidé 2000:214-216; Alvarez and Busenitz 2001] and which role it should or can play for dealing with developments of new technology ventures in the context of technology entrepreneurship.

Resource-based theory was extended to include the cognitive ability of individual entrepreneurs [Alvarez and Busenitz 2001], but having corresponding attitudes, aspirations and intentions to act and pursue resources are also important. *Resource heterogeneity* is the most basic condition of RBV and it assumes at least some resource bundles and capabilities underlying offering generation are heterogeneously distributed within the firms.

Competency and skill heterogeneity of the founder team has been discussed (ch. 2.1.2.5; Figure I.68, Figure I.72, Table I.41). Skill heterogeneity plus a constraint is emphasized, for instance, by a founder's experience: "Early on, one of the most inspiring lessons we learned was the value of bringing people together with different backgrounds and skills" but, furthermore, "almost all {interviewed founders} would agree on the importance of getting the *right people*, based not just on their expertise, but on their attitude as well." [DeFrancesco 2004] This attitudinal aspect was also a reason to dissolve the founding team (in agreement) of the German NTBF Attocube AG (B.2).

Driven essentially by the currently dominant view of corporate strategy RBV regards a *company as a collection of resources and "capabilities*." In RBV a **capability** is usually considered a "*bundle*" of assets or resources to perform a business process (but cf. Equation I.2). The business is composed of individual activities or, in the sense of GST, a "*system of activities*." For instance, the product development process involves conceptualization, product design, pilot testing, new product launch in production, process debugging, marketing etc. across the firm's functions – for NTBFs usually tasks and roles for activities along a value chain (Figure I.7).

Note that in RBV it is generally assumed that resources are tradable and non-specific to the firm, while *capabilities are firm-specific* and are used to engage the resources within the firm. [82]

However, a firm will usually focus on certain capabilities consistent with its strategy or, in case of entrepreneurship, with strategy logics to reach the founders' goal. The resource-based perspective fits the GST framework if it highlights the need for a fit between the whole external context in which a company operates and its internal capabilities and potentiality (Equation I.2).

That is, *dynamic capabilities* (ch. 1.2.1) are required, the adaptability to the environment to renew and re-configure the competencies in response to key factors and conditions of the environment.

The essence of the resource-based perspective is a *knowledge-based view* and taking GST this will include foreknowledge which means *intelligence* (ch. 1.2.3). This is associated with a particular constraint. Tacit knowledge (or technology) which can be learned only through personal experience is an example of know-how as a resource that is difficult to have or transfer *ex ante* (before or on foundation). Furthermore, assuming bounded rationality (ch. 4.2.2) cognitive limitations imply that no two individuals possess identical stocks of knowledge.

That all means, entrepreneurship and RBV adopt precisely one common unit of analysis – the resource. These resources may manifest themselves in several different ways and different phases of NTBFs' developments.

One kind of difference occurs in the ways entrepreneurial leaders and managers of small versus established (large) firms utilize the resources to exploit (business) opportunities. Another important difference is that for NTBFs founders often learn on the job how to utilize and build up resources, for established (large) firms there are educated and trained "professional managers." And importantly, the relevance of resources emerges in the face of competition when the NTBF must answer four questions about its competitors' resources:

- How do they compare in terms of size and components?
- How efficiently are they used?
- How effectively can we learn from their experience and practice?
- How do we maintain our own competitive advantage?

According to RBV each organization is a collection of *unique* resources and capabilities that provides the basis for its strategy (logics) and that is the primary source of its *performance* and, hence, returns. According to common views [Autio et al. 1997] to provide a competitive advantage resources and capabilities must exhibit the attributes listed in Table I.75.

Table I.75: Key attributes to provide competitive advantage.

Attribute (VRIO)	Resources, Effects
Value	Allow the firm to exploit opportunities or neutralize threats in its external environment with the resource/capability
Rarity	Control of the resource/capability, possessed by few, if any, current and potential competitors
Imitability (Non-substitutable)	When other firms cannot obtain them; the significant cost disadvantage to a firm trying to obtain, develop or duplicate the resource/capability
Organization	The firm is organized appropriately to obtain the full benefits of the resources/capabilities in order to realize a competitive advantage (cf. also Equation I.2)

For NTBFs value and imitability in the sense of VRIO is related to *technical value* concerning the producer/supplier (ch. 1.2.5.2). To the supplier or producer technical value is measured by how *protectable from the competition* the product is or how *exploitable* the product is as a basis for further offerings, for instance, based on a platform technology (Table I.12). A discussion of applying the VRIO-approach to the competitive advantage for a startup in the new technical field of “ionic liquids” is discussed for the case of German IoLiTec GmbH (A.1.5, B.2).

The resource-based view suggests that *heterogeneity* is necessary but not sufficient for a sustainable competitive advantage. For instance, it has been shown that often heterogeneity requires interfaces or gatekeepers or management of these, respectively, reducing inherent barriers imposed by the differences of particular (human) resources (ch. 1.2.3; Figure I.20, Figure I.73).

As Conner and Prahalad [1996] argue, any (strategy-oriented) theory that seeks to understand performance differences between firms must incorporate a theory that addresses the question of why firms exist. This key question is also fundamental for GST and its emphasis on purposeful behavior and the strive to reach goals. It is tackled with regard to the entrepreneurs’ reasons and motivations to found a firm (ch. 2.1.2.5; Table I.39, Table I.40), the ideas and opportunities they pursue (ch. 3) and the risk they take and decisions and actions they make (ch. 4.2).

Often it is the founder (or founding team) who possesses much of the technical and managerial knowledge that make-up the assets of the firm. Hence, an entrepreneur’s expanding knowledge base and absorptive capacity may become the entrepreneurial firm’s competitive advantage. Furthermore, concerning intangible assets these are (almost) inimitable because they have a strong tacit dimension and are socially complex.

In the entrepreneurship domain, tacit socially complex assets are often also directly generated by the founder(s) and spread across the organization, such as firm’s culture (Figure I.120) and hiring and developing human capital (Figure I.121). These are *idiosyncratic assets*, distinctive, even unusual features of individuals that are more valuable when used in the particular firm than outside of the firm. Such assets tend to be difficult to observe, describe and value but have a significant impact on a firm’s competitive advantage.

Related, in an interview [Hof 2008], one hears from Eric Schmidt, then Google’s CEO, how Google manages the tricky process of innovation and its relation to corporate culture which is not transferable:

> “Why aren’t many other companies doing this, too? I think it’s cultural. You have to have the culture, and you have to get it right.
>
> So we’re likely to see even more acquisitions by Google? I would think so. But small. The likelihood of us doing big things is pretty low because we’d have to assimilate the culture. Nobody works the way we do. The Google culture makes sense if you’re in it, and no sense if you’re not in it.”

RBV sees companies as different collections of tangible and intangible assets and capabilities, which determine how effectively and how efficiently a company performs its functional activities. To apply RBV it is essential to *identify the firm's potential "key" resources*.

> According to GST, however, the perspective of RBV has to be complemented. Resources are dependent on interactions and combinations with other resources and therefore *no single resource or a set of individual resources* – tangible or intangible – *can become the most important one for firm's performance. Resources and capabilities form open systems* which require time to achieve a quasi-equilibrium but, due to the open system paradigm, they will evolve over time – even in a phase of stable growth (cf. ch. 5.2).

Open system means: the system under consideration is adding or destroying, increasing or decreasing, exchanging or sharing mass-based or power-based assets, information, people and values (including money) with other systems.

Systemic effects in small or large firms do not only emphasize interactions of resources, but also feedback and reinforcement mechanisms, *largely out of the control of leaders/managers, which affect the firms' development (growth)*.

The processes of *combining, organizing and leveraging resources let "new" systemic resources emerge*. For instance, sharing knowledge resources within a network of partner firms may add to the originally shared knowledge resource of the individual partner; close customer relationships and common projects may add to the innovativeness of the "supplier."

For technology entrepreneurship Autio and Garnsey [1997] introduced, for instance, an extended RBV model emphasizing a firm to be an open system interacting with others in its environment to identify incentives and constraints which originate from the environment and those which form through the internal dynamics of growth. This RBV extension concerns the influence of network relationships (Figure I.51, Figure I.125) on growth processes and competence building.

The authors take growth-reinforcing and growth-offsetting effects into account that determine the firm's capacity for resource accumulation. They present a systemic evolution model which, however, is a specialization to NTBFs founded either as a spin-out firm or as a private venture. The technology, application, and the capabilities of the management team determine the potential of the firm to reach stand-alone growth.

The development path follows a link of the NTBF to an innovation network or manufacturing chain. Within these structures there is scope to obtain leverage from resources and to pursue external opportunities. The internal pressures will be reinforced by external pressures in the growing firm, as funders, customers and distributors call for expansion so that as a next step a cluster is formed.

In the approach of Autio and Garnsey [1997], for individual firms there is the opportunity to *grow with the network*. But, at this point, the NTBF is often very dependent on a network's "locomotive firm" which drives the development. As an example that has been observed in practice the many of Nokia Corporation's small supplier companies in the Finnish telecommunications industry are hinted at.

Therefore, apart from the business idea and opportunity, according to RBV *assessing startups* will have to put a strong emphasis on *people and organization*:

- Most of the value of the venture is attributed to people – the entrepreneur and his/her "team" – a key resource.
  People build the startup; leadership, corporate culture and execution associated with a sense of market urgency are important.
- The other large part of value of the venture relates to a successful and *sound structure* and *processes right at the start*.

Without a structured and validated offering development, operation, market, sales, and financial *plan* (reasonable financings) *and team for execution* the entrepreneur(s) will constantly reacting to competitive or other forces and will be often in "fire fighting mode." Entrepreneurs cannot expect, in uncertain businesses, to gather reliable data on potential demand and competition. In many niche businesses the specific information generated by *doing* is therefore more valuable than excessive search for relevant information [Bhidé 2000:59].

One can believe that a technical startup merits a positive "premoney valuation" derived from intellectual properties, human capital and other intangible resources (Table I.8). The capacity of *Inc.* companies in the US [Bhidé 2000:29] and NTBFs in Germany to finance high growth rates through internally generated "funds" (cash flow) suggest that their profit margin were significant.

The founders' capacities to *differentiate their offerings* through their personal efforts seem to be an important reason for profitability (cf. CEOs' knowledge of customers with Hidden Champions; ch. 4.1.1). The entrepreneur(s), rather than a product or technology, represent the source of the startup's profits [Bhidé 2000:47] – and the firm's productivity and performance.

As a summary, the question is whether a firm's model *defining a firm as a distinctive bundle of assets, resources and capabilities* (a firm's "business system") and *characterized by a related portfolio* allows explanation or even reliable expectations and has prescriptive implications for new technology ventures. Here, the following restrictions are notable.

The resource-based model refers to a constellation at a particular point in time, usually in the past to describe and explain the development of a firm to that point in time and often uses that for "predicting" future developments – mostly without considering developments of the firm's human resources and the role played by developments of social interactions of employees, such as the formation of "Communities of Practice" (CoPs) [Runge 2006:372] and reinforcement of behavior (Figure I.129), information resources for decision-making of the firm's leaders etc. (cf. Ashby Memory [84]).

In contrast, for instance, to an Input/Output (I/O) Model, the resource-based view is grounded in the perspective that a firm's internal constitution, in terms of its resources and capabilities, is more critical to the determination of strategic action than is the external environment. "Instead of focusing on the accumulation of resources necessary to implement the strategy dictated by conditions and constraints in the external environment (I/O model), the resource-based view suggests that a firm's unique resources and capabilities provide the basis for a strategy. The business strategy chosen should allow the firm to best exploit its core competencies relative to opportunities in the external environment." [Hitt et al. 2005]

RBV often assumes that resources are relatively immobile. However, both people (with tacit knowledge) and information are transient, both can disappear immediately. And this may be highly critical for young firms (with only few employees). Furthermore, RBV does not consider serendipity or luck as a factor of firm's foundation and growth.

Technology entrepreneurs can use market forms of governance and political/public forms of governance to coordinate many resources necessary to realize an economic opportunity (Figure I.59, Table I.30).

RBV refers essentially to (only) economic markets; the role of other types of markets (Table I.15) is non-existent or underdeveloped.

In particular, the massive interference of policy with technology entrepreneurship and support of (technology-based) SMEs and the direct and indirect resource provisions in terms of financial support, legislation (Box I.1, Figure I.34 ; A.1.1), research grants and networking in terms of competence networks, funding R&D projects, science and technology parks and clusters (ch. 1.2.6.2) restrict applicability of RBV to firm's foundation and early development to only selected aspects.

Finally, strategic orientations of technology ventures often follow several aspects which are complementary rather than exclusive:

- *Resource-oriented* - Resources of the firm push
- *Market-oriented* - The market drives
- *Interrelation-oriented* - Alliances and networking are key
- *Opportunity-oriented* - Fast opportunity identification and exploitation drives.

4.3.3.1 Bootstrapping a Technology Startup

Initial and growth financing of NTBFs relies very often on the founder's (founders') own funds and 3F funding as resources and subsequently on cash flow from business operations (Figure I.52; Table I.23 (for *Inc.* firms), Table I.24, Table I.25, Table I.26).

That means initial funding of a technology venture occurs to a large extent by "**bootstrapping**" (bootstrap financing). However, there is no generally agreed upon definition of the notion "bootstrapping." Often, it means "to start a firm by one's own efforts and to rely solely on the resources available from oneself, family and friends." [Dorf and Byers 2007:411-413] However, for most cases of German NTBF foundation dealt with in this book the startups did not rely only on resources available from the founder(s), family and friends.

A more elaborate definition is given by Eckmann [2008]: “Bootstrapping is a means of financing a small firm through highly creative acquisition and use of resources without raising equity from traditional sources or borrowing money from a bank. In short, ‘bootstrapping’ means starting a new business without external start-up capital.”

Here, on the one hand, emphasizing “creative acquisition and use of resources” opens the spectrum of accessible resources and methods of financing. On the other hand, it remains unspecified what actually “traditional” would embrace. Eckman adds a specification: “It is characterized by high reliance on any internally generated retained earnings, credit cards, second mortgages, and customer advances, to name but a few sources.”

Wikipedia [83] emphasizes that “financial bootstrapping is a term used to cover different methods for *avoiding using the financial resources of external investors*.” And, moreover, bootstrapping can be defined as “a collection of *methods used to minimize the amount of outside debt and equity financing needed from banks and investors*.” (Emphases added)

Emphasizing the notions “avoiding” and “minimize” the author thinks that last definition provides the necessary scope to discuss bootstrapping in the context of technology entrepreneurship where a wide variety of financial and other resources and methods of financing are available for entrepreneurs (ch. 1.2.7.3; Figure I.59, Table I.30).

The financial requirements of the startup and the availability of capital in the market will determine if bootstrapping is an appropriate means (ch. 1.2.7.1). But choosing that way is also related to attitudes toward the various sources of capital for technology entrepreneurs (Box I.20). Software-based ventures typically require less start-up capital than, for instance, either electronics or biotechnology ventures, thus is more likely to rely solely on personal funding (ch. 3.4). Furthermore, growth orientation (Table I.63, ch. 4.1) will also influence the decision for bootstrap financing.

Bootstrapping is often associated with the opportunistic adaptability approach of technology entrepreneurship when time and effort trade-off are considered: Many months spent trying to raise money (with no guarantees!) versus same time spent starting business, establishing proof of customer and product and building traction.

The interconnections of bootstrapping and opportunistic adaptability are lucidly described by Klaas Kersting [2012], the co-founder of German Gameforge AG and Flaregames GmbH (B.2). He put it into several steps for “Building a Startup” with the premise “fail early, fail often – and learn” (ch. 5.1).

- Find some money. (Hint: friends, family or fools are a good starting point.)
- Focus and prioritize (Hint: Just do the important things.)

- Get to market fast. (Hint: you don't know the market until the market knows you.)
- Know your numbers. (Hint: you cannot know too much.)
- Avoid overhead. (Hint: you might not need to hire your cousin as a consultant just yet.)
- Cash flow is everything. (Hint: buy low, sell high; collect early and pay late.)

Key questions for bootstrapping are:

- How much cash do you need, and when (Figure I.57)?
- If nothing changes, when will you run out of money?

For the early phase of NTBFs it is often difficult to separate acquisition of financial resources and methods of financing by business operations. Bootstrapping in the broad sense is characterized largely by high reliance on any internally generated monetary reserves. For understanding the role of business operations for bootstrapping basics of accounting and financing one can refer to Dorf and Byers [2007:403-436] and the author's Course Material (Handout Lectures 10-13; pp. 1-18) of the Technology Entrepreneurship Web.

Bootstrapping offers many advantages for technology entrepreneurs and is a good method to get a startup operating and well positioned to seek equity capital from outside investors at a later time – if needed. In particular, a business that makes money builds its credibility – with suppliers, employees and customers. Keeping costs *consciously* below revenues will position the company to survive in lean times which will always come!

> Fundamentally, NTBFs and RBSUs have the possibilities to go for capital focusing on research and development grants, scholarships, financial contributions or subsidies of federal or state governments, NGOs and national science organizations (such as, NSF or DFG) or grants for technology projects, which are sometimes cooperative projects (ch. 1.2.6, 1.2.7).

Learning the nuts and bolts of running a business takes time. Start learning from the birth of the firm.

The portfolio of bootstrapping targeting sources, methods and activities minimizing external financing (debt and equity) focuses simultaneously on expenses versus profits and cash flow. *Superior execution is the key* for the components of such a portfolio.

Basic operating expenses comprise ("buy low"):

- Location selection (cost of renting offices and laboratories, etc.; in an incubator, science or technology park – ch. 1.2.6) and networking including utilization of infrastructure of the parent organization, if the startup is a spin-out (RBSU) or the founder of an NTBF has strong ties to research institutes or academia.

- Renting (or leasing) sophisticated technical instruments or devices rather than purchasing them.
- Outcontracting selected activities of the NTBF's value chain through external contract services (ch. 4.3.1) or strategic alliances.

Profit orientation means

- Go fast to market (customers); have the ability to adjust to a rapidly changing industry or environment; build experience and know-how as you go.
- Focus on cash-generating activities (Hint: Just do the important things.).
- Look for quick breakeven (ch. 1.2.7.1, Figure I.53).

Offer high-value products or services that can sustain direct personal selling:

- (Bootstrapping) entrepreneurs should pick high-value products and services where personal salesmanship can replace an expensive marketing scheme.
- Meet customers' specifications; do not overshoot (Figure I.88).
- Provide high-value service and support to customers.
- Focus on one offering (of probably few more) which represents a "cash cow."
- Learn from the customer(s) and adjust the business model, if needed.

An issue of going fast to market is the question of *how to bring the product to market.* Is it going to require a change of behavior on the part of intended customers? Most startups *underestimate the difficulty, not to mention the time and money required, to get a product launched and established in the marketplace.*

Overcoming customer inertia is easier and cheaper if a product offers some tangible advantage over the alternatives. Concrete product attributes – with data to support – can lead to sales. Make the risk of dealing with the startup small for the customer as compared with the risks associated with not solving his/her problem (ch. 4.2.1.1).

Cash flow management ("is everything"):

- Keep cost to a minimum and have positive cash flow (ch. 4.2.3).
- Adjust the revenue (income) and expenses (loss) curves, the profit curve.
- Carefully track currency exchange rates, if the startup has international orientation.

In particular, "*working capital*" (ch. 1.2.7.1) is primarily concerned with the day-to-day operations rather than long-term business decisions. Managing working capital has to ensure a company has sufficient cash flow in order to meet its short-term debt obligations and operating expenses.

Following Investopedia "*working capital management*" is a managerial accounting strategy focusing on maintaining efficient levels of both components of working capital (Figure I.130), current assets (essentially cash, accounts receivable, inventories) and current liabilities (such as accounts payable), in respect to each other ("collect early and pay late"; defer your payments as long as possible).

The accounting entry accounts receivable (giving credit or allowing late payment by customers) are assets of the customer and must be financed by the startup. Accounts payable are a way of financing the startup's assets.

Accounts Receivable (collection of what a business/startup is owed)	The receivable conversion period (RCP) is the time between the sale of the final product on credit and cash receipts for the accounts receivable (cf. DSO).
Inventories	The inventory conversion period (ICP) refers to the length of time between purchase of raw material or input for production of the goods or service, and the sale of the finished product.
Accounts Payable (Payment of what a business/startup owes)	The payable deferral period (PDP) is the time between the purchase of raw material or input on credit and cash payments for the resulting accounts payable.

"*Days sales outstanding*" (DSO) is a measure of the average number of days that a company takes to collect revenue after a sale has been made. A low DSO number means that it takes a company fewer days to collect its accounts receivable. A high DSO number shows that a company is selling its product to customers on credit and taking longer to collect money (Investopedia).

Be careful with discretionary expenses, such as

- Going for a highly professional representation on the Web.
- Sales and marketing programs.
- Growth initiatives.

Keep growth in check:

- Start expanding, once the new venture starts growing while keeping the cost curve below the revenue curve (Box I.20).
- Expand at a rate that you can afford and control. This enables you to develop management skills slowly and to iron out problems under less pressure.
- Re-invest profit for growth; target investment and innovation persistence (Figure I.117, Figure I.127).
- Invest in new people if there is no other alternative, not in advance of needs (Box I.20).
- Hire workers the business needs (but only pay what you can afford).
- Develop people internally (Figure I.121).

Cultivate banks before the business becomes creditworthy:

- Keep good financial records, sound balance sheets.
- Look for bank overdrafts and line of credits.
- Prepare early for the next step of financing (ch. 1.2.7.3).

4.3.4 Cybernetic Principles and Concepts for Technology Entrepreneurship

Building on preceding and previous discussions and metaphors (ch. 2.1.2.9, ch. 4.1; Equation I.2) concerning observation and expectation we shall approach understanding and explaining growth of new (technology-based) firms by achieving appropriate qualitative or even quantitative descriptions.

At best, *expectation*, not prediction, will appear as being comparable with weather forecasts which are made by collecting quantitative *data about the current state of the atmosphere* and using scientific *understanding of atmospheric processes* to project how the atmosphere will evolve. However, incomplete understanding of atmospheric processes mean that forecasts become less accurate as the difference in time between the present moment and the time for which the forecast is being made (the range of the forecast) increases – being also one of the issues of RBV.

Observation will refer to *indicators* of tangible output, outcomes or benefits of a conversion process (Figure I.5). But input and the conversion process in terms of variables and parameters (ch. 1.2.1) will address often intangibles which will refer to *intervening variables* – interpretations of observed facts.

An intervening variable reflects theoretical processes that are assumed to take place between what is observed as the "before" conditions and the "after" conditions. The situation is displayed for learning as an intervening variable in Figure I.3. Consequently we shall often follow a "reasons for thinking that" approach rather than a "reasons why" rationale (Figure I.2).

Information on intangibles (firm's culture, leadership, entrepreneurial commitment, team interactions, interactions with the Advisory Board, networking, etc.) can, at least partially, be grasped by direct observation in the firm or by telling of the founders or the firm's employees or reporting by others. But we shall not know how founders will decide to respond to serious events or crises, unless observation takes place during such effects (cf. volition; ch 2.1.2, 2.1.2.9).

It has turned out that fundamental cybernetic principles and concepts can provide a basis for progressing. With regard to measurement of *human-activity systems* one often refers to a difference scale related to a concept of "change."

Following one of the fathers of cybernetics, in line with Ashby [1957], we shall assume in all cases that the *changes occur by finite steps in time and that any difference is also finite*. The change will occur by a measurable jump, a discontinuity or a "turning point" (in German Wendepunkt) of a measured curve reflecting growth or decline, if the change is tracked on the basis of an appropriate, measurable indicator.

In the sense of Equation I.6 we shall follow a differentiation between a *state* and its related characteristic in terms of an observable attribute, a value of the related *indica-*

tor. Within GST we concentrate on a system's states: A **state of a system** ψ is any well-defined representation of the conditions of its existence and an associated property that can be recognized if it occurs again.

Every system will naturally have many possible states. That which is acted on will be called the **operand**; the factor inducing a change will be called the **operator** (given in Script font similar to the Hamilton operator in Equation I.6), and *what the operand is changed to* will be called the **transform**.

The change that occurs, which one can represent by a relation in terms of a mono-directional graph, A → B, is the **transition**. A set of transitions, on a set of operands, is a **transformation.** The series of positions taken by the system in time defines a *trajectory* or *line of behavior* [Ashby 1957]. The transition is specified by the two states ψ_1 and ψ_2 and the indication of which changed to which.

$$\Delta\psi = \psi_i \rightarrow \psi_{i+1}$$

A priori, the transformation is defined in the sense of cybernetics, "not by any reference to what it 'really' is, nor by reference to any physical cause of the change, but by the giving of a set of operands and a statement of what each is changed to. *The transformation is concerned with what happens, not with why it happens.*" [Ashby 1957].

> Cybernetics does not treat things but ways of behaving. It does not ask "what is this thing?" but "*what does it do*?" and "*what can it do*?" (for which purpose) [Ashby 1957].
>
> However, with GST as the overall framework, to make these concepts *applicable* to the field of entrepreneurship, one must consider the related fields (psychology, sociology, economics, business administration, etc.; Figure I.1) and any kinds of their relevant observations and their ways of measurements, principles and concepts. This will provide an *abstract system* of combined theories, empirical basements, principles, concepts, etc. from the various (scientific) disciplines as the basis.
>
> The resulting abstract theoretical system will rely on "borrowed" knowledge, approaches and methods from the various involved fields. This means, a particular approach provided in one abstract system may be "switched" to another (usually higher) system to find an "appropriate" description or explanation or causal interrelationship for presenting expectations (or probably forecasts) for a company system under consideration as characterized in Figure I.128.

A **transformation** will be called **closed** if all the transforms involve only the elements of the original basis set (all transforms restricted to A, B, F, D) [Ashby 1957]. There is no "inflow" and no "outflow as in open systems.	{A B F D} ↓ {D B F A}

This set of transforms obtained contains no element that is not already present in the set of operands. A closed transformation creates no new element, the "domain" and the "range" being identical. And for non-interacting elements the closed transformation corresponds to a permutation. A large capital influx into a firm by investors would represent a typical "open transformation" which is common for open systems.

A test for closure is made by reference to the details of the transformation itself. It can therefore be applied even when one knows nothing of the cause responsible for the changes.

Furthermore, a transformation increasing the number of entities it acts on is an "*exact transformation*" in the sense of *self-replication* if the original is retained (copy of A B F D as above), otherwise it is a "*similarity transformation*" like (D B F A). Hence, in reality forming firm culture (Figure I.120) in this sense should be considered a similarity transformation rather than a copy.

A special transformation is the *identity transformation*, in which no change occurs, in which each transform the same as its operand is.

Which effect of a transformation we observe (or disregard or do not detect) enters essentially into our "*reasons for thinking that*." For instance, the change from a square with four corners to a four-pointed star, one with a fourfold and the other with a twofold rotation axis with regard to the plane in Figure I.2 can be achieved by similarity transformations such that the ratio of the two diagonals in the square and the stars is kept, leaving them invariant.

Hence, investigating or observing just ratios of diagonals and not additionally the shapes of the objects and the lengths of the individual diagonals "make both objects identical," the result of an identity transformation. Furthermore, there may be more attributes associated with change. Including also colors ("colored symmetries" [Shubnikov and Koptsik 1974]) for representing objects the right hand side of Figure I.2 exhibits three different objects (or systems).

A transformation is *single-valued* if it converts each operand to only one transform. If it is not single-valued and not one-to-one it will be *open* and correspond to a "one-to-many" situation.

A transformation of the kind

A	B	C	D
B or D	A	B or C	D

is not single-valued.

We have just seen that after a transformation $\mathcal{T}$ has been applied to an operand α, the transform $\mathcal{T}(\alpha)$ can be treated as an operand for $\mathcal{T}$ again, getting $\mathcal{T}(\mathcal{T}(\alpha))$, which is written $\mathcal{T}^2(\alpha)$. In exactly the same way $\mathcal{T}(\alpha)$ may perhaps become an operand to a transformation $\mathcal{P}$, which will give a transform $\mathcal{P}(\mathcal{T}(\alpha))$. Generally, operators are not commutative: $\mathcal{P}(\mathcal{T}(\alpha)) \neq \mathcal{T}(\mathcal{P}(\alpha))$.

In the current context of time developments a transformation of a firm's state emphasizing a change by an event ("interruption") will always refer to a current state. This means, for instance, an event that a venture capital firm (VC) participates in an NTBF (Figure I.126). Empirically founded, the transformation will induce a change by the combined or interrelated, respectively, effects of several factors which are sufficiently strong to be observable in totality after a certain period of time and described by the transformation Equation I.11. Here $\mathcal{V}\mathcal{C}$ is the corresponding operator changing, for instance, equity, ownership, control, management and number of employees and organization of the firm (Figure I.126).

Similar to Equation I.6 (ch. 2.1.2.9) the following notation will be used to describe the *intrinsic relation between the two components, operator and operand*. The result will be a changed state of the entity associated with an observable and measurable value *VC* induced by several presumed effects given in braces.

Equation I.11:

$\mathcal{V}\mathcal{C}\ |\psi_i> \rightarrow$ *VC* {add equity – (other, more) owners – other firm control – install management – add employees – re-organize firm}$|\psi_j>$

or, in short, $\mathcal{V}\mathcal{C} \rightarrow$ *VC* {add equity – (other, more) owners – other firm control – install management – add employees – re-organize firm}

The above notion separating contribution by dashes represents a "*systemic transformation*" were the various changes represent an overall change by the combined action of the given transforms. The dashes bare the relation to a representation by an "array." Viewed in this sense for an array to be unchanged, each component must be unchanged.

The effects of the individual transforms can rarely be observed in isolation. Moreover, a selected measurement by a selected indicator may not be meaningful due to the "impact time" periods of the individual "(non-systemic") transforms. These may be rather different. Compare adding equity being observable for a particular day or week versus number of employees observed at the end of the year or as a yearly average.

The particular types of measurement have different "time resolutions." In soft sciences the minimum or even common time span between two subsequent measurements that can be meaningfully interpreted (as a change) is the *resolution* of the measurement. For instance, tracking numbers of employees year after year will make most associated transforms with shorter impact time unobservable and will induce the transformation to appear as an overall systemic effect.

On the other hand, if there is a possibility to (largely) separate the individual transforms of a transformation ("weak coupling") we will continue to use the common set notation ("listing"), separating elements by commas {A, B, C, …}.

In our context, a transform with an observable effect would be, for instance, if an NTBF catches a very huge order of the NTBF's product from a major customer. On the other hand, changing the legal form of a limited liability company (LLC, GmbH) to a non-public stock company (AG in Germany) may represent a transform retaining largely everything else of the firm and may be a transform without any measurable effect on the other sub-states of the firm.

If we associate a transform with a measurable quantity of interest, the transform may turn out to be a "positive" ("growth-inducing") or a negative ("decline-inducing") change of the related particular measurable quantity. Consequently, existing *transformations are not necessarily observable*, positive and negative effects may level off, if they occur (almost) simultaneously.

In terms of cybernetics **control** was previously defined as the *purposive influence* toward a predetermined goal involving continuous comparison of current states to future goals ("is" versus "shall" assessment). The above transformation "$\mathcal{V}\ \mathcal{C}\ \rightarrow$ " with attributed transforms has an inherent shortcoming. It does not take into account any possible changes that concern the pace (time) to reach the goal or even modifying the original goal (Figure I.122, Figure I.126).

A *teleological relation* (start to end; Figure I.78) which may be associated with significant changes (observable through appropriate variables, parameters and indicators) can be viewed as a set of transformations. Specifically, according to GST, a *firm's foundation (the "birth") is the first transform* which causes the founder or founding team with their ideas and perceived business opportunities, motivation, aspirations and expectations to strive for their particular goal(s) by means of a firm. And this changes, for instance, their states of personalities (Figure I.16, Figure I.122).

Connected to the goal expectation can be viewed as a transformation of the personality. The entrepreneur as a firm founder, owner and leader with control over the firm has explicit qualitative and quantitative goals which induce expectations. Basically, there are founders who tend to emphasize keeping control over the firm (autonomy and vision) or making money (wealth) accepting venture capital, losing control as seen in Table I.39, Table I.40, Figure I.65 and Figure I.66. The corresponding "*entrepreneurial expectations*" $\mathcal{E}\,\mathcal{E}$ (*type*) can be represented, for instance, by Equation I.12. The second example is not single-valued.

Equation I.12:

$\mathcal{E}\,\mathcal{E}$ (*aspiration*, *motivation*) $\rightarrow$ (*autonomy, vision)* {confidence in own business idea – revealed opportunity – internal locus of control – perseverance – risk taking - tolerance for ambiguity – self efficacy – ownership/control – organic growth}
$\mathcal{E}\,\mathcal{E}$ (*aspiration*, *motivation)*$\rightarrow$ (*wealth*) {confidence in own business idea – revealed opportunity – internal locus of control – perseverance – risk taking – tolerance for ambiguity – self efficacy – accept venture capital – lose OR keep control – organic growth OR non-organic growth – selling firm is an option}

Following Ashby [1957], although the system may be passing through a series of changes, there is (often) some aspect that is unchanging. Hence, some statement can be made that, in spite of the incessant changing, is true unchangingly. The simplest case occurs when a state α and a transformation are so related that the transformation does not cause the state to change. Algebraically it occurs when $\mathcal{T}(\alpha) = \alpha$. That means, the state α is *a state of equilibrium* under $\mathcal{T}$.

The same phenomenon may occur with a set of states. Take $\mathcal{S}(\downarrow)$ to be a non-systemic transformation or one in which the operands of a state are only slightly coupled, that is *open* ("unclosed") and has *no state of equilibrium*, but exhibits a domain that generates no new state. Such a state is **stable** with respect to $\mathcal{S}$.

S(↓):=	*a b c d e f g h*	S(↓):=	*b g*
	p g b f a a b m		*g b*

Using transformations and the stability concept are associated with an issue of reducibility of a complex situation that avoids dealing with a situation that every factor (variable or parameter) had an effect, immediate or delayed, on every other factor. When a dynamic system can vary continuously, disturbances are, in practice, usually acting on it incessantly. For this reason the only states of equilibrium that can, in practice, persist are those that are "stable" in the above sense.

The (last b g) transformation is closed, so something persists, and the observer who looks only at this level of discrimination can say of the sub-system: "it persists," and can say no more [Ashby 1957]. Classification and taxonomy according to given criteria is related to such a persistence (Figure I.128).

> In a new firm's development there is *no invariant overall state* because different problems arise, affect particular sub-states and are addressed correspondingly in different ways leaving the "rest" stable. Without observations at the firm level and identifying the prototypical problems, the mechanisms and processes of growth as linked to expectation or goals remain obscure.

"That something is 'predictable' implies that there exists a constraint." If an aircraft, for instance, were able to move, second by second, from any one point in the sky to any other point, then the best anti-aircraft prediction would be helpless and useless. The latter can give useful information only because an aircraft cannot so move, but must move subject to several constraints. There is that due to continuity – an aircraft cannot suddenly jump, either in position or speed or direction. There is the constraint due to the aircraft's individuality of design" [Ashby 1957:132] and its "resources" (engine and fuel) determine the distance it can cross.

This reference to a process is essentially that of using a mapping – using a convenient (for instance, mathematical or graphical) representation rather than the inconvenient reality.

Figure I.128 summarizes the landscape of elaborated constraints for technology entrepreneurship which provides a "navigator" for the entrepreneur where he/she wants to be or be active in and the advisor or consultant to properly advise, propose and guide the entrepreneur and the entrepreneurship researcher to properly select criteria to create samples and interpret measurements and findings.

Leaving out a constraint reduces the strength of "prediction" and, in case of complexity, requires being very conscious about the limits of the domain of interpretations and even more "predictions."

The many seemingly different, controversial and even contradictional results and findings concerning growth of young firms [Garnsey et al. 2006] means that the people selected different constraints for inquiry and often are talking about different systems of investigation. The related issues of statistics are often associated with selecting a sample which is assumed to provide class properties and, furthermore, how response rates of questionnaires distort the originally selected sample structure.

For the taxonomies of industries related to characteristics of technologies (Table I.1; TVT, HVT) in terms of "*research intensity*" (RI = R&D expenses / total revenues) the differentiation is based on the proportion of financial quantification of research and development expenditures which cuts across industry taxonomies according to business or offerings.

Figure I.128 illustrates a fundamental dilemma of technology entrepreneurship, the complexity of constellations and the question whether and how results of macro-approaches have relevance for practice and, in particular, for individual entrepreneurs and those providing advice and consulting to them.

Industry taxonomy as given in Figure I.128 combined with firm type (RBSU versus other academic NTBFs) and ownership/control and financing (VC-based versus non VC-based) seems to be the bare minimum. How just one industry – biofuels – for understanding technology entrepreneurship has to be boiled down is illustrated in Figure I.183, Figure I.184, Figure I.185 (A.1.1.5) and Table I.17.

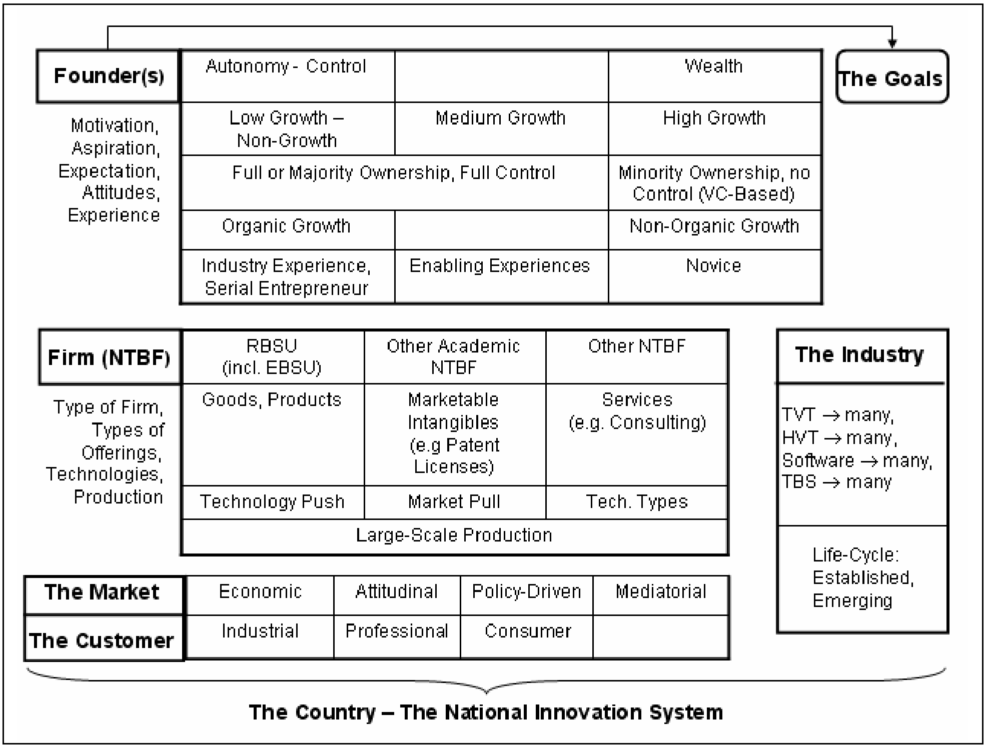


Figure I.128: Constraints as a basis of taxonomies for technology entrepreneurship to characterize configurations of NTBFs (read sub-tables from left to right).

And there seems to be even notable differences in industry segments in attracting entrepreneurial personalities. Entrepreneurs may take big risks to bring the latest scientific tools to market. For instance, the people who take personal risks to bring *new scientific instruments* to market are a special breed. *Many of these entrepreneurs are well-educated scientists* who could make a fine living working as consultants or as employees in high-technology companies. Yet they risk their livelihoods and their own money for the chance to start up their own firms [Reisch 2011a].

Stability is commonly thought of as desirable, for its presence enables the system to combine of flexibility and activity in performance with something of permanence, something “generic” which, for instance, is the focus when dealing with entrepreneurship over time (history) and space (regional culture; comparing Germany and the US).

Goal-seeking behavior is an example that stability around a state of equilibrium is advantageous. Nevertheless, stability is not always good, for a system may persist in returning to some state that, for other reasons, is considered undesirable or proceeding to some new state that is highly necessary, due to a changed environment.

In this way, these concepts may be used to explain and illustrate the transition from core competencies to core rigidities (ch. 2.2.1, Box I.8) as a combined effect of persistence and self-reinforcement ("success breeds success") resulting in a firm's "routines" and "routinized decisions" – how things are done here or how things are decided here (Figure I.129). This kind of persistence is, of course, a special property of the whole system focusing on just one aspect.

Self-reinforcement is essentially determined by decision-making self-reinforcement (that is, past acceptances make future acceptances more likely) and adaptive expectations (further belief in prevalence; Box I.17) (ch. 2.1.2.5).

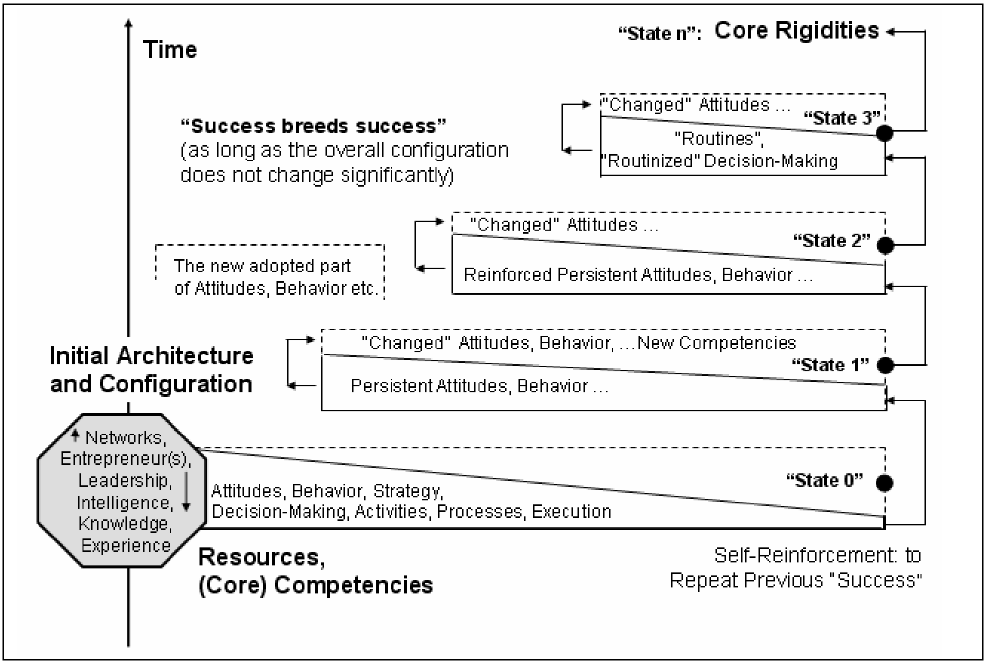


Figure I.129: The progression of core competencies toward core rigidities.

The descriptive path to "core rigidities" can help understand the well-known fact that the founding configuration (including firm culture) and the early development of a start-up influences further development of the firm. This means it can account for *path-dependency of NTBF development*, if observed or searched for.

If the founder has industrial experience (or is a serial entrepreneur) corresponding path-dependency (decision-making, behavior) may already enter the starting configuration of a new firm. The same is true if the founder(s) has hired early on an "experienced manager."

The Special Focus on the Single NTBF

The following approach to technology entrepreneurship and NTBF developments (growth) will have to make more use of concepts and principles of economics and business administration and findings (including situations in large firms) for NTBFs as given in this book so far and the author's previous book [Runge 2006]. The emphasis will be the entrepreneur(s) and the firm and *tracking changes of states of the firm through reference to mainly the finances related indicators*. The corresponding situation and framework is depicted in Figure I.130.

The use of an abstract system of concepts – principles etc. from various scientific disciplines for a GST- and cybernetics-based theoretical framework for (technology) entrepreneurship – refers also to the levels of describing phenomena. When dealing with growth of startups reference will be made, for instance, to how physics approaches the phenomenon of light. For light effects physics refers to a "particle model" (light as composed of discrete quanta called photons) and use this to explain the photoelectric effect and the "model of continuous waves" to explain light interference.

This approach is a reflection not just of the particular subject of inquiry, light, but for explaining experimental settings including interactions with a particular substrate or with itself. Hence, for a given experimental setting "behavior of light" can be explained for the particular context "as if …" According to the Copenhagen Interpretation of Quantum Theory, the wave and particle pictures, or the *visual* and *causal* representations, are "complementary" to each other. That is, *they are mutually exclusive, yet jointly essential for a complete description* of quantum *events*.

Switching between knowledge of different disciplines or using metaphors and analogies also means switching between epistemology. Epistemology is the investigation into the grounds and nature of knowledge itself. It is important because it is fundamental to how we think. Without some means of understanding how we acquire knowledge, and how we develop concepts, describe and explain in the various disciplines, we have no coherent path for our thinking.

Sound, though basic epistemologies are necessary for sound thinking and reasoning to deal with the interdisciplinary phenomenon of entrepreneurship. In particular, we shall switch always between a "why-thinking" (cause-effect thinking) and a "how-thinking" (how an effect of an operator on an operand leads through a process to a result).

It is clear that growth indicators reflect the outcomes of many different interacting causes that influence new firms' growth paths. Figure I.130 does not only indicate that the numbers of employees (as a resource) and revenues (indicative of the financial state) are taken as *indicators for the whole state of the growing firm*.

Furthermore, due to non-accessibility to other data, *performance* during development (growth) and particularly *productivity* as defined in Equation I.2 and referred to in Figure I.130 will be taken as an indicator how efficient the goal is achieved which may be *related to leadership and/or management and organization (specialization, communication, coordination etc.* (Table I.69) of the firm and, hence, an "organizational state."

In doing so we are always aware that even reported revenues in official documents, for instance, in income and loss statements, may contain "Extraordinary Items," one time expenditures for a given year which may "deform" the revenue indicator by an unexplained effect.

Reformulating the productivity, a capacity, defined in Figure I.130 generates an expression for (financial) **strength** or "**energy**" (Equation I.13).This is the typical form used in physics and chemistry for various types of energy and performance, some of them being also listed (in normal font).

Equation I.13:

Revenue = Productivity x Number of Employees
→ (Financial) Strength or "Energy"
[$,€/Employee];

Energy-Related Phenomenon → Capacity ⊗ Intensity

Volume Energy → Volume ⊗ Pressure

Thermal Energy → Entropy ⊗ Temperature

Shaping Energy (Power)→ Form ("Gestalt") ⊗ Elasticity

Note that *capacity* in this sense is different from *capability* as understood by RBV: According to Merriam-Webster capability is *the quality or state of being capable*; the facility or potential for *an indicated use* or deployment; *a feature or faculty capable of development* ("potentiality").

Figure I.130, Figure I.87 and Figure I.5 allow a further metaphor to be established between the factors for development of the state of "total energy" E of a new firm mapping what the firm "has, can, gets and owns" to potential energy E_{pot} and "does" (decision, implementation, execution) to kinetic energy E_{kin}:

$$E \rightarrow E_{pot} + E_{kin}$$

These notions clarify differences between performance and productivity which are often used as synonyms. According to Equation I.2 performance is related to the *comparison of current achievement* on the basis of existing resources and constraints (Actuality, A) and what could be achieved by developing resources and removing constraints (Potentiality, P) which is A / P.

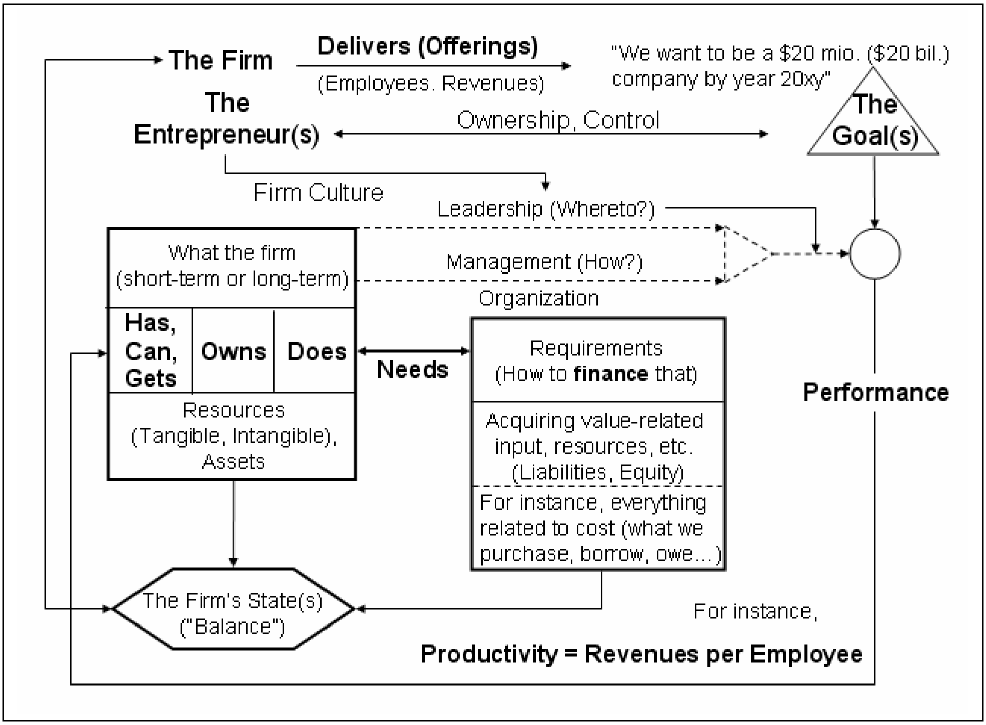


Figure I.130: The constellations and interrelationships that characterize states and performance of a growing NTBF.

On the other hand, productivity was related to Capability C, the possible achievement with existing resources and within existing constraints, as A / C. Actually, as defined in Figure I.130, *productivity is an indicator* derived from other, for NTBFs more or less readily available indicators for NTBF growth. Correspondingly, we view:

> *Change of productivity* is an indicator of performance
> (as illustrated in Figure I.132).

Conceptually, productivity is often related to how well an organization converts input, resources (labor, materials, machines etc.) into output and outcomes (goods and services). This is expressed by ratios of outputs to inputs. That is, for instance, (input) cost per (output) good / service. It is not on its own a measure of how efficient the conversion process is. But this definition is not practical for systematic investigations (of NTBFs) as relevant data are rarely accessible.

Performance is a relation between "what is" and "what could be," or verbalized "more with the same or even more with less." In essence, in the current context *performance is related to the first derivative of productivity* and "*performance persistence*" is expressed by "constant" productivities (cf. also Figure I.10, Figure I.132).

According to these definitions we associate *leadership* with an emphasis on performance and intangible resources (developing firm's culture, employees, etc. to get more out of these resources), but *management* with an emphasis on productivity and tangible resources.

Figure I.130 provides an outline of a model for the description of NTBFs' developments (growths) in terms of sub-states which will be characterized by relevant, accessible indicators. The "has, can, gets" block (essentially non-financial tangible and intangible resources and assets), the "resource state," is interconnected to what the firm needs in terms of financing ("financial state") and how effective and efficient the goal is achieved in terms of leadership and management and organization ("organizational state") related to productivity.

A mismatch between available input and resources (has, can, gets) and required input and resources (needs; finances) to reach the goal(s) may constrain the amount of development that can be undertaken at any given time.

Figure I.132 illustrates performance increase with a "more with the same" or "more with less" constellation, thus, for a firm, achieving higher profitability. Notably, market share as an antecedent of organizational performance is consistent with models proposed in numerous empirical studies [Den Hartigh et al. 2002].

"Full" information concerning relevant indicators about the states of a firm is readily available only for public stock companies in terms of annual reports and documents for the stock exchange. For the overwhelming proportion of NTBFs information about the firms' states is often rudimentary.

Furthermore, the input-conversion-output cycle in Figure I.130 and the extended one of Figure I.5 generate an impression of linearity of the involved processes. However, the GST/cybernetics approach emphasized that for new venture growth a number of systemic interactions generates self-reinforcing processes, such as

- Founder team formation (Figure I.70);
- Building company culture (Figure I.120);
- Organizational learning (the learning curve, ch. 2.1.2.5);
- Scale effects, often referred to as" economies of scale" which imply that the average total cost will decline with growing production volumes (Figure I.154).
- Decision-making self-reinforcement (that is, past acceptances make future acceptances more likely; ch. 2.1.2.5);
- Spiraling innovation persistence and investment persistence (Figure I.127);
- The transformation of core competencies into core rigidities (Figure I.129);
- Adaptive expectations (further belief in prevalence; Box I.17).
- Downfall of the young firm's financial state by interaction of internal factors and processes and external effects and processes bound to customers, markets, factor markets and financing (Figure I.114).

The last aspect represent interaction effects with the environment, *market-bound* self-reinforcing mechanisms whereas the other ones are *firm-bound* self-reinforcing mechanisms. Adaptive expectations are also important for the NTBF's interactions with customers. This occurs when a customer's preference for a product is dependent on the opinions or expectations of other (potential) customers (ch. 4.2.1.1). The interdependence of opinions is based on information sharing and "escalation" (ch. 4.3.5.2). Startups, hence, try to utilize this effect by publishing a list of "reference customers" on their Web sites.

A further market-bound self-reinforcing mechanism refers to "utility of an offering," when the economic utility of using a product becomes larger as its network grows in size. Network size is determined by the number of suppliers and users of products based on a common technology standard. Network size is important in many markets, but most visible in the markets like telecommunications, computer equipment and software [Den Hartigh et al. 2002].

4.3.5 A Bracket Model of New Technology Venture Development

It is the theory that decides what we can observe.
Albert Einstein

The basis of the following "business bracket model" of development (growth) of new technology ventures follows largely the above described lines incorporating aspects of the stage-based and resource-based views and reliance on a number of inferences from empirical observations outlined so far. It concentrates on the social and economic context. It establishes a relation between the firm's development due to internal and external factors and appropriately selected observable indicators.

Focusing on NTBFs it is important to re-emphasizing that we are dealing with relatively low level *organized complexity*. This is we are dealing usually with human-activity organizations of two to forty or rarely one hundred persons, at the highest.

Furthermore, we often encounter young firms with very few (1-3) products and few customers (1-5) whose number does not exceed a dozen – even if their revenues exceed one billion dollars (or euros)(cf. First Solar Inc. in ch. 4.3.5.2 and Figure I.154).

The central constellation for growth (cf. also Figure I.5) is in terms of business processes, functions, resources and capabilities and organization (Figure I.131). The bracket model emphasizes growth, but includes not intended growth, and may also cover firm's failure.

> HP co-founders David Packard and Bill Hewlett "did not believe that growth was important for its own sake," but concluded that "continuous growth was essential" for the company to remain competitive and they continued, "Growth: to emphasize growth as a measure of strength and requirement for survival." (citation [Bhidé 2000:230]).

> In this regard, for NTBFs “growth persistence” is in line with goal persistence (ch. 4.3.2), innovation and investment persistence (ch. 4.2.3).

Pressures for growth and capacity for growth are discussed by Bhidé [2000:230-233]. Apart from d*riven to grow by the entrepreneur’s aspiration and intention* pressures for growth result partially from self-reinforcing processes. Some of these are the following.

- A firm cannot remain small if its rivals increase market share by exploiting economies of scale or if customers believe that size is a precondition for long-run survival. Longevity goes hand in hand with growth.
- The external labor market may initiate pressure for NTBFs to grow. A dependency on highly talented people and researchers means the firm has to offer opportunities for personal development and progress. A stagnant firm risks losing its talented employees.
- The accumulation and experiences and the development of decision-making routines may lead to an increase in the capacity of the firm’s managerial and supervisory personnel, creating more efficient capabilities, which increases the potential for growth.

The bracket model assumes that t*here are no “invariant states of activity” in young firms* the way a stage-based view often suggests. In the sense of open systems with continuous input/resources and output/outcomes (Figure I.5) there is continuous conversion activity including continuous learning of leading and managing, resource and asset re-grouping and resource allocation characterizing a firm’s states which will be interrupted by changes through (*unbalanced* internal and/or external) events and decisions and actions. And, furthermore,

> “A firm cannot easily stop growing after it has reached some fixed critical mass.” [Bhidé 2000:230]

For technology entrepreneurship a critical mass for non-growth NTBFs could be ca. a dozen employees (ch. 4.3.1; Table I.69, Table I.71).

In this regard one can create certain associations with Newton’s First Law of Motion – sometimes referred to as the Law of Inertia. The First Law is often stated as:

An object at rest stays at rest and an object in motion *stays in motion* with the *same speed and in the same direction* unless *acted upon by an unbalanced force* (italics added).

Relating the notion “object staying in motion” to a *firm with continuous growth* one can speak of **dynamic stability of sub-states** of a growing (open) human-activity conversion system or firm (Figure I.5) if it keeps “*growth regularity*” among sub-states. This would be described by a (mathematically) strictly monotonic increasing function between state variables S, like $S_i(t+1) > S_i(t)$ or their respective indicators.

The description would be valid over a certain period of time, the "*dynamically stable interval*" $<t_0, t_{n.}>$ (*uninterrupted* progression in one direction). Though not of particular interest in the current context, the model will allow also monotonic decreasing relations for dynamically stable sub-states, with no stop leading to firm failure.

NTBF growth for a period of observation, hence, will be represented by dynamic stability of subsequent sub-states of the firm in terms of their intervals of existence that appear with unchanged growth regularity (including constancy) of the appropriate indicators separated by a variety of to-be defined interruptions.

This shows structural and functional similarity with what Abrahamson [2000] regards in the context of "change management" for firms as "dynamic stability: a process that alternates major change efforts with carefully paced periods of smaller, organic change."

Dynamic stability in our context of open systems is not what usually is understood as dynamic stability in engineering. Here this is the property of a body, such as a rocket or plane, which, when disturbed from an original state of steady flight or motion, dampens the oscillations set up by restoring movements and thus gradually returns the body to its original state.

> It is important to be noted that dealing with an open system a transition into another stable state does not mean the system may recover the initial stable situation (state). After overcoming the perturbation it will proceed in another, new state targeting the system's goal. Every new dynamics drives the system's states toward the final state of goal achievement. In so far, there is a link to dynamic capabilities.

Inquiring into dynamic stability investigates primarily what happens during the time after a disturbance. To an outside observer a dynamically stable state may appear rather insensitive to certain "small" perturbations as, if necessary, a system may adapt to such effects in a non-observable way.

Conversely, strength and stability means that, for observation, only the severe perturbations may disrupt dynamically stable states to make these distinguishable from "underlying noise" of measurements. A summary of such usually observable perturbbations of dynamically stable (sub)-states based on the outlines in this book will be given later (Table I.76).

The notion of the "small perturbation" is associated with another issue, that changes are relevant due to *unbalanced* internal and/or external events and related decisions and actions.

Observing a particular *indicator* may reflect the combined, interaction of oppositely acting factors which may result in rarely observable small perturbation, though the overall state of the system may be affected significantly. For this reason *the current approach will usually consider not just only one indicator, but usually several ones* which may reflect the perturbation differently. Reference to the details of the firm's internalities, a switch to the micro level, can provide necessary insights.

When accepting that an economic recession can usually be viewed as a severe perturbation of the growth of an NTBF Figure I.123 shows this to be the case for the German WITec GmbH for the Dot-Com Recession (2000/2001). However, the same figure suggests that the even more pronounced Great Recession is not reflected by the growth curve. Understanding and explaining this effect is only possible focusing explicitly on internalities of the firm and the markets it serves.

Internalities of the firm will emphasize a balance of basic business processes of the value chain (Figure I.7), indicated, in the sense of GST, by circular arrows in Figure I.131. It is the responsibility of leadership/management to keep innovation and investment persistence and own continuous learning and build related business experiences. The innovation process is interwoven with all other processes.

For NTBFs with an early on export orientation it is very important to organize distribution, usually by local distributors as these know the specifics of the local markets. And for complex technical products there must be user training, consulting and technical service in the countries.

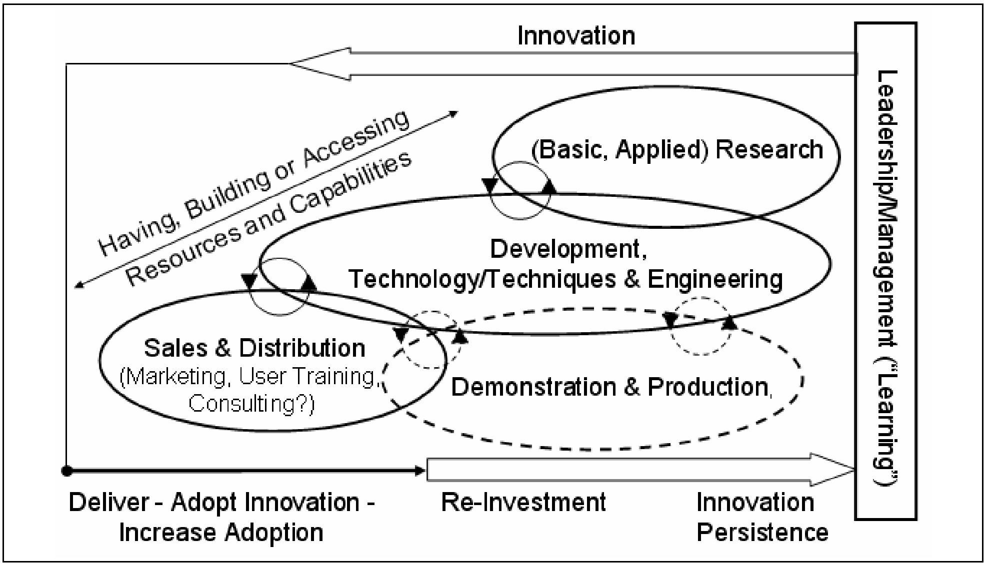


Figure I.131: Key activities to be balanced for a growing NTBF.

Figure I.131 exhibits implicitly the *customer-facing* process when researchers (scientists and engineers) are actually interacting or communicating directly with customers (face-to-face, visits) – which is not a business service feature experienced or seen by the customer. This combination of development, demonstration and distribution by researchers is not only relevant for disruptive innovations, but also for getting ideas.

Formalism, Constraints and Special Cases of the Growth Model

Following the formalism of quantum theory for treating energy levels of molecules which separates electronic, (nuclear) vibrational and (total molecule) rotation states by factoring,

$\Psi = \Psi_{electronic} \cdot \Psi_{vibrational} \cdot \Psi_{rotational}$,

we shall use the "bra(c)ket notation" (Equation I.6, Equation I.12) to describe the overall system state of an NTBF Ψ by *weakly coupled sub-states* (Equation I.14).

This factoring of states means that there is only weak coupling between the states and that their related observables can be measured (almost) independently from each other. Weak coupling, however, may be observable, for instance, for molecular excited states. The dominating bands of electronically excited states measured by UV or CD spectroscopy [85] will often be superimposed by a weak structure of vibrational states.

Equation I.14:

$|\Psi$ (Overall System State)> $\rightarrow$ $|\psi_{SF}$ (Financial State)>·$|\psi_{RS}$ (Resource State)>· $|\psi_{OS}$ (Organizational State)·$|\psi_{NS}$ (Networking and Coop State)>·…

For NTBF development (during the first ten-twelve years) we assume that *for certain time intervals weak coupling between sub-states exists*, such as the financial (FS), resource (RS) and organizational (OS) states. This means, in terms of indicators ("expectation values" for given states in the sense of Equation I.6), for instance, due to only loose correlation increasing revenue is not necessarily associated with increasing productivity or strictly monotonically increased revenues ($S_i(t+1) > S_i(t)$) may not mean strictly monotonically increased number of employees (Figure I.149, but cf. Figure I.145).

And increasing the number of employees very fast may result in organizational coordination problems (ch. 4.3.2) leading to decrease of productivity, as David Packard put it (cited Bhidé [2000:233]), "more businesses die from ingestion than starvation." It is to be noted that some of the entrepreneurs the author had discussion with mentioned to track productivity and used decreasing productivity as a trigger to initiate organizational change.

We associate the organizational state with only the internal situation of the firm, whereas the firm's interconnections to outside entities will reflect "network organization." If we would assume strong coupling between OS and NS for an exceptional case we shall note it and use just one indicator to cover both and continue to call it an "organizational state." Generally NS may contribute to FS and RS ("add-ons").

Concerning the combined organizational and networking states leadership and management capabilities and "coordination capabilities" are important which refer to the maximum heterogeneity that the firm's coordination routines allow to derive a positive net benefit from.

Strong coupling, not separable sub-states, may occur when large amounts of capital infusion by investments or venture capital (financial state) result in adding large numbers of employees (resource state) and adding a management team (organizational state). Strong coupling may also show up for corporate venturing which combines finances, other resources and networking and cooperation (Figure I.125).

Based on *available* observable data and *simplifying complexity* we associate the overall state of an NTBF Ψ to the firm's indicators of sub-states, namely revenues, number of employees and productivity, plus an empirical bulk "multiplier" N which may account for remaining influences on the sub-states' including firm-internal and external effects (Equation I.15).

Equation I.15:

S(Overall System State) $\rightarrow$ N $\otimes$ FS("Financial State"; Revenues) $\otimes$ RS("Resource State"; Employees, R&D) $\otimes$ OS("Organizational State"; Productivity)

We regard revenues (R) as an indicator of the financial state allowing to finance a firm's development – for instance, organic growth via own cash flow or capital infusion via external investments or non-organic growth via acquisition of another firm. The financial state FS is susceptible to self-reinforcing processes with positive or negative effects (Figure I.114). FS may reflect investment persistence and RS innovation persistence (Figure I.127).

As an interesting aspect of new firm development a study by Chandler and Hanks [1993] suggests that the great majority of entrepreneurs have growth concerns that far outweigh their concerns about profitability.

The resource state is assumed to cover non-financial resources, in particular, employees. Specifically, in Equation I.15 R&D means the number of employees in a research and development function (department). R&D as a resource is usually measured by R&D Intensity (ch. 1.1.1; Table I.1; cf. also TVT, HVT in Figure I.128).

R&D is a "potential" and is a resource for innovation by a company-wide process which, when strongly coupled with innovation persistence as an organizational competence and strength, builds sustainable competitive advantage. The role of R&D activities of the R&D function of a firm becomes more obvious in terms of revenues, if the firm's offerings refer to inventions, for instance, by selling IP (licenses) or providing contract research (Table I.3).

As the approach to dynamically stable sub-states allows equality ($S_i(t+1) \geq S_i(t)$) a growing firm with *constant productivity* (P) is a special situation of growth with a stable organizational situation for a particular "*dynamically stable interval*" $<t_0, t_n.>$. For this interval, with revenue (R) and number of employees (EN), one can write the formula

$R_1 \cdot (EN_1)^{-1} = R_2 \cdot (EN_2)^{-1}$ = constant, resembling the well-known relation of ideal gases which is a good approximation to the behavior of many gases under many conditions and leads us to consider the notion equation of state. Classical thermodynamics is much concerned with equations of state.

The *equation of state* for an "ideal gas" is $p_1 \cdot V_1 = p_2 \cdot V_2$ = constant for a given temperature T with pressure (p) and volume (V) as state variables or $p \cdot V = n \cdot R \cdot T$ (R is a universal gas constant and n is equal to number of moles, the mass (m) divided by the molecular mass (M)).

In cybernetics there is a special condition of systems in growth states called the *steady state condition*. This special condition is possible after some time, when all input and output quantities are and remain constant. A relation between input and output quantities for a system in a steady state condition has been called "Static Transfer Response of the Dynamic System" [Ruhm 2008].

In our context, we shall not be so strict when speaking of a steady state condition. For dynamic stability we relax the steady state condition emphasizing OS(Organizational State; Productivity) (Equation I.15) to require only "negligible" change of productivity over a certain period. We shall denote these as "**dynamically stable states**" – of the whole system.

This situation of NTBFs with "constant" productivities shows a metaphorically comparable situation with the notion of a "steady state" as a model in cosmology (an alternative to the Big Bang theory). Accordingly, a steady state has numerous properties that are unchanging in time; the universe is always expanding but, by observation, is maintaining a constant average density (mass in relation to volume).

Therefore, one could speak of a "*steady state firm growth"* for the special case when growing through states of relatively stable organization, when expanding but maintaining a constant average "density" which here would be related to (inverse) productivity. This is illustrated in Figure I.132. Admittedly, such a relation between counts of components and size (firm revenues) does not differentiate components and their interactions in terms of organization including structures of leadership, coordination and communication.

In *purposeful and organized social (human-activity) systems* like firms change is usually associated with resistance by those who are or perceive to be affected by the change. Hence, it requires structured efforts ("energy") of leadership/management of firms to implement necessary changes of activites and processes and organization ("change management"). Such a period of implementing change proceeds via an *unstable "transition state"* (Figure I.133). Due to a lack of observing details such a transition state is regarded as a "black box". However, to a certain degree, a transition state may be compared with the startup thrust phase directly after firm's foundation which is often an unsteady process with considerable risks of failure, searching for structure and organization dealing with changes for all the persons involved in it.

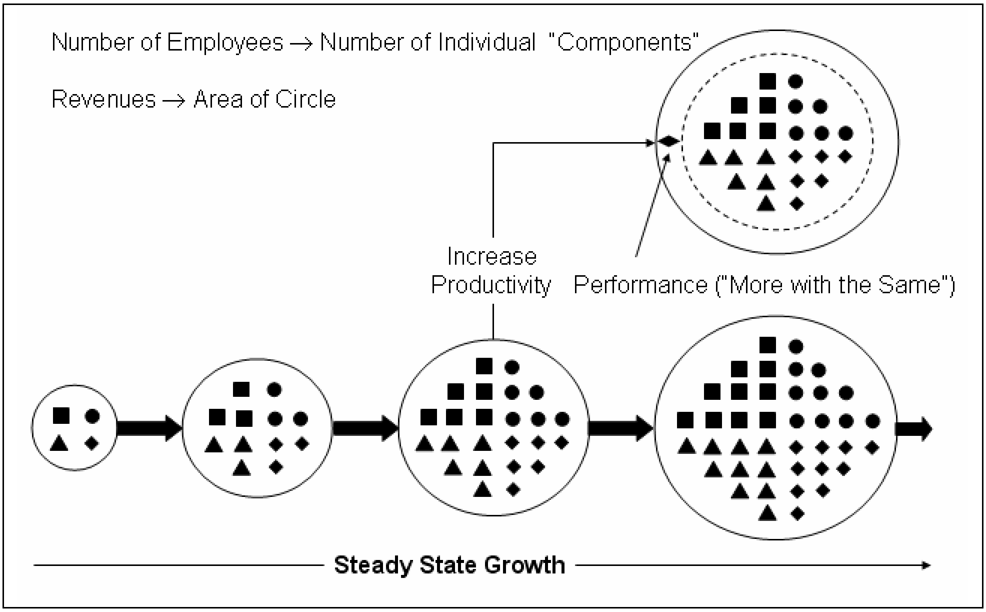


Figure I.132: Illustrated steady state growth and performance versus productivity of an organized entity.

After firm's foundation with a particular purpose and goal in mind and formalized by a transformation (Equation I.12), the startup thrust phase (ch. 4.3.2, Figure I.125) represents the first transition state of more to come for a new firm's development. Due to proportionately high risk of failure a new firm may operate here in "survival mode."

For firms, unless balanced by a simultaneously occurring second change, the transition state will exhibit a change of the relevant indicator function (revenue or employees) in the positive *or* negative direction. It may also be observed by a temporary increase/decrease of productivity and/or performance. Transitions states can be conceptually related to Greiner's "crises" (Table I.68). Internal change of the firm can be initiated by external effects. But there may also be intentional change of a firm's organization by the founder as described for Osmonics by Runge [2006:91-94].

Metaphorically a new firm's development via transition states can be compared with chemical reactions where an energetically stable initial state of educts (A + B) requires energy to bring the (closed) system via a transition state (admittedly with a very short life-time) into a more stable "product state" (C + D).

The non-stable transition state will have certain duration between two dynamically stable (sub-)states. Apart from referring to the startup thrust phase an idea of the duration of such an "intermediate" state can be got from revenue and employee developments of the German Nano-X GmbH, when after catching a big order, it increased first the number of employees, then increased production capacity and finally turned to delivery of the products. (Figure I.137, Table I.77).

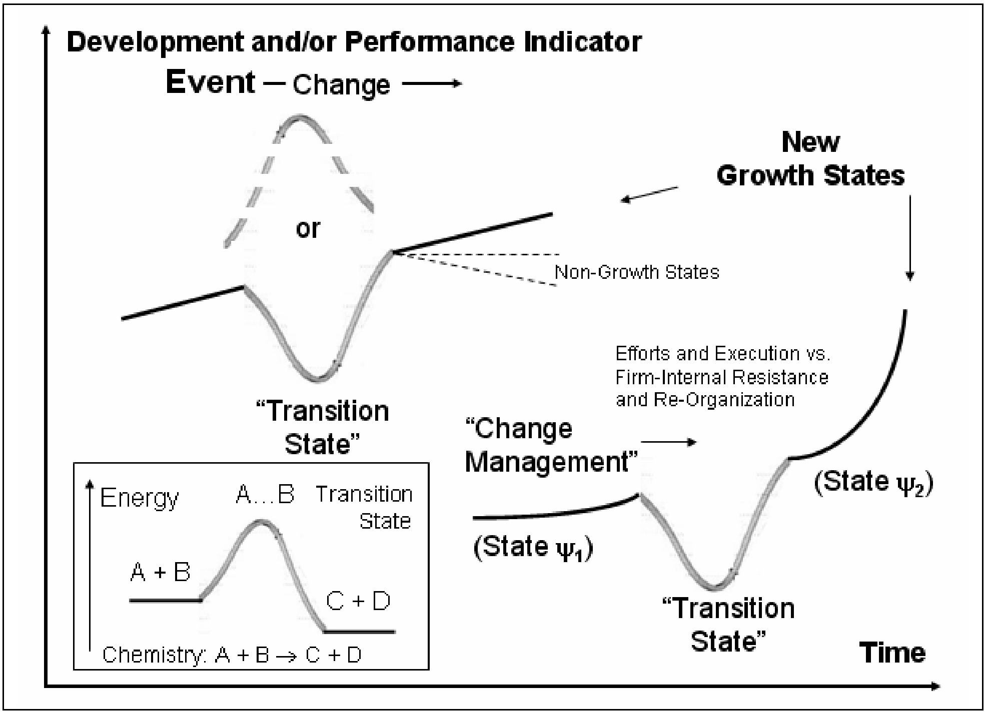


Figure I.133: Interruptions of NTBF developments by "transition states."

A transition state requires usually another style of leadership/management and execution, sometimes even a totally different style if the new firm has to enter "survival mode."

As described previously in various contexts a transition state initiated by a switch to (or start as) a VC-based NTBF or one getting huge private investments follows usually a path into a state that corresponds largely to intrapreneurial states and initiatives of innovation management of existing large firms (Figure I.134). Most notably, change to a VC-based NTBF is usually associated with a change of the leadership/management team, organizational structure and organizational processes (Figure I.126) and expressed by a transformation described formally, for instance, by Equation I.11.

Figure I.134 and Figure I.130 contrast implicitly the challenges of building a firm with those of managing ("running") an established firm. Building requires the entrepreneur(s) to develop tangible and intangible assets, organization and coordination mechanisms more or less from scratch. The focus of executive managers of established companies revolves around existing assets, their strategic uses and related mechanisms.

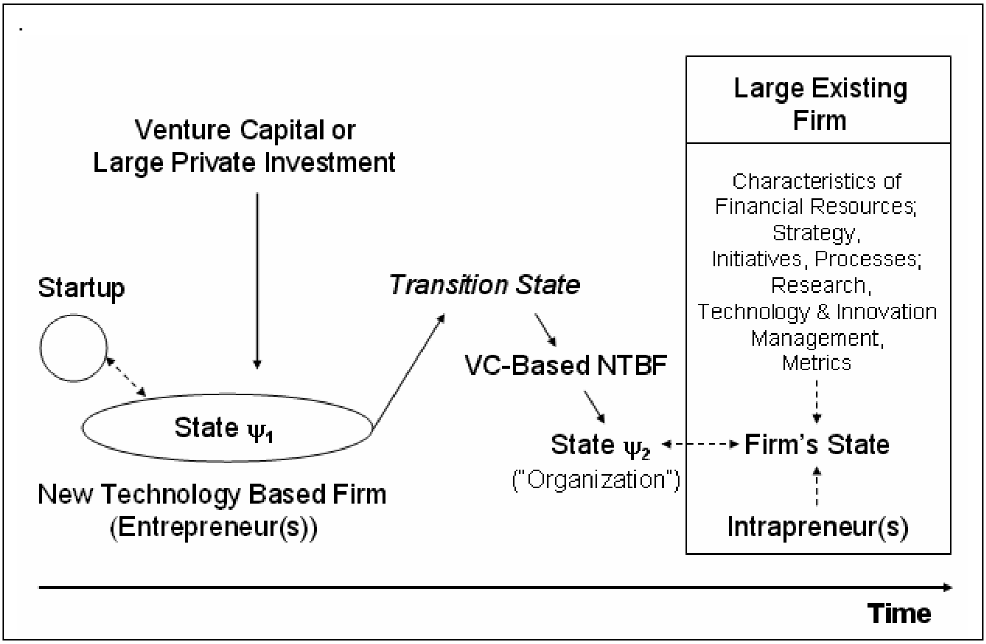


Figure I.134: The transition of an NTBF into a new state after becoming a VC-based NTBF characterized to be similar to those of large existing firms.

VC-Based NTBFs represent an entity intermediate between a privately held or privately controlled firm and a large corporation. Key differences refer firstly to

Opportunities

- Uncertainty is less – VCs tend to go into rapidly growing, large markets with proven teams (or replace founder entrepreneurs by experienced management if things do not develop as anticipated)
- Potential profits are higher than typical privately held or controlled, respectively, firms.

There is more planning than in startups. VC-based startups work from a business plan and run "standard" financial management and technology/offering development processes as in large firms. In particular, fund raising by VC-based startups is synchronized with development phases and achievements of milestones (Figure I.52, Table I.27) similar to the Stage-Gate process of large firms (ch. 1.2.7.2; Figure I.79, Figure I.180). The second aspect concerns resources:

- There are more resources available than in bootstrapped (ch. 4.3.3.1) or private firms, but less than in big corporations (for intrapreneurship).

CleanTech (Table I.52) and particularly biofuels and biobased chemicals (A.1.1) are areas where technology entrepreneurship is focused largely on VC-based NTBFs.

Considering all the previous outlines there are bridges to fundamental concepts used so far in treating new firms' dynamics according to:

- Stage-based views (ch. 4.3.1),
- Resource-Based Views (RBV, ch. 4.3.2)
- Input/output (I/O) models (4.3.2).

The current *phenomenological approach* seeks essentially for qualitative and quantitative descriptions in terms of equations of state rather than explanation. That part relates to a basic cybernetic model (ch. 4.3.4) and relates metaphorically to quantum theoretical and physical fundamentals. The bridge between description and explanation is achieved focusing on "interruptions" or "perturbations of growth, which means, "the transformations concerned with what happens, not with why it happens."

Explanation is approached by providing information on the nature of the "interrupttions," "why it may happen," in terms of a list of assumptions and common ways of perceiving forces in firms and forces in markets and industries and their interactions dealt with by business administration and economics (Table I.76).

4.3.5.1 The Bracket Model

The following approach will focus on NTBFs, young technology ventures in no more than the first twelve years of their existence (ch. 1.1.1.1). It takes the position of an observer and identifies and utilizes mechanisms and drivers of *changes* of *states* of a new firm entrepreneurs being a part of.

> Phased firm growth in the sense of GST is a result of a *relation-oriented purposeful process of development* in which a linear or circular interacting series of *changes from inside or outside the firm* lead irregularly to new development states associated with increases (or decreases) of appropriately selected observable indicators of the developing entity.

That means, the approach focuses on the firm and its relevant super-systems, such as the economic and political systems, and consequently *switches between macro- and micro-levels*.

The model follows a *teleological approach* emphasizing often *not "why things happen*" but emphasizing ways of behaving and asking

- What can it do? (the resources)
- What does it do? (the phased process)
- How does it proceed to reach the goal?
- What can be expected with regard to reaching the goal – often providing "reasons for thinking that" (Figure I.2)?

Necessary resources during the pursuit of the entrepreneurial goal(s) are specifically given in Figure I.120 and Figure I.121, Figure I.125, Figure I.126 and Figure I.130.

“That something is ‘predictable’ {“*expectable*” in our context (ch. 4.1)} implies that there exists a constraint.” [Ashby 1957:132] (Braces added). The below presented “bracket model” of development of NTBFs takes time as an implicit variable (states at given times, usually on a year-by-year basis) and focuses on some fundamental constraints for a hierarchy of taxonomies (Figure I.128):

- Firm type RBSU (“spin-outs from academia”) versus “other academic NTBF” and “other NTBFs” (Table I.2)
- Full and majority ownership and control versus minority ownership, little (almost no) control (*VC-based NTNFs*; Table I.74)
  VC-based NTBF do not only affect ownership and control, but also endowment with large financial resources and change in terms of management and organizational structure and probably strategy as well as execution following closely approaches used by large firms (ch. 1.2.7.2, Figure I.126, Figure I.134; A.1.1).
- Differentiation of organic and non-organic growth (Figure I.127).

It is to be noted that concerning VC-based NTBFs the emphasis will be on combined ownership, control and financial endowment. Other types of (large) investments, for instance, for large-scale *production-oriented NTBFs*, may decouple these categories, for instance, through association with “silent partnerships” in the NTBF.

Furthermore, there may be always cross-roads when NTBFs with full and majority ownership and control change over to VC-based firms (Figure I.52). Prototypes of VC-based NTBFs will catch capital often during or at the end of the startup thrust phase (Figure I.125) or within the first five to eight years of existence. Several new biofuels firms were started immediately with venture capital (A.1.1).

The differentiation between organic and non-organic growth may be a “moving” typology. For its growth and a restricted phase of its development an NTBF may switch between both modes (Figure I.123). Non-organic growth exposes a firm usually to integration risk. While having a stake in another firm mostly improves revenue opportunities. Full acquisition improves often revenues, but iintegration risks means issues of management, coordination and performance.

Development of new firms is irregular. It proceeds via states of different life-times and modes of development. These exhibit three basic observable types of development (growth) as displayed in Figure I.107 depending on the founders’ goals and characteristics of the firm which can be measured by appropriate indicators, for instance,

- *Linear* growth which may be “high” (steep) or “low (cf. Figure I.123, Figure I.137, Figure I.141, Figure I.149);
- *Exponential* (or hyperbolic) growth, which is typically “super high” and proceeds often very fast (EGCs, “gazelles”; for instance, Figure I.145, Figure I.159) or occurs after a delay (Figure I.143, Figure I.144, Figure I.154);
- *Asymptotic* growth, which will express “*non-growth” situations*.

Furthermore, as growth will be “perturbed” or interrupted, respectively, by firm-internal or external factors or both and associated with “transition states” (Figure I.133) change between different phenotypes of growth may occur (cf. delayed growth in Figure I.107). NTBFs with large-scale production will usually show significant growth patterns only after five to eight years of development and scale-up.

Basically, we assume to be sufficient that for growth dynamically stable states exhibit only (continuously and monotonously increasing) linear, slightly curved or exponential behavior for an observable interval <t_1, t_2> (Figure I.133).

If we can associate two subsequent dynamically stable states to the intervals <t_1, t_2> and <t_5, t_6>, then the life-time of the in-between transition state (or states) will be attributable to <t_3, t_4>. For instance, for the German WITec GmbH (Figure I.123) the interval <2000,2002> would relate to a transition state (cf. also Figure I.156). This indicates that *transition states of new firms* may have life-times which are comparable in duration with dynamically stable states.

Formally, transition states may show up as an overlay on the overall growth pattern which let a gross observable indicator appear its indicator function to keep continuity, but not necessarily with increasing character.

If strong change is associated with a very short “life-time” of the transition state, the growth function will exhibit a “jump” as illustrated in Figure I.21 and seen for the revenue curves in Figure I.137, Figure I.139 as well as Figure I.140, where a basically exponential growth pattern of Nanophase Technologies between 1994 and 2000 is interrupted at 1997.

The bracket model is resource-oriented as well as activity- and process-oriented where “events” trigger a corresponding change of the state of the firm including the state(s) of the involved persons or groups of persons, respectively (Equation I.14, Equation I.15).

> We define a **(business) bracket** as a *generally observable, but also expected* (Figure I.136) *impact* of a transform or a transformation into a *new state* of a firm in a specific business area. The associated observable quantity, reflecting the *time development of the impact*, will start with a usually difficult to detect onset, then there will be a peak-like or wider, skewed bell-shaped center representing the essence of the impact, and finally a very long-tail characterizing formally a slowly but continuously reducing effect of the transform or transformation, respectively (Figure I.135).
>
> A business bracket will be represented by a *graphical map of an event*, the “perturbation” of the time-development of a properly selected observable quantity characterizing a change into a firm’s transition state whose life-time ends when a following new dynamically stable state can be detected by an observable regular shape of the indicator function (Figure I.135, bottom).

That means one may identify a "*front bracket*" rather well, but principally never an "*end bracket*." For practical purposes and special cases one could "declare" an end bracket with regard to the point when the impact of the transform/transformation is assumed to become so small that it can be viewed as having no further significant influence on the measurement result – and this may be the end bracket to coincide with the emergence of a new bracket.

Business brackets originate

- externally from *non-controllable* effects or internally (controllable or uncontrollable) ones or
- from *unintentionally or intentionally effects* – initiated by *firm-internal* decisions and actions.

Structurally, a bracket refers to a *relation* associated with a *change of a systemic state* of the entity under consideration. A *long tail of a bracket map* simulates artificially that a "bracket event" leads to a new state of the affected entity which will also influence future states, for instance, in terms of decision-making, actions and behavior. In this regard it simulates "organizational memory" (Figure I.136, Figure I.129) which actually corresponds to an "*Ashby memory*" [Ashby 1957:115-117], a theoretical construct evoked to explain behavior of an incompletely observable system by reference to an event in the past.

> "If a determinate system is only partly observable, and thereby becomes (for that observer) not predictable, the observer may be able to restore predictability by taking the system's past history into account, i.e. by assuming the existence within it of some form of 'memory'." [Ashby 1957:115] Ashby provides a very illustrative example of reference to "memory" for a "living system." [84]

A business bracket reflects a business event which may affect a company's *competitive position* in a positive or negative direction. It reflects influences on the development of a (new) firm as it affects measurably what a firm has, can, gets, owns, does (also as a response to external effects) or delivers (Figure I.130) in relation to the firm's mission and goals.

Business bracketing emphasizes the micro (entrepreneur and firm) level of entrepreneurship with the issue of connection to the macro level.

- It relies on observations at the firm level to reveal mechanisms and processes of growth to be operative and focus on dynamics – through sequencing of events and their interactions and mutual reinforcements (Figure I.114, Figure I.115).
- It provides *explanatory guidance* to make sense of the mechanisms and processes that give rise to new firms' developments.

The business bracket concept has to be differentiated from the concept of "bracketing" of social theory and sociology, in particular, temporal brackets (ch. 1.2.2). Here, bracketing would be a process related to the *entrepreneurial person(s)* in the context of the venture's development, specifically a focus on people.

Temporal brackets, for instance, refer to cognition when a company-internal process or event will start (the *front bracket*) and an expectation how long an event or process will take to complete (*end bracket*) or, after a period of time, the cognition of an event that will start a subsequent event or an intentional start of a new bracket in anticipation of an event to occur. Their identification requires observation and direct inquiry into entrepreneurs' intentions, decisions and behavior. Defining front and end brackets means the entrepreneur is largely in control of the bracket.

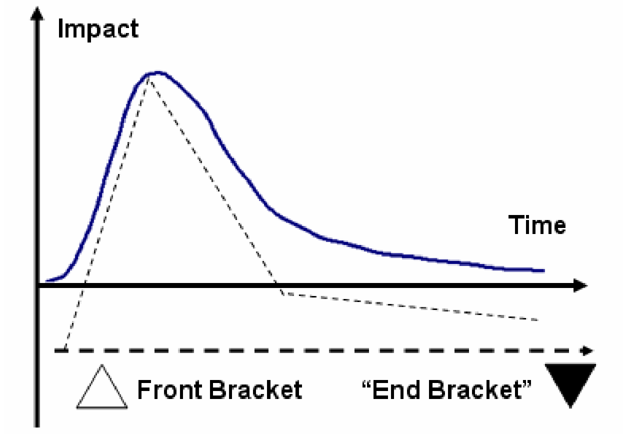
Temporal brackets can, for instance, be related to strategic actions or decisions taken by actors or to planning. That is, each temporal phase started either by cognition of a significant exogenous or endogenous event and a related or an unrelated endogenous decision and action taken by organizational decision-makers. Some of these brackets get formalized into timetables such as business plans. Some critical brackets associated with pacing may be made explicit as sub-goals or milestones. Hence, temporal brackets may structure venture development, which is at least partially controlled by the entrepreneur [Bird 1992].

For ventures to emerge as recognized and reliable entities with a competitive advantage, the timing must be right. For this to happen, the entrepreneur needs to be aware of and understand the time requirements of the different events and processes.

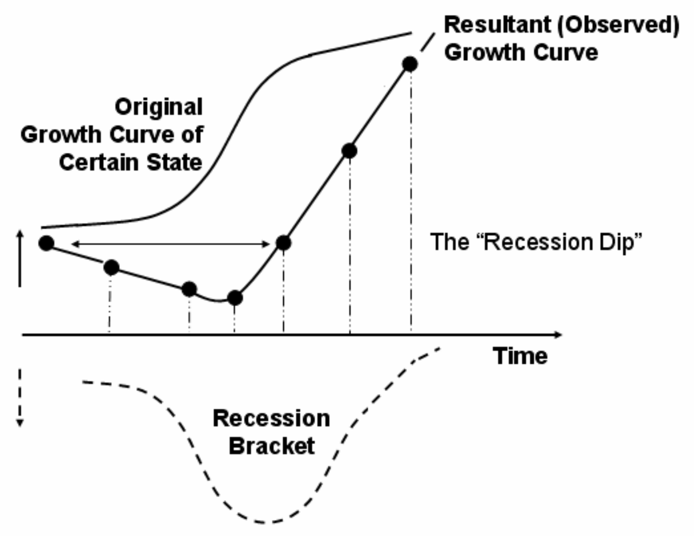
Entrepreneurial growth of NTBFs will be described by periods of *dynamic stability of states* interrupted by transition states (Figure I.122, Figure I.133) initiated by business brackets.

With regard to *observable indicators* maping a business bracket and its time-dependency to *a "wave" with positive or negative amplitude* (the event's impact) has the consequence that, for a curve, overlapping "waves" may exhibit, for instance, a dip or may even "extinguish" each other ("balanced forces"), as is seen for the interference effect of light. This is illustrated for the case of a bracket by an economic recession with a negative impact in Figure I.135 (for an example cf. also Figure I.123).

Depending on the subject under observation it is important to select an adequate indicator as a bracket may show up for one indicator, but not for another. To reveal an indicator Figure I.89 demonstrates this effect referring to the example of choosing the right indicator to demonstrate a relevant macro-trend. For this reason the current *bracket approach* to NTBF growth *will usually consider both, revenues and numbers of employees* (cf. Figure I.149) – and productivity.



Mapping the time-dependent impact of a business bracket to a specifically shaped "wave"



How resulting growth is reduced by the effect of a recession

Figure I.135: Defining a bracket's time-dependent development concerning its impact and how brackets with negative impacts add up through overlap resulting in an observable dip in an observable growth curve.

For instance, recession stems primarily from the (enlarged) economic system and may affect (almost) any kind of an entrepreneurial firm. It is a *general bracket*. If only a particular kind of NTBF is affected, for instance, of a specific industry or market, we have a *special bracket*.

> Concerning observability and meaning the bracket approach depends on an (almost) complete data set for the relevant effects (transforms, transformations) whose collection for NTBFs is generally a challenging exercise.
>
> Brackets may, or usually will, affect the whole system relevant for (technology) entrepreneurship (Figure I.13), but will often be associated with only a particular sub-system's states due to limitations of access to relevant needed data (viewing "pars pro toto"; Equation I.15).

According to the bracket model entrepreneurship appears as a series of transformations accompanying a new firm's development into a viable small or medium-sized firm. Each transformation corresponds to a bracket generating a transition state. The transition state is a critical period of the firm's development into a new dynamically stable state involving decision, actions and activities of change to respond adequately to the initiating bracket or brackets.

> As brackets represent *relations*, between an operator and an operand (or a firm and a market/customers or a firm and the economic system in a recession) they will exhibit *regional dependencies* concerning their impacts.

Differences, for instance, in sales effects to customers may be due to different cultures, attitudes and preferences in different countries. An example for the global level would be: An internationally operating food company introduces a new product based on genetically modified objects (GMOs) and increases distinctly its revenues specifically through this product in the US. On the other hand, in Germany the product may be rejected largely by the public – and, moreover, the firm's reputation may decline generally in Germany so that revenues for all its other products also decrease.

And there may even be country-specific regional differences. A case of introducing one kind of innovative self-cleaning roof tiles in Germany by the firm Erlus Baustoffwerke AG from the south of Germany [Runge 2006:237-239] is an intentional bracket generation. If considered as one bracket for whole Germany, it would have a distinct regional impact – fewer sales than potentially possible. The reason is, there are clear regional differences for color preferences for roof tiles in Germany: In the north preferences are for grey/black, whereas in the south red/brown is preferred.

Focusing on the above growth and bracket indicators (measured revenues, number of employees, probably profit and productivity) sometimes does not allow to detect a bracket by an observer – though the firm "feels" all its impact. This is illustrated in Figure I.136 for a growth situation where two brackets occur within a rather short period of time, and the latter having at least the same impact as the previous one.

Inspecting simultaneously several indicators may be a clue that may reveal the impact of the latter one. This applies to two positive, but also negative brackets.

An example that several brackets occur which will not be resolved by our common indicators is shown in Figure I.144. The brackets may occur so fast after one another that the in-between phases cannot be observed. If the time period between the two bracket events is larger, the corresponding growth curve may exhibit a "*shoulder*" of the clearly emerged latter bracket.

A final remark concerning brackets and their time dependencies should be made. A bracket and its time development is a representation of an individual, single event which will not change sign of the amplitude (impact) over time (Figure I.135). It reflects *a change of a firm's state* in one direction, by a positive or negative impact.

However, brackets may sometimes apparently appear to be reflexive. Envision a pharma firm having launched a new "blockbuster" drug in the market that made $700 million in sales over the first two years – product sales associated with a positive bracket. But, in the third year, after critical lethal side-effects were detected, the firm was subjected to a number of lawsuits, the cost of related litigations amounting to say $600 million (in the US; cf. the Vioxx and Lipobay cases, Table I.66). This seems to be a conversion of the original bracket, a change to a "negative wave" induced in the firm and by the same set of customers that generated the positive impact.

However, we encounter here decoupled brackets! The impact of the first positive bracket, being *an intrinsic part of a relation (to customers)*, means the firm has changed its state and when the firm encounters the negative effect it meets the impact (of the customers) in a different state: these are *separate, different brackets by concept*.

> The result of a bracket in the current understanding and GST approach to initiate a firm's new state has the consequence that its development (and growth) corresponds to *an irreversible process*.
>
> There is no "fall-back position" to the previous state (*status quo ante*) as a strategic option for decision-making. What can principally be re-established is an "empty shell," a constellation which will be used by persons and agents of the system who, however, will have changed knowledge, attitudes, decision-making potential etc. for initiating actions.

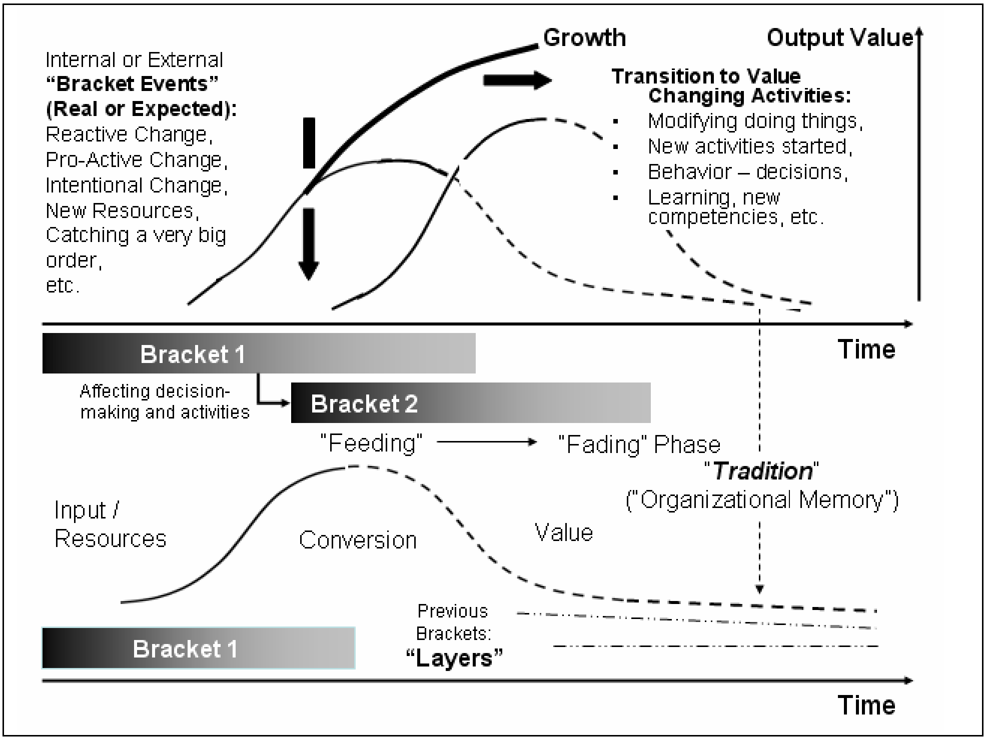


Figure I.136: Burying a bracket from observation such as revenues resulting from impacts within a short time difference.

The bracket approach is a "*perturbation theory*" treating firms' developments and associated states as essentially dynamically stable growth, for instance, with innovation and investment and productivity persistence and appropriate sets of input, resources, activities and decisions, etc. to be perturbed by *company-internal or external effects*.

In this way the notion "back on track" has a particular meaning: After a perturbation of a dynamically stable state the firm will proceed to a new dynamically stable state which, however, may or may not be structurally comparable to the previous one (linear – linear; Figure I.133, left) or (almost linear – exponential; Figure I.133, right).

The bracket model is *an irregular phase model of new firm development* contrasting the common stage-based views, such as that of Greiner (Table I.68) which associates growth with a set of structurally and operationally predefined phases initiated by a very small set of given initiators and related generic activities to proceed through the related phase.

We shall proceed assigning a variation in the measured/observable curve to *changes of the particular state of the firm* (Equation I.11; Figure I.135, Figure I.136) by one or more *unbalanced forces* and providing the *reasons for thinking that* the observed changes are due to particularly significant effects out of a set of conceivable effects.

These possible effects are derived either from empirical facts, cases, experience and/or rules of thumb established for NTBFs or existing large firms or from general theories like Porter's Five Forces Model and the Encapsulated Six Forces Model (ch. 1.2.5.3; Figure I.33, Table I.16, Table I.18) and reference to firms' failures (Figure I.114, Figure I.115) and finally hazards and risks for NTBFs (Table I.65, Table I.66).

A key role will be played by *generally known effects* (of super-systems) affecting NTBF growth like an *economic recession* or, for instance, the "*silicon cycle*" affecting specifically the semiconductor and photovoltaic industries as well as legislation for *policy-driven markets* (CleanTech like wind and solar power or biofuels). In this line, the recent (March 2011) Earthquake/Tsunami catastrophe of Japan affected, at least in certain countries like Germany, the nuclear power industry and attitudinal markets.

It should be noted, however, that for new firms endowed usually with only little resources brackets may emerge which will affect medium-size and large firms to only a little extent.

> The *first business bracket of entrepreneurship has been attributed to firm's foundation* with aspects of initiating the legal form of the firm and ownership and control (Table I.74). This event induces a startup state which can be *viewed as a transition state* (Figure I.133) which including its duration (lifetime) corresponds to the *startup thrust phase* of the initial configuration (ch. 4.3.2, Figure I.125).

Firm's foundation is particularly also a fundamental temporal bracket for the founder person(s) implicitly represented in Figure I.15 (firm's birth) and Figure I.16, the transition from intention to deed.

Instability of that very early state may be due to the formation process of agreement concerning the new firm's mission, roles and responsibilities of the leadership team and, if present, functions of employees and formation of the firm's culture. This state may also require, for instance, to relief initial group tensions as described specifically for a team in Figure I.70.

The startup thrust phase may also be associated with financing issues and establishing network connections, such as building the firm's advisory board or setting up cooperative connections with other firms. And there may be intentional changes of the original business idea or goal – becoming aware of a false start (ch. 4.3.2; 3M, NanoScape) – or revealing a new opportunity to be pursued.

A probably incomplete list of corresponding perturbations of NTBF growth will be summarized in Table I.76 in a structured manner referring partially also to risk classes for technology entrepreneurship (Table I.65).

The suggested growth models will be framed by classifying bracketing along several, often interconnected dimensions, sometimes associated with rough time markers for brackets to occur (Table I.71 - Table I.73). In particular, environment-related brackets reflect that we are dealing with open systems (Table I.76). There is

- Risk taking (ch. 4.2.1; Table I.65, Table I.66)
- Financing steps (ch. 1.2.7.2, Figure I.52; ch. 1.2.6.2)
- Firm growth and internal organizational factors, such as specialization, integration, coordination, communication etc. (Table I.69)
- Scale-up (for production related NTBFs) (Figure I.8, Figure I.9)
- External: economic and industry cycles or legislation (Figure I.34).

Bracket events show up often with “polar” effects, such as the economic boom – bust occurrence, getting a (singular) big order or making big sales versus losing the biggest customer (of only a small customer base), getting a key researcher or leader or manager, the actual company architect (Figure I.126), versus losing one. Loosing key researcher is often observed when technical firms merge.

The unexpected bracketing is often associated with opportunistic adaptation as described by Bhidé [2000:53,61,63].

In this way the bracket model has become a form of *exploratory data analysis*. It seeks to find patterns in data that are of theoretical, empirical and conceptual relevance. It is related to a *sequence analysis* involving the temporal ordering of events that mark the transitions of one stable state into another one. The issue is: getting sufficient data to find out whether hypothesized brackets will show up in the figures. [85]

Table I.76: Selected expected bracket events for new technology-based firms during their first ten years of existence.

Bracket Events	Comments, Examples
General – Global or Local; the Overall Economy or a Special Industry	
General economic recession	Usually reduction in demand; change of a firm’s organization; change of management style (control, execution); some sectors are little affected by recessions, e.g. health and pharmaceuticals (life science”), the same is true for industrial research or public research as a customer
Special industry boom/bust cycle	“Silicon Cycle” of the semiconductor industry (Figure I.152)

Life-cycle stage of the industry, particularly "birth of the industry"	Examples through, SAP, Microsoft, Cisco
Societal changes of attitudes or behavior	
Natural disaster, hurricane, overflooding, earthquake etc.	Hurricane Katrina for the US Golf Coast in 2005; the March 2011 Tsunami and earthquake in Japan
Firm-Related Brackets	
Firm's foundation as the first bracket	This bracket may coincide with selling an offering to the first customer(s) – e.g. WITec, Cambridge Nanotech (Table I.80), etc.
Both growth inducing and growth limiting factors can create organizational problems.	Hitting a critical mass of customers or employees is a "tipping point" which upon crossing leads to significant growth (decline of productivity?)
Issues within the founding team; change of organizational structure (integration, coordination, communication issues); change of the leadership/management team, in particular, a simultaneous change of ownership (Figure I.126) and VCs establishing "professional management" and organizational changes; change of management, for instance, "firing" by VCs, uncertainty, concern and anxiety of employees (effects on productivity); one key person/researcher leaves the NTBF or a key person appears in the leadership or management team	Ca. 14 percent of young German closed firms went bankrupt due to disagreements and tensions within the leadership team without any economic reason (ch. 4.2.3). It is always a negative signal if a CEO and co-founder leaves the NTBF. After firm's foundation a CEO appears from outside as a leader and ultimately the "company architect" (3M, Avery Dennison, Bayer AG; ch. 4.2.3)
Introduction of "quality management" process for NTBFs with production is often seen to be associated with organizational frictions.	This is particularly pronounced for the research function.

Table I.76, continued.

Intentional change of the NTBF’s development and growth direction; “business model innovation,” intentionally changing the business model, stepping up in the value system	False starts (3M, NanoScape); Business Self-Assessment (BSA): Tired of buying reverse osmosis membranes from other companies for use in equipment, the founder of Osmonics, Inc. Dean Spatz wanted to accelerate growth by directly manufacturing membranes himself [Runge 2006:92]; change intentionally firm’s direction totally (Zweibrüder Optoelectronics GmbH, B.2); in 2008 MetroSpec Technology, Inc. was migrating from a service engineering/design company to a manufacturing company (Figure I.167) German Xing AG (ch. 3.4.2.1, B.2) introducing new sources of revenue
Intentional change of organization	Osmonics, Inc.
Breakeven	Reaching profitability, Figure I.53
“Sudden” changes of the NTBF’s financial states	“Sudden” large capital inflows affecting operations; successful IPO; “sudden” stop of capital inflow, for instance, if agreed upon payments do not show up due to problems of the investor (seen during the Great Recession, MnemoScience, B.2) or investors/backers stop financial contributions (Zoxy Energy Systems AG, B.2)

Technology/development steps; a technological milestone (Novaled AG, Zweibrüder Optoelectronics GmbH) or breakthrough; achieving a dominant design, achieving an "industry standard"; achieving the "Holy Grail" of an industry	Affecting a technical process like scale-up or a general break-through effect (large processing cost reduction) or overcoming a "critical mass" effect
Successful launch of a new product, instrument, de-vice or service; disruptive or breakthrough innovation	Henkel (Figure I.138)
Patent, trademark (brand) infringement or other lawsuits	Especially if associated with a big loss
Non-organic growth; getting a stake in or acquiring another firm	Google, founded in 1998; bought Applied Semantics in 2003 that had a little piece of software called AdSense (Box I.24) or merging of new firm's (PayPal, ch. 4.3.2; A.1.7), ATMgroup AG (B.2)
Environment-Related Brackets	
First commercial activities (selling goods/products, services, licenses); specifically start already with a customer or customer base or startup backed by a supply agreement with a customer	Found a firm after having a cus-tomer or having already sold something forming the basis of the startup; IoLiTec and Solvent Innovations (A.1.5), WITec, ChemCon, Attocube, PURPLAN, Cambridge Nanotech Concept Sciences, Inc. (CSI) - Box I.11
Establishing sales and distribution	Own organization of sales and distribution ("sales forces," e-business, franchising) versus "out-contracting" sales and distribution (and probably marketing) includ-ing cooperation and networking with large firms (Figure I.51, Figure I.125). internationalization for an NTBF's offerings (including issues of currency exchange rates; Figure I.116)

Table I.76. continued.

Market-related brackets: catching a very big order from a customer (including military) or special customer segment	Examples: Nano-X GmbH (Figure I.137), Perkin & Sons (Table I.100)
Losing a major customer (from a small customer base) or a large reduction of orders of customers;	Nanophase Technologies (Figure I.140)
"Sudden" appearance of a competitive (substitutive) offering on the market or disappreance of a competitor	
Adverse event due to supplier-customer relationship;	German Nanopool's issues with a customer/distributor [Runge 2010]
Infrastructural effects (enlarging the basis of offerings' usage for technical or other reasons);	The role of IBM for SAP's and Microsoft's growth (Figure I.143, Figure I.144)
Exchange rate issues;	ChemCon, First Solar
Election of a new government	May influence S&T policy, regulations, subsidies etc.
Blocked export by changes of national tariffs or industry standards;	
Changes of national laws, regulations or innovation policy, phasing out materials (chemicals) or technical components	Policy-driven markets; renewable energy and energy efficiency
The Unexpected Bracket, Chance-Related Bracket	
Windfall gains: can occur due to unforeseen circumstances in a product's market, such as unexpected demand or government regulation; luck or serendipitous technical or commercial events	Tsunami/earthquake in Japan: German Heyl GmbH & Co. KG (Berlin) [86] offers e.g. Prussian (Berlin) Blue for treating radioactive cesium contamination by binding and washing out radioactive cesium spilled by the Fukushima nuclear plant. There was not only tremendous demand in Japan, but also in other countries [Dankbar 2011].

Though playing a central role in the models of industry forces (Figure I.33), in Table I.76 a bracket related to competition (rivalry) occurs only once. Competition basically may adversely affect revenues and profitability (decrease in profits or market share).

On the other hand, strong competition has been listed as one of the reasons for firm failure (Figure I.114). Furthermore, the previous outlines strongly emphasized competition or competitive advantage, respectively (Figure I.94, Figure I.114, Figure I.117, Figure I.122, Table I.75).

One rationale for this situation is that the bracket model emphasizes effects which show up observably for a relatively short period markedly in the development indicators of an individual NTBF. This requires competition to induce a "sudden" change of the particular development indicator as given in Table I.76. Or competition in a market corresponds to a permanent activity and represents a "ground noise" which cannot be separated from the development indicator's curve.

Disregarding new Internet and consumer service firms or software firms, most technology startups are not late entrants into a crowded space. They are often innovators entering new fields or new ways of doing business. They need to get to a significant size before established companies take notice. Furthermore, the sizes of the markets startups are operating in are usually too small to satisfy the needs of large firms (ch. 2.2.2).

Referring to 1989 *Inc.* 500 *privately held startups* Bhidé [2000:40,41] found that concerning competition fewer than 5 percent competed against large (*Fortune* 500-type) companies, 5 percent against midsize companies and 73 percent compete against small companies or other startups.

According to Saras Sarasvathy [Buchanan 2011] technology entrepreneurs see themselves not in the thick of a market but on the fringe of one, or as creating a new market entirely. "They are like farmers, planting a seed and nurturing it," she says. "What they care about is their own little patch of ground." However, things may become pronounced, if they get involved in patent issues (Nanion Technologies GmbH; B.2).

Analyzing the cases of competitive groups in nanocoatings (Nanogate AG [87], Nano-X GmbH (B.2), Nanopool GmbH [Runge 2010], Nanofilm LLC – B.2) and ionic liquids (four cases; A.1.5) as well as discussing the issue of competition with other founders of NTBFs who gave presentations at the author's course [1] suggests that technology entrepreneurs worry not so much about competitors.

Not just those following competitive antagonism (Table I.32), but all entrepreneurial firms whose founders address directly the known competition operate consciously and continuously vis-à-vis the competition, but being confident and convinced that their offerings are and must be always better, lighter, higher quality, easier to use etc. (cf. "what if" questions of ideation, ch. 3.3; innovation and investment persistence).

A different situation may occur for VC-based or other startups or NTBFs which have become very large in few years in a densely occupied market. Here adverse effects of competition could result in a sudden reduction of market share – particularly, when there is an "explosion" of startups, many new entrants into a market or industry in a boom period or in policy-driven markets, such as the biofuels field (A.1.1) or other areas of CleanTech.

Here “super-competition” between a very large number of small and large firms may emerge fast based on technologies, types of offerings, processes and business models (Figure I.181, Figure I.184, Figure I.185, Figure I.183, Table I.17).

In this case startup entrants often hope that the market size is so large that even capturing only a tiny market share will satisfy the entrepreneur(s) ambitions and expectations. However, the situation will become soon more complicated when, for instance, for wind energy (wind turbines) and photovoltaic, companies from China and India enter the scene competing fundamentally on price (ch. 4.3.5.2).

Usually, for new market or industry genesis, there are very many market niches to be occupied by startups to avoid a highly competitive field (cf. ionic liquids applications, A.1.5; WITec GmbH versus JPK Instruments AG, Figure I.141).

The faster the startup can define its own market and secure customers the more likely it is to end up being the dominant player in the (new) segment. The time to start looking at competition is later in the life cycle. That does not mean startups do not need to do their homework though. Knowing who else is out there that may be a threat is important, but execution at early stage pays way more dividends than deep competitive analysis and defensive strategy.

The concept of dynamically stable states and transition states and bracketing for new firm development implies that an entrepreneur (leadership/management team) will undertake several *different types of entrepreneurial activities at different times* in relation to the goal of the firm and to “perturbations” from inside or outside the firm. Perturbations require *different competencies* and *different kinds of decision-making* to lead growth, but also lead and execute through a “crisis.”

Different types of entrepreneurial activity require different resources and skills of the entrepreneur, with different types of risks and the rewards. These different types of activity should not all be lumped together in empirical research. But one can hypothesize that viable NTBFs that face similar initial configurations and sensitivities to external effects and similar developmental problems in sequence and access comparable markets will go through similar phases of activity and exhibit similar growth patterns (Table I.80, Figure I.163; A.1.6).

So far, the emphasis to systematize technology entrepreneurship was on types of technology ventures (Figure I.128) and architectures and configurations (ch. 4.3.2, A.1.6). On the other hand, Kunkel [2001] suggested focusing on an alternative approach, classifying types of “entrepreneurial activities” which would be attractive when dealing with NTBF growth. However, we think that the current approach integrating structure, the order of componens, and function, the order of processes, is appropriate for the subject.

4.3.5.2 The Bracket Model for Framing Empirical Observations and Explaining NTBF Development

Observation of actual and continuous development (growth) among NTBFs requires a long period (ten to twelve years) of investigation. But to deal with survival and growth of new firms the startup thrust and early development phases of NTBFs, particularly the initial configuration (ch. 4.3.2), will provide appropriate quantitative variables and parameters and criteria.

The bracket approach provides a way to a systematic analysis of a firm's ability to resist external shocks: "If there is a high probability of any negative event occurring and the hardship it imposes are generic, then one can incorporate the effect of random events through the venture's capacity for withstanding a common set of probable difficulties" [Woo et al. 1994:520]. In this sense the menu of (positive and negative) events in Table I.76 can be seen as a conceptual basis for the following discussion.

> The bracket approach boils down to "*curve analysis*" ("curve resolution"), *origins of change* and *discussions of dynamic stability intervals of growth*.

For instance, when encountering a significant (positive) jump in an early linearly increasing growth curve, as is observed in Figure I.137 for the German nanocoatings firm Nano-X GmbH (founded in 1999), the most straightforward assumption would be to associate the bracket with a remarkable *sales* activity. The earlier increase of the number of employees to prepare the related sales *success* (a further "reason why we think that") indicates such an effect. And, indeed, this is the case. However, the *actual cause* of the jump, what the bracket represents, can only be grasped by switching to inspection on the firm level.

In 2004 Nano-X (B.2) captured a very big order for a new *innovative product* including this order to provide continued demand in the near future. The firm's first reaction was expanding production capacity and manpower (2003/2004 bracket of the employees' curve). The second (2004/2005) bracket is the reflection of the revenues' jump, doubling revenues. The product concerned surface coating (scale protection of metal sheets avoiding high-temperature oxidation) with the automobile industry as the end-user. The product is sold to German steel producer Thyssen-Krupp delivering the coils nano-coated by Nano-X technology for several types of metal sheets for the car body of the Volkswagen Passat model.

The Nano-X case shows that future revenues and profits of young firms cannot be foreseen reliably and single big orders may exhibit tremendous influence – in the positive or negative sense if the firm depends on big orders of one of very few customers (Figure I.115).

A jump in revenues like that of Nano-X is also observed for German ATMgroup AG from 2008 to 2009. Without detailed knowledge about the firm's internalities there cannot be a straightforward explanation – as in the case of Nano-X. The individual details for an explanation are as follows: The firm was founded as ATMvision AG in 2005 and in 2008 it acquired two other firms to become ATMgroup (B.2) which expresses the jump as a “resulting explosion” through non-organic growth (Figure I.127). Other examples of non-organic growth (Figure I.141) do not show such a marked effect.

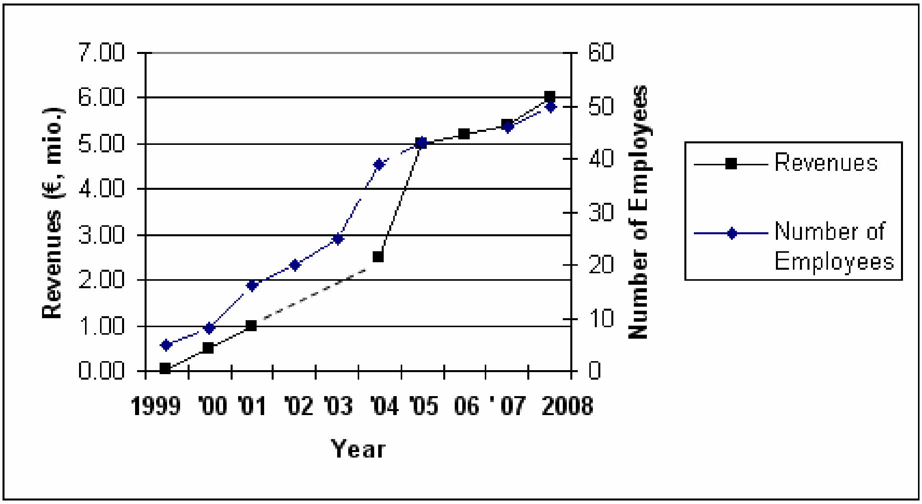


Figure I.137: German Nano-X GmbH with a jump of otherwise linear growth periods (dotted line replaces missing data points).

A linear growth curve changing over into much steeper “linear” shape after a *disruptive innovation* (Figure I.138) can be seen in the historical example of intrapreneurship of the German firm Henkel AG & Co. KGaA (Henkel & Cie. at that time). Founded in 1876 in 1878 the firm’s first branded washing material “Henkel’s Bleich-Soda” (Henkel’s Bleaching Soda) entered the market. Almost linear growth of production from 1902 to 1907 (Figure I.138) is observed. Sales of the “Bleaching Soda” from 1884 (239,000 German Reichsmark (RM) to 1900 (1,155,000 RM) [Feldenkirchen and Hilger 2009] showed roughly exponential growth over the period. For comparison in 1914 the value of the US dollar had a factor of ca. 4.2 to the German Reichsmark [Runge 2006:473,474].

The total production increase after 1907 is due to the Persil innovation [Feldenkirchen and Hilger. 2009]. A rather steep exponential growth of Henkel’s revenues due to sales of Persil, the *first “self-acting detergent,”* was prevented by a very long lasting, terrible global event, World War I (WWI; Figure I.139). On the other hand, the development in Figure I.139 reveals that even an extremely strong force can be largely balanced by an extremely successful innovation assumed to exhibit exponential development (indicated by the dotted curve progression): Henkel’s revenue curve plateaued during WWI, rather than showing a marked dip.

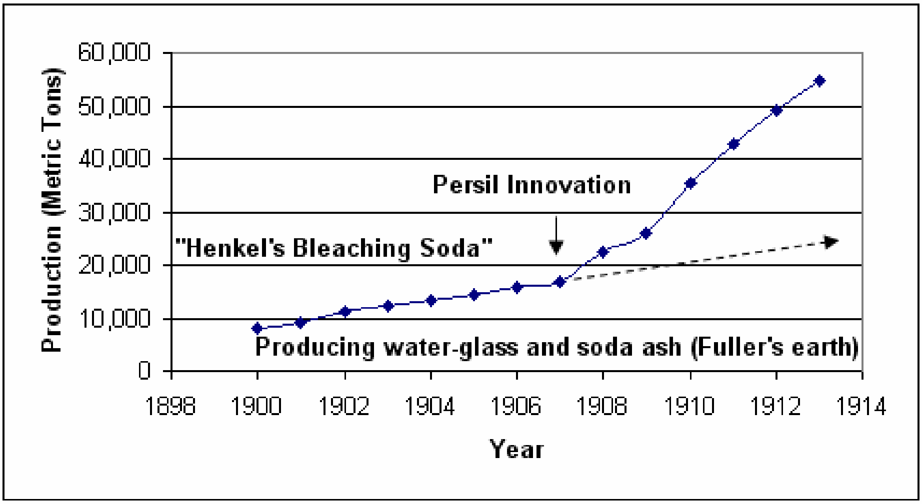


Figure I.138: The bracket of Henkel's Persil innovation in Germany (production of glycerin ca. 1% of total neglected).

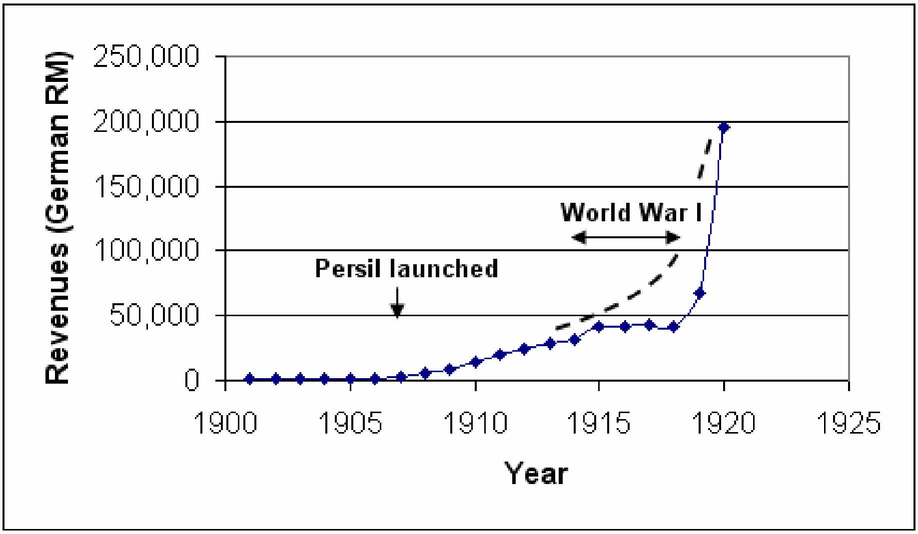


Figure I.139: Bracketing observed for Henkel's revenues by an extremely severe global factor.

It is not uncommon that some few (fast) growing firms exhibit steep exponential growth keeping yearly revenue increase of fifty percent to one hundred percent from startup. Such companies achieve one billion dollar (euro) in revenues in just a few years, usually less than ten years, as achieved by Cisco (Figure I.145), Q-Cells (Figure I.152, Figure I.153) or Google (Figure I.159, Figure I.160; ch. 4.3.6).

More than often assignment of brackets to entrepreneurship-related effects, however, may become tough as the below Figure I.140 shows referring to Nanophase Technologies Corp. Nanophase was founded in 1989 as a spin-out of Argonne National Laboratories. In the early years, Nanophase ramped up manufacturing technologies to commercial scale and established a viable manufacturing facility. In 1996 revenues were still quite small (approximately $600,000).

From its inception in November 1989 through December 31, 1996, the firm was in a development stage of scale-up. Since January 1, 1997, the Company has been engaged in commercial production and sales of its nanocrystalline materials, and the firm no longer considered itself in the development stage. It went public at the end of 1997 and the common stock traded on the NASDAQ.

The example of Nanophase Technologies shows the fundamental risk of new firms, namely dependency of revenues on very few customers. Nanophase shows both associated effects – much gain and much loss.

Furthermore, the example stresses an important issue of the current and almost all approaches to growth of new firms relying on revenues and/or number of employees – the longer-term viability of a firm without positive cash flow and, moreover, rather than profit generating having net losses over years. Here patterns of decreased net losses follow essentially increased revenues.

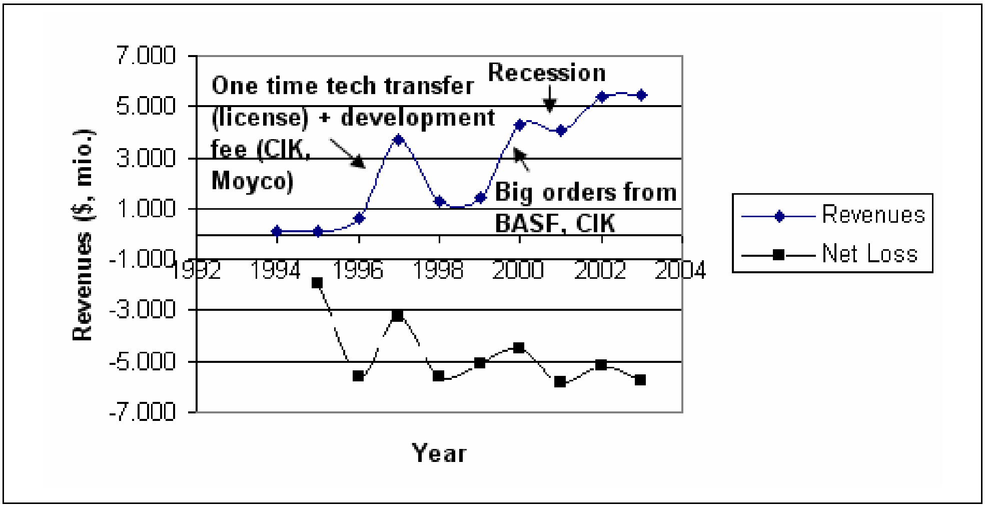
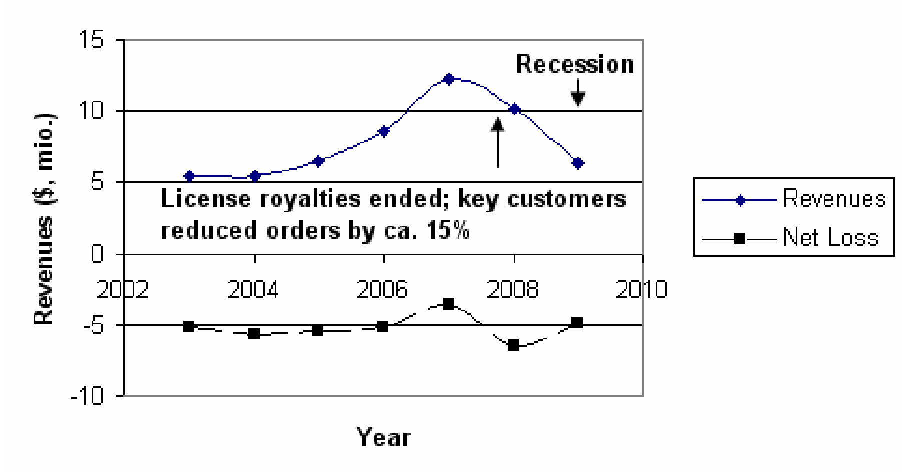


Figure I.140, continued.

The dip at 2001 of the curve is obvious – the Dot-Com Recession. It is not clear, however, whether there is a (negative) dip between 1997 and 2000 and how to assign it. There is no straightforward explanation for one bracket of such a markedly negative effect which stops an exponential growth till 1997.

Comparisons with other firms concerning the period 1996-1998 does not provide a clue. Hence, either there is a large one-time negative influence or the curve represents a one-time large addition to revenues which, for the 1996 – 1998 – 2000 period, would show exponential growth. The last option is indeed is the case.

Revenues from BASF and CIK constituted approximately 68.5 percent and 10.0 percent, respectively, of the company's 2000 revenues.



The reduction of 2009 revenues to the level of 2005 could be a huge effect of the 2009 Great Recession. The decrease of the revenue curve starting already after 2007 and its tremendous magnitude in comparison to revenue reductions of other firms during the recession suggests the existence of an additional (negative) effect. The cause is revealed by inquiry on the firm level.

Since 1996 Nanophase's number of employees was hovering around fifty five (with a peak of 61 employee in 1997 and currently around 55).

Figure I.140: Revenues and net losses of Nanophase Technologies.

The *actual financial state of a firm* and its overall "health" is not generally reflected by revenues. The assumption of revenues to be an appropriate indicator for the new firm's financial state or number of employees to reflect *viability of growth* is generally associated with some implicit premises – and the non-accessibility to more appropriate data unless dealing with the few NTBFs which are already publicly traded at a stock exchange.

Usually, one takes the “income state” (revenues) in the sense of “pars pro toto” as an indicator of a firm’s financial state to be sufficient for further growth. But, ideally at least the “loss state” (net loss) and “financial reserves” (cash, equity, or number of basic and diluted shares outstanding) should be taken into account.

Patterns of *non-organic growth* (Figure I.127), which is essentially growing by having stakes in or acquiring other firms or establishing joint ventures (JVs), provide complex cases. But, for the few cases under consideration, related NTBFs do not show specifically significant patterns. An illustration is presented by the two German NTBFs Nanogate AG and JPK Instruments AG (Figure I.141). These do not only belong to the *same competitive group* as Nano-X GmbH (Figure I.137) or WITec GmbH (Figure I.123), respectively, but are structurally very close – also with regard to years of firms’ foundation, being subjected to the Dot-Com Recession.

In particular, WITec GmbH and JPK Instruments AG show comparable education and leadership structures of the entrepreneurial team (Table I.41; Figure I.73) and for both the founding team is the owner or majority owner, respectively, with full control of their firms. They both are university spin-outs (of physics departments) and offer nanotools (“nano-analytics”) on the basis of optical microscopy for research purposes addressing essentially “hard” substrates versus “soft” substrates like cells and provide “enabling technologies” for use in industrial R&D departments and private or public research organizations.

Furthermore, WITec and JPK have a large proportion of customers from life science (pharmaceuticals) which make them rather resistant against economic crises like the Dot-Com Recession or the Great Recession. Both exhibit dedicated innovation persistence and linear growth curve but have different CAGRs (JPG Instruments has 41 percent between 2002 and 2010, WITec 29 percent between 1998 and 2009), and show different productivities (WITec ca. €270,000 per employee, JPK Instruments ca. €125,000 per employee).

Both firms show marked innovation persistence. Contrary to WITec (Figure I.123). JPK Instruments (founded in October 1999) had it startup thrust phase during the Dot-Com Recession. It launched its first product into the market only in the fourth year after foundation (in 2002). It is not clear whether the strong increase in revenues of JPK between 2002 and 2004 (from €650,000 to €4.5 mio.) is the result of increasing sales of instruments or taking a stake in the firm nAmbition or both.

Furthermore, it is to be noted that, in terms of revenues, WITec and JPK do not show any effect due to the Great Recession in 2008/2009. The most likely reason is that both address to a large extent customers from public or industrial research areas which mostly did not encounter any significant shortages of their budgets during the crisis.

On the other hand, Nano-X GmbH (founded 1999) and Nanogate AG [87] (founded formally 1998), both having experienced leaders or managers, respectively (B.2), are active in nanotechnology for materials and materials' surfaces ("chemical nanotechnology") and are based essentially on "enhancing technologies" and less on "enabling technologies" for industrial and consumer applications.

Moreover, both are spin-outs from the same public research institute at almost the same time and both are located in close proximity. However, as Nano-X is a private company, Nanogate is VC-based, essentially a spin-out that resulted from a cooperation of the German Bayer AG and the public Institute for New Materials (INM) with immediate involvement of the VC firm 3i. Furthermore, it is to be noted that two of the founders from INM left Nanogate relatively soon after foundation.

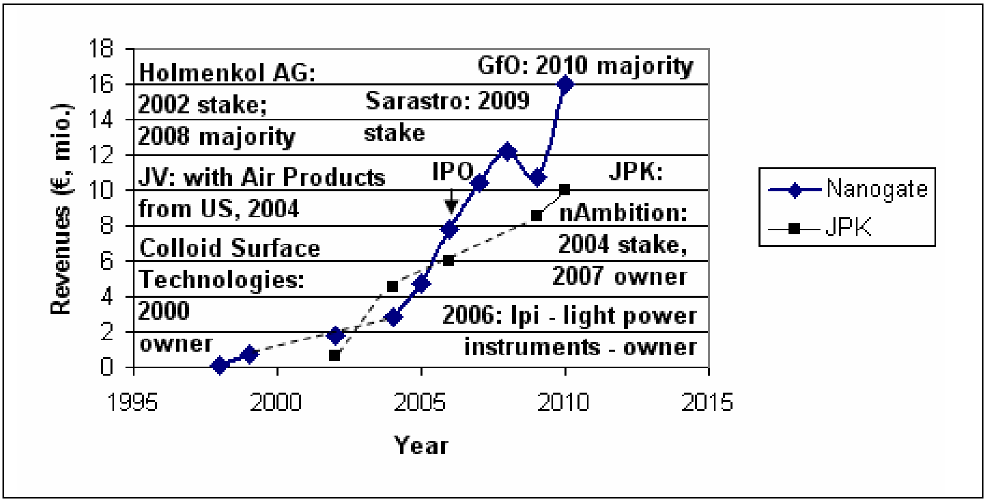


Figure I.141: Revenue developments of German firms Nanogate AG (founded 1998) and JPK Instruments AG (founded 1999).

The linear growth of Nanogate until 2004 and then the steeper linear growth until 2008 do not exhibit any special remarkable effect driving revenue growth. However, the big jump out of the 2009 Great Recession is to be noted. Only knowledge of the non-organic growth strategy and results of Nanogate would provide the clue to assign the jump in revenues to acquiring stakes in other firms rather than acquiring a big customer as observed for Nano-X (Figure I.137).

Productivities of both firms differ markedly: Nano-X (ca. €120,000 per employee), Nanogate (ca. €180,000 per employee). On the other hand, JPK Instruments with a non-organic growth approach follows linear growth, similar to the technologically directly comparable firm WITec (Figure I.123) without any indication about the role of its acquisitions or partial ownership of other firms.

For Nanogate the JV with Air Products and Chemicals from the US in 2004 opened up international markets the company might not have reached alone. But it is unlikely that the steeper increasing revenue after 2004 to be due to the JV event.

One may assume that building of different kinds of resource base involves different kinds of activity. And this may affect different development states and paths. Concerning financial resources for development, like cash flow, loans or equity provision without losing control versus equity from large, private investors, venture capitalists or IPOs, differences do not seem to be mirrored observably by the underlying growth indicators for WITec versus JPK but for Nano-X and Nanogate.

Also US NTBF Osmonics developed via non-organic growth [Runge 2006:91-94]. Considering also that Google in its early years took over another firm with no observable macro-effects (Box I.24; Figure I.159, Figure I.160) it seems that getting a stake in another firm with the possibility of revenues' development to behave like a big order does or massive addition of employees or both do not necessarily show up as a bracket in a revenue curve. Furthermore, the discussion of PayPal indicates that also mergers must be considered.

Related to the relatively small sample of NTBFs discussed in this book, we feel that it is not clear whether NTBF development by non-organic growth should be taken into account as a development path with its own observable specifics if revenues or numbers of employees are considered.

Nanogate exhibits a continuous pursuit of growth by both an internal and external focus. If, however, there is a marked increase in number of employees it can be expected to increase organizational pressure to integrate and consolidate, irrespective of whether it results from organic or non-organic growth.

As observed for NTBFs with organic growth also Nanogate shows a marked decrease in productivity when the number of employees increased significantly (here from 41 (2006) to 68 (2008) employees; Figure I.142). So far, a negative bracket has been associated with management and/or organizational issues. And this seems also to apply here. Nanogate's annual report 2007 tells us:

"As part of the implementation of the strategic growth programme NEXT, a new organisational structure was created, a management stratum was established and the central management strengthened with the addition of a commercial director and a management position for the buildings/interiors business segment."

Furthermore, in 2008 Nanogate Advanced Materials GmbH, the JV with Air Products & Chemicals, was fully acquired by Nanogate and in 2009 the related dip is additionally enforced which should be an effect of the 2009 Great Recession.

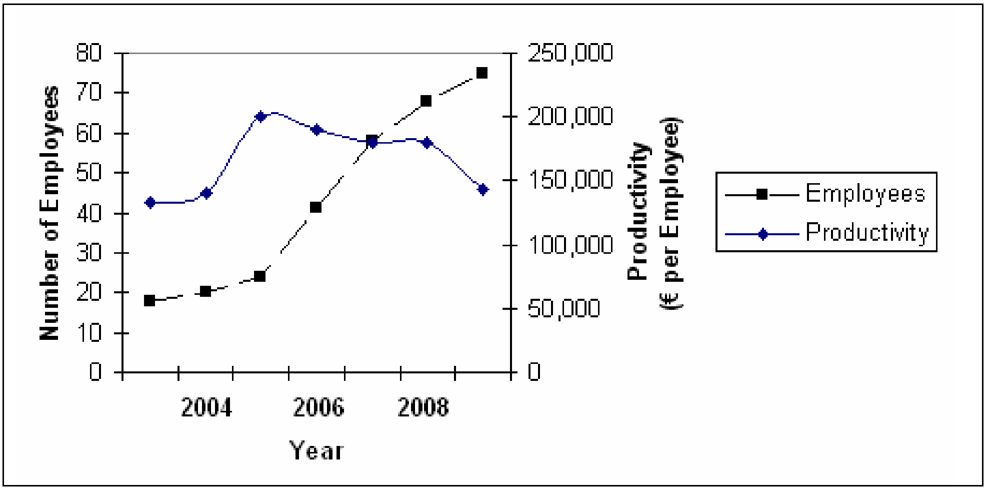


Figure I.142: Increase of number or employees and associated effects on productivity for German Nanogate AG.

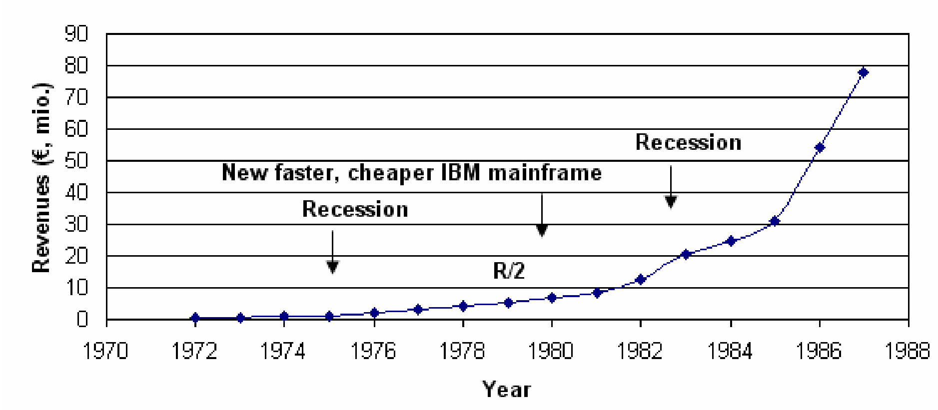
After having taken a general economic and other external effects, recession and WWI, into consideration we shall consider the industrial system, essentially *early growth of particular new industries or markets* (providing high growth opportunities). Macro effects for the synthetic dye and automobile industries including the fast rise of gigantic firms like the German BASF, Bayer and Hoechst were cited by Runge [2006: 274-275] in terms of entry and exit firms of the industry or given by the Ford and General Motors cases in the US [Bhidé 2000:245-247].

The birth of an industry (segment) usually induces a "boom" of firms' foundation (cf. the biofuels situation; A.1.1). It represents a special opportunity for entrepreneurship. However, the particular "growth pushing events" for an individual new firm can rarely be foreseen or expected.

Basically, the growth curve of corresponding (very) successful firms has the phenotype of "continuous – exponential" (Figure I.107). Birth of an industry (or a segment) means everybody is new in the business. And in such markets buyers have to deal with a new company or forgo the product or service altogether.

A first more recent example refers to the "mainframe computer age," here the emergence of Enterprise Resource Planning (ERP) software and the German SAP AG (A.1.4) "grasping" the opportunity (Figure I.143). SAP had to overcome the recession of the first oil-price crisis around 1974, but actually could take advantage from a market-related infrastructural effect. Mainframe dominating IBM on which SAP's software ran introduced a faster and cheaper model which enlarged the customer basis for SAP tremendously.

Early Growth of the Mainframe Computer-Based Enterprise Resource Planning (ERP) Industry Segment



SAP AG – Founded 1972; IPO 1988; (sources for data in A.1.4; compare pattern with that of Henkel, Figure I.138, Figure I.139); R/2 is a modular standard ERP software, the basis of SAP's success (ch. 4.3.6) – cf. also Figure I.189.

Figure I.143: Brackets for the early growth of SAP AG.

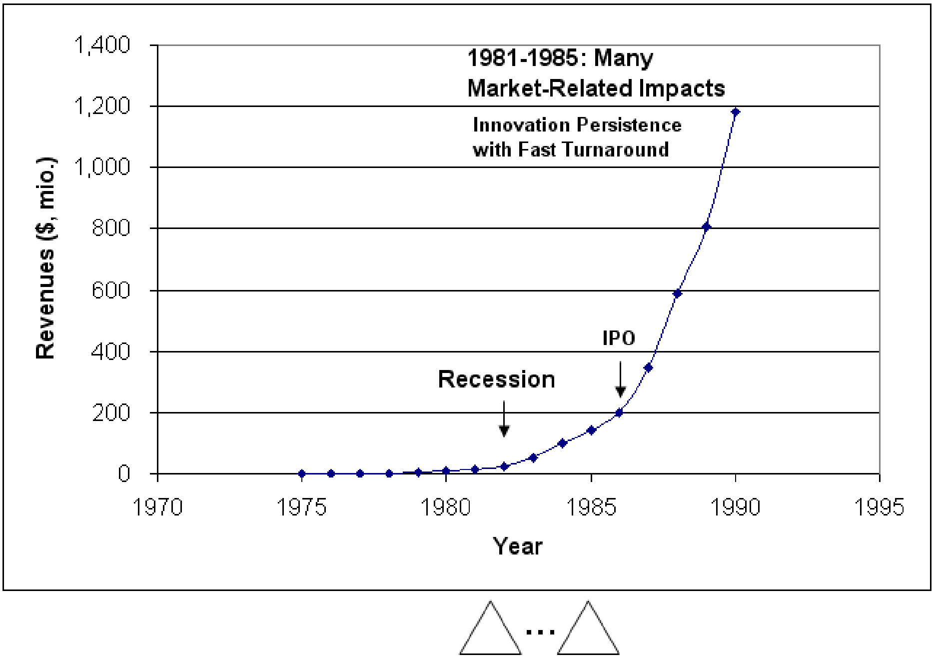
Before being able to fully take advantage from the favorable market effect, SAP had to overcome a further recession. This explanation interprets the middle growth phase (1981-1985) as an overlap of the 1980 bracket and the ca. 1983 recession. This means an interpretation overcoming the recession rather than introducing two brackets at around 1981 and 1985. Further revenues developments of SAP are given in the Appendix (A.1.4). The quite linear revenue increase between 1976 and 1981 is associated with productivity data of SAP (Figure I.147) which are almost constant for the interval <1976,1979> and, hence, represent a dynamically stable state.

In a similar way, increased growth of Microsoft after 1986 is seen as a sharply exponential growth induced by a whole series of brackets between 1980 and 1985, some of them being listed in Figure I.144. Any revenues reducing bracket would be leveled off by these tremendous factors. Early revenue growth data are given in Table I.67.

Microsoft has been very responsive to the demands of IBM to secure the crucial order for the PC operating system MS DOS from IBM in 1980. After the success of the IBM PC Microsoft could drive hard bargains with PC manufacturers to consolidate its position in the existing PC operating system market to ultimately conquer the market.

As for SAP IBM with its new mainframe to run SAP's application also for Microsoft IBM played a key role of "accelerating" the developments of the firm.

Early Growth of the PC-Based Industry



Microsoft Corp – Founded 1975; has been in *the Inc.* 500 List;
Many immediately following brackets and also the IPO in 1986, getting big orders and showing innovation persistence:

1980/1981: Huge contract with IBM to develop languages for their first PC including the operation system (DOS); arrival of the 16-bit IBM PCs.
Becomes the first major company to develop products for the Apple Macintosh.
1983: MS-DOS open to run on non-IBM machines; memory stretch beyond the original 640K limits of the Intel 8086 chip; MS Word for DOS 1.0.
1984: Leading role in developing software for the Apple Macintosh computer, for instance, the Microsoft Excel spreadsheet for Macintosh; provided the essential technology basis for the Windows versions of Microsoft Excel a few years later.
1985: Graphical user interface (GUI) introduced (Windows).

Figure I.144: Bracketing during Micosoft's early development (Sources of data from Note 88).

An example of early growth of a firm which did not suffer from any recession during its early growth phase is Cisco Systems, Inc. (Figure I.145). Furthermore, the Cisco example shows that productivity in addition to other growth indicators to be appropriate to track company internal effects. Cisco exhibits a bracket which correspond actually to two related company-internal effects, getting venture capital, installation of a "professional" manager and adding a huge number of employees (Figure I.126, Equation I.11) – definitely associated with serious organizational problems of integration and coordination seen in the productivity curve.

Cisco Systems represents an NTBF, which, just having passed the startup thrust phase, after three years, became a VC-based NTBF.

Early Growth of the Computer-Based Networking/Telecommunication Industry

Cisco Systems:

Husband and wife Len Bosack and Sandy Lerner, both working for Stanford University, wanted to email each other from their respective offices located in different buildings but were unable due to technological shortcomings.

A technology had to be invented to deal with disparate local area protocols. And as a result of solving their challenge – the multi-protocol router was born. Since then Cisco has shaped the future of the Internet by transforming how people connect, communicate and collaborate.

From the birth of Cisco (founded 1984, IPO 1990) until year seven of its existence no recession showed up and Cisco exceeded one billion in sales in 1993.

Developments of Revenues and Numbers of Employees:

Revenues and number of employees developed almost synchronously.

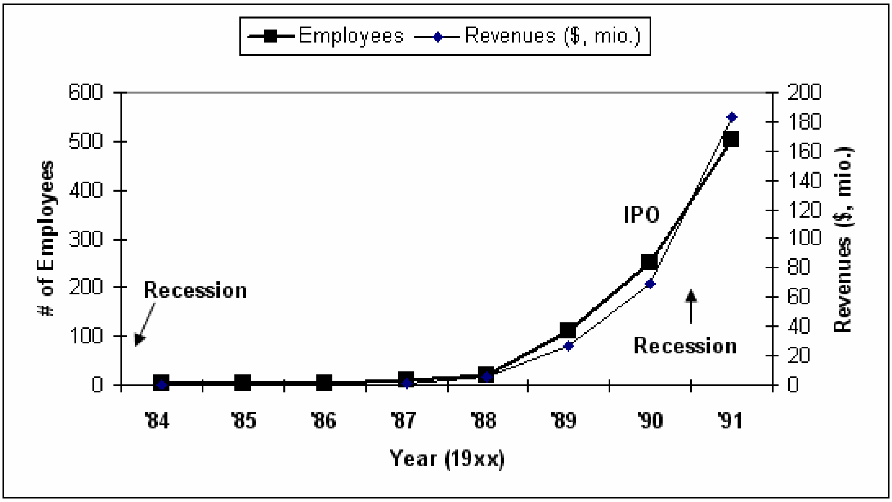
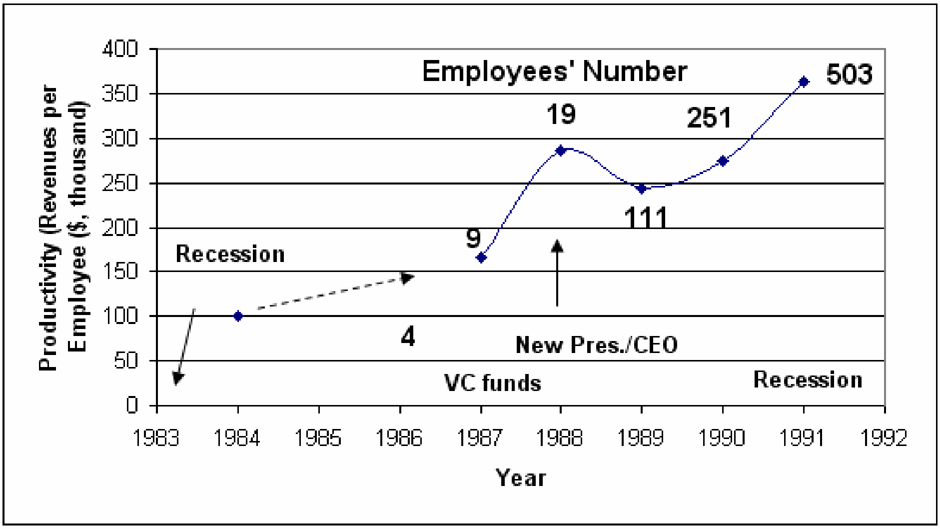


Figure I.145, continued.

Productivity and employees' numbers of Cisco:

There is a marked negative dip. Employees' numbers suggest that the large increase in employees reflects organizational frictions affecting productivity.



John Morgridge joined Cisco Systems in 1988 as President and CEO, and grew the company from $5 million to more than $1 billion in sales.

After 7-8 years of existence Cisco showed a remarkable productivity of ca. $350,000 per employee.

Figure I.145: Characteristics of Cisco Systems (Sources of data from Note 89).

The management crunch (Figure I.118., Table I.72) and the "10 - 25 - 150" rule of thumb (ch. 4.3.1, Table I.72), for instance, reflects essentially organizational issues resulting in decreasing outcomes and results, especially productivity of the firm. This means, this rule is associated with a bracket having a negative impact. Associations to a time-scale of NTBF development (Table I.71 - Table I.73) may facilitate reasoning when attributing observed brackets to related effects as does the knowledge about the occurrences of recessions.

In a similar way to Cisco one can reveal organizational issues of Microsoft while showing strong revenue growth (Figure I.146) and of SAP (Figure I.147; cf. also Table I.67). As Cisco does, also Microsoft shows significant reductions of productivity when employees' numbers were increased by around ninety people (1980/1981). And, furthermore, for Microsoft obviously the dramatic increase in employees' numbers after 1981 induces further organizational issues – and subsequent brackets with *escalating* effects. Additionally, Microsoft data are in line with the “management crunch” and the “10 - 25 -150 rule” (Table I.72).

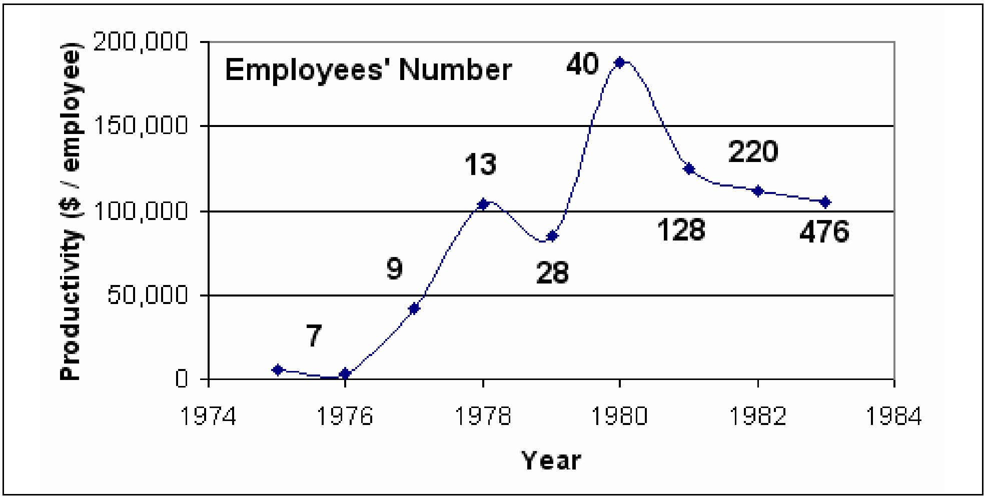


Figure I.146: Early organizational issues of Microsoft comparing productivity and number of employees.

We characterized the tremendous decrease of productivity as an escalating effect when Microsoft’s number of employees tripled or doubled over a short period (40, 128, 220, 476, Figure I.146).

In general, we regard **escalation** as an expression of a *binary relation* originating with a special phenomenon or event and showing up either as an increase or rise, lifting something’s extent, volume, number, intensity or scope *fast stepwise to a higher level* or a corresponding decrease. Escalations can be described in terms of transformations. Escalation is also possible among different kinds of brackets (effects), in particular, by mutually reinforcing interactions.

SAP exhibits two dips (eighteen and sixty-one employees) of the productivity curve paralleled by increasing growth in terms of number of employees and revenues (Figure I.147). One could be tempted to attribute the 1975-dip to effects of the 1973/1974 recession. 1979-data represent definitely pre-recession effects. We attribute the 13-18 employee dip to organizational issues (the “management crunch”; Figure I.118) without ruling out additional recession effects. SAP and Microsoft both have reductions of productivity after increasing the number of employees above thirteen.

After seven to eight years of existence, SAP and Microsoft exhibit productivity of ca. €85,000 or $100,000, respectively – similar to that of Nano-X (Figure I.137).

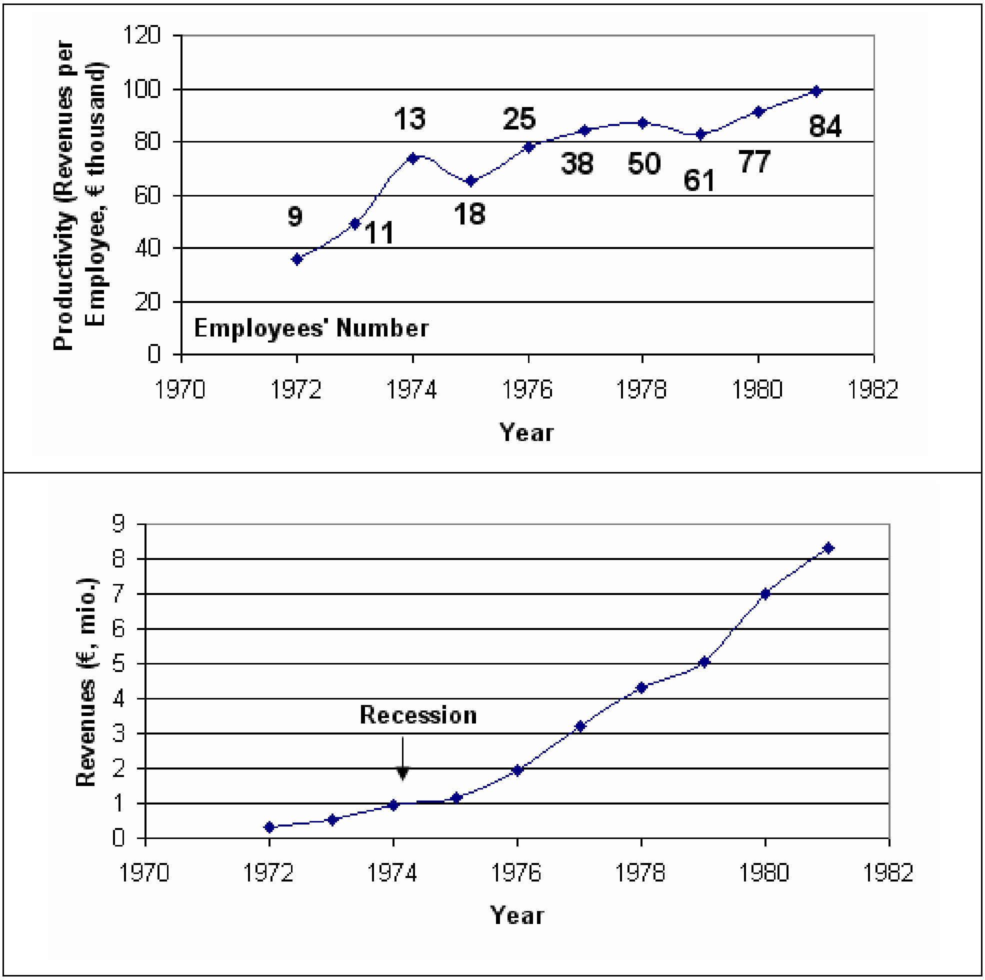


Figure I.147: Early organizational issues of SAP derived from comparing revenues and productivity.

Organic growth of NTBFs in terms of innovation and investment persistence (Figure I.127) can also be viewed as escalations.

For instance, the disappearance of an NTBF due to financial problems (Figure I.114, Figure I.115) is a decreasing escalation. It represents a circular situation of development in which a trigger in a system (a “cause”) leads to an effect in the sub-ordinate system, this effect simultaneously becomes a cause affecting the super-ordinate system and, hence, the original cause initiates a reaction onto itself leading ultimately to an end state.

According to the cybernetic formalism (ch. 4.3.4) one can, for instance, describe such a development (decreasing revenues) triggered by "negative market effects" via the operator $\mathcal{NM}$ as a stepwise process affecting the financial state of the firm and resulting in a disastrous (numerical) financial situation DFS of the firm and, finally, bankruptcy:

$\mathcal{NM} \rightarrow$ {recession – reduced orders/demand – less customers} $\rightarrow n_S(M)$}

$\mathcal{FS} \rightarrow$ {revenues/cost ratio – rejected application/denunciation of loans – bad debts (accounts receivables) – poor financial management} $\rightarrow$ FS

Furthermore, we attribute the results of the transformations to corresponding (numerical) variables $n_S(M)$ and FS quantifying their effects. Disregarding the "hen or egg" problem, the start of the escalation (Figure I.114) is taken as the firm development by the transformation $\mathcal{NM}$, such as losing the most important of only few customers affecting FS.

For the escalation one can take a *logistic difference equation* (Equation I.16; as seen in Figure I.70, Equation I.5) and start from FS = medium = 4 (, then acceptable = 3, bad = 2, very bad = 1) that simulates the path to the disaster of a non-sustainable financial state DFS of the firm. The market influence is introduced by the factor $n_S(M)$ (assuming again -0.25):

Equation I.16:

$$FS_{j+1} = n_S(M) \cdot FS_j \cdot (1 - FS_j) + DFS \rightarrow DFS$$

A summary of many of the brackets and related attributions to effects discussed so far for new technical firm development is provided by the example of German (VC-based) Novaled AG (B.2) in Figure I.148. Novaled is active in and a key leader in the organic LED (OLED) business for flat panel displays (FPD) and lighting. It expected to break even in 2011.

Figure I.148 exhibits the origin of the firm (RBSU, as a GmbH – LLC) and its thrust phase (2001 – 2003), revenues and employee data, financing by venture capital in line with re-organization of the firm and the start of commercial activities, information for breakthrough technology developments and securing IRP by patents as well as further details for re-organizations associated with the first and second financing round.

The first financing round of Novaled is important with regard also to establishing a very experienced CEO, who, with an engineering education, was in high management positions of two firms, each representing one of Novaled's business targets. The related bracket is reflected in data for revenues and employees. The tendency of venture capitalists to establish management (and CEOs) in terms of "*veteran management*" having long experience in managing and in the markets and industries the NTBF is active in can be observed ubiquitously in biofuels startups (A.1.1).

On the other hand, the effect of the Great Recession 2009 is only seen in the number of employees (Figure I.149). The capture of further rounds of financing was definitely facilitated not only by previous progress in revenues but also the tremendous technological breakthroughs in terms of world records, increase of trust and credibility. This means, technological advancements may have also created a bracket which, however, cannot be detected by the used indicators.

Negative effects of re-organizations associated with the first (2004/05) and second round (2007/08) as seen in the productivity curve are probably more than leveled off by income (selling licenses, then also material) and overall productivity increase and probably less by the additional financial resources. Re-organizations associated with significantly increasing numbers of employees refers to building the Chemistry Group (in a more or less physics and engineering environment) and setting up a matrix structure for Novaled.

Notably the financing rounds of Novaled concerning amount of equity and duration until the next round follow roughly the outline of Table I.27. The listed world records and the particular financing rounds occurred (accidentally?) in the same time window.

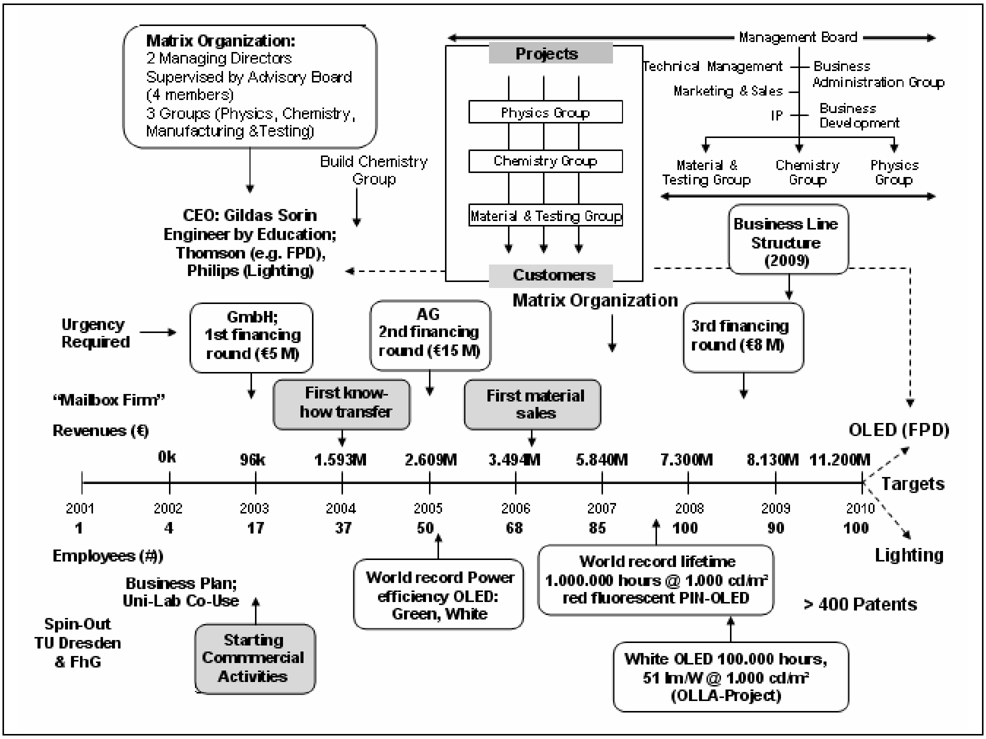
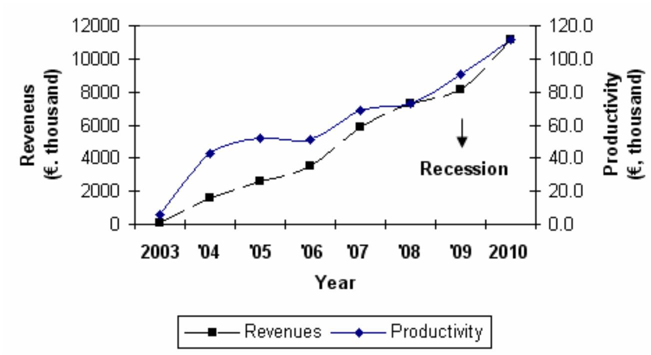


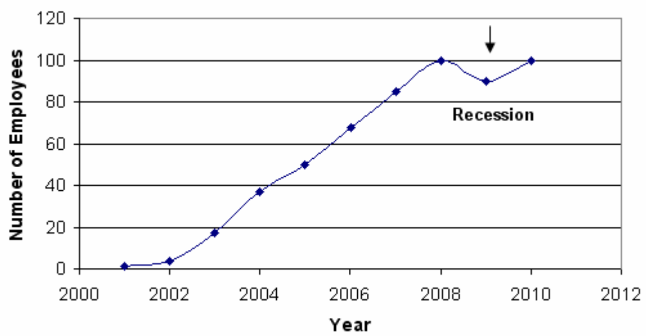
Figure I.148: Developments and characterizations of various states of Novaled AG (Extracted from Blochwitz-Nimoth [2011]).

Figure I.148 exhibits several states contributing to the overall firm state characterized by certain features in different layers. From bottom to top one sees the R&D and technology state (“world records”), the income of the financial state linked with the state of personnel (resource state), the commercial state (selling different kinds of offerings), the financial state (VC financing rounds) and the firm’s organization including management state. For further illustration Figure I.149 displays development curves of Novaled regarding productivity and number of employees.

Re-organization of Novaled (B.2) concerning a business line approach in 2009 is outlined by Muth [2010], profit and loss development until 2008 by Böhme [2008].

<table>
<tr><th>Novaled Productivity</th><th>Novaled AG</th></tr>
<tr><td>
</td><td>Productivity increased during the Great Recession related to leaving employees (no layoffs);

Revenues have two dips in line with productivity and one dip is due to the Great Recession;

2007/2008 dip: new matrix organization</td></tr>
<tr><td>
</td><td>Growth in terms of number of employees:

Dip due to recession not seen in revenues (Figure I.148);

shoulder at 2004 related to jump in number of employees associated with organizational issues</td></tr>
</table>

Figure I.149: Growth patterns of German Novaled AG.

A key founder of Novaled is the entrepreneurial professor Karl Leo (B.2). Key characteristics of an entrepreneurial professor for technology entrepreneurship are not just a business mindset, but also revealing, supporting and encouraging entrepreneurial talents.

Entrepreneurship in Wind Power and Solar Energy

So far, the discussion has focused on (largely) *economic markets*. In Figure I.34 the constellation of the *policy-driven* biofuels segment is outlined and in the Appendix (A.1.1) a rather detailed industry analysis for the *policy-driven* biofuels segment in the US and Germany is presented. However, many other segments of "renewable energy" are also policy-driven, such as wind power (wind turbines) and photovoltaic (PV, solar cells).

The most prominent beneficiaries of the German laws which induced a boom in entrepreneurship in solar cells and modules and windpower are the German Enercon GmbH (wind power) and, for photovoltaic, Q-Cells AG as well as First Solar from the US with its vast majority of revenues from Germany. Ultimately, all showed strong exponential growth in line with the advantages to be taken from the German Renewable Energy Act (EEG – Erneuerbare-Energien-Gesetz, Box I.22.).

Box I.22: **Outlining the German Renewable Energy Act (EEG – Erneuerbare-Energien-Gesetz) referring to solar and wind energy.**

Renewable energy is supported by governments of developed nations in various ways. In the US the solar incentive regime, for instance, is mainly on the basis of tax credits. Tax incentive programs exist at both the federal and state level and can take the form of investment tax credits, accelerated depreciation and property tax exemptions.

In Germany the Renewable Energy Act (EEG) [90] provides a favorable legal framework based on German power grids; not just solar power (Figure I.152, Figure I.153, Figure I.154), but also wind power (Figure I.150, Figure I.151). Since 2003 the focus has been on grid-connected ground or large roof mounted solar power plants in Germany and other European Union countries with feed-in tariff subsidies that enable solar power plant owners to earn a reasonable rate of return on their capital.

Governmental subsidies, economic incentives and other support for solar electricity generation generally include feed-in tariffs, net metering programs, renewable portfolio standards, rebates, tax incentives and low interest loans.

Under a feed-in tariff subsidy, the government sets prices that regulated utilities are required to pay for renewable electricity generated by end-users. The prices were set above market rates and may differ based on system size or application. Net metering programs enable end-users to sell excess solar electricity to their local utility in exchange for a credit against their utility bills. The policies governing net metering vary by state and utility. Some utilities pay the end-user upfront, while others credit the end-user's bill.

Under a renewable portfolio standard, the government requires regulated utilities to supply a portion of their total electricity in the form of renewable electricity. Some programs further specify that a portion of the renewable energy quota must be from solar electricity, while others provide no specific technology requirement for renewable electricity generation.

The EEG was designed to level the playing field by taking into account external costs of conventional electricity generation, provided investment subsidies guaranteeing fixed income of suppliers of renewable energy fed into the grid and usually had a time table for cuts of these kinds of benefits. The German EEG became a model for other European countries.

Already in the 1990s Germany required utilities to connect generators of electricity from renewable energy technology to the grid and to buy the electricity at a rate which for wind and solar cells amounted to 90 percent of the average tariff for ultimate customers. There was support of private and professional customers of PV through special interest rates and additionally a guaranteed feed-in subsidy to be *pari* by the big energy suppliers for two decades (reduced every year by 5 percent). This induced the photovoltaic boom in Germany – and corresponding technology entrepreneurship.

The 1991 Power Feed-In Law (Stromeinspeisegesetz – StEG) required "big" owners of the electrical grid in Germany to accept feed-in of power by suppliers of renewable energy. Furthermore, suppliers were guaranteed a minimum royalty linked to the average earnings through the big electrical power producers. For the producers of wind power these tariffs kept cost of the suppliers of wind power and, hence, led to a wind power boom in Germany – and associated firms' foundation. On the other hand, for suppliers of solar electricity the tariffs were far from cost recovery.

The 2004 Renewable Energy Act, on the one hand, reduced support of electricity by wind turbines. On the other hand, there was a re-orientation of the Federal Government toward solar energy after a significant impact of the so-called "100,000 Roofs Program" concerning solar energy.

A drive in addition to issues of lifting oil dependencies and climate change and change to renewable energy occurred after the Chernobyl disaster in 1986 in the Ukraine [91] focusing on replacing nuclear power. The related societal attitude was strengthened particularly in Germany. And the nuclear Fukushima disaster in Japan in 2011 again led to a societal and also political drive to phase out nuclear power by renewable energy. This means again opportunities for technology entrepreneurship.

The privately held German ENERCON GmbH (B.2) is a production-oriented wind power firm that illustrates how a policy-driven market in Germany influences firm development (Figure I.150) – taking advantage from the Renewable Energy Act (EEG) and its precursors. On the other hand, from its start ENERCON showed innovation persistence with regard to building wind turbines and wind farms and occupying step by step the whole value system for constructing and distributing wind turbines.

Already in 1986 ENERCON built the first ENERCON wind farm with ten E-16 / 55 kW wind turbines. In 1988 there was construction of the company's first own production facility and development and installation of E-17 / 80 kW as well as E-32 / 300 kW models. The year 1991 was occupied with development of the gearless ENERCON concept and the first prototype which was the fundamental technical breakthrough.

In the below Figure I.150 growth of ENERCON, a German Hidden Champion (ch. 4.1.1), is shown in terms of installed (electric) power by various types of wind turbines (usually for wind farms). Innovation persistence of the firm as the basis of growth in general and further growth strategies are displayed and the two growth "accelerating effects of legislation in 1997 and 2000. On the other hand, the two changes of the German EEG to the disadvantage of the supplier show up. These changes following reductions of feed-in tariffs weakened demand in key European markets. Notably, the 2000 EEG more than outweighed the Dot-Com Recession at that time.

Revenue data (with some specific ones missing) given in Figure I.151 do not indicate the effects as markedly as the data in Figure I.150.

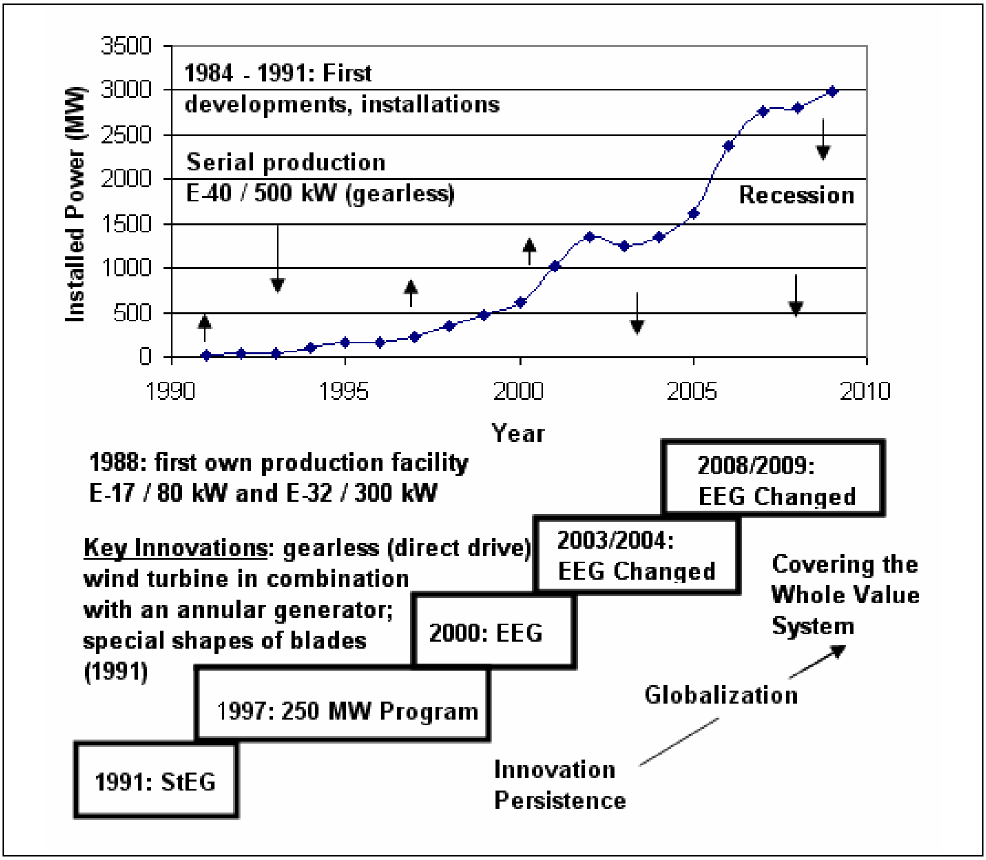
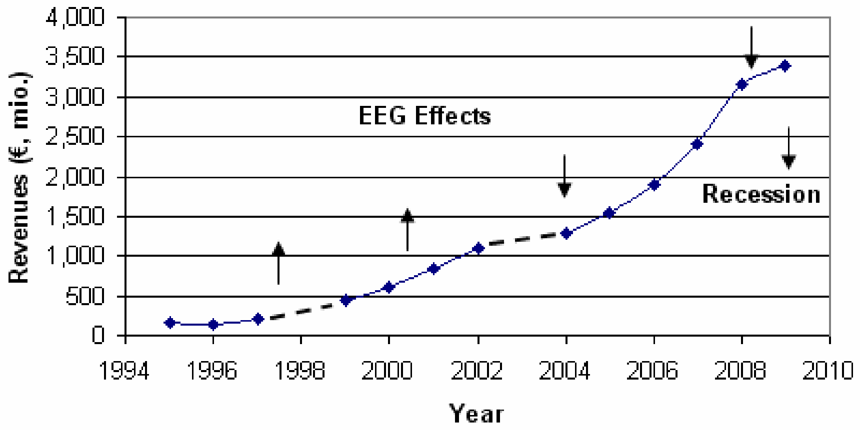


Figure I.150, continued (time line for Enercon's product development).

1995	**2002**	**2004**	**2006**	**2007:**	**2010**
E-66 / 1.5 MW	E-112 / 4.5/6 MW	E-48 / 800 kW, E-70 / 2,000 kW	E-82 / 2 MW	E-126 / 6 MW	E-126 / 7.5 MW

Figure I.150: Installed (electric) power by German ENERCON GmbH through various types of wind turbines in relation to the German Renewable Energy Act (EEG) and its changes.



ENERCON GmbH: 2009 – revenues €3.4 bil., employees > 13,000;
founder Aloys Wobben (net worth €3.5 bil. according to the current Forbes World's Billionaires list);
in 2009 No. 4 (global market share 8.5%) of 10 firms covering ca. 80% or the global market, market share in Germany 60%;
holds ca. 40% of wind turbine related patents in the world (more than German Siemens and US General Electric together; cf. also Box I.7);
Business basics: gearless technology meaning less maintenance (> 50% of wind turbine failures are due to damages of the gear), innovation and investment persistence, high compatibility with electrical grids, longevity of windmills, quality and reliability, high level technical service.

Figure I.151: Revenue development of German ENERCON GmbH in relation to the Renewable Energy Act (EEG).

Growth of ENERCON can be viewed as the combined effects of the (German, European) Renewable Energy Acts, innovation persistence, global reach and integrated offering along the whole supply chain. Adverse effects of the EEG changes are probably levelled off by innovation efforts.

Growth accelerating effects of the German EEG for the photovoltaic solar cell areas show up for two marked representatives. German Q-Cells AG and First Solar from the US are production-oriented, but originally not VC-based firms. Both used publicly supported investment organizations and subsidized loan possibilities or wealthy private investors as their financial basis. Q-Cells and First Solar differ with regard to several aspects, most notably technology, position in the value system and (low) cost strategies (Figure I.11, Figure I.12).

Q-Cells (updated analysis of [Runge 2006:281-282]) was founded in 1999 and, after starting production in 2001, could take immediate advantage from legislation and exceeded one billion euros in sales already in 2008 (Figure I.152). In 2009 it suffered considerably from the Great Recession.

Q-Cells was founded in Berlin (Germany) by an entrepreneurial team of four experienced persons (engineers and physicist); two of them participated in the foundation of the German PV-NTBF Solon AG (also founded in Berlin) and one was a former employee of Solon. The foundation team was complemented by a (McKinsey) consultant Anton Milner with an engineering background who became CEO. Q-Cells co-founder Reiner Lemoine, also a co-founder of Solon, was the Director Production and Technology of Solon.

To establish production Q-Cells took advantage from more favorable financing conditions in the German state Saxony-Anhalt than those in Berlin. It had several financing rounds: The initial financing of ca. €15 million for the first factory and a further ca. € 20 million in a second round financing for the expansion of the Q-Cells 1 and Q-Cells 2 factories. For development in 2004 the company invested further € 20 million.

Investments were essentially by publicly supported investment organization, such as MBG and IGB, creating a private stock company. Investors had essentially silent partnerships getting a fixed rate for a given period plus a participation component of the firm’s profit. In 2005 Q-Cells issued an IPO.

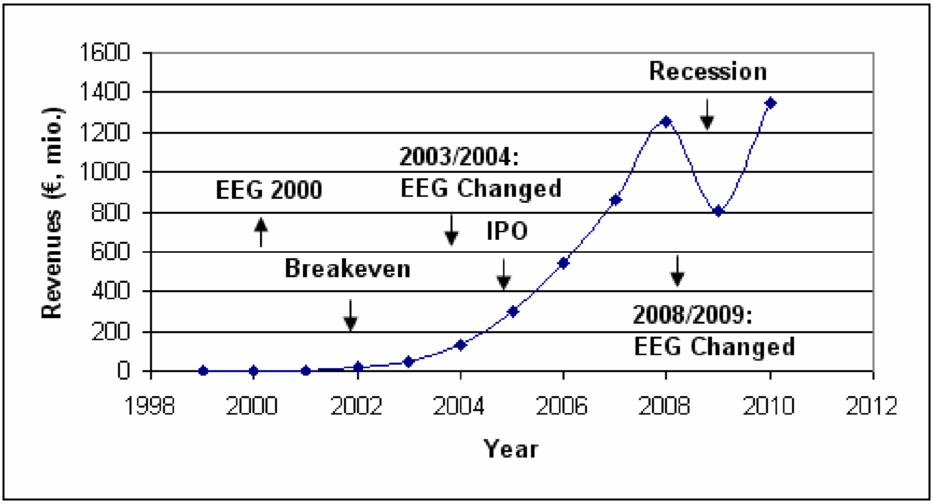


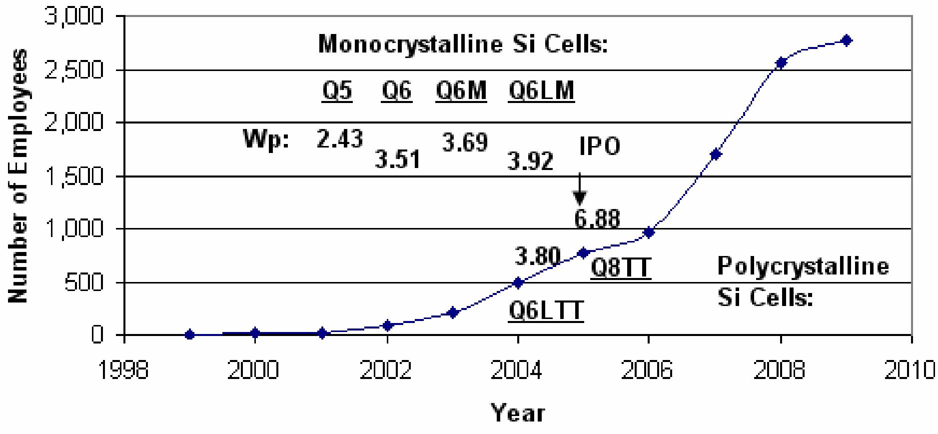
Figure I.152: Revenue development of German Q-Cells in relation to the German Renewable Energy Act (EEG).

Figure I.153 shows the innovation persistence of the firm. Concerning technology Q-Cells started being active essentially based on monocrystalline and polycrystalline silicon solar cells.

Between 2003 and 2005 in each year the number of employees almost doubled (from 207 to 767) which can be expected to reduce the productivity due to organizational and management issues. This is seen in Figure I.153 in the productivity chart. On the other hand, productivity provides another dip at 2006/2007. The time period of this dip coincides with the "silicon cycle" which is the economic upturns and downturns unique to the semiconductor market.

Usage of high purity silicon by the electronics and solar sectors (Figure I.11) had increased from approximately 31,000 tons in 2004 to approximately 35,000 tons in 2005 and 39,000 tons in 2006. The increase was driven by 5 percent year on year growth in the electronics sector usage and by a whooping 20 percent growth in solar sector usage. In the absence of an equivalent increase in capacity, the prices for high purity silicon increased sharply due to strong demand growth. [92]

Effects of the silicon cycle with higher cost of raw material could essentially affect profit of the firms. Or, if availability of silicon in the market is reduced, output would decrease and, keeping the firm's workforce, would affect productivity negatively.



Large capital inflow (IPO) led to fast increase of employees' numbers and correspondingly can induce decrease in productivity – jump in Wp to polycrystalline Q8TT.
Photovoltaic power capacity is measured as maximum power output under standardized test conditions in "Wp" (Watts peak).

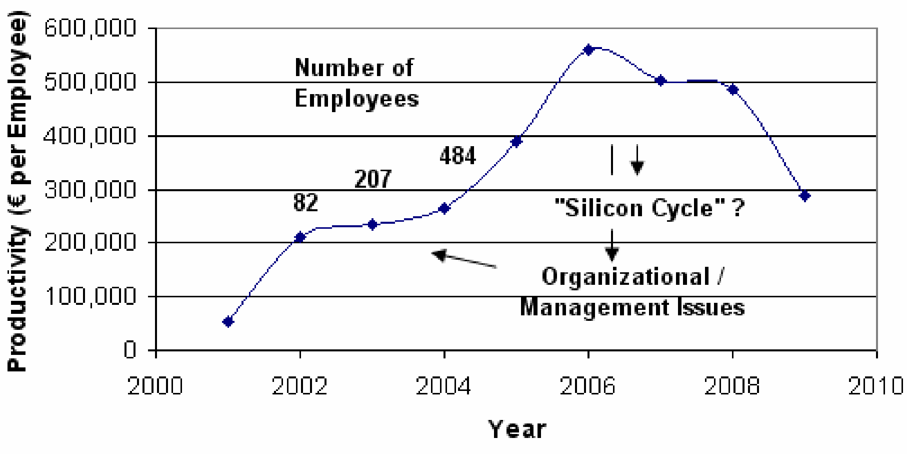


Figure I.153: Development of employee numbers of German Q-Cells AG in relation to innovation persistence and productivity.

However, the steady, continuous growth of Q-Cell's revenues (Figure I.152) makes it unlikely that the silicon cycle is significantly responsible for the 2006/2007 dip in productivity. Again it can be assumed that the tremendous rise in numbers of employees from 767 in 2005 to 2,568 in 2008 led to organizational problems.

The US company First Solar Inc. (as Closure Medical [Runge 2006:98-103]) represents a firm with a two decades history of entrepreneurial efforts (see below) and finally a breakthrough and big success based on the German Renewable Energy Act. For instance, its net sales in 2007 were obtained in Germany by 90.7 percent and 98.8 percent of net sales were generated from customers headquartered in the EU. Even after efforts to bring down this dependency in 2009 Germany still accounted for 65 percent of First Solar's net sales.

Furthermore, according to First Solar's annual report 2010: "During 2009, principal customers of our components business were Blitzstrom GmbH, EDF EN Development, Gehrlicher Solar AG, Juwi Solar GmbH, and Phoenix Solar AG. During 2009, each of these five customers individually accounted for between 10% and 19% of our component segment's net sales. All of our other customers individually accounted for less than 10% of our net sales during 2009. The loss of any of our major customers could have an adverse effect on our business."

Germany has become an aggressive subsidizer of solar power – well known in the world and especially also in China.

First Solar's production did not reach 25 megawatts until 2005 (in Perrysburg, Ohio in 2002 only 1.5 MW). The company built an additional line in Perrysburg, Ohio. But then First Solar took advantage form massive loans with favorable conditions from IKB Deutsche Industriebank AG, a long-term lender and service provider to medium-sized German companies ("Mittelstand").

When First Solar installed four 30 MW production lines in Germany cash outlays for the German plant were partially recovered through the receipt of $9.5 million and $16.8 million in 2007 and 2006, respectively, of economic development funding from various German governmental entities. The substantial German production incentives accounted for about 50 percent of capital costs. Additionally, it took advantage from feed-in tariffs though the 2003/2004 change of the EEG reduced these.

Furthermore, the Company has participated, or is currently participating, in laboratory and field tests in the US with the National Renewable Energy Laboratory (NREL), the Arizona State University Photovoltaic Testing Laboratory, and in Germany the Fraunhofer Institute for Solar Energy, TÜV Immissionsschutz und Energiesysteme GmbH and the Institut für Solar Energieversorgungstechnik.

First Solar had a predecessor Solar Cells Incorporated (SCI). SCI was founded in 1990 as an outgrowth of a prior company, Glasstech Solar (founded 1984) founded and led by the US inventor/entrepreneur Harold McMaster. McMaster was an expert at making glass plates. During the energy crisis in the 1970s, photovoltaic technology gained recognition as a source of power for non-space applications. In the 80s, McMaster became interested in solar technology and experimented with different ways to put photovoltaic materials on glass. He worked first with silicon and then cadmium-telluride (CdTe) as the company was called Solar Cells.

Viewed as “The Glass Genius” he developed a process for making high quality strengthened, or tempered, glass used for architectural glass (for instance, windows in skyscrapers) and automotive glass. By selling the machines to produce these glasses he made a fortune.

McMaster was aware that glass could easily be coated with thin layers of chemicals that change its color or ability to pass light. Glass is also an electrical insulator. Those two properties are essential for construction of photovoltaic cells – “solar cells” that change sunlight directly into electricity. Harold McMaster’s treated the actual *solar cell* as simply *a different kind of coating on glass* and his vision was to use that technology in commercial-scale production of electricity that would ease America’s dependence on imported oil.

McMaster revealed the essential cost element of large area solar arrays to be glass. At first, McMaster looked into amorphous silicon research but gave up. He then raised yet again money to create Solar Cells Inc., to work on a different thin-film technology, cadmium telluride. By 1997, Solar Cells had a prototype production machine. According to a former head of the Thin Film Partnership program at the Department of Energy’s National Renewable Energy Laboratory (NREL), SCI was clearly the industry leader in thin-film photovoltaic technology.

In 1999, True North Partners LLC, an investment arm of the Walton family, purchased controlling interest, and renamed the company First Solar LLC. John T. Walton (heir of Sam Walton [Bhidé 2000], who founded Wal-Mart, the largest retail organization of the world) put ca. $150 million into the firm until his death in 2005. Simultaneously, he installed professional management.

The firm almost shut its doors. It is said that it was begging for government contracts with NREL. But it was lucky to have a generous supporter, John Walton. The ca. $150 million investment is not the amount of money that a single VC might fork over to a solar startup these days. First Solar did not set up a pilot line until 2002. It began production at its first commercial factory in the US in 2004, but as early as 2008 its revenues exceeded one billion dollar (Figure I.154).

Within the photovoltaic industry, First Solar faces competition from numerous crystalline silicon solar cell and module manufacturers, but also from efforts to commercialize silicon thin-firm solar cells/modules (Figure I.11).

The thin-film based solar cells or modules, respectively, are generally less efficient than silicon cells. However, thin-film systems can be utilized at various temperatures and light/radiation situations. Basically, production cost for thin-film systems are lower. The value proposition of First Solar is to deliver a high performance and high quality solar module at a more affordable price.

First Solar developed considerable competitive (cost) advantage over German solar cell producers which, like Q-Cells, relied on mono- or polycrystalline cells, by using

CdTe thin-film technology thus avoiding the silicon cycle and operating as a module supplier on a higher stage of the value system (Figure I.11). In contrast to the silicon batch process,

Si-Feedstock – Ingot – Wafer – Solar Cell – Module (Figure I.11),

First Solar's CdTe thin-film PV is a fully integrated and automated continuous process:

Glass in – Deposition – Cell Definition – Final Assemby & Test – Module Out.

Additionally, for the end of the modules' life-times it offers a module collection and disposal program in the PV industry.

Even when competing with falling polysilicon prices, First Solar still had a ca. "40 cents-per-watt installed cost-per-watt advantage," which delivers lower-levelized cost of electricity.

Figure I.154 shows that First Solar could take advantage from economy of scale reducing average manufacturing cost from roughly 3 $/W to 1$/W, and even to $0.74/W by the end of 2010. **Economies of scale** for a firm primarily refers to reductions in average cost (cost per unit) associated with increasing the scale of production for a single product type. Economies of scope are conceptually similar to economies of scale.

Economies of scope refer to lowering average cost for a firm in producing different products. Economies of scope make product diversification efficient if they are based on the common and recurrent use of proprietary know-how (cf. also platform technologies – Table I.12) and the learning effect (ch. 2.1.2.5). Further economies of scope occur when there are cost-savings arising from by-products in the production process (biofuel production with biobased chemicals as by-products; A.1.1).

Existing business firms usually grow by increasing their scale and scope. The scope of a firm then relates to the number of its products. The scale of a firm is given by the size of its products. A firm like Microsoft gets few big products while Amazon sells a huge variety of goods, each of small size in terms of sales. For startups, often only having one to three products, both these concepts rarely apply.

Overall competitive advantage of First Solar, expressed in terms of positive factors on revenue development, rests on the following number of combined factors compared, for instance, with Q-Cells. Compared with other PV firms which are not operating in Germany both have an additional support factor (n(EEG)) related to the German EEG.

- The value system advantage, modules versus cells – n(VS)
- Production cost reduction, advantage as a result of economy of scale – n(PCR)
- Being independent from the silicon cycle – n(non-Si).

Focusing on key components First Solar's overall growth driver n_{CA} can be expressed as:

n_{CA} = n(EEG) ⊕ n(market demand) ⊕ n(VS) ⊕ n(PCR) ⊕ n(non-Si) ⊕ n(internalities).

Finally, due to gaining most of its revenues in Germany favorable foreign exchange rate between the US dollar and euro could partially offset a price decline of First Solar's products in Germany. The other way round was observed for German ChemCon GmbH (B.2) which, after foundation, had ca. 80 percent of sales in the US (ch. 4.2.3; Figure I.116).

Considering these special effects as well as no indications of extreme sensitivity in the other considered NTBF cases in this book (B.2) one may suggest that dollar-euro exchange rates will not, or rarely, show up as an observable bracket effect in revenue data.

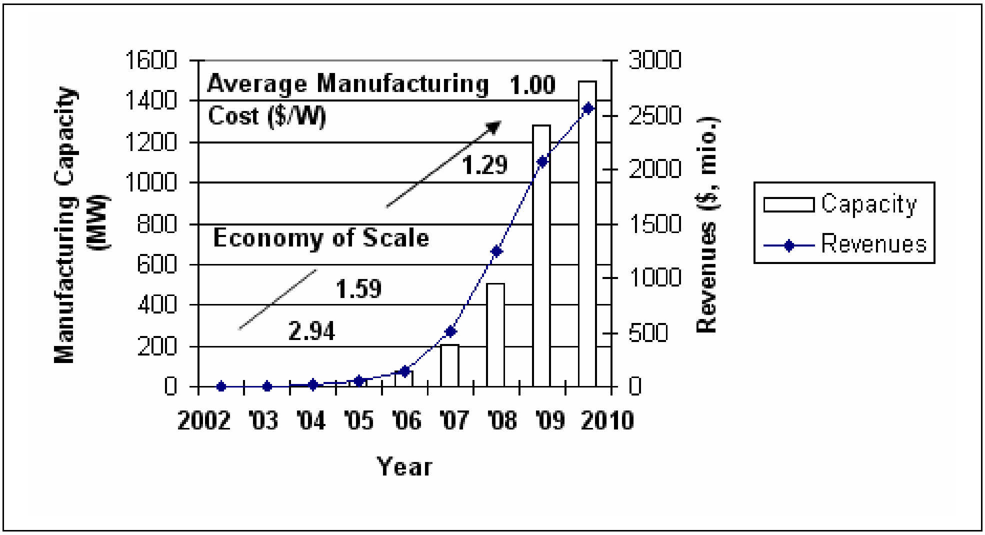


Figure I.154: Manufacturing capacity and revenues of US First Solar in relation to average manufacturing cost demonstrating economy of scale.

Figure I.154 reflects a fundamental dichotomy of firms for decision-making associated with production. It is the question whether (increasing) production capacity (or expand space of labs and offices) shall follow demand (indicated by revenues) – as seen for the 2006 - 2008 period – or whether increasing production capacity shall precede demand (2009/2010).

In the first case the firm can lose money that could be earned, in the second case you lose money due to "unnecessary" investments. And, in the particular 2009/2010 case, expected increase of manufacturing capacity to meet demand was hit by the Great Recession with distinctly reduced demand. NTBFs relying on cash flow and loans mostly follow the first approach – as described also for Nano-X GmbH (Figure I.137) or ChemCon GmbH (Box I.20).

The next foreign NTBFs taking advantage from the German and European policy-driven markets were the Chinese seeing firms Suntech and JA Solar emerging as "giants" based on their low cost positions.

Overall, the global PV market had entered into a phase of strong consolidation associated with disappearance of firms, mergers of firms and business model innovations of surviving firms and simultaneously capturing market share of thin film cell and module suppliers from suppliers of silicon-based offerings. Leading and surviving firms in the PV solar cells/modules area have left the class of NTBFs. They have achieved the situations of "normal" large to very large firms and operate correspondingly.

For the area of CdTe *thin-film* solar cells and modules First Solar had almost a monopoly or monopoly-like position. However, for First Solar there was a risk of disruption from higher efficiency technologies, and especially other thin-film technologies. For instance, there were some startups or other developing firms which were active in innovative CIS (copper-indium-disulphide) or CIGS (copper indium gallium diselenide) thin-film photovoltaic (Figure I.11), such as in Germany Würth Solar GmbH & Co. KG [Runge 2006:257-258], a subsidiary of the Würth Elektronik Group which belongs to the Würth Group (Box I.23).

The privately held Würth Group, with revenues of €8.6 billion in 2010 originally emerged as a Hidden Champion [Runge 2006:256-258]. It is a world market leader in its core business, the trade in *assembly and fastening material*. It currently consists of over 400 companies in 84 countries and more than 3 million customers all over the world. The group has been set up by (now) Professor Reinhold Würth who has become one of Europe's richest men. He has transformed a two-man business dealing with screws of his father since 1954 into a worldwide active group emphasizing the "*fastening business*."

While manufacturing can be scaled (Figure I.154) turning the modules into systems is mostly "variable" cost since the majority of the cost is materials (cabling, aluminum) and labor (BOS, Figure I.11).

Box I.23: German Würth Solar and its Approach to CIS Thin-Film Photovoltaic.

By 2009 Würth Solar saw itself as the world's leading manufacturer of innovative *CIS solar modules* and also *a provider of complete solar installations*. Its revenues were €116 million with 280 employees in 2009 and a manufacturing capacity of 30 MW (in 2005 €5.3 million and 103 employees; in 2004 €3.9 million with ca. 67 employees). In autumn 2006, Würth Solar started the first large-scale series production of its GeneCIS solar modules worldwide at its CISfab factory in Schwäbisch Hall, Germany which was especially built for this purpose.

This kind of technology, utilizing a fully integrated and automated continuous production process, put the focus on copper indium gallium selenium sulfur compounds (depending upon composition called copper indium gallium diselenide Cu(In,Ga)Se2

(CIGS) or CuInS2 (CIS)). Würth's CIS technology and CIS modules can be used under the harshest environmental conditions, making them especially suitable for use in extreme climatic zones.

Würth Solar with the Würth (Elektronik) Group as the majority and controlling owner (of ca. 80 percent) had two partners, utilities (energy) supplier EnBW (Energie Baden-Württemberg) and ZSW (Stuttgarter Zentrum für Sonnenenergie- und Wasserstoff-Forschung) or Stuttgart Center for Solar Energy and Hydrogen Research. The *University* of Stuttgart (IPE; Institute for Physical Electronics) *developed the CIS cell technology* in the 1980s. *ZSW developed the CIS prototype modules* which continued to *carry out research and development work for Würth Solar.* Development and installation of a pilot plant cost ca. €40 million.

The timeline of Würth Solar's emergence is as follows:

- 1996 a predecessor firm, Würth Solergy, starts first photovoltaic activities as a subsidiary of the Würth Elektronik Group.
- 1999 foundation of Würth Solar GmbH & Co. KG
- 2000 Würth Solar and ZSW enter the commercialization phase running a pilot plant.
- 2006 Start of the first large-scale production of CIS PV-modules called GeneCIS in the world in the "CISfab plant" having a capacity of 15 MW
- 2008 Capacity of CISfab extended to 30 MW.

€55 million were invested in CISfab. Würth Elektronik Research provides support for and optimization of day-to-day production at the Würth Solar and CISfab production sites in Schwäbisch Hall (Germany).

Related to the electronics group and based on the extremely wide and deep distribution and sales force of the Würth Group Würth Solar occupied all positions of the whole PV value system, emphasizing not just electricity for private homes (roofs), but also integration of their modules into architectural designs and architectural components and module integrations into other customized products from a variety of applications. The firm showed up as a supplier of whole systems and solar power plants (utility-scale systems) as well as engineered, individual system solutions for solar energy.

First Solar and Würth Solar share a rather close "initial" configuration:

- Both relied on research results of public research institutions and relied for developments on public research institutes (NREL versus ZSW).
- Both are (or were) financed by wealthy persons related to large international firms.
- Both had to go a long way before finally launching their primary offerings, thin-film PV modules.
- Both could make use of subsidies or other financial support of (State or Federal) Government.
- Both make heavy use of the German Renewable Energy Act (EEG).

Concerning thin-film technology in the US Solyndra, Inc. founded in 2005 went for designs and manufacturing of solar photovoltaic (PV) systems, comprised of panels and mounts, for the commercial rooftop market. It used thin film CIGS technology as Würth Solar and was producing cylindrical modules depositing CIGS on the inside of glass tubes rather than using plates of glass. The company had approximately 1,050 employees around the world, revenues in 2010 were approximately $140 million.

The US Department of Energy (DOE) offered the Californian firm a $535 million loan guarantee of construction to expand its manufacturing capacity to 500 MW per year, expecting the new facility to employ some 1,000 people. After raising $1 billion (!), the company was forced to slash costs, close a factory, restructure the executive team and cancel an IPO. As a competitor for Würth Solar the Solyndra star faded in 2011 [Kuo 2011; RenewableEnergyWorld 2010].

Solyndra's CEO admitted to have made the twin mistakes of expecting too much growth and not putting enough focus on market development. Its $535 million loan guarantee from the Department of Energy was under investigation by the US Congress [GreenBeat 2010].

By the end of 2010 concerning the high cost of module production – the most troubling issue – the company said to have its average sales price over $3.20 per Watt, about 65 percent more than leading crystalline-silicon PV manufacturers and its cost of manufacturing to be over $6 per Watt. The major cost and price declines in the crystalline PV sector hurt the competitive chances of Solyndra's modules. The company's next step was planning on having over 600 MW of capacity online by 2013. But soon Solyndra said [RenewableEnergyWorld 2010] it will have around 300 MW of capacity.

In the second half of 2011 Solyndra filed for bankruptcy and was the subject of several federal investigations. Republicans on Capitol Hill have been critical of the Obama administration's handling of clean energy programs, saying that it gave out a $535 million federal loan in 2009 to a California solar energy company, Solyndra, without properly evaluating if its business plan made sense [Johnson 2011].

Worldwide solar photovoltaic (PV) market installations reached a record high of 18.2 gigawatts (GW) in 2010. This represented growth of 139 percent over 2009. The PV industry generated $82 billion in global revenues in 2010, up 105 percent Y/Y (year on year) from $40 billion in 2009.

In 2010, the top five countries by PV market size were Germany, Italy, Czech Republic, Japan, and the US – representing over 80 percent of global demand. European countries represented 14.7 GW, or 81 percent of world demand in 2010. The share of global PV demand in 2010 [93] were:

- Germany, 42 percent
- Italy, 21 percent
- Other Europe, 18 percent
- Japan, 5 percent
- United States, 5 percent.

The tremendous growth of photovoltaics let “giants” enter the photovoltaic scene largely determined so far by “grown up” NTBFs to build businesses in renewable energy – emphasizing the role of NTBFs for innovation approaches and new business development of large firms. These large firms usually waited until there is sufficient demand.

For instance, the German giant privately held Robert Bosch GmbH, the world’s largest auto supplier (sales of €47.3 billion in 2010), but a global supplier of technology and services in the areas of automotive and industrial technology, consumer goods and building technology, took over Ersol Solar Energy AG which started as ErSol Solarstrom GmbH & Co. KG in 1997 with production of multi-crystalline silicon solar cell and modules. Bosch became majority owner of the firm in 2008 and in 2009 Bosch Solar Energy AG emerged.

From 2009 to 2012 Bosch invested around two billion euros in solar technology and bought with Ersol, Aleo and Voltwerk three companies [Weishaupt 2012].

In the US, General Electric (GE) took a bold step into solar PV with several announcements, mainly its acquisition of PrimeStar Solar (with whom it had been working on CdTe thin film R&D). The startup created an NREL-confirmed record 12.8 percent efficiency (aperture area) panel on its 30 MW line in Arvada, CO, the company said in a statement [ElectroIQ 2011].

GE’s CdTe push was part of a planned $600M+ investment into solar technology and commercialization. The company projected global demand for solar PV will surge to 75 GW over the next five years, much of that in utility-scale plants, an attractive market to be in. But more importantly, there were clear opportunities to bring costs down.

While First Solar was leading the cost/W charge, GE seemed to think it can compete there too. Not only does GE planned to push efficiencies “much higher” than the current 13 percent, but “we probably can cut costs 50% over the next several years.”

Further, GE said it will build a 400 MW thin-film solar panel in the US (employing 400 workers), what would be currently the largest in the country, reportedly ready by 2013. Monocrystalline-silicon firm German SolarWorld had the biggest US solar PV site, with its cell and module operation in Oregon scalable to a combined 500 MW.

French oil giant Total SA agreed to buy as much as 60 percent of SunPower Corp. for $1.38 billion, taking advantage of increased global interest in renewable energy. SunPower, with sales of $2.219 bil. in 2010 was the second-largest US solar panel maker. The deal was supposed to lead to more solar industry acquisitions as US and European suppliers sought for help competing against rival suppliers in Asia [Herndon et al. 2011].

But by early 2013 the PV market, particularly in Germany, had changed dramatically. Already by 2007 solar energy, the former niche market, had become a global business. The industry was growing rapidly – too fast [Zeller-Silva 2007].

Moreover, the order situation was good and positive long-term forecasts estimated the annual growth of the market by 2020 to about 20 percent annually. But this deceived the businesses around the world to increase their capacity strongly. And skeptics feared that the demand would not grow to the same extent as the range. Additionally, the emerging, lucrative markets attracted competitors. In the US and in Asia powerful companies emerged that could be a real competitor for the German solar industry [Zeller-Silva 2007].

It was envisioned that tougher competition, the threat of overcapacity and declining public subsidies would make it hard for the industry in the future, to make money. And Frank Asbeck, chairman and founder of German firm SolarWorld, even spoke of an impending shakeout, despite the growing global demand [Zeller-Silva 2007].

And, indeed, starting in late 2008, the solar market shifted from supply-related to demand-driven. This was due to the plunging price of crystalline silicon cells and modules caused mainly by 1) falling silicon cost, 2) constrained availability of credit, 3) demand decline in certain previously high volume regions such as Spain, 4) oversupply and 5) unfair competition of Chinese suppliers due to their extremely low prices bound to high export subsidies of the Chinese government. Furthermore, in Germany there were cuts of feed-in tariffs and a shift of emphasis from private rooftop installations to commercial utility-scale PV installations.

As a result, the state of the industry changed over to consolidation of weak competitors and NTBFs and bankruptcy of several PV companies, notably the above mentioned Solyndra in the US and Solon AG in Germany and even Q-Cells stumbled toward insolvency.

Q-Cells and others had responded to Chinese competition by outsourcing some of their own production to Asia to cut costs. But that was not enough to save them.

By 2010 the era of the founders was over. Si-based PV had become largely a mature technology which means it can be used and built anywhere in the world, particularly in China. The original PV startups had become large-size firms with different requirements for operation in a highly competitive environment with the Si-based PV technology having changed over into commodity products.

For too long, many solar companies have rested on the high subsidies. A concentration of the industry was imminent. And it was clear that from about 50 German companies only a handful would survive in the next two years probably as independent companies.

In February 2012 German installers and dealers could buy a Chinese module already for €0.77 per watt in wholesale. Modules from German production cost €1.03 per watt. Just the year before, the solar module prices had fallen by 30 to 40 percent. The share of German companies in 2011 in the total market was just 20 percent. The share of Chinese companies accounted for 54 percent [Weishaupt 2012]. Ca. 75 percent of the German solar cell market was governed by non-German firms.

Early in 2012 the largest solar cell manufacturers in the world were (DE = Germany, Ch = China) [Handelsblatt 2012]: Solarworld (DE, No. 20, 2007 No. 7), Q-Cells (DE, No. 13, once the world's largest producer of silicon-based solar cells), Trina (Ch, No. 5), Yingli (Ch, No. 4), JA Solar (Ch, No. 3), First Solar (US, No. 2), Suntech (Ch, No. 1).

Policy tried to help the endangered firms looking for tariff on imports of Chinese silicon photovoltaic panels – but in vain. A cascade of insolvencies showed up. Most prominent among the herd of PV startups, in 2012 Q-Cells with ca. 2,200 employees became insolvent and was taken over by Seoul-based Hanwha Chemical Corp.

And in 2013 Bosch decided that the company had no choice but to abandon solar energy, to shut down the Solar Energy division – along with its roughly 3,000 employees. According to Bosch, cuts to European renewable energy incentives and the drastic changes in the market, particularly the rapid increase in capacity in China, had put "unrelenting" pressure on Bosch's Solar Energy division, which sustained a loss of one billion euros. Consequently, Bosch announced to cease production of all wafers, ingots, solar cells and Bosch solar panels by the end of 2014. However, the company will hold on to Bosch Solar CISTech GmbH – its thin-film research facility in Brandenburg, Germany [Energy Matters 2013].

In 2012 Würth Solar (Box I.23) divested substantial parts of its solar business to the Agricultural Trade Group Baywa and sold the rest to a second partner in 2013.

And lately also Chinese solar cell and panel suppliers turned out not to be immune to insolvency. Chinese panel producer Suntech Power has put its largest subsidiary into bankruptcy [Riley, 2013] and a second Chinese solar company, LDK Solar Co., has defaulted on a debt payment to investors [Ma 2013].

4.3.5.3 Selected Quantitative Applications of the Bracket Model

It is the mark of an educated person to look for precision
only as far as the nature of the subject allows.
Aristotle (Stanford Encyclodia of Philosopy, Episteme and Techne)

For a quantitative discussion of NTBFs' growth we shall follow cybernetics (4.3.4) and use a *heuristic approach of reinforcement* for *periods of* growth of sub-states of a new firm. We use a phased process interrupted by brackets and associated transition states (Figure I.133, Figure I.134) and are guided by situations described by Equation I.16, Equation I.5 and Figure I.70. The heuristic will be verbally expressed by the well-known saying

Growth breeds growth.

In the same category of algorithm, but including growth or decline (Figure I.114 and Equation I.16) one can cite the "Matthew Effect." The Matthew Effect [Merton 1968] specifically refers to a statement in the Christian Bible (XXV:29):

> "For unto every one that hath shall be given, and he shall have abundance; but from him that hath not shall be taken away even that which he hath."

In this context of "growth breeds growth" and emphasizing VC-based NTBFs Gompers et al. [2008] present evidence of "*performance persistence"* (definition of Gompers et al. [2008])) in entrepreneurship and that entrepreneurs with a track record of success are much more likely to succeed ("success breeds success") than first-time entrepreneurs and those who have previously failed.

Similarly, related to *innovation persistence*, Flaig and Stadler [1994] revealed a *positive impact of previous innovative success to further innovations in the following years.* They studied product and process innovations of private German firms from the manufacturing sector (data between 1979 and 1986). And there is a combined internal and an external effect paralleling growth by innovation and investment persistence: As entrepreneurs build a track record, uncertainties about their ability and business propositions diminish; the entrepreneur gets more self-confidence, confidence in the firm, experience of raising money from external financial backers as well as getting suppliers and customers.

We focus on dynamic stability during firm development which will be expressed by "*equations of state*" for a given "*dynamically stable interval*" of time $<t_0, t_n>$ to describe time-dependent relations under a given set of conditions in terms of appropriate indicators, such as revenues. Concerning firm growth we look at its financial sub-states (Equation I.15) and regard these is indicative for the firm's growth (ch. 4.3.5.1).

Let R(t) be the value (of revenue) at time t for the financial sub-state taken also as a growth indicator for the whole system and R(t+1) the value of one unit of time later. Following conceptually and structurally "growth breeds grows," the innovation and investment persistence growth cycles (Figure I.127) and Equation I.13 for an equation of state for dynamically stable states of NTBFs, intensity ⊗ capacity, makes R(t+1) proportional to R(t): R(t+1) → n_R·R(t).

The factor n_R is an intensity covering interacting firm-internal and external effects. In particular, it may include responsiveness of the startup toward (changes of) the market environment. To account for this effect and self-reinforcement of the capacity factor we complement R(t) by an additional factor [1 + (R(t+1) / R(t))] to finally suggest Equation I.17 as a fundamental systemic reflection of "growth breeds growth" for dynamically stable states of NTBFs. In particular, it shall cover *dynamically stable states* with a *steady state condition* as defined above (Figure I.132).

We interpret the capacity term R(t)·[1 + (R(t+1) / R(t))] as being related to capability in the sense of RBV (ch. 4.3.3). The factor n_R is assumed to be a constant for a specific bracket interval and treated as an empirically determined factor.

Equation I.17:

$$R(t+1) = n_R \cdot R(t) \cdot [\, 1 + (R(t+1) / R(t))]$$

t = 0, 1, 2, …n; n_R a state and environment characterizing (empirical) factor;

R(t+1) ≥ R(t) for all t; asymptotic behavior for n_R = ½ gives R(t+1) = R(t)

The equation of state describes the state over a period of time beginning after a front bracket at the time when the firm has adapted a new "dynamically stable" state (t = 0, R(0) until the occurrence of a new bracket ends the development of this dynamic state (cf. right part of Figure I.133)). This new bracket may be identifiable.

On the other hand, based on an equation of state like Equation I.17 we regard a strong deviation of calculated values of an otherwise good fit between calculated and observed values as evidence for the impact of a bracket that cannot be directly observed on the basis of indicator data.

Equation I.17 is defined "recursively" – resembling to a certain degree the Fibonacci numbers [WolframMathWorld].

For R_i (i ≥ 2) we proceed taking R(0) and R(1) as the basis and then start with the mappings, e.g. R(1) → R_1 and (R(1)/R(0) → R_2/R_1.

Then the factors n_R and (R_2/R_1) are fitted to acceptably describe the whole sequence of data on the interval <t_0, t_n>:

$R_2 = n_R \cdot R_1 \cdot (1 + R(1)/R(0)) \rightarrow R_2 = n_R \cdot R_1 \cdot (1 + R_2/R_1)$ → Numerical fit for all data

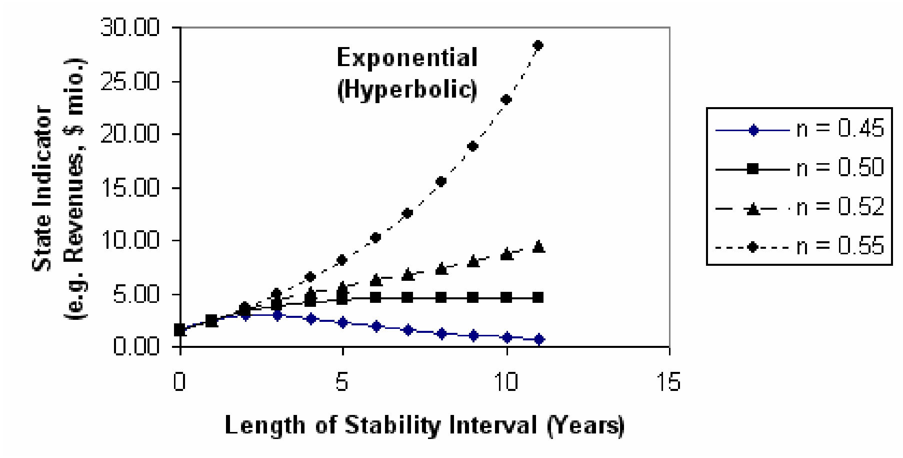
We are primarily interested in an *equation of state for monotonically increasing revenue growth R* on a given interval <t_0, t_n> The numerical values of the state-characterizing factor n_R and the starting quotient R(t+1)/R(t) of Equation I.17 will shape the curve, usually after a bracket.

Curves as determined by different values of the factor n_R and fixed values for an initial growth rate (R(0) and R(1) may exhibit various appearances as are given in the below Figure I.155. Shapes range from exponential (hyperbolic) to asymptotic growth and non-growth shape (Figure I.107).

Equation I.17 reflects also a mechanism when early growth of revenues, due to an unfavorable situation and insufficient magnitude of the intensity factor n_R, can turn into decreasing revenues, as is illustrated in Figure I.114, and ultimately disappearance of a firm:

- Failure paths all begin with one or more fundamental problems;
- They all lead to a situation where the symptoms of the worsening situation become visible in the financial situation.

Furthermore, Equation I.17 can simulate the case that the "thrust capacity" for a startup's development does not suffice for a successful "lift-off" for (revenue) growth.



R(t+1) = n·R(t)·[1 + (R(t+1) / R(t))] (Equation I.17);

Start: R(0) = 1.5, R(1) = 2.5 units;
initial growth ratio: R(1)/R(0) = 1.67
(simulating very strong growth of the particular state)

An expansion of the curves for n = 0.50 and n = 0.52 is given on the next page.

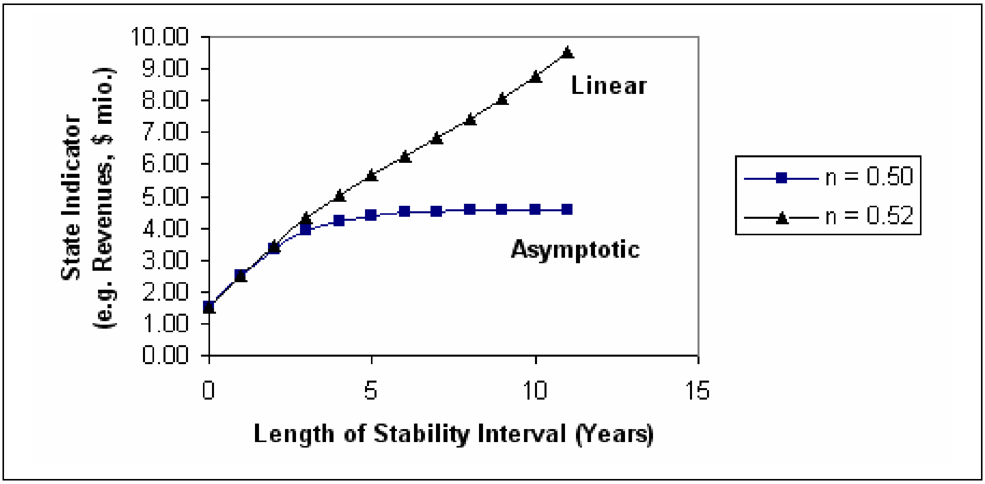


Figure I.155: Prototypical development curves as shaped by relevant parameters.

Equation I.17 becomes extremely simple if the quotient R(t+1)/R(t) is very small compared to 1 and, hence, can be neglected or can be viewed as a non-negligible constant g’. Then either we have

$R(t+1) = n_R \cdot R(t)$ or

$R(t+1) = n_R \cdot (1 + g') \cdot R(t)$

Therefore, at least for a particular interval $<t_0,t_n>$, we propose a growth period of an NTBF to be described by the very simple formula Equation I.18 ($n_R \cdot (1 + g') \rightarrow (1 + g)$). Though we shall denote g as a “growth factor” it should be noted that its numerical closeness to a common growth rate, such as CAGR (Equation I.10), must be viewed as accidental.

Through its relation to interwoven company-internal and external effects the growth factor g is related to n_R. If we interpret growth of a new firm to be determined essentially by growth of the market and firm-internal response (capacity) toward the market opportunity we can differentiate the *development categories for new firms* as:

- *Grow less than the market*
- *Grow with the market* and
- *Grow more than the market*.

Equation I.18:

$$R(t+1) = (1 + g) \cdot R(t) \text{ for } <t_0,t_n>$$

The following examples calculating revenue values for dynamically stable *financial sub-states* do not intend to provide numerically optimized solutions, but solutions with "simple" numerical relations that will *suffice to illustrate the essentials* of the bracket model.

The simplest case is provided by WITec's closely linear growth (Figure I.123) or the linear growth periods of Nano-X (Figure I.137).

The example of WITec (founded 1997) can be used to illustrate the essentials of the bracket approach. It is not about (statistical) curve fitting for an interval <1999,2009> or <2002,2009>. The bracket theory interconnects a time interval for development of states started by a front bracket as displayed in Figure I.123.

The first bracket is firm's foundation (ch. 4.3.5.1) with the startup thrust phase extending over the next three to four years being associated with rather unstable firm states and usually decreasing year on year growth rates (Table I.71).

In Figure I.156 Equation I.18 could be used as a numerically sufficient approximation for the interval <2002,2009>. But this interval is "perturbed" by the Dot-Com Recession. In Figure I.156 it is argued why <2004,2009> would be most appropriate interval characterizing a dynamically stable growth state of WITec. The interval would probably start at 2003, but there are no revenue data available for 2003.

Similar to WITec almost *linear,* parallel developments of revenues and number of employees for Nano-X GmbH (Figure I.137) express *almost constant productivities* for the intervals <2000,2003) (productivity ca. €63,000 per employee) and <2005,2008> (productivity ca. €118,000 per employee) and indicate these periods to be associated with dynamically stable organizational states.

Corresponding effects are observed for SAP productivity (Figure I.147) which show little changing for the interval <1976,1979>.

On the other hand, the Microsoft's revenues (Figure I.144) between 1977 and 1982 as well as 1980 and 1989 with starting growth proportions of ca. 3.6 or 2.1, respectively, exhibit *exponential* growth. The recession of 1981/1982 separates both phases.

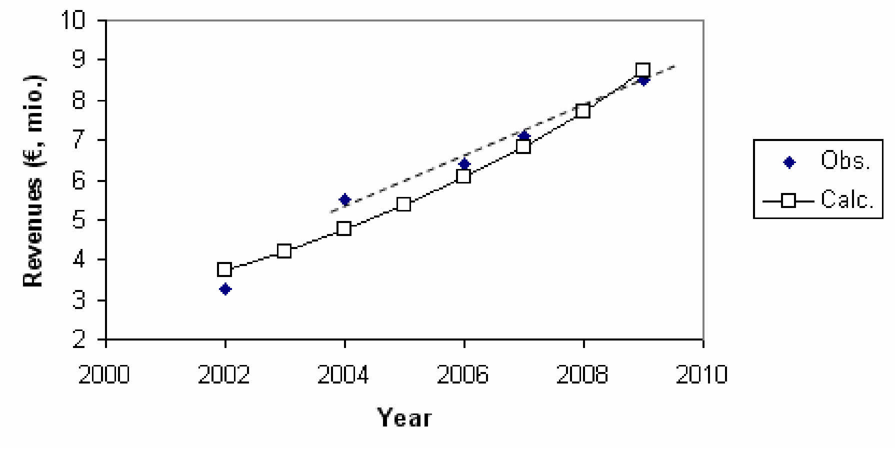
Moreover, the period <1981,1986> is associated with many positive brackets and the IPO which together lead (probably) to accelerated growth expressed by a larger n_R-factor. The interval <1977,1982> of Microsoft's early growth is organizationally rather unstable (Figure I.146).

Equation I.17 is sufficient for the calculations (Figure I.157) of two dynamically stable financial sub-states of Microsoft separated by a recession bracket which, however, is not observable and obviously more than balanced by several positive brackets.

Formula: **R(t+1) = (1 + g)·R(t)**

The *tempting* approach:

Growth factor g = 0.13; R(0) = €3.29 mio. at 2002; CAGR (2002,2009) = 14.5%



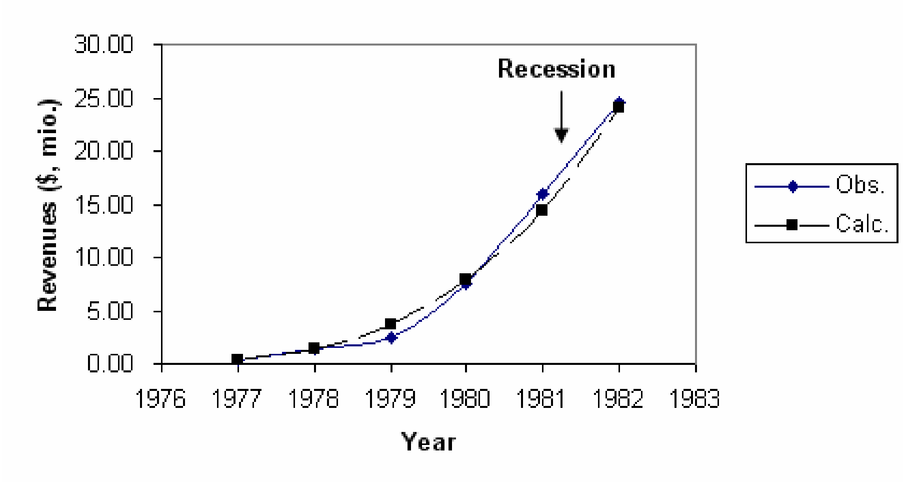
Comments: Actually, a very good fit is seen for the interval <2004,2009> (dashed line, g = 0.09) which is the most appropriate characterization of a *dynamically stable financial state* as the observed data for 2002 may still be affected by the Dot-Com Recession, data for 2009 by the Great Recession.
Furthermore, WITec exhibits *almost constant productivity* (Figure I.123). This means, for the related interval it has a financially dynamically stable state – and also a dynamically stable organizational sub-state showing a steady state condition with almost constant productivities (Figure I.123).

An approach with

growth factor g = 0.17; R(0) = €1.55 mio. at 1999; CAGR(1999,2009) = 18.6%

provides a *numerically acceptable approximation* for the 1999-2009 period. However, it covers also the Dot-Com Recession. Such *pure numerics* are not in line with the bracket theory and, hence, are lacking explanatory power.

Figure I.156: Calculated and observed revenues of WITec GmbH for a "perceived" dynamic stability interval <2002,2009> and contrasted with the theory-related <2004,2009> interval (dashed line).



Microsoft Corp., founded 1975, IPO 1986; Equation I.17 used:

Above figure: R(0) = \$0.38 mio. (1977), R(1) = \$1.36 mio. (1978); n_R = 0.585; R(1)/R(0) = 3.57

After 1882 there are large deviations between calculated and observed revenues (calculated values much larger than observed ones) indicating a transition state.

Below figure: R(0) = \$7.52 mio. (1980), R(1) = \$16.06 mio. (1981); n_R = 0.605; R(1)/R(0) = 2.13

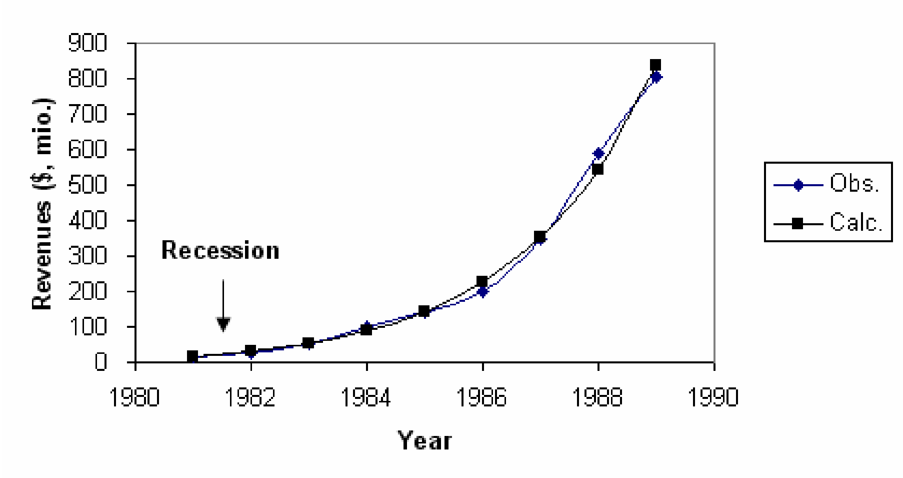


Figure I.157: Calculated and observed revenue growth of Microsoft.

When looking at the examples of Cisco and First Solar (Figure I.158.) Equation I.17 turned out to be inadequate and required modification. Cisco's starting growth proportion was 3.63 and that of First Solar is 4.21.

For both cases it has turned out that Equation I.19 different from Equation I.17 by the reinforcement factor is more appropriate for calculations. Its applicability is also shown for Google in Figure I.159.

"Similar" to Equation I.10 for CAGR growth relates to a fixed starting value R(0) in the series of R(t) across the dynamically stable state. Disregarding the construction of some sort of geometric mean through the t-eth root the emphasis on a fixed value of R(0) for the state seems to show that for the (financial) growth a particular initial constellation exerts a decisive influence.

For Cisco a good fit is observed and its revenues for the 1991 recession are obviously more than balanced by sales (and more employees). On the other hand, referring to productivity Figure I.145 shows that Cisco's organizational state is by no means stable across the early 1987-1994 period.

Due to the small number of cases treated by Equation I.19 one can only speculate about what is behind R(0) – a large capital injection at the start of the dynamically stable period adding to the "base line" development of each of the R(t)'s which will drive the growth over the whole period, a jump in other resources like employee number, or an extremely successful shift to another source of revenue.

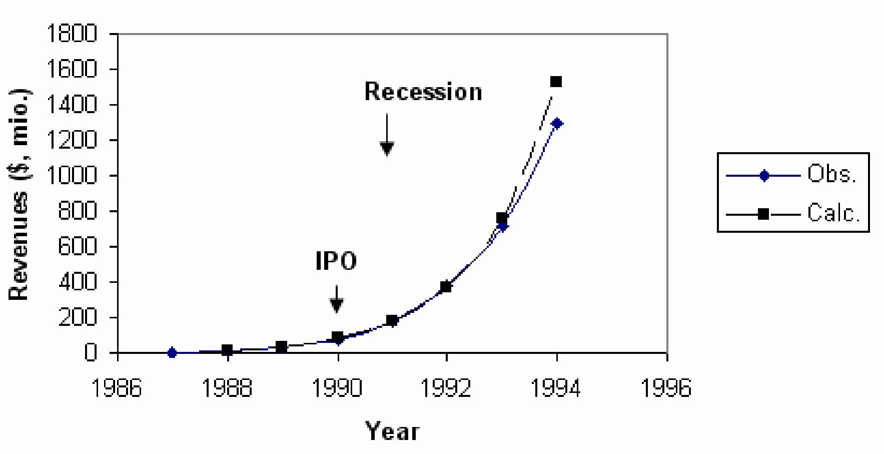
Equation I.19:

$$\mathbf{R(t+1) = n_R \cdot R(t) \cdot [\ 1 + \{R(t) / R(0)\}^{1/t}\ ]}$$

t = 1, 2, …n; n_R a state-characterizing (empirical) factor

Calculations using Equation I.19

Cisco Systems: R(0) = \$1.50 mio. (1987), R(1) = \$5.45 mio. (1988); n_R = 0.585; R(1)/R(0) = 3.63



First Solar: R(0) = \$3.21 mio. (2003), R(1) = \$13.52 mio. (2004) ; n_R = 0.650;

R(1)/R(0) = 4.21

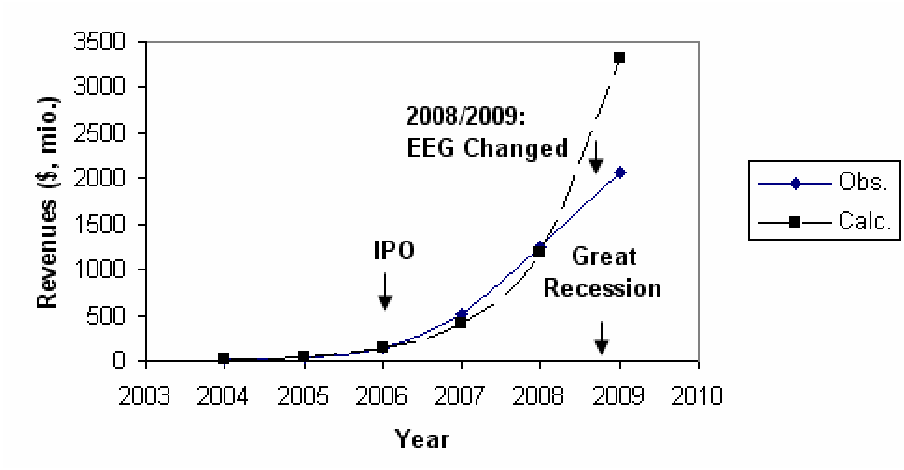


Figure I.158: Calculated (Equation I.19) and observed revenues of Cisco Systems and First Solar.

The large deviation between observed and calculated revenues for First Solar after 2008 due to the Great Recession and the change of the EEG in Germany shows that the financial sub-state to grow regularly only between 2004 and 2008. This is different from Cisco whose regular growth was obviously not affected essentially by a recession.

As a summary, the preceding discussions have presented *growth categories* (Figure I.155) for early development states of young firms (NTBFs) in terms of equations of state which are essentially recursive relations (Equation I.17 - Equation I.19) and reflect self-reinforcement verbalized as "growth breeds growth." This means, a series of interacting internal sub-states' changes leads to increases in size (observed for revenues) accompanied by not necessarily synchronous changes of the characteristics of other sub-states of the growing entity over a certain period of time (Figure I.149).

> Based on the calculational results in this chapter it appears that irregularities ending an otherwise good fit when comparing calculated and observed revenues may provide a means to detect brackets which may not show up in observed curves.

The development patterns represent systemic features of different types of growth paths of new firms for a given time period starting at a specified point in time that may initiate the search for explanations on the firm level. In the above text it has been pointed out that after a perturbation, a bracket, the firm will not return to the original state, but rather develops further into a new state.

This shall be illustrated by different theoretical descriptions in terms of different formulas to be used before and after a bracket for the German NTBF Nano-X (Figure I.137; Table I.77) and Google (Figure I.159).

For Nano-X the discontinuity, the bracket R(2004) $\rightarrow$ R(2005) of +2.33 units for the interval <2002,2008>, is surrounded by two states differing by the g-factor of Equation I.18. Table I.77 provides a "full" theoretical description of the (financial) states of Nano-X. The jump suffices qualitatively to identify the different states. Admittedly, the quantitative approach of the early state with g = 1.52 is not satisfying.

The significantly more pronounced growth rate for the 2000 to 2004 period cannot be explained straightforwardly. This period covers the Dot-Com Recession with no observable negative impact for the revenues. However, Nano-X financed the first years essentially via R&D projects ("Verbundprojekte"; ch. 1.2.6) of the German federal/state governments, the EU and NGOs as well as cooperation with other SMEs. As project money is usually counted as revenue, it can be hypothesized that the significant revenue growth during the first years, from almost its start, are due to larger contributions from projects to revenues.

Therefore, the theoretical description of the pre-2005 dynamically stable state of Nano-X should be confined to the interval <2002,2004>, though it cannot be ruled out that it covers also the 2000 and 2001 range.

On the other hand, more successful applications of Equation I.18 are discussed later (Figure I.163, Figure I.164, Figure I.165, Figure I.166).

Table I.77: Theoretical descriptions (Equation I.18, <2002,2004>) of two developing financial states of the German Nano-X GmbH separated by a bracket with pronounced discontinuity, a "jump."

Year	Revenues (€, mio.)	Calculated Revenues (€, mio.)	
R(t+1) = (1 + g) * R(t)		g = 0.52	g = 0.05
2000	0.50	0.50	
2001	1.00	0.76	
2002	1.4 *)	1.16	
2003	N/A	1.76	
2004	2.50	2.67	
R(2005) = R(2004) + 2.33			
2005	5.00		5.00
2006	5.20		5.25
2007	5.40		5.51
2008	6.00		5.79
*) Estimated from average productivity (70,000)		Average Productivities (€ /employee):	
		70,000	118,000

It is interesting to note that in its early years also SAP's growth follows Equation I.18 (g = 1.70 for <1972,1974> and g = 1.63 for <1975,1978>; Figure I.147).

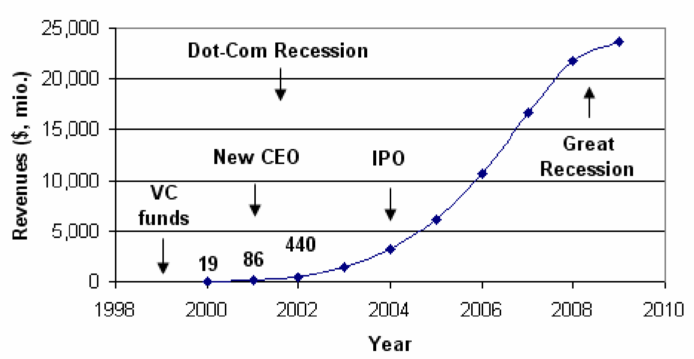
For Google (Box I.24) two growth periods according to different theoretical approaches can be identified with a transition state ("bracket") at 2002/2003 (Figure I.159) when revenues "jumped" from $86 million (2001) to $440 million (2002). Starting with the period 2000 – 2003 it turns out that after 2003 the gap between calculated and observed revenues widens drastically. Hence, by trial, it was found with which formula to describe the 2003 – 2008 period.

Early Growth of Contextual Advertisement on the Web.

After 2002 ca. 97 percent of Google's revenues were from advertisement! In 2001 ad revenue accounted for 77% and in 2002 it was already 92%. Advertising income is earned as Google operates its own Web sites, but it distributes ads also to partner Web sites. Its software AdWords (launched in 2000, major overhaul in 2002) is Google's unique method for selling online advertising. AdWords analyzes every Google search to determine which advertisers get each of up to 11 "sponsored links" on every results page. It is one component for the link between searching and advertising. The second part is AdSense which relates to semantics [Sullivan 2004].

In 2003 Google launched its AdSense contextual ad program and then greatly expanded AdSense, meaning ad serving application. AdSense placements are almost certainly the reason why Google has seen network-derived ad revenue rise so sharply.

There is another factor whose effects, however, cannot be assessed. Google bought Applied Semantics in 2003 and also three other companies [Sullivan 2004].



Google: Founded 1998 by Larry Page and Sergey Brin

primary focus: a better search engine for the Web (Box I.24)

Calculated values according to

Equation I.18 (small chart), g = 3.75, R(0) = \$19 mio.);
Equation I.19 (large chart), R(0) = \$440 mio., R(1) = \$1,467 mio., n_R = 0.50

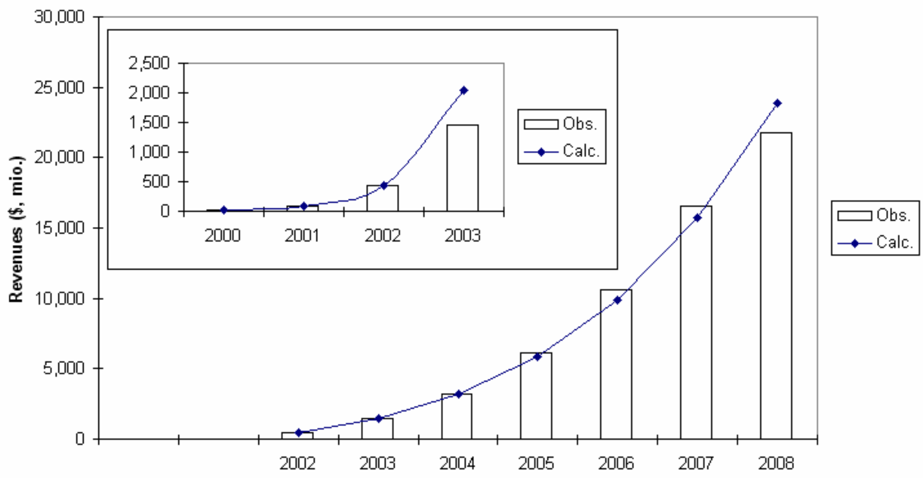


Figure I.159: Theoretical descriptions of two developing financial states of Google separated by a bracket with pronounced discontinuity, a “jump” (data from [Tech Crunchies 2010]).

So far, brackets were identified on the basis of revenues or employees/productivities. In case of Google revenue data do not reveal a 2002/2003 bracket (cf. Figure I.136). Fortunately, for Google the theoretical description is corroborated by other data: The pronounced “jump” characterizing the transition into the second state in clearly seen in the development of Google’s profit (Figure I.160).

Based on the limited number of cases, it has turned out that IPO brackets could not be detected consistently though they may represent drastic changes of a firm’s sub-states. Change will relate to ownership and potential change of control (change of leadership or management), respectively, to huge addition of capital (financial resources) which can be used, for instance, to pay back debts or increase of human resources in terms of R&D and marketing, sales and distribution (exploiting existing markets and enter new markets) or increase capacity of production.

IPO brackets are sometimes associated with increase of the number of employees which is observable by a decrease of productivity (Q-Cells, Figure I.153). But for Cisco (Figure I.145) in a steady state this does not show up.

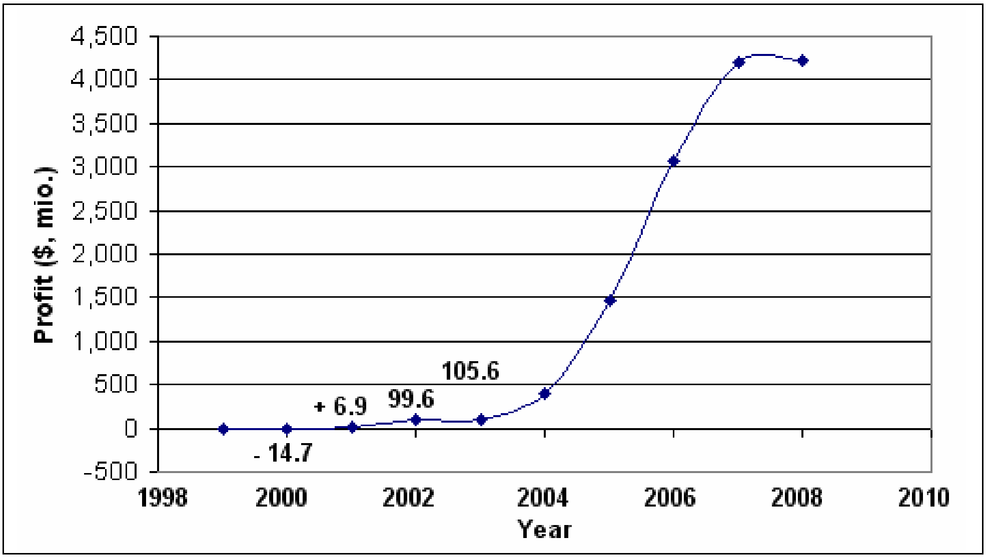


Figure I.160: Timeline for development of Google’s profit (data from [Tech Crunchies 2010]).

Summarizing the presented aspects of the theoretical approaches to early growth of NTBFs one is led to suppose that for early unperturbed growth phases Equation I.17 and Equation I.18 are appropriate if the growth is essentially driven by cash flow from income (WITec, Nano-X, SAP, Microsoft and Cambride Nanotech and US LED given in ch. 4.3.6). This would be reflected by the cyclic process of innovation and investment persistence in Figure I.127. On the other, if large capital comes from outside sources, but not through an IPO (Cisco, First Solar, Google), Equation I.18 seems to be adequate. However, this is still a proposition.

The equations do not only provide numerically satisfying descriptions of dynamically developing growth states for NTBFs, but in certain cases various structures for different intervals may differentiate states without prior identification of brackets. In so far, for the developmental processes of NTBFs' patterns of growth are created that characterize growth states. However, a more detailed understanding of the observed effects must be bolstered by reference to the micro-level of the firm under consideration if common features for such states shall be revealed.

Specific initial startup configurations and random occurrences of largely conceivable bracket events and related proceedings concerning decision-making will lead to overall differences in the growth of new firms. But there are periods, time intervals of growth, which are structurally comparable for the dynamics of developments of different firms.

4.3.6 Expectations of Growth of Technology Ventures

Past performance is, as investors like to say, no guarantee of future results.

In the context of entrepreneurial success (ch. 4.1) various perspectives of success and aspirations were discussed, in particular, those of the entrepreneur(s), financial backers, such as venture capitalists, and policy with a special focus on job creation (Table I.64). Currently, particularly in the US and Germany, there is great interest of policy in *high growth* and *fast growth* young firms that become major employers. In the following discussions we shall put the emphasis on details of generating and "measuring" expectations (Box I.17).

The issue is the assessment of technical startups by third-parties and entrepreneurs to generate *expectations* of survival and growth or even growth levels which is often associated implicitly with mixed arguing along the lines of "reasons why" versus "reasons for thinking that" (Figure I.2).

Covering samples of technical and non-technical samples various studies have shown that *the activity pursued in the startup process (organizational effort) has a major impact on founding success*. Furthermore, both *the founding success and (short-term) new venture survival of nascent entrepreneurs improved when the nascent entrepreneur engaged in early and careful planning activities* [Keßler et al. 2010].

In particular, one can argue that, disregarding cases with issues of scale-up for production, a *talented team*, with a *large market in which to innovate* and *excellent execution* justifies expectations of survival and good growth of a startup.

Bhidé [2000:209] has argued generally "that the ambition and the capability of individual entrepreneurs have a significant impact on firm longevity and growth." High growth of NTBFs is essentially related to the aspirations of the founders if aiming to maximize long-term value of the business, or merely seeking an increase in income, wealth creation and independence, for instance, by selling a successful firm after a few years (cf. William Henry Perkin; A.1.2).

In the following discussion we shall focus on expectations of growth, in particular, high growth of startups/NTBFs from an observer's or venture capitalist's point of view rather than "high-expectation" startups which, according to Autio [2005], refer to "all start-ups and newly formed businesses which expect to employ at least 20 employees within five years' time." (ch. 4.1)

In the teleological environment of GST expectations make special connections between goals of the firm founders and their related strategy, their opportunities in terms of markets and industries including competition and accessible resources and should reflect *ex ante* statements (Box I.17).

In order to inquire into expectations of the evolutions of NTBFs we use *comparative approaches*. One of it is looking for features which make the NTBFs' next steps of development – become a medium- and large-size firms – survive, be successful and keep competitive advantage for their evolution. This relates also to Bhidé's aspect of firm longevity.

As this is a frame for the transition between two constellations looking at medium- and large-sized firms in a particular industry (Figure I.118) can be useful to create expectations of developments of NTBFs by searching for fits between relevant features of both these classes. Furthermore, we shall focus on top *decision-makers* who control the enterprise and who have a significant stake in its fortunes.

This is to a certain degree in line with Bhidé [2000:2009] who stated that "knowledge of the origins and destinations of the origins and destinations of the typical long-lived corporations will help us identify the important common elements of their evolution."

Another way to create even semi-quantitative expectations compares the initial configurations of startups (ch. 4.3.2, A.1.6). A given NTBF with a given initial configuration providing information of its modes of growth and achievements will be used to generate expectations. Hence, knowledge and tools derived from *ex post* analyses are used to generate *ex ante* expectations (Table I.80, Table I.81).

Success Factors of Mid-Sized Enterprises

So far, we have learned that developments of privately held or privately controlled technical SMEs (Table I.4, Table I.74, Figure I.128) in the US and Germany are rather similar and reference to the German situation will allow some generalizations. Notable differences may occur with regard to extent of globalization and internationalization, where generally German firms put much more emphasis on than American SMEs.

As will turn out small and large high growth firms put much emphasis on strategy and execution, summarized, for instance, by the characteristics 1-7 of the German Hidden Champions (ch. 4.3.5.2). Thus there will be a relation to **strategic groups**, defined by

M. Porter as "*a group of firms pursuing similar strategies along strategic dimensions*" [Runge 2006:221].

An investigation of 1,300 German mid-sized firms, usually family-controlled, and comparisons with the 180 firms showing the strongest growth revealed that the top firms have growth rates of 10 – 39 percent, far exceeding the others. And, furthermore, they also *invest significantly* more than others. This was attributed to the following factors [Fröndhoff 2008].

1. Taking advantage from megatrends.
   Adapting the business model very early to global market trends, in particular, mobility, health, energy and process and control technologies.
2. Strong internationalization
   The firms with the highest growth rates have an export rate of 50 percent and more. Even small firms have set up a distribution network including sales and service offices or even production facilities.
3. Premium products and services
   The firms with the highest growth rates have decade-long experiences in their segments and focus on premium products. They have high innovation rates and thus can keep their lead times and withstand competition. They specialize and focus on few businesses in global markets. Their lead in knowledge and experience allow them to launch tailored products in the markets. Furthermore, they offer additional services for their products.
4. Manufacturing and networking
   Bundling product and associated service is seen as a successful strategy for competing with young firms from developing countries. Firms with the highest growth rates set off themselves through difficult to copy knowledge of producing high-tech products. And they often cooperate with universities and public resource institutes and develop products together with customers or firms of other branches.
5. Local roots
   The high growth firm has local ties expressed by social engagement.

A study of Ernst & Young [2011] inquired into 68 mainly technically oriented (German) mid-sized and large firms, actually finalists of the "Entrepreneur of the Year" contest, which showed above average growth over a series of years. They had on average revenues of ca. €115 million per year and 815 employees. The majority of the firms generate their revenues in the home market.

The majority of these firms (ca. 60 percent) operated in *lucrative niches* or *promising and growing market segments.* A high proportion of sales – on average 14 percent – is attributed to the *research and development* departments. Sustainable growth relies on *permanent innovations* including internal processes and *high appreciation of the firm by employees and customers* [Ernst & Young 2011]. Main success factors include:

1. Look at the bigger picture ("Über den eigenen Tellerrand schauen").
   During an upturn 45 percent of the firms turn to new markets, ca. 30 percent turn also to new target groups. Apart from the well-known European markets growth markets in Asia and South America are seen as big opportunities.
2. Perceive competition as chance.
   Though three quarters of the firms complain about higher competition they accept the challenges to optimize their offerings and arouse new needs. Globalization is not seen only as a threat, but also an opportunity to access ideas, talents, customers and businesses.
3. Innovation and investment persistence (Figure I.127).
   cf. for instance, German Erlus AG [Runge 2006:237/238].and its cooperation with Nano-X GmbH (B.2).
4. Continuously improve not only offerings, but also organizational processes.
   During an upturn, if competitive pressure tends to decrease, 75 percent of the firms take the time to assess their organizational processes and to reconfigure them so that new ideas can spread and get promotion and support.
5. Inform and motivate employees.
   The majority of the firm sample has a style of cooperative leadership concerning firm orientation, strategy and goals of the firm. The targeted incentives, but also demands of employees are appreciated – 80 percent of the firms can trust that their employees are committed to these plans and new developments.
6. Plan ahead.
   The firms prepare for possible uncertainties and issues in their business, in particular on those, which they can influence even in the worst case.

All the above success factors correspond essentially also to those which are typical for the class of the German Hidden Champions (ch. 4.1.1).

In a comparative study of technical and non-technical high-growth companies from around the world in ca. 30 industries versus their less successful competitors Kim and Mauborgne [1997] presented a rationale for the differences. They found high-growth to be achieved by small and large organizations, in high-tech and low-tech industries and private and public firms. The origin of the differences was the companies' fundamental implicit assumptions about *strategy* which sought to make their competitors irrelevant through a strategic logic they called "*value innovation*."

They inquired into the five textbook dimensions of strategy given in Table I.78. For value innovation logic the first and last dimensions exhibit typical systemic features. They found that managers of less successful companies all thought along conventional strategic lines.

The high-growth companies used a value innovation approach, and it was consistently applied to business initiatives in the market place. This means, value innovation logic requires *execution* (Figure I.87).

Table I.78: Two types of strategic logic for value innovation [Kim and Mauborgne 1997:106]. Reprinted by permission of Harvard Business Review. Copyright ©1997 by Harvard Business Publishing; all rights reserved.

Five Dimensions of Strategy	Conventional Logic	Value Innovation Logic
Industry assumptions	Industry's conditions are given.	Industry's conditions can be shaped.
Strategic focus	A company should build competitive advantages. The aim is to beat the competition.	The competition is not the benchmark. A company should pursue a quantum leap in value to dominate the market.
Customers	A company should retain and expand its customer base through further segmentation and customization. It should focus on the differences in what customers value.	A value innovator targets the mass of buyers and willingly lets some existing customers go. It focuses on the key commonalities in what customers value.
Assets & capabilities	A company should leverage its existing assets and capabilities.	A company must not be constrained by what it already has. It must ask: What would we do if we were starting anew?
Product & service offerings	An industry's traditional boundaries determine the products and services a company offers. The goal is to maximize the value of those offerings.	A value innovator thinks in terms of the total solution customers seek, even if that takes the company beyond its industry's traditional offerings.

Value innovation is expressed by the departure from the conventional logic of the particular industry and can emerge from a so-called "value curve" which relates valuation of the customers (Table I.13) versus experiences of the customer (Figure I.161).

Value innovation provides inquiries into answering four key questions [Kim and Mauborgne 1997]:

1. What factors should be eliminated that our industry takes for granted?
2. What factor should be reduced well below the industry standard?
3. What factor should be raised well above the industry standard?
4. What factors should be created that the industry has never offered?

This often is a relation of the kind: increase utility drastically while reducing similtaneously own costs or, alternatively, give customers more of what customers need or appreciate most and much less of what they are willing to do without.

As an example in curve 2 in Figure I.161 the customer will get a device from three suppliers with above average advantages for elements C, D. E concerning functionality (C and E) and delivery, but the price (A) is rather high and it is not easy to use (B). Curve 1 represents a device with extremely favorable elements A and B (price and ease of use), but serious disadvantages concerning C, D. E.

The innovation displayed by curve 3 means combining advantages of D and E concerning delivery, functionality and B (ease of use) and disregarding C, which is optional features and meaning cost. The offering of curve 1 (maybe by an entrant) targets essentially customers who so far did not use the particular device due to a high price and learning efforts.

Value innovation is different to technological innovation, considered as innovation that integrates interfaces, marketing and operations. The emphasis is on product, service, and delivery. Competition is the key building block of strategy and positioning is by differentiation from the competitive pack by "breaking" the rules of the "standard game" to create fundamentally new and superior customer value.

In so far, value innovation can be useful as an instrument to assess young firms concerning growth in a competitive market by assessing in how far the they may provide appropriate answers to the above four questions.

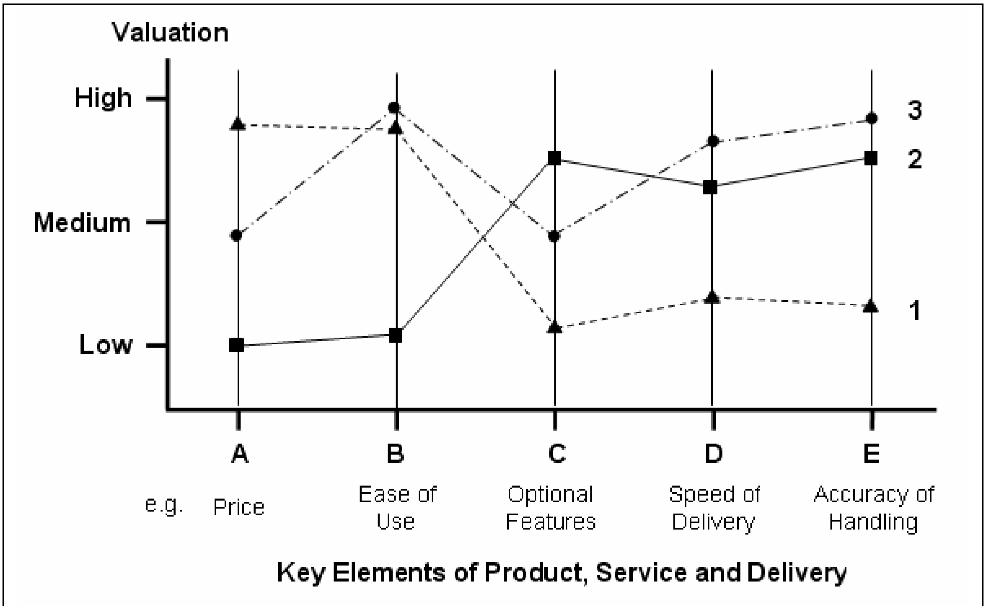


Figure I.161: A "value curve" for value innovation.

How the logic of value innovation translates into a company's offerings in the market has been described by Kim and Mauborgne [1997], for instance, for the German originally Hidden Champion SAP AG (ch. 4.1.1; Figure I.143; A.1.4) as follows.

Until the 1980s Enterprise Resource Planning (ERP) appeared as "business-application software." Providers focused on sub-segmenting the market and customizing their offerings to meet buyers' functional needs, such as payroll, human resources, production management and logistics. And the emphasis of the makers was focusing on improving the performance of particular software products.

Instead of competing on customers' differences, SAP sought out important *commonalities in what customers value*. SAP's founder/leaders correctly hypothesized that for most customers the performance advantages of highly customized, individual software modules had been overestimated. Such modules forfeited the efficiency and information advantages of an integrated system, which allows real-time data exchange across a company.

In 1979, SAP launched R/2 (Figure I.143), a *real time integrated business-application software* for mainframe computers. R/2 had no restriction on the platform of the host computer; buyers could capitalize of the best hardware available and reduce their maintenance cost dramatically. Most important, R/2 led to huge gains in accuracy and efficiency because a company needed to enter its data only once. And R/2 improved the flow of information. A sales manager, for instance, could find out when a product will be delivered and why it is late by cross-referencing the production database. SAP's growth and profits have exceeded its industry's.

Concerning technology entrepreneurship our interest in expectation of levels of success is the top ca. 20 percent of firms that create ca. 80 percent of jobs by high or fast growth (Figure I.119). The interest is to assess the fate of a startup from its initial configuration, its "birth" including the "startup thrust phase" (ch. 4.3.1, 4.3.2; Figure I.125) in a given environment.

We shall tackle the scope of *ex ante* expectations referring to three situations

- Statements about essentially survival and rough growth levels at the time of firm's foundation based on its initial configuration ("year 0" of existence and the first year at the highest)
- Statements about the situations after the startup thrust phase (year three or four of existence when the period of highest level for a firm's failure has successfully passed) or generally,
- Firms' development after a significant bracket in terms of dynamically stable states (as outlined in ch. 4.3.5.3).

In restricting to the time one must keep in mind that startups with (anticipated) production often need a period of four to eight years before they can commercialize their offerings ("delayed growth"). Such long "projection" into the future restricts expectations seriously, as not only the market and competitive landscape will have changed. The expectation would require assumptions about the scale-up process into large-scale production and a successful entry into the market.

The first case will be similar to that of natural science when usually the initial conditions and corresponding equations of motion (or situation-related differential equations) suffice to predict time-dependent trajectories. For the current discussion the initial configuration (ch. 4.3.2) would be the starting point.

We shall take care as far as possible of the caveat that the very dynamic developments of new firms in the first years in business (Table I.71) and short-term success does not allow inferences about sustainable success.

Serious issues for *ex ante* approaches are raised by the high complexity of new technology-based firms (Figure I.128) which makes statistical approaches largely questionable due to sample selection and keeping the structure in the answer sets. The multi-dimensionality of factors contributing to survival and growth of an NTBF and the much randomness of environmental changes impacting firm size result in situations which are often not expectable.

The Unexspectable

Intrinsic to a discussion of expectations is the *unexpected*, the "surprise" which may lead to:

- the unexpected success,
- the unexpected failure
- the unexpected outside "unique event," the unexpected development of a situation or an entity (ch. 1.2.1, 3.2.1).

Drucker [1995] illustrates the unexpected for systematic innovation which monitors the innovative opportunity from the point of view of innovators or management of firms.

The *unexpected success* is described as the area in which no other area offers richer opportunities for successful innovation. "In no other area are innovative opportunities less risky and their pursuit less arduous. Yet the unexpected success is almost totally neglected; worse, managements tend actively to reject it" (p. 37). The unexpected success is seen as an opportunity, but it does make demands (p.45). "In exploiting the opportunity for innovation offered by unexpected success requires analysis" (p. 41).

Unexpected success is a symptom; however the question remains; a symptom of what? Drucker describes the unexpected success as the underlying phenomenon which may be nothing more than a limitation on our own vision, knowledge and understanding (p. 41).

Then there is the *unexpected failure*. "Failures, unlike successes cannot be rejected and rarely go unmotivated. But they are seldom seen as symptoms of opportunity. A good many failures are of course, nothing but mistakes, the results of greed, stupidity, thoughtless bandwagon climbing, or incompetence whether in design or execution" (p. 46).

Finally, there is the *unexpected outside event* (cf. the German firm Heyl; Table I.76) This area indicates that "outside events that is events that are not recorded in the information and the figures by which a management steers its institution, are just as important. Indeed they often are more important" (p. 52).

Unexpected events or developments are often associated with the metaphor of the "Black Swan." And specifically (according to Nassim Nicholas Taleb) technological breakthroughs are referred to as "positive Black Swans" – *unexpected events or developments* with huge positive consequences *that in retrospect look inevitable*. Some of them, such as Google (Box I.24) in technology entrepreneurship, come seemingly out of nowhere to dominate within a short time. Others take years to mature and are surprising only as people forgot they were there.

In the GST context expectation of a startup's development by an outside observer is teleologically bound to known, explicitly measurable goals (objectives) or an explicit definition of what is viewed as "success" (Figure I.78, Figure I.122, Figure I.130) by the founders referring to the level of achieving the objectives – making intrinsic connections with varieties of strategy expressed in various forms.

Therefore, Google does not represent a "Black Swan." Its early success is incommensurable (impossible to measure or compare in value or size or excellence) with its early intentions and goals. It was "unexpectable" (Box I.24)!

Box I.24: Could one have expected extremely high growth on and soon after Google's foundation?

Google Inc. is an American multinational Internet and software corporation specialized in Internet search, cloud computing, and advertising technologies. It hosts and develops a number of Internet-based services and products and generates profit primarily from advertising through its AdWords/AdSense programs. The company was founded by Larry Page and Sergey Brin in 1998 while the two were attending Stanford University. [94]

For Google an exorbitant jump in revenues is observed very few years after foundation (Figure I.159, Figure I.160). Google achieved crossing explosion-like the marker of $10 billion just eight years after foundation. Google has grown into one of the world's biggest Web companies by market capitalization since its 2004 initial public offering.

According to Larry Page Google's rise was due to being an *innovator in both technology and business*. In order to be successful in technical innovation, said Page, you must understand the business and marketing side of the equation [Page and Schmidt 2002].

We shall consider the first five to six years of existence of Google, but shall focus, in particular, on the business orientation at and shortly after foundation (the first three years). This would provide the relevant information input into the expectation of further development (and growth) of the firm by an outside observer.

Google began in January 1996 as a *research project* by Larry Page and Sergey Brin when they were both PhD students at Stanford University in California. [94] The primary focus of "the "Google project" was to create a better search engine for the Web – better, for instance, than AltaVista or Excite. The project was called "The Anatomy of a Large-scale Hypertextual Web Search Engine" or simply, The Anatomy of a Search Engine.

The challenge was to crawl the Web efficiently and provide more relevant results than the search engines that were available at that time (better search and information handling). The project should provide a *solution of the following problem*: The dramatic growth of the Web presented problems for crawling the Web – keeping the crawled information up to date, storing the indices efficiently, and handling many queries quickly. The Google project relied on the *PageRank technology* that the pair developed. [Woopidoo].

The famous search algorithm of Larry Page and Sergey Brin is essentially applying the ranking method used for academic articles (more citations equals more influence) to the sprawl of the Internet.

PageRank is not *the* Google ranking algorithm. Instead, it is just one of many different factors. However, it is the most known and a key element of what Google does. Stanford University, where PageRank was developed by Google's co-founders, owns the patent on PageRank. However, Google's IPO filing revealed that Google has been granted a perpetual license and that in October 2003, it extended an agreement giving it exclusivity to PageRank through 2011 [Sullivan 2004].

Page and Brin decided to convert their research project in Stanford University's computer science graduate program into a formal company. Originally, Google was run from within the university under the Stanford University Website, with the domain google.stanford.edu. [94]

The founders started with their own funds and those of their friends and family, but the site quickly outgrew their own available resources. In its early year Google allowed no advertising in their search engine results. The search engine became profitable in 2000 with the introduction of unobtrusive text advertisements placed along side search results. They eventually received private investments [Woopidoo].

The early assumption was that although ads would be an important source of revenue, but licensing search technology and selling servers would be lucrative. However, Internet search was considered such a low priority at the time that Page and Brin could not find anyone willing to pay a couple of million dollars to buy their technology [Lietdke 2008].

The first external funding for Google was an August 1998 contribution of $100,000 from Andy Bechtolsheim, co-founder of Sun Microsystems, given before Google was even incorporated. They filed incorporation papers so they could cash a check made out to Google Inc. (incorporated on September 4, 1998). Google was based in a friend's (Susan Wojcicki) garage in Menlo Park, California. And Craig Silverstein, a fellow PhD student at Stanford, was hired as the first employee. [94]

Early in 1999, while still graduate students, Brin and Page decided that the search engine they had developed was taking up too much of their time from academic pursuits. They went to Excite CEO George Bell and offered to sell it to him for $1 million. He rejected the offer, and later criticized Vinod Khosla, one of Excite's venture capitalists, after he had negotiated Brin and Page down to $750,000. On June 7, 1999, a $25 million round of funding was announced, with major investors including the venture capital firms Kleiner Perkins Caufield & Byers (KPCB) and Sequoia Capital. [94]

After foundation in 1998 Larry Page and Sergey Brin channeled their energy into its free search product and left much of the business planning to a 22-year-old Stanford graduate named Salar Kamangar, Google's ninth employee. Larry Page and Brin managed the company up until it reached more than 200 employees in 2001, when they handed over the CEO position to Dr. Eric Schmidt [Woopidoo]. Eric Schmidt joined Google as chairman and chief executive officer – and revenues jumped tremendously for 2001-2002 (Figure I.159, Figure I.160).

“Kamangar joined Google after graduating from Stanford University in 1999, five years before the initial public offering, and his meteoric rise mirrored the company's own comet-like trajectory. In seven years, Kamangar has gone from newbie to key player in one of the most remarkable corporate success stories of the decade. Among his accomplishments were writing the first business plan, becoming a founding member of the Google product team, and leading the engineering team that launched *AdWords*, Google's proprietary method for tailoring Web ads to search terms.” [DeBruicker 2006]. Google generated profit primarily from advertising through its *AdWords* program.

In 2000, against Page and Brin's initial opposition toward an advertising-funded search engine, Google began selling advertisements associated with search keywords. [94]

Google's rapid growth since its incorporation triggered further developments, acquisitions and also partnerships. In particular, there was another piece of software important for Google, “one they stumbled into when they bought Applied Semantics.” [Altucher 2009] Sergey Brin has long been friends with Applied Semantics co-founder Gil Elbaz, Google pointed out. Interestingly, both Google and Applied Semantics had similar beginnings, as search engines with funky names launched in the late 1990s.

However, Applied Semantics moved more properly into the contextual advertisement, when it launched its AdSense program [Searchenginewatch 2003].

Google did not invent AdSense. Instead, they acquired the AdSense technology lock, stock and barrel – including the AdSense name – from Applied Semantics that Google purchased in April 2003 which was known as Oingo Inc. "Applied Semantics tooted their own Adsense horn well before Google picked them up." An Oingo press release mentioned AdSense already on December 4, 2000 and an application for a trademark on October 22, 1999 showed the name already [FirstMention].

AdSense [95] is a proprietary search algorithm that was based on word meanings and built upon an underlying lexicon called WordNet, which was developed by researchers at Princeton University. The AdSense program places paid listings into Web pages, by analyzing the content of those pages and then selecting ads that seem most appropriate [Altucher 2009].

"Applied Semantics is a proven innovator in semantic text processing and online advertising," said Sergey Brin, Google's co-founder and president of Technology. "This acquisition will enable Google to create new technologies that make online advertising more useful to users, publishers, and advertisers alike." [96]

When Google acquired Applied Semantics in April 2003 Susan Wojcicki, director of product management, explained more benefits. "Bringing on additional engineering support is also a key component." [Searchenginewatch 2003]. With the acquisition Google gained additionally employees already versed in the contextual ad space, an engineering team with its own unique ideas and methods of powering contextual ads plus a few existing partnerships [Sullivan 2003].

Furthermore, the acquisition of Applied Semantics gave Google new traffic for its paid listings, new strengths in the contextual advertising space, which Google entered and also potentially hurt then major Google-competitor Overture [SearchEngineWatch 2003]

Google's core business of selling search-based advertising, which allows companies to purchase ads tied to specific keyword searches, became one of the most lucrative and rapidly growing markets in the high-tech sector. A detailed description of Google's contextual ad business, Googlenomics, is described by Ley [2009].

Google's early years were during the Dot-Com Recession and the disruptive jump in revenues in 2001/2002 cannot be attributed straightforwardly. However, reference to the origins to Google's profits (search services versus advertisement contributions) provides the answer: It is the explosion based to a large extent on its AdSense approach (Figure I.159).

As a summary, given the original intention when founding the firm on focusing on Web search Google's later shift to contextual advertisement including the enforcement of the ad orientation and the related change of the business model, the role of Salar

Kamangar for developing AdWords and by taking over the firm Applied Semantics with its AdSense program, stumbling into that as Altucher [2009] described it, the explosive growth of Google (Figure I.159, Figure I.160) could not be expected considering founding intentions and orientations, but could not even expected looking at the development over the first two to three years.

What and How to Expect

For NTBFs there are two situations for which survival can be expected and the lowest level concerning growth:

- Non-growth or very low growth by intention, for instance, growth in line with or slightly above the inflation rate.

Basically, for *configurationally similar young companies* according to class properties outlined in Figure I.128 with similar growth aspirations (Figure I.122), one can assume that they face and solve similar developmental problems and will be exposed to similar *unbalanced* internal and/or external factors or events and will go through similar phases of decision-making and actions which will affect their growth states.

Therefore, we propose to generate expectations by comparisons (and call the related approach "*ex comparatio*ne"):

- Expectation of growth referring to the configurationally "nearest" case (growth parallel to the nearest similar, analogous or competitive firm).

The fundamental variable of the initial configuration of a startup for dealing with growth developments of a firm reduces basically to "measure" (ask for) the intention or aspiration of the entrepreneur whether he/she wants the startup to grow or is satisfied with "non-growth" (ch. 4.1).

However, it may well be that an original non-growth attitude may change over time, if the NTBF has the "potential" to grow (Figure I.97). The entrepreneur's intended mode of growth has an important consequence for expectations. If entrepreneurs do not rule out non-organic growth for the early development phases, there is, at best, only a qualitative statement of future growth possible: will (likely) survive and grow.

In a GST context, not knowing about the entrepreneur's growth intention or aspiration (Figure I.122) has an important consequence. Whenever there is a researcher's (or any third party's) assessment of a startup based on the initial configuration he/she is in the situation that his/her expectation actually induces a statement with conditionals (Figure I.2), a "reason for thinking that" ("… will grow significantly unless the founder(s) do not want to grow", "… unless a serious event/bracket prevents that.").

Following an *ex comparatione* approach the fundamental statements with regard to a firm's growth, for instance, in terms of revenues, would refer to "more, equal, less" or "higher growth, equal growth, less growth" compared with a "standard." This can be extended numerically to an "average growth," if a class of "nearest cases" is considered or even to semi-quantitative statements, if variables and parameters of the related configuration are considered and mapped. Correspondingly, concerning expectations referring to growth we may have “growth above average” or “growth below average.” An average-related expectation of growth could refer to (statistical) averages of (non-VC controlled) NTBF types, such as TVT or HVT or both combined (Table I.1, Table I.70, Table I.71).

As the definition of an entrepreneurial configuration contains the firm’s environment, particularly the market it operates in, statements about growth of a firm *ex comparatione* can become statement with conditions concerning the market or industry, respectively.

The related approach would assess the capability of a new firm to capture a share of a developing market and focus expectations on relations of the firm’s growth to its markets using the following level of qualitative scores. Such an approach does not usually apply to disruptive innovations, as there may be no markets (exception: a Holy Grail; ch. 1.2.5.1). The assessment would have to focus on the firm’s potential to create a new market (cf. also ch. 4.3.5.3 for assessments related to “growth factors”).

- Growth less than the market/industry
- Growth with the market/industry
- Exceeding the growth of the market/industry
- Exceptional high growth (“super growth”).

However, one must admit that expecting super-growth at or shortly after NTBF foundation is almost impossible. One situation one can think of will again refer to a Holy Grail of an industry (ch. 1.2.5.1).

The *ex comparatione* approach represents essentially a *measurement of order* against a fixed point or constellation, in particular, against a “*standard*” (as for personality disposition, Figure I.60). *Ex comparatione* relies on knowing the class properties of the “standard.” And establishing the level of match between the new firm with the “standard” is a way of “*multidimensional case-based reasoning*” to generate expectations. For very close matches one can assume expectation to fit realities with acceptable reliability.

However, an external, scientific observer of a startup may miss a bracket (Figure I.136) for the standard or the target firm. Thus the observer may lack some information, fact or event to fully understand developments and outcomes. That means, the observer may not be aware that, for his/her understanding and explaining outcomes, rather than dealing with the “reason why”, he/she is about to deal with “reason why thinking that” (Figure I.2).

A semi-quantitative *ex comparatione* approach referring to a “standard” is presented by The Venture Alliance (TVA) which targets *fundability of startups by investors* (Box I.17).

TVA addresses *fundability of firms and entrepreneurs* [TVA]. They intend to help entrepreneurs in their quest for funding by providing how an investor would view their offering (ch. 4.1) and what areas of their business need improvement.

TVA's methodology measures how well a company conforms to "fair and acceptable" funding criteria at a specific point in time and results in three products and associated services which represent a stepwise process to the Fundability Assessment.

1. TVA's Qualifier is a specialized test designed to function as a reverse business plan. It is occasionally offered for free but, has a variety of upgraded options. Its 65-question test covers the aspects of the business and will give applicants a clear look at what their business is providing to a potential investor and where it needs work.
   The Qualifier is the starting point for determining which companies make the Forbes list "America's Most Promising Companies" (AMPC; Box I.17).
2. The Vulnerability Feedback is a follow-up to the Qualifier. During this process, professional analysts at TVA work one-on-one with applicants to explain the results of the Qualifier, what the Qualifier results reveal about their business.
3. The Fundability Assessment which also serves for the Forbes AMPC list is a 1,000+ question questionnaire. It enables TVA to produce a 12-15 page report on the business that will enhance every aspect of the applicant's business plan as presented to investors.

TVA has a consistent methodology. It developed a scoring algorithm based on a vast range of variables that determine a company's potential – ultimately, its worth to investors defined by the fundability. Aggregation of measurements – conversion of a 1,200 point scoring system – leads to one "Fundability Score" and to twelve categories for macro interpretations to be visualized by a "TVA Radar Graph" (Figure I.162). The categories present criteria investors typically focus on as part of their due diligence.

The overall Fundability Assessment provides a view of the assessed business as it *currently* stands and includes, apart from a report,

- The numerical TVA Fundability Score (required to continue the funding process).
- Two of TVA's trademarked Radar Graphs showing 1) how the company compares to an "ideal" model related to type and stage of company and 2) how the company *compares* to other companies that are "similar" ("competing" and "comparable").

As the entrepreneurs' situations usually change fast TVA places an expiration date to every analysis they do of six months.

For those TVA clients whose score exceeds 800, help with funding sources may be available. Those whose score exceeds 1,000 will have a broader range of funding opportunities including, but not limited to, being published in one of more of TVA's TIGER (Top Investment Grade EntrepreneuR) lists, such as the Forbes list.

Hence, TVA's approach has many features of the *ex comparatione* approach described previously. Specifically, TVA takes input by the entrepreneur and determines which of its twenty-four models ("standards") is the most appropriate one to measure the new firm against. Each model examines and weighs twelve key areas to reach an assessment against the perceived "ideal" represented by the template model. The Radar Graph of Figure I.162 is a visualized example of this approach. In this regard it is similar to "measurement of personality disposition" (Figure I.60).

Apart from "Investment Value" all the other TVA categories, by sense not terms, will play also a role in the current approach to expectations based on firms' configurations (Table I.80; A.1.6).

Typical questions related to each of the twelve categories are given below with score points in parentheses (Total: 1070). A corresponding listing with largely explanatory character of the categories is given by Nelson [2009].

1. **Management Team:** Who are they? What's their track record? Etc. (170)
2. **Founder Commitment:** What have the founder's done to show they are serious? (20)
3. **Entrepreneurial Experience:** Does the team have a track record we can believe in? (60)
4. **Accomplishments:** What has the team done to show progress? (100)
5. **Market Opportunity:** Is there a real market for the products? (170)
6. **Marketing/Sales Strategy:** Do we believe in their value proposition? (110)
7. **Competition:** What is their "unfair" competitive advantage? (140)
8. **Intellectual Property:** Can they protect their advantage? (100)
9. **Directors & Advisors:** Who does this team listen to? (40)
10. **Financial Performance:** What have they done since founding the company? (100)
11. **Corporate Structure & Ownership:** Does ownership and structure make sense and help or hurt the company? (20)
12. **Investment Value:** Is this a good investment for what is being offered at the anticipated risk level? (40)

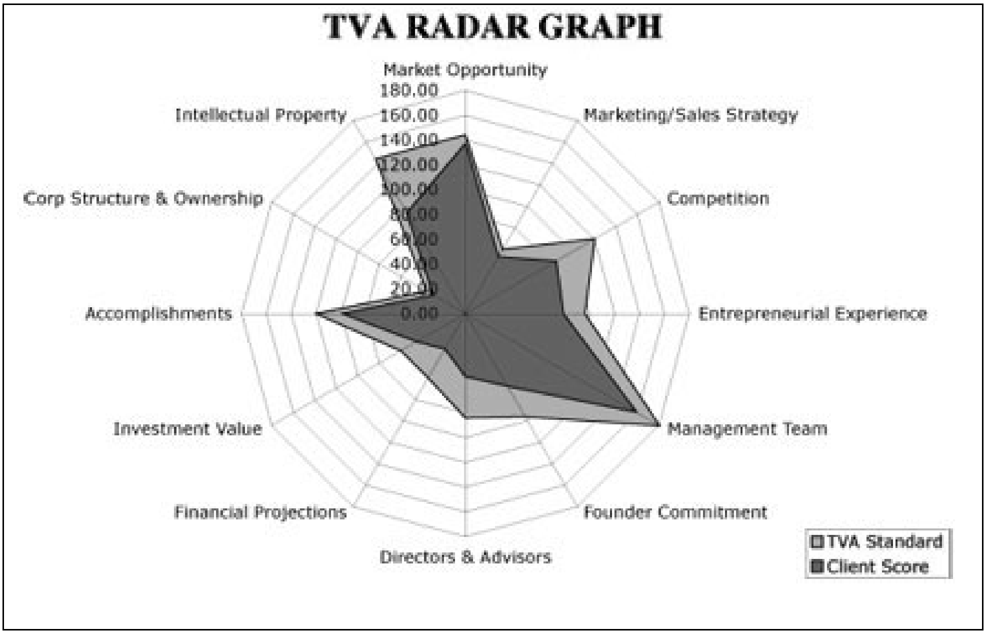


Figure I.162: The TVA Radar Graph to assess fundability of startups by investors – "The more (light) GREY you see (RED in the original), the greater the room for improvement." (Source: [TVA], courtesy of James W. Casparie).

A similar scorecard-like approach to assessing young firms is presented and illustrated for university "spin-out" companies (RBSUs) as compared with a group of companies arising from the community as a whole by De Coster [2004; 2005]. The assessment was based on key success criteria (Table I.79) and on information provided by the business plan of the new venture plus an interview with key personnel – plus secondary research. The scoring system focuses on criteria that have been identified in the research literature. The assessment methodology has been developed and operated over a period of four years by Clive Butler, HSBC Chair of Innovation at Brunel University, UK.

The methodology was primarily designed for the use of a major UK bank (HSBC) and now widely employed to assist in deciding whether *debt financing* is appropriate. Compared with VC investments, such funding tends to be early stage and the amounts relatively small. Such funding cannot bear the cost of in-depth due diligence procedures.

To improve the reproducibility of the assessment method the scoring method is seen to have the benefits that the assessments are more objective and there is less reliance on the individuals undertaking the assessment. A scorecard-type approach will usually also be used for business plan contests to judge all submitted business plans consistently.

To each key success criterion a verbal description is employed. The best fit determines the scoring number. The scales were developed by identifying the two end-points presenting the extremes of expectations of successful development of an early stage NTBF (most negative and most positive expectation; for instance, scoring between 1 and 10). The mid point of the scale for the scale will represent a median state of an NTBF when seeking funding. The overall maximum achievable score represents the ideal business in their industry/stage of development [De Coster 2004; 2005].

Not all the criteria of this approach are considered to be of equal importance or independent of one another. Weightings (not shown) were assigned to each of the criteria to reflect the levels of importance.

Table I.79: Criteria for assessing RBSUs according to De Coster [2004; 2005].

No.	Criterion	Aim
1	Technological and Commercial Risk	To assess will it work
2	Level of Product Innovation	To assess the Unique Selling Proposition (USP)
3	Market Criteria – How it satisfies a market sector	To assess market demand
4	Market Criteria – Timeliness	To assess the market timeliness
5	Product Extensions – Longevity/ Repeat Orders	To assess whether it fits into a family of products to permit company establishment or development
6	Product Extensions – Family of Products	To assess the longevity of product or product line
7	Entrepreneurial Background	
8	Protecting Competitive Advantage – Sustainable	To assess the intellectual property rights

The proposed "*ex comparatio*ne" approach in this book to generate expectations about new firms' development referring to a configurationally "near" case will require a set of criteria to be matched similar to those discussed in this sub-chapter and simultaneously a match between comparable dynamically stable states of the two firms.

As indicated in Figure I.128 there will be several criteria to describe an entrepreneurial configuration by "major coordinates," which house a number of attributes ("specifications"). The last ones could provide values (usually numerals for scores) if a scoring procedure should be built. The gross criteria would be associated with weights. It must be admitted, however, that a scorecard approach is not in line with GST: It treats the significance of an individual factor as independent from all the other factors. The lacking systemuc effects would be partially mitigated by weighing the “major coordinates.”

As an example of how to proceed with generating *ex comparatione* statements one can look at two *poster child companies* offering *nano-tools*, with *well growing markets (“scientific instruments”), proprietary technologies, real products and real customers*. Here, the earlier founded German firm WITec (Figure I.123) is the standard against which Cambridge Nanotech from the US will be matched.

Table I.80 provides the suggested configurational categories following largely the taxonomies discussed in Figure I.128. This makes the approach explicit and let emerge the close similarities of the two firms’ configurations – simply by inspecting and comparing textual descriptions of related categories rather than performing a quantified approach based on scoring, such as the TVA Radar (Figure I.162).

Cambridge NanoTech founder and CEO Jill Becker turned her Harvard chemistry thesis research into a rapidly growing company whose revenue hit $17.6 million in 2010 (B.2). Due to strong roots in Atomic Deposition Layer (ALD) research, Cambridge NanoTech enjoys exceptional access to novel ALD applications and many great opportunities to nurture these applications to maturity.

The successful transition from serving academic customers to manufacturing customers has been in response to specific market needs and to developing products working closely with industry partners, research collaborators and key customers. Gross margins of the business are around 70 percent [Yang and Kiron 2010].

Atomic Deposition Layer originates in chemical nanotechnology and means a method of creating thin film materials by laying down a layer material a single atom’s thickness at a time. ALD is an ideal *coating technology* because of its perfect, conformal, ultra-thin films that are scalable to large-area substrates. ALD simultaneously offers excellent thickness uniformity, film density, step coverage, interface quality, and low temperature processing, making ALD beneficial for both roll-to-roll flexible substrates and rigid substrates.

As both firms have very close configurations, apart from being sure about the firm’s survival, Cambridge Nanotech would be assumed to further develop solidly and dynamically similar to WITec (Figure I.163). Furthermore, one can assume the development curve in terms of revenue to be described with the formula (Equation I.18) used for WITec’s dynamically stable period (Figure I.156).

Though all this has turned out to be true from the start of the firm (2003) until 2008 and seemingly also until 2011 two *unexpected*, seriously negative brackets led Cambridge Nanotech to close doors by the end of 2012.

Table I.80: Matching entrepreneurial configurations of US Cambridge Nanotech against WITec GmbH to derive growth expectations for the former one.

Configurational Categories	**WITec GmbH (Germany; B.2)**	**Cambridge Nanotech, Inc. – CNT (US; B.2)**
Basic Firm Characteristics (Industry: Both in Nano-Tools, Scientific Instruments)		
Vision/Mission – Growth Strategy	"Focus Innovations," constantly introducing new technologies and a commitment to maintaining customer satisfaction through high-quality, flexible and innovative products; Organic growth (Box I.20; B.2)	Co-founder Jill Becker: "My fantasy was to marry science and business; sell a version of an ALD system, and evangelize this beautiful technology." [Yang and Kiron 2010] Organic growth
Firm Type	RBSU – university spin-out; direct commercialization of science (founded 1997)	RBSU – university spin-out; direct commercialization of science (founded 2003)
Legal Firm Form	Private, GmbH (LLC)	Private, Inc.
Special Externalities	Suffered early from Dot-Com Recession soon after start	
Initial Financing	Own resources and debts (bank loans)	Own resources, "bootstrapping" (plus loans?)
Further financing	Essentially cash flow	Essentially cash flow
Research (or R&D Intensity)	TVT (top value technology; Table I.1)	TVT (top value technology; Table I.1)
Networking	Ongoing contacts/coop with "home university"	Ongoing contacts/coop with "home university" and other universities
Founders' Personalities, Leadership and Corporate Culture		
Founders	Entrepreneurial Triple	Entrepreneurial Pair 1); 50:50 equity share in CNT

Motivation/Experience	Originally, team wanted to found an IT firm, grasped other opportunity; Father-in-law of one founder is self-employed (contributed also to initial funding)	Key founder Jill Becker always wanted to have own firm, marry science and business; father was serial entrepreneur [Yang and Kiron 2010] Entrepreneurial professor during doctoral thesis
Leadership Team: Managerial Roles and Execution	Personality and competency oriented distribution of management roles (Table I.41); Founders learning on demand; Strong business plan and financial planning [Koenen 2010]	Founder (Jill Becker) grasped first organizational skills managing university group, became Harvard Professor Roy Gordon's Chemistry lab *de facto* office manager; in charge of procurement, managing vendor relationships, tracking inventory and managing the lab's budget [Yang and Kiron 2010], gathered experienced team. By mid 2007 Becker hired Jay Ritter, a semiconductor industry veteran, as a manager
Technology, Innovation and Products/Services		
Technology	Enabling technology (nanotool); *nano-analytical* microscope systems (Raman, Atomic Force Microscope – AFM, Scanning Near-Field Optical Microscope – SNOM); with the first Confocal Raman Imaging system, WITec outperformed the existing Raman mapping techniques	Platform technology for *coatings*; Atomic Deposition Layer (ADL); creating *thin film* materials by laying down a layer material a single atom's thickness at a time.

Table I.80, continued.

Technology, Innovation and Products/Services		
Innovation Persistence	Steadily developing different types of instruments; first, combining SNOM and AFM in one single instrument; then, modular design allows the integration of Confocal Raman and Scanning Probe Microscopy (SPM) in one system; this innovation instigated a boom in combined Raman/SPM systems	Steadily developing different types of ADL systems and coatings devices
Technology Ownership (Own Development, Partnership, Licensed)	Own research and development at the University of Ulm, Germany	Developments based on Becker's dissertation; not known whether there is licensing with Harvard; presentation of Rogers and Mead [2011] induce some evidence for licensing
IP Protection	Own Patents	Patents
Regulatory Factors for Technology	None	None
Instrument Production	Utilizing university infrastructure to develop instruments including assembly of first instruments	Utilizing university infrastructure to develop instruments including assembly of first instruments; founder Jill Becker hand-assembled the first 13 units
Production	Own facilities	Contract manufacturers located in Massachusetts

Market and Opportunity		
First Customer Available (Startup Thrust Phase)	Sales of scientific (lab) instrument to (US) academics led to nano-tools startup: initial sales – research to research	Started with academic customer (sales to Stanford University); initial sales – research to research
Commercialization or Business Model	Research, development, production and sales / distribution of scientific instruments; user education and support; technical service; consulting concerning applications; analytical (nano)tools focusing on material and life sciences	Research, development, production and sales / distribution of scientific instruments and devices; user education and support; technical service; consulting concerning applications; providing coating services for a variety of materials the products are used in various applications, including optical, nanostructures, electronics, energy, biomedical, anti-corrosion, anti-stiction, chemical, etch resistance, internal tube liners, magnetic, roll to roll, semi and nanoelectronics, MEMS, and wear resistant.
Real Customers	From academic and industrial research, immediately ("real" products or services, e.g. no selling of licenses); international orientation	From academic and industrial research, immediately ("real" products or services, e.g. no selling of licenses); international orientation

Table I.80, continued.

Market Characteristics	Economic and policy-driven markets; global; almost recession proof; industry: scientific instruments (in a broad sense); analytics; Starting with customers primarily from academia; in 2005 the estimated SPM world market was €113 mio., Japan ca. 30%; in many cases, researchers order an SPM customized to their research purposes, and it is estimated that such a special SPM occupies 30% to 50% of the entire demand for SPMs	Economic and policy-driven markets; global; almost recession proof; industry: scientific instruments (in a broad sense) and surface coatings Almost none for the time of foundation! Starting with customers primarily from academia; currently: by 2012 observers expected the global ADL market to be \$1 billion or 10% of the total market for deposition equipment. CNT estimated to have captured a 5-10% share of the current market for ADL equipment sold for R&D [Yang and Kiron 2010] – often customized products
Competition, Competitive Advantage	A few known "big guys" and a lot of "little guys;" however, small firms are in a better position to supply specialized instruments and accessories to the companies and research and educational institutions that work at the micro and nano levels; small firms look for lucrative niches (e.g. German JPK Instruments AG focuses on BioSMP, Figure I.141) Advantages: leadtime, Raman/SPM leader, innovation persistence	The top-five ALD equipment suppliers had an 81% share of the global ALD equipment market, middle tier of ALD equipment suppliers, most with less than \$10 mil. CNT knows their most significant threats and competitors with the potential to become significant threats. [Yang and Kiron 2010]. Advantages: Innovation persistence

Marketing/Promotion and Customer Education	Customer workshops ("WITec Academy"); online webinars (home page); conferences, exhibitions and fairs	Online tutorials (home page); literature database (Knowledge Center); webinars, Customer Papers; conferences, exhibitions and fairs
Sales and Distribution	Subsidiaries: US, Singapore (US sales office 2002; Singapore sales office 2010); early on worldwide network of distributors (sales and customer support)	Subsidiary (UK 2009); early on worldwide network of distributors (sales and customer support)

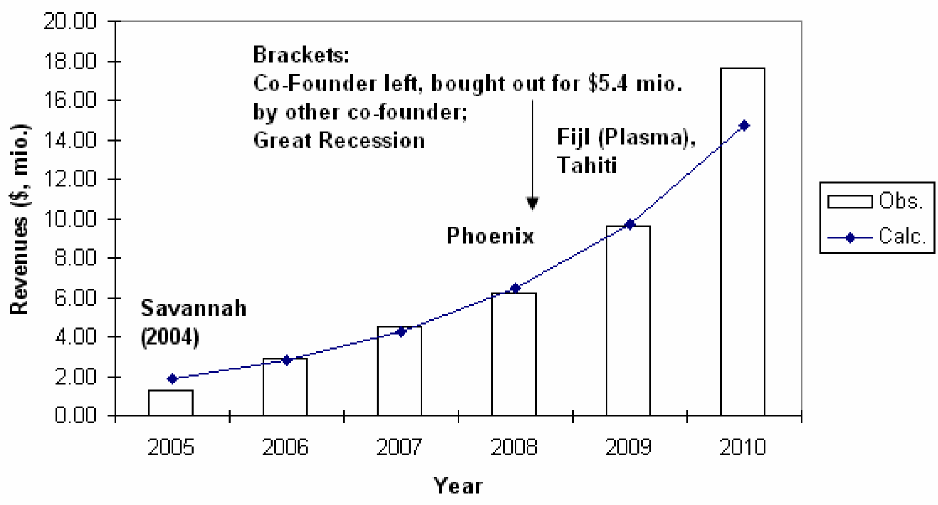
1) One founder – Douwe Monsma – left CNT in 2008: company experienced serious friction between the co-founders, was resolved when in Oct. 2008, Monsma accepted a $5.4 mio. buy-out offer from Becker financed by a bank loan; Jill Becker further developed the firm – till its end.

Comparisons between CNT and WITec have to be made for equivalent dynamically stable states after the startup thrust phrase. However, immediately after the startup development of WITec was perturbed by the Dot-Com Recession. Therefore the <2004,2009> period may serve as a guide (Figure I.123, Figure I.156). The actual growth factor of Cambridge Nanotech for good fit is 0.51 (Figure I.163) for <2005,2008>. The introduction of the Phoenix instrument let a new bracket emerge in 2009 amd immediately after that two additional new instruments were introduced.

According to the bracket theory the data of 2010 comprise the occurrence of two new brackets. Indeed, the bracket is likely to be associated with launches of two new products which got a lift-off adding to revenues in 2010 (B.2) – despite the Great Recession. And also 2009 data should be affected by this recession. This situation of crowded brackets with negative effects being leveled off is similar to the situation of Microsoft depicted in Figure I.144.

Concerning technology there is plasma and thermal ALD. By mid of 2009 Cambridge Nanotech announced the launch of its first line of plasma ALD systems, the Fiji Series, but with the ability to conduct thermal ALD as well. According to Jill Becker "the Fiji is a breakthrough in ALD system design." "We built it from the ground up for the specific purpose of plasma ALD, but with the ability to conduct thermal ALD as well." Furthermore, in 2009 Cambridge Nanotech also launched its Tahiti system engineered for large-area manufacturing operations ensuring repeatable, exceptionally uniform, pinhole-free thin films on substrates.

Expectations (of the author) that CNT would follow a secure and successful development did not materialize due to frictions in the founder team in 2008. By the end of 2012 its auctioned assets and intellectual property were acquired by Ultratech, Inc.



Cambridge Nanotech, Inc.: Founded 2003;
Expected growth relation after startup thrust (Figure I.123, Figure I.156) beginning at 2006;
R(t+1) = (1 + g)·R(t); using R(0) = $1.24 mio. at 2005, g = 0.51
End of 2007: Ray Riiter (20 years experience) hired as a full-time COO;
net profits of $3.6 mio; $1.8 mio. net income in 2008 [Yang and Kiron 2010]

Figure I.163: Calculated and observed revenues of US Cambridge Nanotech and innovation persistence by launch of of instrument series.

Currently the broad analytical and life sciences instrumentation market enjoys considerable growth rates. It is reported, for instance, that the life sciences (academia and government) segment has a magnitude of $10 billion and annual growth rate of 8 percent, pharmaceutical and biotechnology is $9 billion with 5 percent growth rate, industrial (computers and semiconductors) has $5 billion and 4 percent growth rate and chemical & energy exhibits $2 billion and 5 percent growth [Thayer 2011].

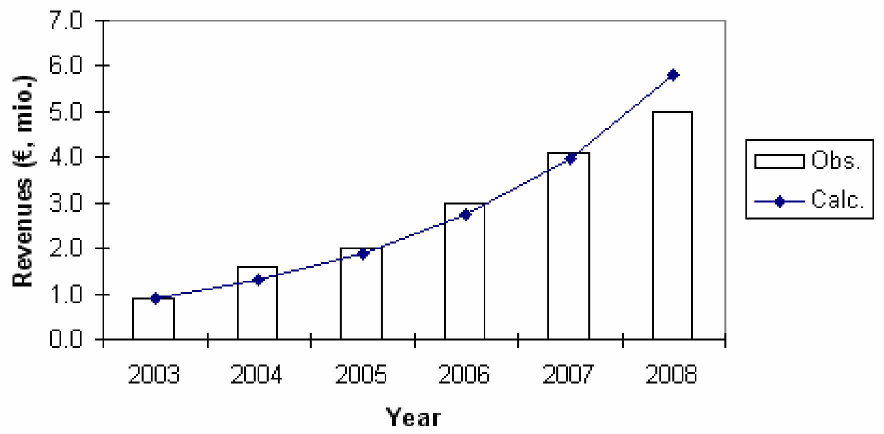
Another technology startup with a configuration rather close to those discussed is the German firm Attocube Systems AG founded in 2001 (B.2). The then founders of the RBSU Attocube also had a sale of a university laboratory device to recognize the opportunity and after firm's foundation they grasped fast real customers.

Though founded during the Dot-Com Recession Attocube already made a profit in its first year of existence. It was financed essentially with own resources, used an enabling technology for its offerings to deliver international customers from academia and industry and proceeded with innovation persistence. The major differences to the above cases are that Attocube got early involvement of an angel investor who occupied a key role in the leadership team. Attocube is a private stock company.

Attocube's technology covers those of CNT ("moving atoms") and WITec (special microscopes). Attocube targets positioning of atoms which requires having them at rest with no fluctuations due to thermal energy – close to the absolute zero temperature 0 deg.K (which is -273.3 deg.C).

It provides the research market and industry with a reliable, compact, nano-precise and micro-precise positioning system that is capable of executing sample movement from the sub-nanometer to a centimeter range even in a large variety of extreme environments, such as ultra-high vacuum, extremely low temperatures (-273 deg.C) or at high magnetic fields. Simultaneously it provides tools to control and observe the positioning which are special microscopes allowing to operate under such extreme conditions.

In Figure I.164 the expectation to describe the growth of Attocube analytically by the same formula as used for WITec and Cambridge Nanotech with g between 0.35 and 0.51 is corroborated. Observed data for 2008 are incomplete, but, moreover, according to theory Attocube's dynamically stable state for the period <2003,2007> ended in 2008 due to the new front bracket of the "Wittenstein event."



Attocube Systems AG

Founded 2001

Expected growth relation after startup thrust beginning at 2003;

R(t+1) = (1 + g)·R(t);

using R(0) = €0.9 mio. at 2003, g = 0.45; data for 2008 reported in September 2008

Productivity <2005,2007> almost constant, ca. €214,000 per employee

Figure I.164: Calculated and observed revenues of German Attocube Systems AG.

By September 2008 the German Hidden Champion Wittenstein AG acquired a 74 percent equity stake in Attocube keeping the two founders as executive managers and the angel investor as a member of the Supervisory Board.

Next we shall consider generating expectations *ex comparatione* for non-RBSUs, in particular, expectations for survival and growth related to *experience* of the founder(s) including expectations of *execution*. The emphasis will be on serial entrepreneurs and those with profound industry experience, relying on technical, commercial and managerial experience from previous jobs (Figure I.64).

Based on the fundamentals of US LED (Table I.81; B.2) one can expect the firm to successfully catch market share in its field of activity. Particularly strong arguments are the founder to be an experienced serial entrepreneur, initial financing being secured, detailed market knowledge and a favorable customer interface and distribution system and a focus on a strongly growing segment. Hence, there is little arguments why not expect US LED to grow at least with the market.

Table I.81: Key characteristics of a firm, here US LED Ltd., for generating expectations of firm growth.

Firm Type	Other NTBF (Table I.2, Figure I.128) (founded 2001)
Legal Firm Form	Private (Ltd., LLC); majority ownership/almost full control (Table I.74)
Initial Financing	Financed as a spin-off of US Signs
Research Intensity	HVT (high value technology; Table I.1)
Founder	Single entrepreneur (Ron Farmer)
Motivation/Experience	Serial entrepreneur; founded several companies but the most noteworthy are US Signs (founded in 1980) and US LED, both of which he still owns and participates in. Though relatively small with $22 million revenue, US Signs focused on neon lighting; ranks in the top 100 of the 30,000 sign companies in the US
Leadership//Management	As CEO for US LED , Ron Farmer helps manage the company and contributes to product development and sales

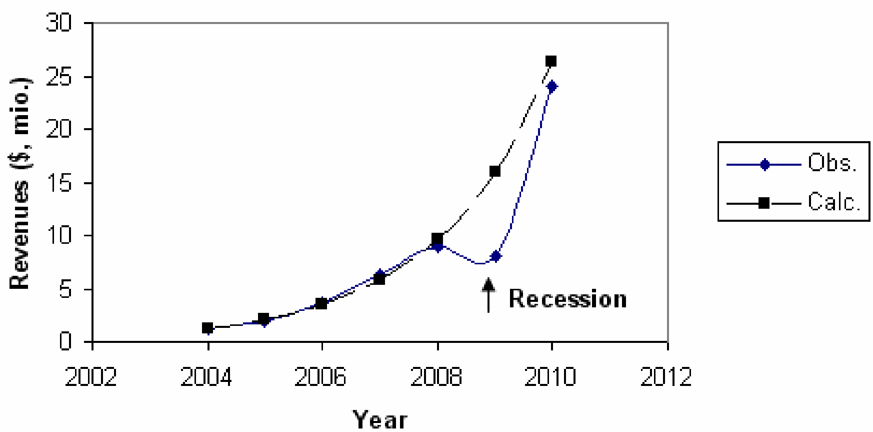
Technology and Application Focus	LEDs – light emitting diodes; impact as a generic (and emerging) technology for the lighting area; US LED focuses primarily on “channel letter lighting” for illuminated signs for advertising and creating attention. Promoting LED relies on large cost savings as LED uses nearly 80 percent less electricity and lasts up to 16 years with no maintenance. Neon was and is still a strong illumination provider of channel letter lighting, but LEDs have already overtaken neon in 2008 in general-purpose channel letter signs in North America
Market and Opportunity	Economic market with strong components of (“green”) attitudinal and policy-driven markets (Table I.15). In 2011 it was reported that the “high-brightness” LED market is forecast to grow to $19 billion in 2014 from last year’s $5.3 billion, at an average annual rate of 29 percent. The fastest-growing segment is in displays and signs, which is predicted to grow 61 percent annually in the five years. It will also be the largest sector, accounting for 51 percent of the market, up from 36 percent this year. The general illumination segment is the next fastest-growing, at 45 percent a year, to $4.2 billion from $645 million during the period. Automotive applications are also projected to grow rapidly during the forecast period. LED lighting is one of the last analogue-to-digital transitions in the technical area. When so-called smart grids (computerized electricity distribution systems) are commercialized in 5 to 10 years’ time, the energy-saving features will be magnified by demand-driven automatic dimming capabilities. In 2007 the worldwide market for “high-brightness” LEDs used in lighting applications reached $337 million, up from $205 million in 2006. *Haitz’s Law*: the performance of an LED doubles every two years; this may explain the exponential growth of the LED lighting industry; every decade, the cost per lumen (unit of useful light emitted) falls by a factor of 10, the amount of light generated per LED package increases by a factor of 20, for a given wavelength (color) of light

Table I.81, continued.

Regulatory Factors for Technology	None
Attitudinal or Political Aspects Affecting Sales	Positive, energy efficiency (energy saving) aspects
Initial Customers, Real Customers	After its startup thrust phase US LED as a spin-off could rely on customers of US Signs. Generally, ca. 10-20 percent of customers are about retro-fitting neon with equivalent LED products and, thus, US LED could take advantage from existing customers of US Signs. LEDs are deployed in two areas of channel letter lighting; the first is *new signs* where the preferred lighting source is LEDs. The second area is *replacement for previously installed sign projects*, where for reasons of cost savings, the sign owners have opted to change out the neon with an LED system. US LED targets the home (US) market.
Innovation Persistence	LED as a platform technology; US LED started with lighting for signage, but expanded applications; it migrated into lighting for convenience store refrigeration, for parking lights, under canopy lights, industrial lighting, warehouse lighting, etc.; is working on the fluorescent tube lighting replacements for office lighting.
Competitive Advantage	US LED does not only provide LED for lighting, it also focuses on making it easy to install and easy to work with. US LED can rely on the widespread sales and distribution organization of US Signs, seems to be able to protect competitive advantage
Special Externalities	Ron Farmer: "…in 2009, we actually dropped back for the first time since we've been in business. We dropped back by about nine percent, but our piece count sales actually were up 50-percent."

According to the market data in Table I.81 one could expect US LED to grow with the market and have an average annual growth rate between 30 percent and 60 percent after its startup thrust phase, suggesting.to assume $g \approx 0.5$ in Equation I.18.

Actually it turned out US LED to grow in line with the maximum value estimated for the related markets (Figure I.165). It should be noted that according to the bracket theory calculated and observed values are restricted to the interval <2004,2008> stopping with the Great Recession. The nice fit for 2010 data is accidental; picking up previous growth occurs in a new firm's state!



US LED Ltd.: Founded: 2001

R(t+1) = (1 + g)·R(t); using R(0) = \$1.30 mio. at 2004, g = 0.65 for <2004,2008>

Figure I.165: Calculated and observed revenues of US LED.

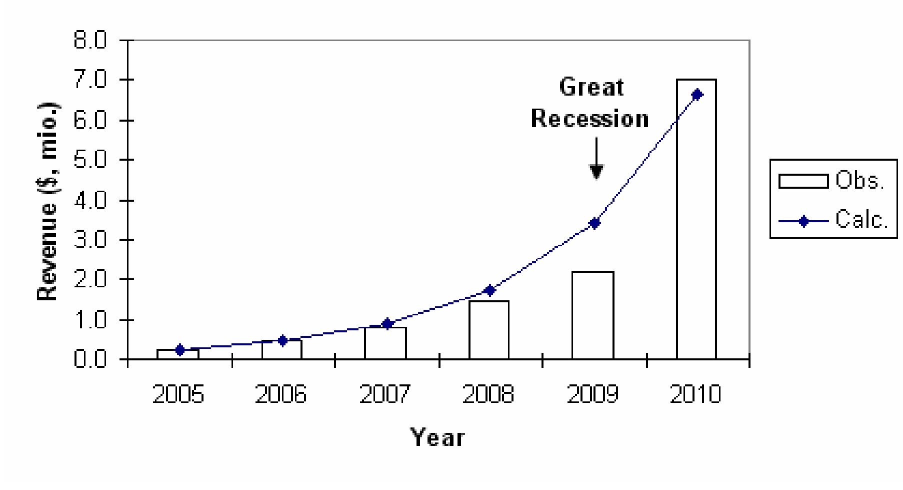
US LED can serve as a model for expectable development of US Albeo Technologies Inc., founded 2004. Its firm type is "Academic Startup" (Table I.2) and is active in LED. The founder and members of the management team have 20+ years industrial experience, specifically also in the LED area ("veterans approach"). Founder and owner of the firm Jeff Bisberg spent more than 25 years developing and marketing innovative solid-state technologies (SST), with 20 years focused on light-emitting technologies, including developing novel organic LED, miniature LED print-heads, and an award winning laser printing system.

Albeo Technologies Inc. is a pure LED lighting company. It designs, manufactures and sells white LED lighting systems (intelligent lighting fixtures) for commercial and industrial indoor general lighting applications. Its products replace traditional fluorescent and high-intensity discharge lighting to decrease energy usage and maintenance.

Albeo targets the home (US) market. Albeo sells its lights for both new construction and retrofit projects, with the latter growing to 85 percent of sales. Albeo has designed a *flexible system* so that it is very easy to customize. Albeo delivers the "exact solution” to the clients (“solution provider”). It sees itself as a leader in the white-LED general-illumination fixture market.

Albeo’s products and systems benefit from the “green” momentum as they reduce power consumption and maintenance for commercial and industrial facilities, and exhibits simultaneously environmental benefits (reduce carbon dioxide emissions). Its primary goal is to enable businesses to lower their total operating costs (total-cost-of ownership, TCO). The advantages over traditional lighting technologies, significant efficiency, lifetime and environmental advantages, mean also providing a short return on investment.

Expectation of Albeo’s growth includes the applicability of Equation I.18, growth roughly comparable with that of US LED ($g \approx 0.7$) and an observable front bracket due to the Great Recession after a dynamically stable state for the <2005,2008> period. This can be seen in Figure I.166. The fit for 2010 must be viewed as accidental – not in line with theory.



Albeo Technologies Inc.: Founded in 2004

$R(t+1) = (1 + g) \cdot R(t)$; using $R(0) = \$0.23$ mio. at 2005, $g = 0.96$ for <2005,2008>

Revenue data were obtained from values given for 2007 and 2010 in “The 2011 Inc. 5000 List of America’s Fastest Growing Companies”; other data were derived from various statements of growth rates for the firm in the literature.

Figure I.166: Calculated and observed revenues of US Albeo Technologies.

Contrary to the situation of US LED the Great Recession shows up here only as a dip of revenue reflecting reduced continuous growth. The much larger absolute growth of Albeo Technologies ($g = 0.96$) is only partially surprising as for Albeo Technologies reference is made to the very early growth state of the firm which will exhibit generally much higher growth than later phases (Table I.71).

Actually, the previous discussions focused on the top 20 percent of NTBFs contributing most to job creation (Figure I.119) through related growth which makes sense from the point of view of economics of the country. We have dealt with “promising firms” or “promising NTBFs” (ch. 4.1, 4.3.1), respectively, which show good or high growth and the 33 – 46 percent of entrepreneurs who intended their firms to grow (Table I.63).

There is one fundamental issue of semi-quantitative expectations of growth for technical startups for the very early phase. Starting on a rather low level of revenues (200,000 – 300,000 dollars or euros per year) and catching just one big order valued double or triple the previous level of revenue in relation to the current revenue level would make any semi-quantitative expectation impossible. Moreover, the observed jump – similar to that in Figure I.137 – would mean a front bracket and a new firm state with different growth characteristics (Table I.77).

In line with US LED and Albeo Technologies Inc. privately-held MetroSpec Technology LLC (incorporated in Minnesota) also from the LED field represents a notable case to be discussed in the context of expectations utilizing the bracket model. “The 2011 Inc. 5000 List of America’s Fastest Growing Companies” puts MetroSpec on #439 of the 2011 ranking with a “3-year growth” (2007, 2010 revenues) of 795 percent.

If one looks into the TECH{dot}MN company directory one will find [TECH{dot}MN]: “MetroSpec Technology manufactures FlexRad LED light sources exclusively *for light fixture manufacturers* for use in architectural lighting, streetlights, and signage. *The company has grown from a provider of engineering design and short-run production services to a high-volume manufacturer* of its patent-pending FlexRad LED technology.” Three patent applications of MetroSpec from 2008/2009 have been converted to granted patents in 2011/2012.

Originally, MetroSpecc engineered products from concept through to production – involving and teaming with its customers at every step of the path to provide speed and quality in product development that can go hand in hand.

From Web-based job announcement (“Diversity Minnesota”) of MetroSpec one learns that it “is the manufacturer of the “FlexRad™“ brand of *high intensity* LED light systems. These systems are used by light fixture manufacturers to convert over their present incandescent and fluorescent products into highly reliable and lower operating cost products using LEDs.”

Finally, on MetroSpec’s Web home page one can read that its focus is on *high volume production* of *LED light circuits*. Utilizing its unique, patented FlexRad LED technology and working with “*customers* daily to fulfill all *their specific LED light circuit needs*.” This allows providing superior LED light *circuits* and *services*. MetroSpec has an *out-*

standing market position by offering the only *high intensity flexible* LED light circuit which is *customizable to any shape and size*. It is not the typical low wattage flexible circuits which are limited in light output due to poor thermal performance. FlexRad is the exact opposite of these solutions; its flexible circuits are customizable to use 1W, 3W or even higher wattage LEDs. All this means the ability to perfect fit light fixtures.

Referring to the similarity with US LED as a manufacturer of LEDs and targeting also light fixture manufacturers for use in architectural lighting and signage we would expect for MetroSpec to exhibit growth in revenue in its LED segment in a comparable way as US LED (Figure I.165; g = 0.65) for the time period when it operated as a high volume LED circuit manufacturer.

However, considering the transition from an engineering firm to a manufacturer we would expect the appearance of a related bracket (Table I.76; “business model innovation”) somewhere between 2001 (year of foundation) and 2010 showing up as either a jump or a steep increase in revenue extending over ca. two years.

This indeed is the case (Figure I.167). For Metrospec Technology one can see a jump in revenue from 2007 to 2008 which means a transition from the original “engineering state” into a new “manufacturer state.” This coincides with the fact that MetroSpec reviewed its business plans in 2008 with SBDC consultants, “just as the company was migrating from a service engineering/design company to a manufacturing company.” [SBDC 2012]

The growth of the “manufacturer state” for the period <2008,2011> with g = 0.45 is distinctly smaller than anticipated (g = 0.65), but can be accepted as a crude estimate on the basis of a correctly anticipated structure of the state equation. Based on comparisons with US LED and Albeo Technologies (Figure I.165, Figure I.166), however, it could not be expected MetroSpec to exhibit no or only a small recession dip at 2009.

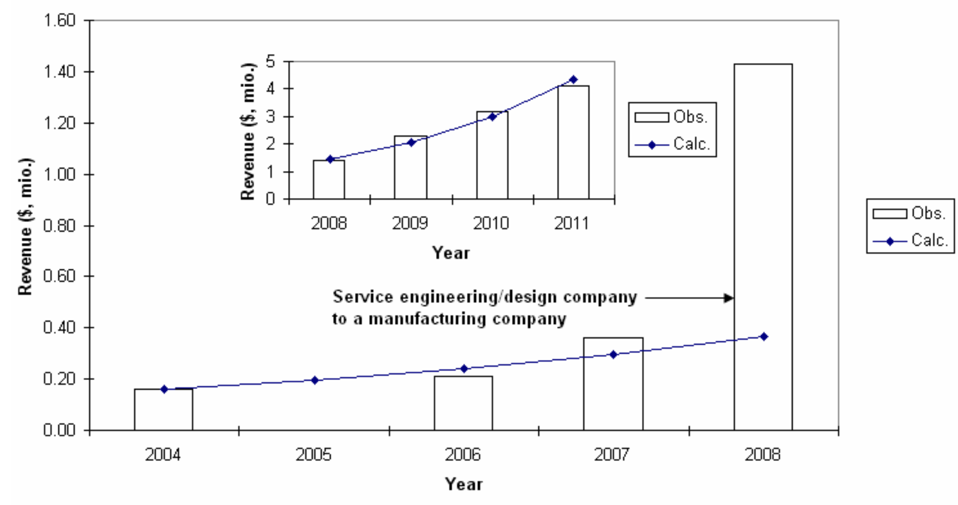
The example of Metrospec Technology re-emphasizes the need of differentiating a *firm’s states for growth periods* rather than focusing indiscriminately on “firm growth.”

Metrospec Technology shares its path of migrating from a service engineering and design company to a manufacturing company with German PURPLAN GmbH (Box I.21) and British Quiet Revolution, Ltd. (Table I.60; B.2) which started as an engineering and design studio providing low carbon solutions for the urban environment.

As a conclusion the bracket model in the context of GST contributes to understanding and explanation of technology entrepreneurship. And even its (semi)quantitative use concerning expectations provides promising facets though, admittedly, it refers to only a relatively small number of case-based examples for corroboration.

As no surprise the bracket model is plagued by the fundamental issue of soft sciences. This is the occurrence of not expected or unexpectable events (“brackets”) which impact a firm’s development and the related observable indicator, respectively, significantly in a positive (Figure I.167) or a negative way (Figure I.163). In the last case the 2008/2009 bracket ("co-founder issue") as well as the coincident Great Recession do not even show up in the revenue curve.

As vision, mission, leaders and and culture (ch. 2.1.2.7; Figure I.120) provide the framework for attitudes, motivation, behavior and achievement of a new firm employee development (Figure I.121), organizational learning, resources and resource development, organization (particularly coordination) and systems of activities form the basis for sustainable development of the new venture (ch. 5.2).



MetroSpec Technology LLC:

Founded in 2001

In 2008 the company was migrating from a service engineering and design company to a manufacturing company.

$R(t+1) = (1 + g) \cdot R(t)$; using $R(0)$ = \$0.16 mio. at 2004, $g = 0.23$ for <2004,2007>

$R(t+1) = (1 + g) \cdot R(t)$; using $R(0)$ = \$1.43 mio. at 2008, $g = 0.45$ for <2008,2011>

Revenue data were obtained from values given for 2007 and 2010 in "The 2011 Inc. 5000 List of America's Fastest Growing Companies," 2009 and 2006 data from Inc.'s 2010 list; 2006-2011 data were also obtained from PrivCo's database; 2004 data are from "Allbusiness" company profiles (no longer available on the Web).

Figure I.167: Calculated and observed revenues of US MetroSpec Technology.

5. PATHS OF TECHNOLOGY ENTREPRENEURSHIP

Paths are made by walking. Wege entstehen dadurch, dass man sie geht.
Franz Kafka

By relying on General Systems Theory (GST) for technology entrepreneurship we are ultimately led to the question of the relation of founding and developing a technology venture and Systems Design or its partial revival in terms of Systems Thinking. In the context of GST the notion "design" is a process, an action, a verb not a noun. It is a protocol for *solving problems* and revealing new opportunities.

Systems Design can be seen as a *methodology of change* which proceeds essentially from the system *outward*, understanding the system and its relation to all other systems larger than it or interfacing with it (ch. 1.2.1).

In our context of Systems Design [Van Gigch 1974:2] there is currently in the US a new wave (and probably hype) with *Design Thinking* [Dziersk 2008; Wong 2009a, 2009b] which we shall critically consider for the framework of Systems Design.

In our context, apart from chance detection or serendipity, we have differentiated recognizing, identifying and discovering opportunities and ideas as different processes (ch. 3.2; Figure I.87).

As cited by Dziersk [2008] Herbert Simon, in the "Sciences of the Artificial" (MIT Press, 1969), has defined "*design*" as the "transformation of existing conditions into preferred ones" (p. 55). Design Thinking is, then, always linked to an "improved" future. Unlike critical thinking, which is a process of analysis and is associated with the "breaking down" of ideas, Design Thinking is a creative process based around the "building up" of ideas. Herbert Simon describes Systems Design by a seven steps process: Define, Research, Ideate, Prototype, Choose, Implement and Learn.

Designed systems necessarily always include *the goal of the designer* as the main driving instance. Corresponding artifacts are built as *purposeful systems* since the specification requires the dualism of *a priori* defining the components and their interactional relationship with the "environment" before the entire system starts to work. Systems Design for entrepreneurship focuses on *establishing a relation* of value creation between a new firm and its founders or owners, respectively, and its market(s) and customers as part of an all-embedding environment. Design will depend largely on *constraints*.

For the establishment of the relation there is a corollary:

> Go fast to market to learn about the market and as Kersting [2012] put it, "you don't know the market until the market knows you."

Systems Design is a creative process which for specific situations may be subjected to formalization. It means initiate and implement change in or through man-made things or entities which includes totally new things or entities. The focus is the *problem* at hand and the manner in which *problem-solving options* are considered, *ideas* are created and refined and *selections* are executed (Figure I.80, Figure I.87).

In our context we shall not consider design generally as a *prescribed* process. It is not consistently a rational process. It *may* begin with the identification and analysis of a problem or need and proceeds through a structured sequence in which information is researched and ideas explored and evaluated until the “optimum” or satisficing solution to the problem or need is devised.

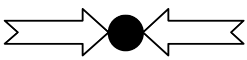
In the context of social systems and entrepreneurship Systems Design is a *future-oriented,* partly disciplined inquiry. People engage in this inquiry in order to design a system that realizes their vision of the future, their own expectations, and the expectations of achieving them.

The *future environment of the system* has to be forecasted! If the design of the system has been set and is established, “*systems improvement* “refers to the process of ensuring that a system, or systems, perform according to expectations (ch. 1.2.1, ch. 3.2.1). Systems Design firms stand apart in their intention and willingness to cross the chasm to engage in and execute *continuously re-designing their business*. They do so with an eye to creating advances in both innovation and efficiency.

> The result of Systems Design has to pass the test of personal commitment – it requires conviction.

One question to be dealt with is how Systems Design and Systems Thinking affect foundation of new technology-based firms and interconnection of today’s decisions and actions with past and future contextual factors. For the reasoning process underlying design one should be aware of whether following a line of “reasons why” versus “reasons for thinking that” (Figure I.2).

Systems Thinking will include past and future and that determines behavior in the present.

Past	**Present (“Today”)**	**Future**
Analytic (Explain)	Context	Synthetic (Build))
Experiences, Perception		Imagination, Perceptiveness
Observations, Patterns		Opportunities, Possibilities
Extrapolations, Strategy		Trends, Stories
Achievements, Certainty		Expectations, Uncertainty

Systems Design questions assumptions on which old forms have been built or common or “standardized” recommendations on which new forms (“startups) have to be built. Correspondingly, the role of a system’s *leader* is to *influence trends* rather than satisfying trends [Van Gigch 1974:9]. Intuition-oriented firms wax and wane with individual leaders.

In essence, Systems Design for value creation in terms of innovation or entrepreneurship requires bringing together two prevailing points of view on business today, analytically structured processes and intuitive originality.

Using GST means that instead of relying exclusively on analysis and deduction deeply ingrained into Western thinking we proceed also with synthesizing and being inductive (ch. APPROACH). Design Thinking means *intuitive thinking* – the art of subjectively knowing without reasoning and “*strategy logics*” (ch. 1.2.2, 2.1.2; Table I.33) being subjective logics. It relates to *perceptiveness*, a feeling of understanding.

According to mainstream approaches business organizations are dominated by *analytical thinking*. Strategy is based on rigorous, quantitative analysis. In this model analytical thinking harnesses the familiar Western forms of logic, deductive reasoning, to declare truths, facts and certainties about the (business) world. This model means mastery through formalized, continuously repeatable analytical processes. Judgment, bias and variation are the enemies. However, by sticking closely to the tried and true, organizations dominated by analytical thinking enjoy one very important advantage: they can *build size and scale*.

To summarize, neither rational reasoning nor intuition alone is enough. Using Systems Design and Design Thinking for entrepreneurship do not try to reconcile the two modes throughout the foundation of a new technology venture and its first dozen years of development. Both approaches will have different levels of significance for the various stages of firm development putting more emphasis on “designed” pre-start, foundation and early growth phases as illustrated in Figure I.1, but addressing particular sub-processes like financing in a rational and analytical manner.

As has been discussed (ch. 2.1.2.3) prevalence of one over the other mode of thought may be related to culture conditioned by higher education, in particular, for technology entrepreneurship by scientists versus engineers (Figure I.62) or scientists versus people for economics or business administration.

Engineers and application-oriented natural scientists tend to prefer rational, analytical thinking; they are “doers” (exception: software developers). They are used to plan, implement and execute “experiments” (or preparations) and measure outcomes. They are used to look for “recipes” and instructions and examples of how to do the experimental setups and what may go wrong. Hence, they appreciate “recipes” for founding and running a firm. And, therefore, writing a business plan matches often their education and culture.

The systems view provides some connections with "contingency theory" [124] which is a class of behavioral theory that claims that there is no best way to organize a corporation, to lead a company or to make decisions. Instead, the optimal course of action is contingent (dependent) upon the internal and external situation.

Key aspects close to GST are:

- Organizations are *open systems* that need careful management to satisfy and *balance internal needs and to adapt to environmental circumstances*. The design of an organization and its subsystems must "fit" with the environment.
- There is *no one best way of organizing*. The appropriate *form depends on the kind of task or environment* one is dealing with. An organizational/leadership style that is effective in some situations may not be successful in others.
- *Different types or species of organizations are needed in different types of environments*

In other words: The optimal organization/leadership style is contingent upon various internal and external constraints. And the needs of an organization are better satisfied when it is properly designed.

5.1 Firm's Foundation as Systems Design

Today perceptiveness is more important than analysis
Peter Drucker [Business Week 2005]

Who misses the first buttonhole
will not manage buttoning up.
Johann Wolfgang von Goethe

Wer das erste Knopfloch verfehlt,
kommt mit dem Zuknöpfen nicht zurande.

For technology entrepreneurship we have seen that for a significant amount of NTBF foundations started with customers and knowing or, at least, having a good estimate about the market(s) they may address. This means, the path to growth and success can rely to a large extent on planning (and having or writing business plans).

Apart from planned (goal-driven) approaches there are also *goal seeking approaches* based on a "seed of ideas," testing hypotheses and creating an options set of opportunities from open-ended business ideas, and also paths following *opportunistic adaptability* (ch. 1.2.1, 2.1.2.4).

Finally, we encountered situations where entrepreneurs created opportunities by creating new markets or even industries, in particular, in a "technology push" manner. This last aspect covers disruptive and sometimes discontinuous innovation and ultimately also intrapreneurship in existing large firms. All these situations can be assumed to take advantage from Systems Design and Design Thinking.

Opportunistic adaptability refers to a style of reasoning and behavior. It means to "adapt to unexpected circumstances in an opportunistic" fashion." It relates also to the fact that many ventures do not find success in their initial business idea. And, for instance, both the US firms YouTube and Yelp, Inc. learned a valuable lesson from

PayPal: The first idea is not always the best. YouTube started as a video dating play. After an aborted start as an email recommendation service Yelp, Inc. is a company that operates yelp.com, a social networking user review and local search Web site (A.1.7).

Furthermore, entrepreneurs with limited funds cannot afford to spend much time and efforts to prior research and planning. Sketchy planning and high uncertainty requires adapting to the many unanticipated problems and opportunities. They "cannot afford to sacrifice short-term cash for long-term profits" [Bhidé 2000:18] – and follow opportunistic adaptability.

Moreover, there is no point in engaging in elaborate strategic planning which is based solely on what the entrepreneur would wish to happen in a more or less ideal setting. It is necessary to adapt aspirations to what is achievable in terms of access to resources and to build in a capacity for opportunistic adaptability as external circumstances change. And "achievable" means the *goals and preferences* of the entrepreneur for financial (ch. Box I.20) and other resources are distinct variables before implementing and testing a strategy.

Preference for financial sources by entrepreneurs has been treated by the "Pecking Order Theory" (ch. 4.2.2). Preferences of an entrepreneur (Box I.20), for instance, rejecting venture capital, is part of the entrepreneur's disposition and thus part of the *decision environment* (Figure I.111).

Examples of the opportunistic adaptability are also observed for animals. There are birds which are always looking for new sources of food. They observe other birds eating and try it for themselves. The coyote's opportunistic adaptability emerges if one examines the coyote's feeding habits. Coyotes in the US, or foxes in Europe which are settling in large cities, will eat almost anything they can chew – demonstrating the enormous flexibility and opportunistic adaptability of biological systems.

For entrepreneurship and innovation aspects of Systems Design (ch. 1.2.1) for open (human-activity) systems key concepts or drivers, respectively, were distributed across the previous text in various contexts. These and some further concepts for firm's foundation shall be summarized and specified.

The System

The issue of systems and, hence, entrepreneurship, will be in how far to "compose" or "organize" the "entrepreneur system" into larger systems (Figure I.13, Figure I.16).

For composing a firm as a system one needs (ch. 1.2.1)

> to recognize or identify, respectively, "what is connected with what," "with what intensity/strength," and "what follows after what ("order," "function")?"

The system's (new firm's) environment fundamentally also includes the position of a new firm in a value system (Figure I.7), if it already exists.

For Systems Design the *The Environment-Modification Principle of General Systems Theory* states (ch. 1.2.1 – for instance, for technology push approaches): To survive, systems have to choose between two main strategies. One is to *adapt to the environment*, the other is to *change it*. And dealing with the future is in line with the old saying of Samuel Johnson (1709-1784), Peter Drucker (1909-2005) and Dennis Gabor (1900-1979) (the mottos of ch. 1.2).

Transferring these chapter mottos into a Systems Design paradigm for entrepreneurship and managing research and innovation they should read:

- Assess the businesses and current competencies;
- Find out how business and technology has changed recently and find the key factors for these changes;
- Get a sense and good feeling how things could change in the future;
- Develop a system that meets current needs and opportunities, identifies and responds to threats and positions the company for the future and supports future decision-making.

For composing systems and their stability note *The Variety-Adaptability Principle* (ch. 1.2.1): S*ystemic variety enhances stability by increasing adaptability***.** Variability refers also to paths to goal achievement for NTBFs and opportunistic adaptability versus goal persistence (Figure I.122).

In technology-based businesses dealing with the future means an emphasis on technology and commercial intelligence, which is "foreknowledge." A detailed overview on "intelligence" and intelligence systems is given by Runge [2006:520-531; 978-835; 934-970]. The systems approach is invariably bound to the foreknowledge part of intelligence (ch. 1.2.3; Box I.17), which has to position "technology forecasting," foresight, prognosis, technology trends, scenarios (Box I.19) etc. into appropriate contexts.

Accordingly, what distinguishes leaders from followers and laggards is the ability to have a unique imagination of what could be. Leadership is not to benchmark the competition and imitate its methods and offerings, but to develop an independent point of view about tomorrow's opportunities and devise a strategic architecture with which to implement and exploit them.

> In our world with an always increasing complexity and pace of change imagination and perceptiveness – a feeling of understanding and the "known unknowns" – become key for Systems Design.

Technology entrepreneurship occurs often in cross-industries environments with people from various scientific or engineering disciplines. In this book, in particular, the role of chemistry and material science and the chemical industry for co-evolutions with other industries were emphasized.

Systems Design suggests to put teams in situations where they are forced to synthesize meaningful opportunities out of incomplete and highly subjective information about the world (environment) and the future needs of end-users. Multi-disciplinary teams or persons interwoven in a multi-disciplinary environment are particularly appropriate to reveal opportunities across technologies or industries. Of special importance are *boundary spanners,* also called *gatekeepers* (ch. 1.2.3; Figure I.20).

The means, for firm founders having or hiring so-called *T-shaped individuals* may pay off. These tend to be professional in one area, but are skilled in many other areas. They are highly intuitive. The advantages of *"diverse experiences" for problem-solving* (ch. 3.2, Figure I.86) result from "mental restructurings," as the problem is only solved after someone asks a completely new kind of question.

According to GST decision-making (ch. 4.2.2) will occur in a *decision environment* (Figure I.111).

Business Ideas

As characterized previously (ch. 3.1) for entrepreneurship a "**business idea**" is actionable and associated with the following *processual* features

- A business idea acts as the basis for detailed considerations and targeted inquiries concerning a related commercial *opportunity* and a decision of firm's foundation and is associated with *expectation*.
- A business idea is associated with *implementation* – *execution*. For a startup the assessment of the significance or *value* of the idea is coupled to execution – with a disproportionate ratio which puts high weight on execution.
- Execution for the realm of technology entrepreneurship is coupled with 1) associated *contextual* insight in and options for *applications* in "real life" and 2) characteristics of the commercial *opportunity*.

Implementation and execution of a business idea means *testing a hypothesis*. It is in the same category as "strategy" as viewed generically in this book (ch. 1.2.1) and also the business model as a hypothesis to be tested (ch. 1.1.1.1). The "thrust approach" of exploratory research and technology explorations in the laboratory of large firms [Runge 2006:608, 726-727] are also testing hypotheses (thrust: research directions essentially given, more specifications needed).

Firms' foundation processes of technology ventures were specifically outlined for "bootstrapping startups" (ch. 4.3.3.1). Though accounting for only a small proportion of NTBFs (around 5 percent) VC-based NTBFs are at the center of MBA-style approaches in standard (text)books of technology entrepreneurship. Foundation processes and early phases of *VC-based NTBFs* can be seen as intermediate between bootstrapping and innovation and intrapreneurship in large firms (ch. 4.3.5, Figure I.134).

As described by Dorf and Byers [2007] foundation of a VC-based NTBF focuses on a business plan, its financial plan emphasizing financing by venture capitalists and the firm's IPO [Dorf and Byers 2007:379-399, 414-419, 428-436]. After "presenting the plan and negotiating the deal" details of executing the business plan are given [Dorf and Byers 2007:456-465].

If strictly applicable, firm's foundation and the early phase of a new firm based on principles of Systems Design can be boiled down to a six steps process (modifying the suggestion of Herbert Simon and Dziersk [2008]): Define the Problem; Create and Consider an Options Set, Refine and Test Selected Directions; Choose, Implement and Execute; Learn. And firm's foundation will have to ask: What are the critical success factors (CSFs) for a related "problem-solving project"?

Define the Problem

In our context an idea can be an expression of a hypothesis for solving a problem (Figure I.80, Figure I.87) and a problem is associated with an explicit or implicit need. Problems can be framed by questions, such as

- Whose problems shall be solved?
- Are there generics in the problem to be solved?
- Is the offering a complete solution for the customer or only part of the solution?
- What is the level of urgency to solve the problem?
- Can the addressees, the customers, state the problem explicitly without bias (specifications, latent needs)?

Talking to your end-users will bring fruitful ideas for later design as a response to a problem. Observation can discern what people really do as opposed to what you are told that they do. Getting into the field and involving oneself in the process and offering is fundamental. Cross-functional insight into each problem by varied perspectives as well as constant and relentless questioning – target the right problem to solve, and then to frame the problem – is a way that invites creative solutions.

Asking the right questions is fundamental to understand and solve a problem. Problem-solving by reference to existing information and knowledge has to

- review the history of the issue; revealing or remembering any existing obstacles and
- collecting examples of attempts to solve the same issue (Figure I.80).

Related issues of information overload for problem-solving and asking the right questions are described by Runge [2006:520].

Accessing information and the number of information resources has increased dramatically, and the information changes more rapidly than our ability to acquire or master it. And accordingly it is said that "The educated person used to be the one who could find information. Now, with a flood of data available, the educated mind is not the one that can master the facts, but the one able to ask the '*winnowing question*'." (Emphasis added).

Concerning the efforts that have to be put into *searching for the right questions* one can refer to Einstein: "Einstein once remarked that if he were to be killed and had only one hour to figure out how to save his life, he would devote the first 55 minutes of that hour to searching for the right question. Once he had that question … finding the answer would take only five minutes."

Problem solving and generating related (business) ideas is also seen as an issue of *creativity* (Table I.9; ch. 2.1.2.2) which can be related essentially to recognize and interrelate that which is not obvious – whether it is chunks of data and information, patterns of entities, similarities, associations, metaphors etc., such as mavericity (ch. 2.1.2.2).

Cognition will be used to deal with revealing solutions of problems and opportunities as will rational processes. We tend to order our experience and perception in a manner that is regular, orderly, symmetric and simple within borders. Boundaries differentiate essentially thinking and perception in Western from Eastern cultures.

Concerning Western reductionism as a basis for recognition and reasoning Aristotle wrote about Pythagoreans that for them *emptiness* serves to divide things and define their boundaries. Crossing the borders of a (real or conceptual) system for problem-solving represents a fundamental barrier for cognition.

The nine dot puzzle of Figure I.81 introduced as stepping out of perceived boundaries of a system defined by the nine dots can be more generally interpreted comparing Western and Eastern thinking concerning *emptiness* (or "void") serving to divide entities and define their *boundaries*.

Referring to Innocentive (ch. 3.2; Figure I.86) and the posted problems people created a solution for it was found that often "problem solvers" were most effective at the margins of their own fields of expertise ("outsider thinking"), not inside their field of expertise and thus avoiding to run into the same stumbling blocks that held back their more expert peers by their "*cognitive frameworks*" (ch. 3.2). Furthermore, there is a trap of solving a problem the same way every time. Especially when successful results are produced and time is short.

Many times we are not aware of the filters we may be burdened with when we create answers to problems. In this stage opportunities may appear. The trick is to recognize them as opportunities. Multiple perspectives ("diverse experiences") and teamwork are crucial to overcome the barriers.

Create and Consider an Options Set

When we have needs to satisfy or a problem to solve decision-making is required (ch. 4.2.2). Systems or Design Thinking requires that no matter how obvious the solution may seem, many solutions be created for consideration. Generate as many ideas as possible to serve identified needs. Ideation may be used to create an options set for problem-solving or opportunities (Figure I.80; Box I.13) as well as researching ("exploration") in the laboratory or experimenting in a workshop. A model for the *search process* by which the mind generates alternatives is given in Figure I.113.

Seeking opportunities for Systems Design may rely on "technology intelligence" and "commercial intelligence" to generate *a "choice set"* of alternative market opportunities, an "*opportunity landscape*." Assessing the choice set to reveal the most promising ones may induce consideration of *opportunity cost* (ch. 1.2.5.2).

For the "choice set"

- Reserve judgment (ch. 4.2.2; Box I.17) and maintain neutrality.
- Seek feedback from a diverse group of people; include your *end-users* (customers).

Refine and Test Selected Directions

A handful of promising results need to be embraced and nurtured for hatching protected from the idea-killers (Table I.46) of previous experience and cognitive frameworks. On the other hand, decision-making is often constrained because the *time and effort* to gain information or identify alternatives are limited. The *time constraint* simply means that a decision must be made by a certain time ("*urgency of decision*") utilizing accessible resources (ch. 4.2.2).

Design Thinking requires allowing the potential of business ideas to be realized by creating an environment conducive to growth and experimentation, and the making of mistakes in order to achieve out of the ordinary results. This means not only refining and expanding ideas but also combining promising ideas.

In terms of Systems Thinking evaluation of outcomes means:

- The envisioned outcomes of a decision are evaluated for fit with the objectives, but also more possible positive and negative consequences (Figure I.111).
- The decisive actions are taken, and additional actions may be taken to prevent any adverse consequences from becoming problems and starting both problem analysis and decision-making all over again.

"Prototypes of solutions" representing hypotheses shall be tested to find the "best" path to problem-solving – similar to the "thrust" approach to exploratory research (ch. 2.2).

> Test hypotheses! – “If they are confirmed, you have learned something; if they have failed, you also have learned something.” [Kersting 2012]

The importance of testing ideas on customers using rough-and-ready prototypes has been emphasized also based on the following argument: Customers “will be more willing to give honest opinions on something that is clearly an early-stage mock-up than on something that looks like the finished product.” [The Economist 2011]

Furthermore, R. Hoffman, the co-founder of LinkedIn (B.2), pointed out that entrepreneurs should take “intelligent risks” comprising how he or she sees something others do not and emphasized the importance of holding and testing contrarian views.

Choose, Implement and Execute

After enough paths have been traveled to expect success (Figure I.122) it is the time to decide which one to follow, implement the design and finally commit resources to achieve the early objectives. The by-product of the process is often other unique ideas and strategies that are tangential to the initial objective. Key activities have to be balanced for a fledgling NTBF (Figure I.131).

- Plan processes, tasks and roles; make task descriptions; determine necessary resources (cf. overt strategy logics, Table I.33)
- Assign tasks/roles.

Feasibility and workability of designs is an important distinguishing feature of a business design. Designers repeatedly ask, “Does it work?” and “Does it work better than what we have now?” According to Figure I.87 feasibility interconnects the revealed opportunity options set and opportunity evaluation and the related offering option(s). Feasibility does not only refer to have or to access, respectively, resources, but should also include first contacts with (potential) customers testing the offering(s) as outlined for creating and considering the options set.

Feasibility relates the designed firm to the addressees of its offerings for problem-solving. Operational feasibility is a measure, an expectation, of how well a proposed system solves the problems, and takes advantage of the opportunities identified during scope definition and how it satisfies the requirements identified in the requirements analysis phase of system development. [122]

> As a final assessment let outsiders know why this will work and be able to support what you believe in!

“Implementation is the utilization or adoption of change,” the actions of accomplishing some goal or executing some order where “utilizing” will refer to find a practical or effective use for something, especially to find a profitable or practical use for (ch. 1.2.1).

The success of implementation have been found to depend on the extent to which goals are “operational,” that is (cf. Figure I.10), when a means of testing actions is perceived to relate a particular goal or criterion with possible courses of action. For implementation of change to occur it has to be timely ("Window of Opportunity"; Figure I.4, Figure I.92). Execution comprises

- Determine if the solution of the problem met its goals.
- Gather feedback from the customers.
- Discuss what could be improved.
- Measure goal achievement by collecting relevant data. (Kersting [2012]: "Know your numbers"; ch. 4.3.3.1).

Failures and Learning

As we have seen (false starts of 3M or NanoScape AG; ch. 4.3.2) failure to meet initial goals is a poor indicator of success to come. "Success and failure are not polar opposites: you often need to endure the second to enjoy the first. Failure can indeed be a better teacher than success. It can also be a sign of creativity." "One must do is distinguish between productive and unproductive failures." [The Economist 2011]

On the other hand, poor preparation of firm's foundation (including poor design, implementation and execution) leading to the startup's disaster is definitely an unproductive failure if insights of the founder(s) were lacking that it would be better not to start, that their proper self-assessment would reveal that they do not have what is needed to get the job done or that founders are not in the position to convert their business idea into a functional company design.

Additionally, a further challenge is notable, *getting a good handle on the competitive environment that the business will face*. Many startups make the major mistake of dismissing the competition.

When to stop or terminate a venture may also be important as knowing when to start. The particular aspect of **sunk cost** [123] may enter decision-making. Sunk cost is cost that has already been incurred and thus cannot be recovered. Sunk costs are independent of any event that may occur in the future and cannot be affected by any present or future decision. Sunk costs greatly affect actors' decisions, because many humans are loss-averse and thus normally act irrationally when making economic decisions.

When making business or investment decisions, organizations typically look at the future costs that they may incur, by following a certain strategy (logics) and plan. For instance, investment in a plant for manufacturing a particular material by a process which is entirely dependent on just one particular intermediate (irreversibly committing resources) may become sunk cost if, for instance, a legal regulation prohibits the use of that intermediate. It represents a total loss of the original expenditure. Similarly sunk cost may emerge if a firm exits a particular business (ch. 1.2.5.3).

Generally a more tolerant attitude to failure can help entrepreneurs and companies to avoid destruction. Here national cultural difference are important (ch. 2.1.2.3). Among the countries by many metrics the US actually has a bad education system. Why is it that the US has a superb entrepreneurship and innovation track record?

It is because, the author believes, culturally: The US has a lot of people who have no fear of failure and failure is not "punished" by society. The advantage of the US culture is that people will rebound from failure. And as from a nation's or a firm's point of view entrepreneurship and innovation is a numbers game (ch. 4.1, last paragraph) this bodes well for the US with overall very many firms' foundations (and very many failures).

Concerning failure there is the old saying "Fail early, fail often" [Kersting 2012], but there is no point in failing fast if you fail to learn from your mistakes [The Economist 2011] – "fail early, fail often – and learn." "Failing fast" is also a principle of innovation projects of large firms – to minimize innovation cost [Runge 2006:787].

> Though "failure is the opportunity to begin again, more intelligently" (Henry Ford) it is better to do it right from the start of the firm (ch. 4.3.2).

Learning: occurs on the individual or the group level (ch. 1.2.1; Table I.7). In the context of Systems Design *organizational learning*, which is a systems characteristic, must be emphasized. Conditions under which organizational learning occurs, its five disciplines and learning for the future, are relevant (ch. 1.2.3). As a venture evolves the entrepreneurs will transform resources, largely through organizational learning, into valuable and ideally unique organizational resources.

Learning business activities and processes during firm evolvement occurs on the individual and the organizational level. For instance, J. Koenen, a co-founder of German WITec GmbH (Table I.41) learned management and administration on the job and on demand (ch. 2.1.2.4) and N. Fertig and the team of Nanion Technologies GmbH learned professional project management for developing a new very complex product for growth after having launched already successfully products.

Hence, one can differentiate resources and *skills* which are related to learning. An entrepreneur who wants to be successful must learn to develop his or her skill set. Once learned, the skill set is something the entrepreneur can use routinely.

5.2 The Startups' Evolvements for Growth

The next question concerning the role of Systems Design after firm's foundation concerns to look into the process of firm's growth in more detail (Figure I.130).

So far some systemic processes associated with foundation and growth (or decline) were described. These include, for instance, the phased formation of the founder team by self-reinforcement (Figure I.68, Figure I.70) or decline and "death" of startups by reinforcing sub-processes leading to a non-viable financial state (Figure I.114) or setting up corporate culture by the founder or founder team, respectively, by the founder's leadership by self-replication and leading by example (Figure I.120). The leadership team and corporate culture represent two important resources for a firm's development.

For explaining or understanding, respectively, evolvement for growth of a micro NTBF (1-9 employees) to a small (10-49 employees) and then to a mid-sized company (50-249 employees; Table I.4) one can assume that the starting resource endowments are qualitatively not so different for "similar" ventures, but the *resource development* pathway (Figure I.130, Figure I.131) will be affected to a considerable extent by systemic principles embedded in the concept of the "initial configuration" of the NTBF (ch. 4.3.2; ch. 4.3.3). The initial configuration provides a way to differentiate evolvement in terms of relevant variables and parameters.

In the framework of the bracket model (ch. 4.3.5) venture development is described as a sequence of a firm's dynamically stable states, interrupted by transition states induced by internal or external events (Table I.76), such as setbacks, challenges or particular management tasks, which may lead to new growth states. The bracket model implicitly emphasizes *adaptability* of an NTBF/SME and related responsiveness to any effect that influences its competitive position as an important systemic resource.

Resources (and input) are fundamental for the *conversion processes* **("**throughput") of the firm by which elements in the system change state ("systems dynamics", Figure I.5). This brings in the resource-based view (RBV) of venture growth (ch. 4.3.3) for the early stage of startups.

> The essence of the resource-based perspective is a *knowledge-based view* and in the context of GST this will include foreknowledge which overall means *intelligence* perspectives (ch. 1.2.3) which are important for adaptability.

While it is important to know the industry sector of a business to assess which type of market (Table I.15) and growth factors come into play even within sectors there will be differences in the type (Table I.12) and stage of technology and processes used. For instance, in biotechnology and the related biofuels sector (A.1.1), at the greatest level of industry and market sector detail, there remains a great deal of heterogeneity.

The timing for entrepreneurs to enter a particular life-cycle stage of the industry (ch. 1.2.4; Figure I.32) has revealed the significance of the markets' birth and emergence phases for SAP (Figure I.143), Microsoft (Figure I.144), Cisco (Figure I.145) and Google (Figure I.159).

The entrepreneur is the primary resource, and his or her expectations about the future of the venture are central to its strategic direction. Each entrepreneur begins with a personal resource endowment at the start of the resource building process. The first resources (for instance, education, experience, credibility and reputation, network contacts, knowledge of the industry etc.) exist in the entrepreneur rather than the new venture.

According to Bhidé [2000:47] the founders' capacity to differentiate their offerings through their personal efforts seem to be an important reason for profitability (cf. CEOs' knowledge of customers with Hidden Champions; ch. 4.1.1). The entrepreneur, rather than a product or technology, represents the source of the startup's profits – and the firm's productivity and performance (ch. 4.3.3).

However, there are a number of technology startups, RBSUs, whose foundation is induced because the to-be founders can start already with a product and customers (to name some: ChemCon GmbH, WITec GmbH, Nanion Technologies GmbH, Cambridge Nanotech, Inc., all in B.2; IoLiTec GmbH (A.1.5) and PURPLAN GmbH – Box I.21).

Founding a firm means a decision which is often made after consulting with other people and taking also *advice* from others into account. In particular, firm's foundation of new technology ventures is often associated with the establishment of an *Advisory Board*. The Advisory Board does not only provide advice and consulting to the leadership team of the new firm, but, depending on "names," may add reputation and credibility for the leadership team which may affect funding and hiring talented people.

The Advisory Board or other stakeholders of the new firm and their advices are part of the decision-environment of the firms' founders and in this way represent also a systemic aspect (Figure I.111; ch. 1.2.6.2, ch. 2.1.2.4).

Many technology entrepreneurs begin with a rather complex and often instrumental human and social capital that they have developed in another professional enterprise or work setting. They achieved industrial experience or management experience in large firms or gained experience of funding by public sources in public research institutions or acted as a serial entrepreneur (Figure I.64). They leverage these resources to acquire financial and physical resources, and to hire and develop qualified individual personnel.

Notably, serial entrepreneurs use often a totally different resource base when they start another firm (for instance, Klaas Kersing with Gameforge – B.2; Lars Hinrichs with Xing – B.2; Reid Hoffman with LinkedIn (B.2)) and can additionally utilize extended networked resources (cf. the PayPal Mafia – A.1.7).

> Ventures that are unable to transition from reliance on the individual resources of the founder(s) and extend those to organizational resources will be constrained in growth. To make the transition happen a strategic resource development plan may involve creating systems and routines, defining policies by which people work, and creating incentive systems for employees [Brush et al. 2001].

The process of building an initial resource base from scratch and transforming it for growth is a complex task – and even more for technology entrepreneurship. And its description is too – due to the broad variety of existing resources and usable resources by the startups – depending on their proper classification according to many dimensions (Table I.74, Figure I.128) and the potential to combine these dimensions in a meaningful way.

There are fundamental types of technology startups referring to taxonomies of financial structures of technical startups' initial architectures in terms of ownership and control by founders versus VC-based firms (Table I.74), RBSUs and Other (academic) NTBFs with/without large-scale production, the industry the startup is operating in (Figure I.128), networking (Figure I.51, Figure I.127), and organic versus non-organic growth (Figure I.127).

Describing entrepreneurial efforts striving for growth as a teleological relation ("startup → mid-sized firm"; Figure I.78) allows to describe and discuss a development path from a given NTBF configuration to a configuration of successful mid-sized firms, such as Hidden Champions (ch. 4.1.1) or by mapping an NTBF's growth of a given configuration to a known, successful NTBF with a compatible configuration and its growth path in terms of the *ex comparatione* approach (ch. 4.3.6; Table I.80, Figure I.164).

A more prescriptive approach would look for an NTBF to fit or implementing CSFs of mid-sized firms (ch. 4.3.6; Table I.78). This would be a quasi *top down* approach for a startup to SME path by a perspective from the end result.

Such an approach is oriented toward *growth factors* which may be interdependent as is done by Bordt et al. [2004] who looked into characteristics of technology ventures, mainly from biotechnology as well as electronics, information and communication, that grow from small to medium size. Growth factors may correspond to resources, such as IPR, but also processes, such as R&D and combined "innovation and investment persistence" and managing finances.

RBV sees *companies as different collections of tangible and intangible assets and capabilities*, which determine how effectively and how efficiently a company performs its functional activities. To apply RBV it is essential to *identify the firm's potential "key" resources*. However, the processes of *combining, organizing and leveraging resources let "new systemic resources" emerge.*

> According to GST resources are dependent on interactions and combinations with other resources and therefore no single resource or a set of individual resources can become the most important one for a firm's performance (ch. 4.3.3).

Moreover, s*ystemic effects* in small or large firms do not only emphasize interactions of resources, but also feedback and reinforcement mechanisms, *largely out of the control of leaders/managers, which will affect the firms' development/growth* (ch. 4.3.3).

For NTBFs one typically encounters multi-dimensionality of resources. Concerning systemic effects this can be lucidly seen, for instance, considering the roles of angel investors or corporate venturing companies (CVC) which can be treated primarily as financial resources. However, angel investors may act additionally as a member of the leadership team or an adviser of founders for various aspects of the business. In these role angels may act *reflexivety* affecting the financial situation of the firm, adding not only money to the company, but increasing the monetary return ("smart money") of the firm (ch. 1.2.7.2) and of themselves.

Corporate venturing (ch. 1.2.7.2) may result in leveraged startup resources in the sense of a "networked economy" (Figure I.125) inducing a three-way interaction between the NTBF, the investing large firm which is supporting financially or cooperatively and public research institutes (Figure I.51). With regard to financial resources the large firm may not only provide a particular investment sum, but additionally increase the NTBF's credibility and become a lead investor inducing more investments.

Furthermore, the NTBF may have access to other, non-monetary resources of the large firm, such as access to analytical or information services and advice, thus saving expenses compared with getting these otherwise. And, finally, there are often established joint research or development alliances (JRAs, JDAs), production alliances or contract production, sales and marketing agreements or the large firm acts as a customer for the NTBF.

Qualitatively, NTBF growth depends on financial resources (Table I.30). In the context of organic growth generating profit and cash may initiate a *self-reinforcing cycle* of innovation and investment (*innovation and investment persistence*; Figure I.127).

According to RBV entrepreneurs in emerging organizations must first assemble and acquire or access resources to meet a perceived opportunity, then combine them to build a resource platform that will yield *distinctive capabilities* before they are allocated to fit an offering and market strategy. But this does not cover the non-negligible set of NTBFs whose foundation is initiated by customers as described above providing cash to the to-be entrepreneurs.

Furthermore, RBV suggests that, related to NTBF growth, building an initial resource base in a new venture and then further develop the resource base may not only lead to growth but also achieve *sustainable competitive advantage* – a quasi *bottom up* view concerning the path "from startup to SME."

Strategies for attaining competitive advantages emphasize developing and configuring existing resource strengths into a valuable and *unique* resource base. Such a process requires for technology-based startups three fundamental differentiations:

- Tangible and intangible resources (Table I.8) and
- Internal and external resources in the sense of a "networked economy" (Figure I.51).

The third important differentiator for applying RBV to NTBF growth concerns ownership and control of the startup (Table I.74) where in VC-based startups venture capitalists may decide on types of resources to be used and the way to develop a resource base rather than the founder(s) who may have different ideas how to initiate and keep venture growth. Venture capitalists may also establish a leadership or management team whose strategies are not in line with those of the founders.

Following Brush et al. [2001] we differentiate resources by their application to the productive process as

- *Utilitarian* resources that are applied directly to the productive process or combined to develop other resources and
- *Instrumental* resources that are used specifically to provide access to other resources.

Financial resources are considered instrumental because they can be used to obtain other resources, such as people or equipment (or needed technology licenses).

Proprietary technology may be either utilitarian or instrumental depending on whether it resides in an individual (intangible; tacit technology - Table I.12) where it might be instrumental, or whether it is, for instance, a patented process applied directly to the production process of the firm – or sold on the basis of Intellectual Property Right (IPR) in terms of licenses.

Applying RBV to growth of a startup means also considering instrumental resources over a period of time. If, for instance, financial resources relate to public funding, such as research or development projects which are funded by government or research associations for some few (two to four) years, the time restriction may not only affect the financial situation, but at the end of the funding period may mean laying off important personnel. And there are more constraints (ch. 4.3.3).

Generally, each resource type will have different dimensions along a scale of complexity ranging from the simple and discrete to the complex and systemic. Furthermore, we regard resources that can be acquired by learning as simple, such as learning behavior as well as processes (like financial management and controlling) by outside education and training courses as well as inside employee development (Figure I.121) or learning by imitation focusing on "best practice" or learning by example, doing or mistakes (trial and error) (Table I.7).

The set of resource dimensions, simple to complex and utilitarian to instrumental, provides a basis for mapping possible combinations and applications of resources at the launch of a new venture in a quadrant and additionally specifying the resource type as tangible versus intangible and firm-internal versus external (Figure I.168).

One of the qualitative differences between small and medium-sized firms is the degree of functionalization, specialization, formalization of their organization and planning. The medium-sized firm will exhibit management specialization (development, marketing, human resources, administration, etc.) as well as more formal business planning (Figure I.72, Table I.69) with an emphasis on coordination and communication in the organization, and complementing leadership by various levels of management (Figure I.118) upon growth. Issues of coordination as a resource in growing ventures were emphasized by the "10 - 25 - 150" rule of thumb (ch. 4.3.1; Table I.72).

A challenge for a successful entrepreneur(s) will be to transfer the personal resource base into organizational resources to grow the enterprise. Correspondingly, resource development of startups entails building and transferring knowledge by creating a shared understanding among employees of the venture's direction and focus (vision, mission,goals). The entrepreneur may need to engage in intense and frequent communication to develop this shared understanding.

But a necessary condition to transfer the resource base into organizational resources is to obtain buy-in from employees, associates, management, suppliers and customers. Knowledge and reputation are not sufficient to gain organizational buy-in.

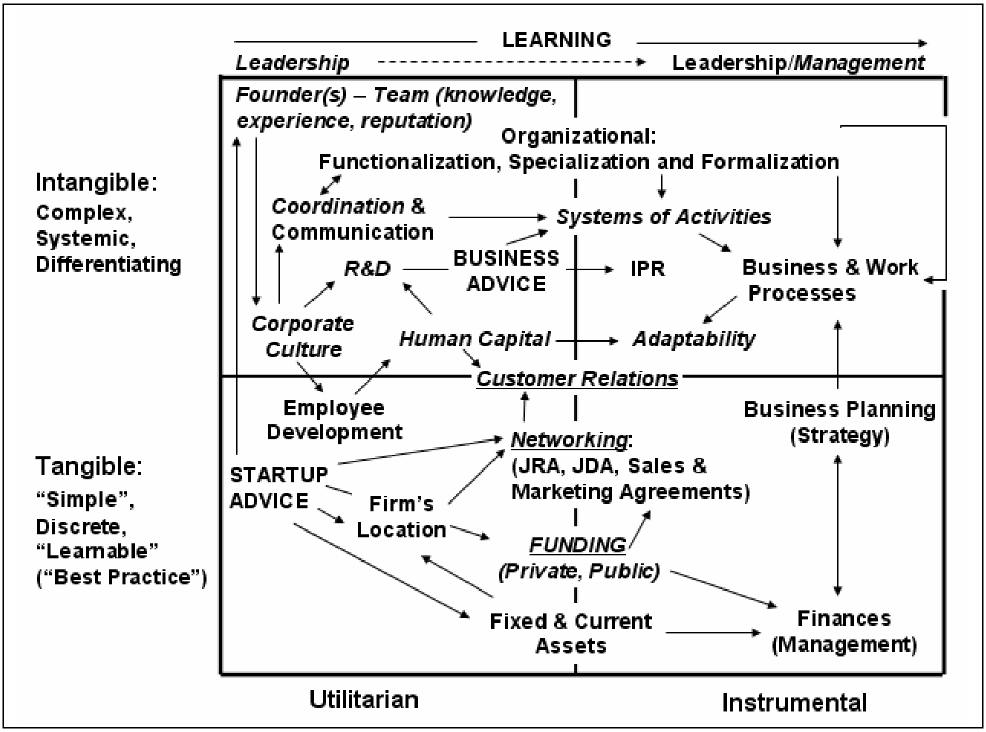


Figure I.168: Types of resources to be acquired or developed with selected interrelations to have an NTBF grow (underline – external; italics – systemic; capital – internal or external – except R&D and IPR).

Understanding the resource development pathway in terms of initial inputs (types of resources) and early uses (application of resources) is central to efficient, effective, and timely management of the resource building process as well as development of a competitive advantage.

In both exercises, one can sort resources into several differrent bins: *human* (individual traits and skills, knowledge and experience), *social* (team work, external relationships, networks, communication), *financial* (personal wealth, access to funds), *physical, technological, and organizational* (internal structures, processes, coordination and relationships).

It should be re-emphasized that we regard *coordination capability* as a key resource for NTBF development and view the competency for coordination as a "critical meta-asset of long-lived companies" (ch. 1.2.1).

In Figure I.168 resources assumed to be relevant for technology venture growth are displayed. But specification of the enterprise's needs will include not only estimates of types of resources needed, but also of quantity, quality, timing, and sequence of delivery. This enables the entrepreneur to stage resource acquisition and development.

While consulting and advice to found and grow a firm can be purchased from external services or received from friends, families or other persons of the social environment of the founder(s), the Advisory Board of a new NTBF is viewed as an entity with systemic features. Networking and customer and supplier relations viewed as "*organizational capital*" (Table I.8) also have systemic characteristics.

For working with a set of tangible and intangible resources (assets) two different directions seem to be advisable which have to be related to *execution*.

- "Tangible assets" are *managed efficiently according to "best practice*"!
- Working with "intangible assets," the founder's personality and the firm's employees (the human resource), firm culture, relations with customer or suppliers, networking etc., can create *a fundamental differentiator for sustainable competitive advantage and growth*. They can be transformed into *core competencies*.

Human capital (Table I.8) is likely to be particularly important in the context of technology entrepreneurship. A significant percentage of the value of technology-based new ventures is likely to be determined by the quality of the company's employees, especially the top management team (TMT) [Shrader and Siegel 2007].

When we ask whether one can *identify prototypical paths for developing a resource base of NTBFs* referring essentially to those resources given in Figure I.168 we shall look at a resource development pathway that allows the entrepreneur to *begin with starting (initial) endowments* and connect the specification or identification steps to acquisition of resources or to having access to specific ones.

The entrepreneur must consider how one type of resource can be leveraged to acquire another one (as exemplified in Figure I.125). Such an assessment allows for acquisition strategies specific to the situation at hand to be developed. As the period of building a resource base the emphasis will be on the NTBF's first five to six years of existence, which cover more than the startup thrust phase (ch. 4.3.2, Figure I.125).

In the context of GST, to account for interrelations of resources, we propose a process of resource acquisition and development to be represented as a layered rather than a simply staged process. The development process of the resource base will be visualized by *layered phases* and "cyclic arrows" indicating interdependencies and feedback between resources of the layers as is also used for displaying a firm and its supersystems by shells of relevant interacting systems (Figure I.13).

Figure I.169 provides a first example of privately held NTBFs of the TVT industry (all using nanotechnology) with an almost compatible taxonomy (Figure I.128) producing scientific instruments or devices for (first) academic and (then) industrial research customers – WITec GmbH, Cambridge Nanotech, Inc. (Table I.80, Figure I.163, B.2) and Nanion Technology GmbH (B.2) as well as Attocube AG (Figure I.164, B.2).

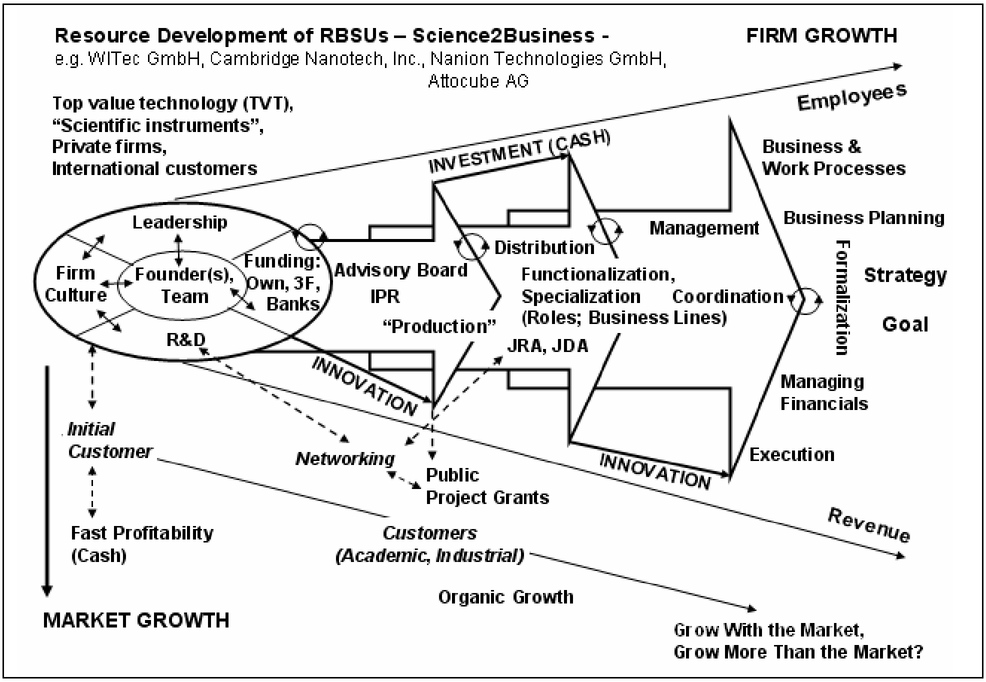


Figure I.169: Building a resource base of structurally compatible RBSUs in the field of nanotechnology-related scientific instruments or devices.

Nanion used capital from public investment firms, partially with a silent partnership, and Attocube an angel investor with no interferences in the firms' leadership in addition to 3F and bank loans as sources of financing. Firms' foundation occurred as university spin-outs (a science2business process) based on research of the founders.

Specialization in terms of business lines here means essentially types of instruments or devices and their related applications in the markets.

Firm development followed essentially a *bootstrapping* process (ch. 4.3.3) for an RBSU and all the above firms as well as IoLiTec (Figure I.170) generated a business plan. All these RBSUs were *located* close to their parent universities and *started with customers* (Figure I.124) and achieved profitability fast. This means, also cash was generated as a resource and innovation and investment persistence characterize the firms' *organic growth* process. For instance, WITec was always profitable (from year 1 on) and Nanion founded in 2002 became profitable in 2004. Having already customers (*market pull*) facilitated considerably access to bank loans for these RBSUs to complement own funds.

Further monetary resources, mainly for R&D, were pursued catching project grants of related ministries of government or public non-governmental organizations (NGOs) and capital-equivalent support by using university infrastructure free-of-charge. Sometimes grants were for cooperative projects.

The *initial endowments* are essentially associated with the founder team in terms of R&D and technology knowledge and financing contributions and its leadership capability to establish the firm culture. For Cambridge Nanotech there were serious frictions in the entrepreneurial pair with one of the founders eventually left the firm (Table I.80, [Yang and Kiron 2010]).

It is to be noted that *industry growth* has been found to have a positive effect on both profitability and sales growth of new technology ventures [Shrader and Siegel 2007].

For building a resource base by a different approach we shall consider an academic NTBF, the German IoLiTec (Ionic Liquids Technologies) GmbH founded in 2002/2003 (Figure I.170), which followed also a science2business path, but is not a typical university spin-out. Only one of the three founders came directly from a university.

IoLiTec entered and survived the entry into the new technology area of ionic liquids for which commercial interest emerged around 2000 though the technology has been known for decades (A.1.5). This case may also shed some light on the reasons why two other startups in ionic liquids, one from Germany and one from the UK, did not survive: One (Solvent Innovation GmbH) was purchased by a large firm and the other went bankrupt (Bioniqs Ltd.).

Ionic liquids represent a platform and enabling technology. The basic approach for entrepreneurship in the new class of materials is looking for their applications and related potential markets. Correspondingly, there was much need of educating (potential) customers or even generating new markets. For instance, IoLiTec promoted the new technology and its applications since 2005 by a free-of-charge newsletter "Ionic Liquids Today" (news and need-to-know facts) with currently globally ca. 6,500 subscribers.

Hence, for its development IoLiTec is essentially on a *technology push* path and furthermore, it has a major *barrier for market entry* of a new technology associated with the *high cost of ionic liquids*. It has a strong emphasis on research and development activities and its R&D intensity is 40-50 percent (A.1.5).

IoLiTec's technology is protected by *IPRs*. Between 2004 and 2007 IoLiTec submitted six patent applications, most of them citing two of the firm founders (A. Bösmann and T. Schubert) as inventors and some of them in cooperation with the University of Freiburg (Germany).

A key resource of IoLiTec is *technology intelligence*, emphasizing tracking scientific developments in the field, state-of-the-art and current awareness, by searching the scientific literature and tracking technology development and applications and protection of technology and applications by patent searches including competitor and market tracking.

This means organizing and managing the flood of data and information by appropriate data processing systems and, furthermore, utilizing the existing information and knowledge base for consulting and revealing optimum offerings to meet customer specifications on the basis of the existing data and information set using structure-property and structure-activity relations and corresponding software for data processing.

Furthermore, technology intelligence can also help identify not only commercial opportunities, but also spot opportunities for financing the startup's development by "public money" (Figure I.59).

In Figure I.170 the building process of a resource base for IoLiTec GmbH (A.1.5, B.2) is displayed. The formal foundation of IoLiTec (legal status: German GbR) occurred in November 2002 in Cologne/Aachen (Germany;). The search for a proper *location* anywhere in Germany (criteria: cost and networking) led to the BioTechPark in Freiburg with the near Freiburg University providing a potential for networking with academic ionic liquids experts.

Operation started in May 2003 (changed legal status to GmbH & Co. KG). In October 2003 the first employee was hired. For needed expansion in June 2005 the firm moved to the industrial area (in German "Gewerbegebiet") in Denzlingen near Freiburg as renting cost in the BioTechPark, particularly for laboratories, was very high.

IoLiTec started with an *entrepreneurial triple* (three chemists with experience in the technical field) and having a customer. One of the co-founders who brought in the customer left already after three months. *Having a customer* (a manufacturer of *sensors*) who placed an €180,000 order had a decisive influence to get a *bank loan* of €200,000. In 2005 and 2006 further funding occurred by loans from banks [Schubert

2008a]. IoLiTec was profitable from day 1 on. Hence, IoLiTec could rely also on *cash* for its operations.

In January 2004 it began offering custom synthesis of ionic liquids. During the startup phase IoLiTec used its Web site as a resource to promote its offerings. It could take advantage from the general interest in ionic liquids in academia and industry which ultimately led firms to directly contact IoLiTec via telephone or email. But due to its technology push approach it had often to create ("grow") its market.

In 2004 the "residual team" was complemented by a *business angel* (focused on financial, tax and law). Funding by an angel did not only affect the financial structure of the startup, but, as the angel took over administrative and financial responsibilities, IoLiTec could rely *very early on professional financial management* as a resource (B.2 – IoLiTec – Figure 1, Figure 3).

In 2006 IoLiTec's original leadership team lost again one of its founders. A. Bösmann, the CSO with broad technical experience in ionic liquids based on his dissertation at the Technical University of Aachen with Germany's key scientist in the field, left the firm to return to academic research. T. Schubert who drove the foundation and acted as a Managing Director (CEO) remained in his position (B.2 – Figure 1, Figure 3).

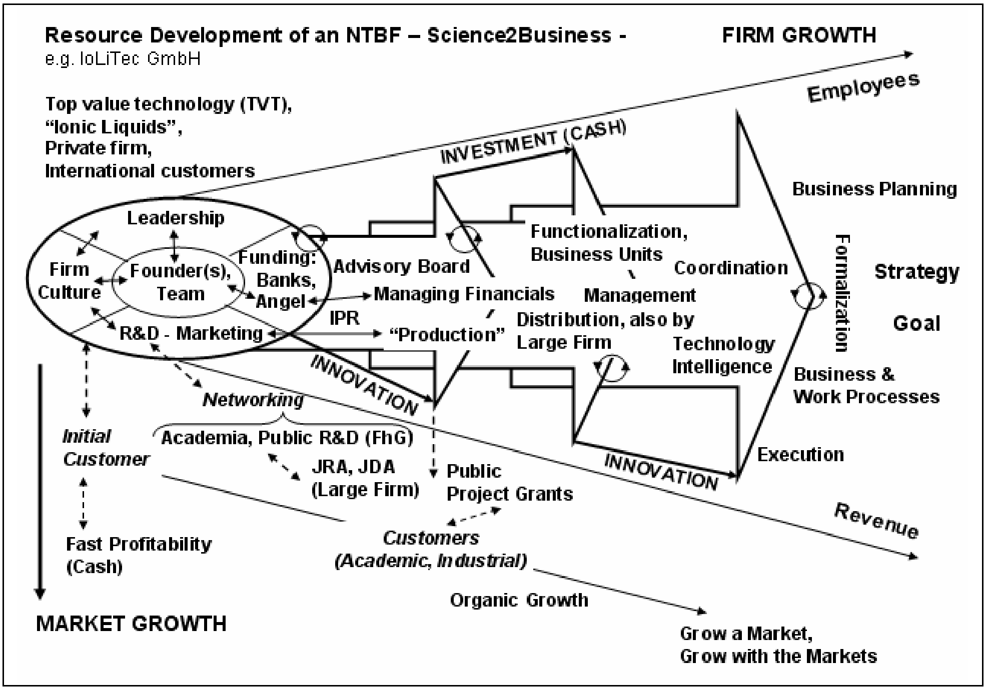


Figure I.170: Building a resource base of NTBF IoLiTec GmbH in the field of ionic liquids.

Schubert earned his doctoral degree in the group of Prof. Berkessel of the University of Cologne in bioorganic chemistry; the latter one became a member of the Scientific Board (B.2 – Figure 1, Figure 3).

Before founding IoLiTec T. Schubert gained experience (2001-2003) as a Sales Manager responsible for the technical synthesis and marketing of ionic liquids working for the startup Solvent Innovation GmbH in Cologne being also active in ionic liquids which actually meant a competitor for his startup.

Hence, Schubert could contribute a variety of resources to IoLiTec, technical, market, marketing and sales knowledge in the field and having networking contacts with large firms. Therefore, Schubert could *earlier complement leadership by management* (Figure I.118) and establish faster *formalized business processes* for running the firm's growth.

IoLiTec GmbH founder T. Schubert [2004, 2008a] lists twenty six specific applications clustered into six different general areas for applications of ionic liquids. This broad spectrum show what choices IoLiTec could make from existing options (A.1.5) and which ones it finally made.

Concerning organization in 2004 IoLiTec decided to focus on five areas of *specialization* [Schubert 2005]:

1. Contract R&D services
2. Special chemistry (ionic liquids)
3. Sensor technology
4. Energy
5. Nanotechnology.

Corresponding product lines according to these five areas are given by Schubert [2008a:slide 27].

The plan was to develop each focus into an independent division each one relying on the core platform technology "ionic liquids." Various fields of applications for ionic liquids let *business lines* emerge which showed up in 2006 (B.2 – Figure 2).

For the science2business path "out of the ivory tower" [Short 2006] into the market IoLiTec put much emphasis on its Advisory Board which functions as a "Scientific Board." Leveraging the Scientific Board occurs for consulting activities and analytical services for customers mediated through IoLiTec (B.3).

The very intense networking of IoLiTec with academia is reflected by defined links between IoLiTec's researchers with members of the Scientific Board or other professors from universities in related scientific fields (B.2 – Figure 3). Networking with public research institutes (B.2) as "partners" is essentially with relevant institutes of the Fraunhofer Society (FhG). FhG institutes became often partners in publicly funded cooperative projects of consortia which represented a significant factor of financing IoLiTec's R&D activities.

In June 2004 IoLiTec organized distribution of its products via Merck KGaA and JDA (cooperation contracts) with Degussa AG (now Evonik Industries) as strategic partners.

Apart from the above NTBFs which started from a unique technology or design as described above many NTBFs take advantage of market disequilibrium, "catch a wave," such as biofuels (A.1.1) or CleanTech, to anticipate profits. But they have to share the markets with many new entrants – small and large, attracted by potential profits. Related NTBFs belong largely to the class of VC-based startups and, specifically in biofuels, are addressing policy-driven markets (Table I.15).

In biofuels corresponding NTBFs often target large-scale manufacturing, but most of them are still struggling with the associated scale-up process. Financing these firms is often from the beginning or in an early stage of the scale-up process. Venture capitalists do not only infuse *money* into these firms but establish simultaneously an extended management team with *massive experience in target or related markets and in leading a firm* – and even having *ties to policy* concerning plant and production permits ("*veterans approach*"; A.1.1). The original founders of these firms, when being scientists or engineers, usually took the roles of a CSO or CTO in the management team.

Biofuel firms additionally take advantage from "public money" in terms of loan guaranties and tax exemption by public entities, cooperative R&D projects with national or federal research institutes and seek cooperative projects with large firms of the oil or chemical industry (Figure I.179, Figure I.183).

Such NTBFs *behave like a large sophisticated company* very early on or even from the start. For the innovation and firms' development processes they follow essentially the highly formalized processes of large firms (Figure I.134), in particular, the phase gate process or RD&D staged path for scale-up of production (Figure I.79, Figure I.180).

In particular for biofuels, venture capitalist V. Khosla refers to an innovation architecture which he calls an "innovation ecosystem at work," solving large problems by harnessing the power of ideas fueled by entrepreneurial energy of scientists, technologists, and entrepreneurs – very bright people working on solving a problem. Khosla's innovation architecture is often to be characterized as a *VC-based spin-out* (RBSUs) with *experienced managers* ("professional managers"; Figure I.118) from almost the point of firm's foundation (A.1.1.5).

Building the resource base in such an NTBF is driven essentially by connecting founder/management team *experience and strategy* – and execution. Fast growth in the number of employees often leads to *issues of coordination* as an important resource.

Shrader and Siegel [2007] assessed the role of human capital (Table I.8) in the growth and development of new technology-based ventures via an analysis of a large sample of publicly traded, technology-based new ventures using information available on initial public offerings (IPOs) in IPO prospectuses. They suggest that the fit between strategy and team experience is a key determinant of the long-term performance of these high-tech entrepreneurial ventures.

In particular Shrader and Siegel [2007] found that experience with previous startups helped ventures pursuing broad strategies (for instance, numerous customers, segments and products) achieving higher sales growth. As expected, marketing experience was shown to be highly significantly related to the pursuit of marketing-based differentiation.

Their findings provide also striking evidence of a clear and consistent fit between team backgrounds and competitive strategy among their sample. More specifically, they believe that *specialized experience in functional areas relates to the strategies* pursued by a new venture.

5.3 Some Concluding Remarks

When we embarked a journey following a purpose to outline the not-well and not adequately explored territory we have observed that Applied General Systems Theory (GST) and its principles and approaches provide a framework to tackle technology entrepreneurship which is characterized by high complexity in terms of numbers of variables and parameters that determine the developments of new technology ventures.

GST as an all embracing framework allowed a consistent, context-sensitive exploration and treatment of the subject to increase understanding and explanation. Here, we targeted rationalization to differentiate "reasons why" versus "reasons for thinking that." However, presented claims and propositions remain partly tentative. But many tentative propositions were driven to the point that will allow or induce, respectively, further inquiries.

For technology entrepreneurship rather than leveling off differences by methods that enforce compatibility of what does not fit human activities in various contexts the emphasis was on sources of variations which conventional theories and approaches dismiss as random. Variations were studied to reveal patterns of structure and dynamics within the variation ("Variations on a Theme"; A.1.6).

We think our APPROACH is a response to Schumpeter's [1939:44] criticism of research based on only aggregate data:

"It keeps analysis on the surface of things and prevents it from penetrating into the industrial processes below, which are what really matters. It invites a mechanistic and formalistic treatment of few isolated contour lines and attributes to aggregates a life of their own and a causal significance that they do not possess."

We did not neglect the entrepreneurs' personalities and the important role of individual entrepreneurs or founders in a "team system." And we did not neglect the time span the entrepreneurs are active in requiring detailed knowledge about related constellations of technologies, markets, industries and national economies. This is expressed by William Hewlett, one of the founders of HP (Hewlett – Packard, founded in 1939):

> "As I talk about the start of the company, it is important to remember that both Dave {Packard} and I {William Hewlett} were products of the Great Depression." [Hewlett]

First steps have been presented to handle development and growth of NTBFs. Focusing on growth states of firms and *equations of state* give up the idea that data can be forced into a one-size-fits-all model. Concepts and regularities in firms' evolutions were presented, some require refinement, but more regularity await discovery.

We did not just observe! We filtered and organized "observable" data, information and facts – whether from the literature or own observations. And epistemologically following Einstein that "it is the theory that decides what we can observe" we introduced "The Bracket Model of New Technology Venture Development" and emphasized expectations rather than predictions. The Bracket Model deals with processes of change paying equal attention to expected observations and events and to exceptional events or phenomena.

Finally, we do not claim to have developed a standard or a direction for further scholarly inquiry. We – with a strong background of natural sciences – made a suggestion how to approach the exciting real world issues of human activities leading to economic change based on changes of technology and utilization of new scientific results.

Concerning the comparative approach in this book, apart from basic inter-cultural and socio-economic differences, technology entrepreneurship in Germany and the US is generically closest for privately held or controlled new firms.

It is very different for VC-based startups which is largely related to the fundamentally different financial systems, in particular, based on availability of a gigantic amount of "loose money" in the US due to the dollar still being the world's reserve currency and the Federal Reserve being in a position that the world's economic, financial and policy systems accept the Fed to print as much dollars as the US is perceived to need. Hence, how VC-based startup emerge and develop in the US cannot be compared and be a general model for Germany's VC-based startups. In particular, the level of related technology speculation is negligible in Germany compared to that in the US.

The German national innovation and entrepreneurship system has emergeed with high systemic performance due to a rather organized, smooth and strong interplay of the Science & Technology, Economic, Financial and Policy Systems.

REFERENCES

A123 (2011): *Annual Report 2010*. http://files.shareholder.com/downloads/ABEA-3DGNI7/1400969767x0x492428/4CAEC6AA-6BDF-4417-A285-DA6D6C4472F6/AONE_2010_10-K.pdf (last access 9/14/2011); *Annual Report 2011.* http://files.shareholder.com/downloads/ABEA-3DGNI7/2084852290x0x559734/6496992D-F3B6-4634-ABB4-C86C8AE1F364/A123_2011_Annual_Report.pdf (last access 8/22/2012).

Abrahamson, E. (2000):*Change Without Pain: Dynamic Stability*. HBS Working Knowledge, 9/11/2000. http://hbswk.hbs.edu/archive/1683.html (last access 5/12/2011).

Abramson, H. N.; Encanação, J.; Reid, P. P.; Schoch, U. Eds. (1997): *Technology Transfer Systems in the United States and Germany – Lessons and Perspectives*. National Academy Press, Washington, D.C., 1997. http://books.nap.edu/openbook.php?record_id=5271&page=R1 (last access 12/10/2009).

Accel Partners (2005): *Accel Partners Invests in thefacebook.com*. Portfolio Company New, May 26, 2005. http://www.accel.com/news/news_one_up.php?news_id=1 (last access 10/5/2011).

Ackerman, R. (2009): *Valero Sees Dollar Signs In Ethanol*. Forbes Online, Mar. 18, 2009. http://www.forbes.com/2009/03/18/valero-energy-ethanol-markets-equity-verasun.html (last access 11/9/2009).

ACS – American Chemical Society (2011): *Innovation, Chemistry, and Jobs – Meeting the Callenges of Tomorrow*. ACS Presidential Task Force on Innovation in the Chemical Enterprise. http://web.2.c2.audiovideoweb.com/va92web25028/InnovationChemistryJobsReport-PDFs/InnovationChemistryandJobs.pdf (last access 9/25/2011).

ADAC (2011a): *125 Jahre Automobil – Motoren des Fortschritts (125 years automobile – Engines of progress)*. ADAC Motorwelt, Jan. 2011, 21-29.

ADAC (2011b): *Platz da, für alle*! (Have space, for all!). ADAC Motorwelt, May 2011, 24-29.

Admin (2012): *2012 Merger mania gets underway: Green Biologics, Butylfuel merge.* Biofuels Digest, Jan. 20, 2012. http://www.biofuelsdigest.com/bdigest/2012/01/20/2012-merger-mania-gets-underway-green-biologics-butylfuel-merge/ (last access 4/27/2012).

Admin (2011a): *Coskata's $100 million IPO*: *The 10-Minute Version*. Biofuels Digest, Dec. 20, 2011. http://www.biofuelsdigest.com/bdigest/2011/12/20/coskatas-100-million-ipo-the-10-minute-version/ (last access 4/23/2012).

Admin (2011b): *Cobalt taps Mayer as new CEO*. Biofuels Digest, Nov. 29, 2011. http://www.biofuelsdigest.com/bdigest/2011/11/29/cobalt-taps-mayer-as-new-ceo/ (last access 5/3/2012).

Admin (2011c): *Mascoma's IPO: The 10-Minute version*. Biofuels Digest, Sep. 20, 2011. http://www.biofuelsdigest.com/bdigest/2011/09/20/mascomas-ipo-the-10-minute-version/ (last access 1/26/2012).

Admin (2011d): *KiOR files $100M IPO – the complete Digest analysis*. Biofuels Digest, Apr. 13, 2011. http://www.biofuelsdigest.com/bdigest/2011/04/13/kior-files-100m-ipo-the-complete-digest-analysis/ (last access 6/2/2011).

Admin (2011e): *KiOR raises $150M in IPO, 30 percent below latest forecast*. Biofuels Digest, Jun. 24, 2011. http://www.biofuelsdigest.com/bdigest/2011/06/24/kior-raises-150m-in-ipo-30-percent-below-latest-forecast/ (last access 6/30/2011).

Admin (2011f): *Genomatica's $100M IPO: The 10-Minute Version*. Biofuels Digest, Aug. 25, 2011. http://www.biofuelsdigest.com/bdigest/2011/08/25/genomaticas-100m-ipo-the-10-minute-version/ (last access 11/23/2011).

Admin (2011g): *The Magic Word is…Adipic. Looking at Verdezyne and its bull markets*. Biofuels Digest, Dec. 21, 2011. http://www.biofuelsdigest.com/bdigest/2011/12/21/the-magic-word-is%E2%80%A6adipic-looking-at-verdezyne-and-its-bull-markets/ (ast access 1/9/2012).

Administrator (2010): *Amyris – Farnesene and the pursuit of value, valuations, validation and vroom*. Biofuels Digest, Jun. 25, 2010. http://www.biofuelsdigest.com/biotech/2010/06/25/amyris-the-pursuit-of-value-valuations-and-validation/ (last access 8/13/2011).

Agarwal, R.; Echambadi, R.; Franco, A. M.; Sarkar, MB (2004): *Knowledge Transfer Through Inheritance: Spin-out Generation, Development and Survival*. Academy of Management Journal 47 (4), 501–522. http://www.rotman.utoronto.ca/facbios/file/Agarwal%20Echambadi%20Franco%20and%20Sarkar%20AMJ%202004.pdf (last access 7/6/2010).

Agrinova: http://an.agricola-tech.de/index.php?id=49 (last access 3/16/2010).

Ahlm, P. (2012): *Algenol*. Presented at DOE's 2012 Biomass Conference, July 10, 2012. http://www1.eere.energy.gov/biomass/pdfs/b12_ahlm_1-b.pdf (last access 5/7/2013).

Ahrens, R. (2005): *Flower-Power – Bodo Wolf und sein Sonnensprit aus Biomasse* (Flower-Power – Bodo Wolf and his Sunfuel from biomass). Radio WDR5, Leonardo, Broadcasted Nov. 22, 2005. http://www.wdr5.de/sendungen/leonardo/sendungsdetailseite.html?tx_wdr5ppfe_pi1%5BshowUid%5D=175768&tx_wdr5ppfe_pi1%5BbeitragsUid%5D=2102&cHash=c8bde7b440&tx_rlmpflashdetection_pi1%5Bhtml%5D=1 (last access Nov. 30, 2005; no longer accessible);
Choren Industries: History. http://www.choren.com/en/choren_industries/company/history/ (last access 12/17/2009).

Ainsworth, S. J. (2008): *Entrepreneurial Trailblazers – Women build businesses around their passion for science*. Chemical & Engineering News 86 (44), 50-54. http://pubs.acs.org/cen/coverstory/86/8644cover2.html (last access 1/29/2010).

Ainsworth, S. J. (2010): *Empowered Entrepreneurs – Downsized out of big companies, scientists are creating satisfying job opportunities in their own firms*. Chemical & Engineering News 88 (28), 57-60. http://pubs.acs.org/cen/employment/88/8828employment1.html (last access 7/14/2010.

Algae Industry Magazine (2011): *HR BioPetroleum to Acquire Shell's Share in Cellana Algae JV*. AlgaeIndustryMagazine.com, Jan. 27, 2011. http://www.algaeindustrymagazine.com/hr-biopetroleum-to-acquire-shells-share-in-cellana-algae-jv/ (last access 7/7/2011).

Altucher, J. (2009): *The Internet Is Dead (As An Investment).* Wall Street Journal, Jul. 17, 2009. http://online.wsj.com/article/SB124784696163158721.html (last access 7/18/2009).

Alvarez, S. H.; Busenitz, L. W. (2001): *The entrepreneurship of resource-based theory*. Journal of Management 27 (6), 755-775 (2001). http://www.udec.edu.mx/BibliotecaInvestigacion/Documentos/2009/Mayo/The%20entrepreneurship%20of%20resource-based%20theory.pdf (last access 1/19/2011); http://faculty-staff.ou.edu/B/Lowell.W.Busenitz-1/pdf_pro/2001%20jom%20the%20entrepreneurship%20of%20rb.pdf (last access 12/12/2010).

Amyris (2012): *Annual Report 2011*. http://files.shareholder.com/downloads/ABEA-4QL2IU/1899075180x0x559486/A7E56B05-7866-4E3C-9A7D-67A4E4001BC3/2011AnnualReport.pdf (last access 5/6/2012).

Anderson, C. W.; Moran, T. (2009): *Ethanol, biofuel industry in flux – Plants shut down in Modesto, Stockton*. Central Valley Business Journal 2009. http://www.cvbizjournal.com/local-news/ethanol-biofuel-industry-in-flux.html?option=com_content&catid=98&id=370&lang=en&view=article&option=com_content&catid=98&id=370&lang=en&view=article&fontstyle=f-smaller (last access 1/2/2010).

Andreessen, M. (2011): *Why Software Is Eating the World.* Wall Street Journal, Aug. 20, 2011. http://online.wsj.com/article/SB10001424053111903480904576512250915629460.html?mod=WSJ_hp_us_mostpop_read (last access 8/24/2011).

Amit, R.; Schoemaker, P.J.H. (1993): *Strategic assets and organizational rent.* Strategic Management Journal 14(1), 33-46.

Anonymus (2004): *Was bewegt ... Dietmar Hopp? (What drives … Dietmar Hopp?*). Die Zeit, Oct. 21,.2004. http://www.zeit.de/2004/44/Portr_8at_Hopp (last access 8/3/2010).

Anonymus (2006a): *Put A Termite In Your Tank*. Business Week Online, Dec. 18, 2006. http://www.businessweek.com/magazine/content/06_51/b4014081.htm?chan=tc&chan=technology_technology+index+page_best+of+the+magazine (last access 12/23/2009).

Anonymus (2007a): *Nuthetaler Institut mit Partnern in den USA (Nuthetal institute with partners from the USA).* Potsdamer Neueste Nachrichten, Jan. 6, 2007. http://www.pnn.de/pm/56144/ (last access 11/10/2009).

Anonymus (2007b): *Kampf gegen den Klimawandel: Der Hoffnungsträger ist grün und glitschig (Fighting climate change – The object of hope is green and slippery).* Handelsblatt, Nov. 2, 2007. http://www.handelsblatt.com/technologie/forschung/der-hoffnungstraeger-ist-gruen-und-glitschig;1346018 (last access 1/25/2010).

Anonymus (2008): *DuPont and BP targetingmultiple bio-butanol molecules; biofuel allows for highwe blending ratios*. Biopact, Feb.14, 2008. http://news.mongabay.com/bioenergy/2008/02/dupont-and-bp-targeting-multiple-bio.html (last access 1/26/2010).

Ante, S. E. (2009): *'Super Angels' Shake Up Venture Capital*. Business Week, May 21, 2009. http://www.businessweek.com/magazine/content/09_22/b4133044585602.htm?chan=technology_technology+index+page_best+of+the+magazine (last access 5/ 28/2009).

Ardichvili, A.; Cardozob, R.; Ray, S. (2003): *A theory of entrepreneurial opportunity identification and development*. Journal of Business Venturing 18, 105–123. http://www2.sa.unibo.it/summer/testi/11_grimaldi_tagliaventi/ardichvili_2003.pdf (last access 4/5/2010).

Ardichvili, A., Harmon, B., Cardozo, R.N., Reynolds, P.D., Williams, M.L. (1998): *The New Venture Growth: Functional Differentiation and the Need for Human Resource Development Interventions*. Human Resource Development Quarterly 9 (1), 55-70.

Arenius, P; Ehrstedt, S. (2008):*Variation in the Level Of Activity Across the Stages of the Entrepreneurial Startup Process-Evidence From 35 Countries.* Estudios de Economía. Vol. 35 - N° 2, Diciembre 2008. Págs. 133-152. http://www.scielo.cl/scielo.php?pid=S0718-52862008000200002&script=sci_arttext (last access 8/10/2009).

Ashby, R. W. (1957): *An Introduction to Cybernetics. Second Impression*. Chapman & Hall, London, 1957, 1999. http://pespmc1.vub.ac.be/books/IntroCyb.pdf (last access 9/22/2009).

Associated Press (2009a*): BP and Martek form biodiesel partnership*. Business Week, Aug. 11, 2009. http://www.businessweek.com/ap/financialnews/D9A0ND9O1.htm (last access 8/11/2009); cf. also http://www.topix.net/content/prweb/2009/08/bp-and-martek-biosciences-enter-joint-development-agreement-to-deliver-advanced-biodiesels (last access 11/9/2009).

Associated Press (2009b*): Race to turn pond scum and other algae into affordable fuel heats up with new money, research*. , WGN Radio, Dec. 2, 2009. http://www.wgnradio.com/lifestyle/green/resourceguide/sns-green-affordable-fuel,0,7069152.story (last access 1/24/2010), cf. also http://bioenergyuiuc.blogspot.com/2009/12/race-to-turn-pond-scum-and-other-algae.html.

Aulet, B. (2006): *Generating Exponential Revenue Growth*. Presentation at HCT MIT Entrepreneurship Conference. Dubai, United Arab Emirates, September 20, 2006. http://www.hctmit.com/Conf2/Presentation/Day%202/AULET%20Generating%20Expo nential%20Revenue%20Growth%20HCT.ppt#429,8,Technology Adoption Over History (Last access 7/24/2009). Slide 8 – no longer accessible; http://www.authorstream.com/Presentation/Irvette-15652-AULET-Generating-Exponential-Revenue-Growth-HCT-Desired-Outcomes-Presentation-Upfront-Caveat-Executive-Summary-Recommended-Reading-Material-Techn-trb2007-ppt-powerpoint/ (last access 10/30/2013).

Austin, A. (2009): *BlueFire, Arkenol process cofounder form agreement*. Ethanol Producer, posted Mar. 11, 2009. http://www.ethanolproducer.com/article.jsp?article_id=5492 (last access 1/7/2009).

Autio, E. (2007): *Global Report on High-Growth Entrepreneurship – 2007 Global Report on High-Growth Entrepreneurship*. http://www.gemconsortium.org/download/1285757314657/GEM%20High%20Growth%20Report%2007b.pdf (last access 9/28/2010).

Autio, E. (2005): *Global Entrepreneurship Monitor – High-Expectation Entrepreneurship 2005. Summary Report*. http://www.gemconsortium.org/download/1285693721657/18436%20GEM%20summary.pdf (last access 9/28/2010).

Autio, E., Garnsey, E. (1997): *Early Growth and External Relations in New Technology-Based Firms*. http://usasbe.org/knowledge/proceedings/proceedingsDocs/USASBE1997proceedings-P183Autio.PDF (last access 1/19/2011);
Autio, E., Garnsey, E. and Yli-Renko, H. (1997) "*Early growth and external relations in new technology-based firms*." In Kunkel, S. and Meeks, M. (Eds.) Entrepreneurship: the engine of global economic development: Proceedings of the World Conference of the International Council for Small Business (42nd), 21st-24th June 1997, San Francisco, California, USA. St Louis, Mo.: ICSB;
Yli-Renko, H.; Autio, E. (1996): *The catalyzing impact of new, technology-based firms in industrial technological renewal: Developing a systemic evolution model*. Proceedings of the 41st ICSB World Conference, Stockholm.

AUTM – The Association of University Technology Managers (2008): *THE BETTER WORLD REPORT PART ONE: The Art of Collaboration: The Relationships That Bring Academic Innovations to the Marketplace*. http://www.enterprise.cam.ac.uk/uploads/File/Publications/AUTM_BWR1_08.pdf (last access 12/1/2009); THE BETTER WORLD REPORT PART TWO: Technology Transfer Works: 100 Innovations from Academic Research to Real-World Application.. http://www.enterprise.cam.ac.uk/uploads/File/Publications/AUTM_BWR2_08.pdf (last access 12/1/2009).

Ball, P. (2006): *Chancing upon chemical wonders*. Chemstry World, June 2006. http://www.rsc.org/chemistryworld/Issues/2006/June/ChancingUponChemicalWonders.asp (last access 10/20/2010).

Banathy, B.H. (1968): *Instructional Systems*. Fearon Publishers: Belmont, Palo Alto, CA.

Banathy, B.H. (1996): *A Taste of Systemics*. An activity of the Primer Group – The First International Electronic Seminar on Wholeness. A Special Integration Group (SIG) of the International Society for the Systems Sciences (ISSS) and IISII

INTERNATIONAL INSTITUTE for SYSTEMIC INQUIRY AND INTEGRATION, December 1, 1996; to December 31, 1997. http://www.newciv.org/ISSS_Primer/asem04bb.html (last access 9/21/2009).

Bandyk, M. (2009): *Why We Should Be Worried That Washington Is the New Job Creator*. U.S. News & World Reports, posted December 08, 2009 04:07 PM ET. http://www.usnews.com/mobile/blogs/capital-commerce/2009/12/8/why-we-should-be-worried-that-washington-is-the-new-job-creator.html (last access 1/12/2010).

Baron, R. A. (2004): *Opportunity Recognition – Insights from a Cognitive Perspective*. Chapter 3 in Butler, John E., Ed. (2004): Opportunity Identification and Entrepreneurial Behavior. A Volume in Researrch in Entrepreneurship and Management. Information Age Publishing, Inc. 2004.

Baron, R. A.; Ensley, M. D. (2006): *Opportunity Recognition as the Detection of Meaningful Patterns: Evidence from Comparisons of Novice and Experienced Entrepreneurs*. Management Science 52 (9), Sep. 2006, 1331-1344.

Barrett, A. (2009): *Venture Capitalists Head to Washington*. Business Week, Aug. 7, 2009. http://www.businessweek.com/magazine/content/09_68/s0908019273796.htm?chan=smallbiz_smallbiz+index+page_small+business+policy (last access 8/10/2009).

Barron, R. (2007): *Are Biofuels Pushing VCs Into a New Role?* GreenTech Media Newsletter, Sep. 14, 2007. http://www.greentechmedia.com/articles/read/are-biofuels-pushing-vcs-into-a-new-role-67/ (last access 11/30/2009).

BASF: *BASF History 1865 – 1901 – The birth of the chemical industry and the era of dyes*. http://www.basf.com/group/corporate/en/about-basf/history/1865-1901/index; http://www.basf.com/group/corporate/de/about-basf/history/1865-1901/index (last access 2/23/2010); http://www.basf.com/group/corporate/en/function/conversions:/publish/content/about-basf/history/1865-1901/images/1865-1901_en.pdf.

BASF (2013): *BASF plans production of butanediol from renewable feedstock using Genomatica technology*. Joint News Release of BASF and Genomatica, May 10, 2013. http://www.basf.com/group/pressrelease/P-13-268 (last access 5/14/2013).

BASF (2012a): *BASF participates in US American technology company Renmatix*. Press Release, Jan. 3, 2012. http://www.basf.com/group/pressrelease/P-12-101 (last access 1/30/2012).

BASF (2012b): BASF, *Cargill and Novozymes target commercial bio-based acrylic acid process.* Joint Press Release, Aug. 17, 2012. http://www.basf.com/group/pressrelease/P-12-363 (last access 8/23/2012).

BASF (2012c): *BASF and CSM establish 50-50 joint venture for biobased succinic acid*. Joint News Release of BASF and CSM, Oct 5, 2012. http://www.basf.com/group/pressrelease/P-12-444 (last access 10/16/2012).

Bates, T. (1995). *Self-employment entry across industry groups*. Journal of Business Venturing 10(2), 143-156.

Baumol, W.; Litan, R. E.; Schramm, C. (2007): *Sustaining Entrepreneurial Capitalism*. Capitalism and Society 2 (2), Article 1. Available at: http://www.bepress.com/cas/vol2/iss2/art1.

Baumol, W.; Litan, R. E.; Schramm, C. (2008): *Good capitalism and bad capitalism*. The Japan Time Online, Mar. 13, 2008. http://search.japantimes.co.jp/cgi-bin/eo20080313a2.html (last access 3/2/09).

BBC (2007): *Quick guide: Biofuels*. BBC News Jan. 24, 2007. http://news.bbc.co.uk/2/hi/science/nature/6294133.stm (last access 10/25/2009).

BBC: *Richard Trevithick and the First Railway Locomotive*. http://www.bbc.co.uk/wales/southeast/halloffame/historical_figures/richard_trevithick.shtml (last access 2/13/2013); http://news.bbc.co.uk/dna/place-lancashire/plain/A14113838 http://en.wikipedia.org/wiki/Richard_Trevithick; http://en.wikipedia.org/wiki/London_Steam_Carriage.

Bellis, M.: *The History of MP3 - Fraunhofer Gesellschaft and MP3*. ©2010 About.com, a part of The New York Times Company. http://inventors.about.com/od/mstartinventions/a/MPThree.htm (last access 6/18/2010).

Benda, C. (2003): *A Kernel of an Idea*. University of Minnesota Alumni Association., May 12, 2003. http://www.chem.umn.edu/alumni/patrick_gruber.pdf (last access 6/6/2012).

Berkum, S. (2008): *Thoughts on Google's 20% time.* Mar. 12, 2008. http://www.scottberkun.com/blog/2008/thoughts-on-googles-20-time/ (last access 9/1/2010).

Bessant, J.; Möslein, K.; von Stamm, B.: *In search of innovation*. http://businessonmain.msn.com/browseresources/articles/print.aspx?cp-documentid=25253702#fbid=61V6MW9dNrq; http://userhome.brooklyn.cuny.edu/irudowsky/EmergingTechnology/lectures/InSearchOfInnovation.ppt (last access 7/15/2011).

Bevill, K. (2012): *Target for Innovation*. Ethanol Producer Magazine, Mar. 2012, 40-45. http://www.greenbiologics.com/pdfs/gblinthenews1.pdf (last access 4/25/2012).

Bhidé, A. V. (2000): *The Origin and Evolution of New Businesses*. Oxford University Press, New York.

Bidaux, T. (2009): *Free to Play games in Europe – 2009*. Presentation Develop, Brighton, Jul. 14-16, 2009. http://www.slideshare.net/ICOPartners/free-to-play-games-in-europe-2009 (last access 7/31/2009).

Bigelow, B. V. (2008): *Sapphire Energy, Backed by Bill Gates, Tries to Tone Down the Hype as it Makes Gasoline From Algae*. Xconomy, Nov. 13, 2008. http://www.xconomy.com/san-diego/2008/11/13/sapphire-energy-backed-by-bill-gates-tries-to-tone-down-the-hype-as-it-makes-gasoline-from-algae/ (last access 3/14/2010).

Bigelow, B. V. (2009a): *Big Energy Collaborations Seen to Jump-Start Emerging Biofuels Technologies*. Xconomy, from Nov. 19, 2009. http://www.xconomy.com/san-diego/2009/11/19/big-energy-collaborations-seen-to-jump-start-emerging-biofuels-technologies/ (last access 11/21/2009).

Bigelow, B. V. (2009b): *Two Things I Learned During My Tour of Sapphire Energy*. Xconomy, Oct. 27, 2009. http://www.xconomy.com/san-diego/2009/10/27/two-things-i-learned-during-my-tour-of-sapphire-energy/ (last access 3/13/2010).

Bruce V. Bigelow (2009c): *After Re-Engineering Itself, Verdezyne Sets Course to Develop Biofuels and "Green" Industrial Chemicals*. Xconomy, Nov. 20, 2009. http://www.xconomy.com/san-diego/2009/11/20/after-re-engineering-itself-verdezyne-sets-course-to-develop-biofuels-and-green-industrial-chemicals/2/ (last access 3/23/2010).

Bingham, F.G.; Quigley, Jr. C.J. (1989). *Venture team performance to new product development.* The Journal of Business and Industrial Marketing, 4 (2), 49-59.

Biofuels Digest (2012): *USDA gives Zeachem conditional commitment of $232M loan guarantee*. Biofuels Digest, Jan. 27, 2012. http://www.biofuelsdigest.com/bdigest/2012/01/27/usda-gives-zeachem-conditional-commitment-on-232m-loan-guarantee/ (last access 3/9/2012).

Biofuels Digest (2008): *Germany to reduce biofuels target from 17 percent to 12 percent in 2020*. Biofuels Digest, Jul. 21, 2008. http://www.biofuelsdigest.com/blog2/2008/07/21/germany-to-reduce-biofuels-target-from-17-percent-to-12-percent-in-2020/ (last access 11/2/2009).

Bilton, N; Rusli, E. M. (2012): *From Founders to Decorators, Facebook Riches*. The New York Times, Feb. 1, 2012. http://www.nytimes.com/2012/02/02/technology/for-founders-to-decorators-facebook-riches.html?google_editors_picks=true (last access 1/2/2012).

BioFuelWatch (2009): *Shell's investments in agrofuel*. BioFuelWatch, Apr. 2009. http://www.biofuelwatch.org.uk/docs/Shell.pdf (last access 5/20/2009).

BioMCN (2011): *Dutch consortium takes initiative to build the world's largest biomass refinery in Delfzijl.* BioMCN New, Feb. 11, 2011. http://www.biomcn.eu/news/news/128-dutch-consortium-takes-initiative-to-build-the-worlds-largest-biomass-refinery-in-delfzijl.html (last access 12/12/2011).

BioMCN (2009): *BioMCN Annual Report 2008*. http://www.biomcn.eu/images/stories/BioMCN_2008_annual_report.pdf (last access 1/19/2010).

BioMCN (2008): *BioMCN Annual Report 2007*. http://www.biomcn.eu/images/stories/downloads/biomcn_annual_report_2007.pdf (last access 1/21/2010).

Bird, B. J. (1992): *The Operation of Intentions in Time: The Emergence of the New Venture*. Entrepreneurship: Theory and Practice 17 (1), 11-20. FindArticles.com. 08 Jul, 2009. http://findarticles.com/p/articles/mi_hb6648/is_n1_v17/ai_n28620138/.

Birds Eye Foods: *The Birds Eye Story*. http://www.birdseyefoods.com/ourcompany/story.aspx (last access 9/11/2009).

BIU – Der Bundesverband Interaktive Unterhaltungssoftware e. V. (2011): Association of Interactive Entertainment Software. *Market Data*. http://www.biu-online.de/.

Blanco, S. (2009): *China turns to methanol for flex-fuel cars.* Autobloggreen, Nov. 10, 2009. http://green.autoblog.com/2009/11/10/china-turns-to-methanol-for-flex-fuel-cars (last access 1/19/2010).

Bläske, G.; Kiani-Kreß, R. (2010): *Wie OHB zum Raumfahrt-Konzernschreck aufstieg (How OHB emerged as a scare for space companies)*. Wirtschaftswoche Jun. 30, 2010. http://www.wiwo.de/unternehmen-maerkte/wie-ohb-zum-raumfahrt-konzernschreck-aufstieg-433997/ (last access 7/4/2010);
http://de.wikipedia.org/wiki/OHB_AG;
OHB AG: http://www.ohb.de/; http://www.ohb.de/historymilestones.html.

Blochwitz-Nimoth, J. (2008): *Novaled – von der Idee zum Produkt oder was macht eine erfolgreiche Ausgründung? (Novaled – from the idea to the product or what makes a successful spin-out?*). In Zukunft Ingenieurwissenschaften – Zukunft Deutschland. Beiträge einer 4ING-Fachkonferenz und der ersten Gemeinsamen Plenarversammlung der 4ING-Fakultätentage am 14. und 15.07.2008 an der RWTH Aachen, 51-60. Springer, Berlin-Heidelberg, 2008.

Blodget, H. (2009): *Mark Zuckerberg – The Man Behind The Company*. Business Insider, Oct. 8, 2009. http://www.businessinsider.com/henry-blodget-zuckerberg-personal-story-2009-10 (last access 9/10/2009), including linked videos to an interview with Zuckerberg.

BlueFire Ethanol Biofuels (2004): *Izumi Biorefinery – NEDO's Application of Arkenol's Concentrated Acid Hydrolysis Technology for the Conversion of Biomass to Ethanol*. http://bluefireethanol.com/images/IZUMI_Status_2004_for_BlueFire_051606.pdf (last access 12/23/2009).

BMBF – Bundesministerium für Bildung und Forschung (2007): *Entstehungspfade von Nachhaltigkeitsinnovationen (Development paths of sustainability innovations*). Expert Workshop of the research project nova-net, Feb. 13, 2007.
http://wiki.iao.fraunhofer.de/images/novanet/Exp3.pdf (last access 7/4/2007).

BMFB (2008): *Schwerpunkt: Gründungen in außeruniversitären Forschungseinrichtungen (Center of gravity: Foundations in non-university research institutes)* – EXIST 2, 2008, 7-11. http://www.exist.de/imperia/md/content/exist-news/exist-news_2-2008.pdf (last access 7/12/2010).

BMBF (2011): *Federal Ministry of Education and Research – Innovation Alliance Carbon Nanotubes: Innovation for industry and society*. http://www.cnt-initiative.de/en/ (last access 2/22/2011).

BMWi – Federal Ministry of Economics and Technology (2011): *IGV Institut für Getreideverarbeitung GmbH – Profile*. Innovationskatalog,: Jan. 17, 2011 http://www.inno-watt.de/ikat/katalog/unternehmen.php?dataid=68&navanchor=2210003 (last access 6/5/2011).

BMWi - Federal Ministry of Economics and Technology – Germany: EXIST-Gründerstipendium: *Gründungsbeispiel - Cyano Biotech GmbH (Foundation Example – Cyano Biotech GmbH). Interview mit (with) Dan Kramer*. http://www.exist.de/exist-gruenderstipendium/gruendungsbeispiele/00156/index.php (last access 2/7/2010).

Böhm, U. (2005): *Kompetenz für deutsch-amerikanische Geschäftsbeziehungen (Competency for German-American business relations).* Lift Report, 07/01/2005. http://www.lift-report.de/index.php/news/57/328/Kompetenz-fur-deutsch-amerikanische-Geschaftsbeziehungen; English version http://www.lift-report.de/index.php/news/142/384/Competence-in-German-American-business-relationships (last access 9/21/2011).

Böttcher, C. (2006): *Füttern mit Treibhausgas (Feeding with green house gas)*. Financial Times Deutschland, Apr. 27, 2006. http://www.ftd.de/wissen/:fuettern-mit-treibhausgas/68484.html (last access 3/15/2010).

Bomgardner, M. (2012a): *Biofuels Bloom In The South*. Chemical & Engineering News 90 (21), May 21, 2012. http://cen.acs.org/articles/90/i21/Biofuels-Bloom-South.html (last access 5/13/2012).

Bomgardner, M. (2012b): *LanzaTech Buys Range Fuels Facility*. Chemical & Engineering News 90, Jan. 11, 2011. http://cen.acs.org/articles/90/web/2012/01/LanzaTech-Buys-Range-Fuels-Facility.html (last access 1/14/2012).

Bomgardner, M. (2012c): *Money Flows For Biobased Chemicals*. Chemical & Engineering News 90, Feb. 28, 2012. http://cen.acs.org/articles/90/web/2012/02/Money-Flows-Biobased-Chemicals.html (last access 3/10/2012).

Bomgardner, M. (2012d): *Bioplastics Venture Is Off*. Chemical & Engineering News 90 (4), Jan. 23, 2012, 5. http://cen.acs.org/articles/90/i4/Bioplastics-Venture-Off.html (last access 1/28/2012).

Bomgardner, M. M. (2011a): *Genomatica wheels and deals with bio-based chemicals – Renewables: Firm inks butanediol partnership, makes bio-based butadiene*. Chemical & Engineering News, Aug. 22, 2011. http://pubs.acs.org/cen/news/89/i35/8935news.html (last access 9/6/2011).

Bomgardner, M. M. (2011b): *Advanced Biofuels: pipedream or solid investment*? Chemical & Engineering News, Dec. 16, 2011. http://cenblog.org/cleantech-chemistry/2011/12/advanced-biofuels-pipedream-or-solid-investment/ (last access 12/3/0/2011).

Bomgardner, M. (2011c): *US Cleantech firms in white-knuckle mode*. Chemcial & Engineering News, Dec. 7, 2011. http://cenblog.org/cleantech-chemistry/ (last access 12/202011).

Bomgardner, M. (2011d): *Algae Plans Bloom*. Chemical & Engineering News, Jul. 18, 2011. http://cen.acs.org/articles/89/i29/Algae-Plans-Bloom.html (last access Jul. 26, 2011).

Bomgardner. M. (2011e): *Making Rubber From Renewables*. Chemical & Engineering News 89 (50), Dec. 12, 2011, 18-19. http://cen.acs.org/articles/89/i50/Making-Rubber-Renewables.html (last access 12/15/2011).

Bomgardner, M. (2011f): *Genomatica To Go Public*. Chemical & Engineering News 89 (35), Aug. 29, 2011, 8. http://pubs.acs.org/cen/news/89/i35/8935notw7.html (last access 9/2/2011).

Bomgardner, M. (2011g): *BioAmber Files For $150 Million IPO*. Chemical & Engineering News 89, Nov. 15, 2011. http://cen.acs.org/articles/89/web/2011/11/BioAmber-Files-150-Million-IPO.html (last access 11/30/2011).

Bomgardner, M. M. (2011h): *Renewable Chemicals: OPX collaborates with Dow for biobased acrylic acid.* Chemical & Engineering News 89 (16), Apr. 18, 2011, 9. http://pubs.acs.org/cen/news/89/i16/8916notw5.html (last access 4/22/2012).

Bomgardner, M.(2011i): *Intermediates Start-ups Star in Green Chemistry*. Chemical & Engineering News, Jun. 20, 2011. http://cenblog.org/cleantech-chemistry/2011/06/intermediates-start-ups-star-in-green-chemistry/ (last access 8/28/2011).

Bonstetter, R.; Bonnstetter, B. J.; DeAnne, P. (2010): *Do you have what it takes to be a serial entrepreneur?* Target Training Systems, Ltd. 2010. http://www.perpetualdevelopment.com/files/serial-entrepreneurs.pdf (last access 11/5/2010.

Bordt, M.; Earl, L.; Lonmo, C.; Joseph, R. (2004): *Characteristics of Firms that Grow from Small to Medium Size – Growth Factors-Interviews and Measurability*. Statistics Canada, Science, Innovation and Electronic Information Division, Working Paper, Catalogue no. 88F0006XIE – No. 021, December 2004. http://publications.gc.ca/Collection/Statcan/88F0006X/88F0006XIE2004021.pdf (last access 7/7/2008).

Bosma, N.; Acs, Z. J.; Autio, E.; Coduras, A.; Levie, J. (2009): *Global Entrepreneurship Monitor – 2008 Executive Report*. http://www.gemconsortium.org/download/1250171096411/GEM_Global_08.pdf (last access 8/13/2009).
The Global Entrepreneurship Monitor (GEM): http://www.gemconsortium.org/.

Bosma, N.; Levie, J. (2010): *Global Entrepreneurship Monitor – 2009 Executive Report.* http://www.gemconsortium.org/download/1280664967554/GEM%202009%20Global%20Report%20Rev%20140410.pdf (last access 7/31/2010).

Bosma, N.; Harding, R. (2007): *Global Entrepreneurship Monitor – GEM 2006 Summary Results.* http://www.gemconsortium.org/download/1319374624384/GEM_2006_Global_Results_Summary_V2.pdf (last access 12/1/2007).

Böhme, H. (2008): *The New OLED Generation*. Deutsches Eigenkapitalforum 2008 Technology & Industrial Forum, file of 11/11/2008. http://www.eigenkapitalforum.com/082/presentations/f2/Company%20Presentation%20Novaled.pdf (last access 12/12/2010).

BP (2006): *BP Pledges $500 Million for Energy Biosciences Institute and Plans New Business to Exploit Research*. Release Jun. 14, 2006. http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7018719 (last access 11/10/2009).

BP (2007): *BP and D1 Oils Form Joint Venture to Develop Jatropha Biodiesel Feedstock*. Press Release, Jun. 29, 2007.

http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7034453 (last access 11/7/2009).

BP (2009): *BP and Verenium Form Leading Cellulosic Ethanol Venture to Deliver Advanced Biofuels*. http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7051362 (last access 12/7/2009).Birgeneau, R. (2007): *Energy Biosciences Institute*. Berkeleyan, Feb. 08, 2007. http://cio.chance.berkeley.edu/chancellor/Birgeneau/remarks/2-8-07-ebi.htm (last access 11/10/2009).

Brandon, G. – European Commission – Enterprise Directorate (2003): *General European Trend Chart on Innovation.* Thematic Report: Start-up of Technology-Based Firms. Covering period: October 2002 – September 2003. From INBIS Ltd, File TR_ntbfs_september_2003.pdf (last access 5/11/2010).

Brightman, J. (2011): O*nline Games Market to Nearly Double to $29 Billion by 2016*. Industry Gamers, posted Jun. 23, 2011. http://www.industrygamers.com/news/online-games-market-to-nearly-double-to-29-billion-by-2016/ (last access 9/26/2011).

Breuer, R. (2009): *Carpe Diem – Interview mit Klaus Tschira*. Spektrum der Wissenschaft, Apr. 2009, 66-67. File sdw_2009_4_S66[1].pdf download from http://www.google.com/url?sa=t&source=web&cd=3&ved=0CBoQFjAC&url=http%3A%2F%2Fwww.wissenschaft-online.de%2Fartikel%2F986552&rct=j&q=%22carpe%20diem%22%20tschira%20wissenschaft%202009&ei=06ZbTOeiBYiBOOKO8dYP&usg=AFQjCNG0wOHTJJwPcZi1rq93xEmzkmNdIg&cad=rjt (last access 8/3/2010).

Brooks, D. (2011): *The Modesty Manifesto*. Aspen Ideas Festival in Aspen, Colo., Jun., 29, 2011. http://www.aifestival.org/session/modesty-manifesto (last access 7/1/2011); The New York Times, Mar. 10, 2011. http://www.nytimes.com/2011/03/11/opinion/11brooks.html (last access 3/11/2011).

Brooks, D. (2009a): *Yanks in Crisis*. The New York Times, Apr. 23, 2009. http://www.nytimes.com/2009/04/24/opinion/24brooks.html?_r=2&ref=todayspaper (last access 4/24/2009).

Brooks, D. (2009b): *The Nation of Futurity*. The New York Times, Nov. 16, 2009. http://www.nytimes.com/2009/11/17/opinion/17brooks.html?_r=1&hp (last access 11/17/2009).

Brosin, A. (2011): *Erschießen erlaubt, betäuben verboten - Aus Stasi-Akten: Forscher schlug dem MfS 1986 Betäubung von Mauer-Flüchtlingen vor, aber der Stasi war scharfe Munition lieber (Shooting allowed, to stun banned – Researcher suggested to the Stasi in 1986 stunning wall-refugees, but the Stasi preferred live ammunition*). Der Bundesbeauftragte für die Unterlagen des Staatssicherheitsdienstes der ehemaligen Deutschen Demokratischen Republik (BStU), http://www.bstu.bund.de/DE/BundesbeauftragteUndBehoerde/Aktuelles/2011_05_27_ardenne_betaeubung.html (last access 9/9/2012).

Brush, C.G.; Gieene, P. G.; Hait, M. M. (2001): *From initial idea to unique advantage: The entrepreneurial challenge of constructing a resource base*. IEEE Engineering Management Review 30 (1), :64-78 (2001)

Buchanan, L. (2011): *How Great Entrepreneurs Think*. Inc. Magazine, Feb. 1, 2011. http://www.inc.com/magazine/20110201/how-great-entrepreneurs-think.html (last access 4/5/2011).

Buckman, R. (2008): *Venture Capital's Coming Collapse*. Forbes, Dec. 18, 2008, Forbes Magazine, Jan 12, 2009. http://www.forbes.com/forbes/2009/0112/066.html (last acces 1/12/2009).

Buley, T. (2010): *Mark Zuckerberg – Richer Than Ever With An Estimated $4 Billion*. Forbes, Mar. 10, 2010. http://blogs.forbes.com/velocity/2010/03/10/mark-zuckerberg-richer-than-ever-with-an-estimated-4-billion/ (last access 4/2/2010).

Bullis, K. (2006): *The Methanol Economy – Forget about the hydrogen economy. Methanol is the key to weaning the world off oil. George Olah tells us how to do it*. Technology Review, Mar. 2, 2006. http://www.technologyreview.com/biztech/wtr_16466,296,p1.html?a=f (last access 1/22/2010); cf. also http://en.wikipedia.org/wiki/Methanol_economy.

Bullis, K. (2007): *Will Cellulosic Ethanol Take Off? Fuel from grass and wood chips could be big in the next 10 years – if the government helps*. Technology Review, Feb. 26, 2007. http://www.technologyreview.com/Energy/18227/?a=f (last access 11/27/2009).

Bullis, K. (2008a): *Fuel from Algae – A startup's new process could make fuel from algae as cheap as petroleum*. Technology Review, Feb. 22, 2008. http://www.technologyreview.com/Biztech/20319/ (last access 12/28/2009)

Bullis, K. (2008b): *Cheaper Butanol from Biomass. A startup has raised $25 million for inexpensively producing biofuel*. Technology Review, Oct. 27, 2008. http://www.technologyreview.com/business/21602/ (last access 12/30/2009).

Bullis, K. (2012a*): Sapphire Energy Raises $144 Million for an Algae Farm*. Technology Review, Apr. 6, 2012. http://www.technologyreview.com/energy/40073/ (last access 5/3/2012).

Bullis, K. (2012b): *Amyris Gives Up Making Biofuels*: *Update*. Technology Review, Feb. 10, 2012. http://www.technologyreview.com/blog/energy/27570/ (last access 2/19/2012).

Burmeister, K.; Schade, C. (2007)): *Are entrepreneurs' decisions more biased? An experimental investigation of the susceptibility to status quo bias*. Journal of Business Venturing 22, 340–362. http://opim.wharton.upenn.edu/risk/library/J2007JBV_KBur,CSchade_Entrepreneurs.pdf (last access 7/12/2010).

Burkeman, O. (2012): *The Power of Negative Thinking*. Wall Street Journal, Dec. 7, 2012. http://online.wsj.com/article/SB10001424127887324705104578147333270637790.html?mod=WSJ_MostPopular_Europe (last access 12/20/2012).

Burns, E. (2006): *Online Games Market to Hit $4.4 Billion by 2010*. ClickZ, Aug. 30, 2006. http://www.clickz.com/clickz/stats/1707790/online-games-market-hit-usd44-billion-2010 (last 9/26/2011).

Burtis, P. A. with Epstein, B. and Parker, N. (2006): *Creating Cleantech Clusters – 2006 Update*. E2 and cleantech VENTURE NETWORK, May 2006. http://www.e2.org/ext/doc/2006%20National%20Cleantech%20FORMATTED%20FINAL.pdf (last access 5/17/2010).

Business Week (2006*): Mistakes Made On The Road To Innovation.* Business Week, Nov. 27, 2006. http://www.businessweek.com/magazine/content/06_48/b4011421.htm (last access 7/31/2010).

Business Week (2005): *The Man Who Invented Management – Why Peter Drucker's ideas still matter*. Business Week, Front Cover, Nov. 28, 2005. http://www.businessweek.com/magazine/content/05_48/b3961001.htm (last access 5/30/2006).

Busse, J. (2011): *U.S. Firms, China Are Locked in Major War Over Technology* . Wall Street Journal, Feb. 2, 2011. http://online.wsj.com/article/SB10001424052748703439504576116152871912040.html (last access 2/2/2011).

Butler, J. E., Ed. (2004): *Opportunity Identification and Entrepreneurial Behavior*. A Volume in Research in Entrepreneurship and Management. Information Age Publishing, Inc. 2004.

Cain Miller, C. (2009): *Venture Capitalists Look for a Return to the A B C's.* The New York Times, Jul. 6, 2009. http://www.nytimes.com/2009/07/07/technology/start-ups/07venture.html?ref=todayspaper (last access 7/7/2009).

Campbell, J. (2007): *Science, Engineering, and Systems*. Lecture 2, Part 1, CSC340 - Winter 2007. http://www.cdf.toronto.edu/~csc340h/winter/lectures/w2/L2part1-4up.pdf (last access 8/11/2010.

Canada, A. (2009): *Company Growth Through Opportunity Maps*. Business Week, Feb. 9, 2009. http://www.businessweek.com/innovate/content/feb2009/id2009029_618352.htm?chan=innovation_innovation+%2B+design_innovation+strategy (last access 5/18/2010).

Carayannis, E. G.; Alexander, J.; Hausler, D.: *Government-University-Industry Partnerships*. Reference for Business. http://www.referenceforbusiness.com/management/Ex-Gov/Government-University-Industry-Partnerships.html (last access 6/4/2010).

Cardwell D. (2012): *Solazyme and Bunge Plan Factory to Make Oil From Algae*. The New York Times, Apr. 3, 2012. http://green.blogs.nytimes.com/2012/04/03/solazyme-and-bunge-plan-factory-to-make-oil-from-algae/ (last access 4/20/2012).

Carey, J. (2009): *The Biofuel Bubble*. Business Week, Apr. 16, 2009. http://www.businessweek.com/magazine/content/09_17/b4128038014860.htm?chan=top+news_top+news+index+-+temp_top+story (last access 4/18/2009).

Carlson, N. (2010): *How Mark Zuckerberg Hacked Into Rival ConnectU In 2004*. Business Insider, Mar. 5, 2010. http://www.businessinsider.com/how-mark-zuckerberg-hacked-connectu-2010-3 (last access 7/27/2010);
Carlson, N. (2010): *At Last – The Full Story Of How Facebook Was Founded*.

Business Insider, Mar. 5, 2010. http://www.businessinsider.com/how-facebook-was-founded-2010-3 (last access 7/27/2010).

Carroll, D. J. (2005): *Distributed R&D Case Study: InnoCentive. Managing Innovation: Emerging Trends*. Massachusetts Institute of Technology, Mar. 3, 2005. http://ocw.mit.edu/courses/sloan-school-of-management/15-352-managing-innovation-emerging-trends-spring-2005/lecture-notes/mit_mar07_2005.pdf (last access 9/24/2010).

Carter, R.; van Auken, H. (2006): *Small Firm Bankruptcy*. Journal of Small Business Management 44 (4), 493-512. http://www.allbusiness.com/management-companies-enterprises/3897245-1.html (last access 12/13/2010).

Casselman, B. (2009): *U.S. Gas Fields Go From Bust to Boom*. Wall Street Journal, Apr. 30, 2009. http://online.wsj.com/article/SB124104549891270585.html (last access 4/30/2009).

CeGaT (2012): *CeGaT– Center for Genomics and Transcriptomics*. Presentation, August 2012. http://www.cegat.de/files/CeGaT_Presentation.pdf; cf. also the German Founders' Award ("Deutscher Gründerpreis"), http://www.deutscher-gruenderpreis.de/owx_1_3619_1_5_0_00000000000000.html (last access 6/25/2011).

Chandler, G. N.; DeTienne, D.; Lyon, D. W. (2004): *Outcome Implications of Opportunity Creation / Discovery Processes*. Babson College, last updated May 2004. http://www.babson.edu/entrep/fer/BABSON2003/XVI/XVI-P1/XVI-P1.html (last access 10/8/2009).

Chandler, G. N.; Hanks, S. H. (1993): *Market attractiveness, resource-based capabilities, venture strategies, and venture performance*. Journal of Business Venturing 9, 331-349.

Charlton, B. (2005): *From inspiration to reality*. The Plain Dealer, Aug. 3, 2005. http://www.nanofilmtechnology.com/news/pdf/05AU01.pdf (last access 8/25/2009).

ChemSystems (2010): *Adipic Acid*. ChemSystems PERP Program, PERP 08/09, Feb. 2, 2010. http://www.chemsystems.com/reports/search/docs/abstracts/0809_2_abs.pdf (last access 6/2/2012).

Chen, M.-C.; Chang, Y.-C.; Chen, T.-M. (2004): *Entrepreneurial Leadership, Team Creativity, and New Venture Performance in Taiwan's SME Start-Ups*. Created: Nov. 23, 2004. http://www.yzu.edu.tw/admin/rd/files/rdso/G04/93/G04061(1).doc (last access 7/27/2010), and references therein.

Chernova, Y.; Ramsey, M. (2013): *How the Wheels Came Off for Fisker*. Wall Street Journal, updated April 24, 2013. http://online.wsj.com/article/SB10001424127887324874204578440640183079794.html?KEYWORDS=fisker+automotive (last access 4/29/2013).

Childs, D. (2007): *Diversa and Celunol become Verenium*. Cleantech News, Jun. 21, 2007. http://cleantech.com/news/1355/diversa-and-celunol-become-verenium (last access 12/1/2009).

Choia, K. S.; Deekb, F. P.; Imc, I. (2009): *Pair dynamics in team collaboration*. Computers in Human Behavior 25 (4), Jul. 2009, 844-852. Abstract and References:

http://portal.acm.org/citation.cfm?id=1551441&dl=GUIDE&coll=GUIDE&CFID=98428695&CFTOKEN=58683947.

Choia, K. S.; Deekb, F. P.; Imc, I. (2008): *Exploring the underlying aspects of pair programming: The impact of personality.* Information and Software Technology 50 (11), 1114-1126. Abstract and References: http://portal.acm.org/citation.cfm?id=1405313&dl=GUIDE&coll=GUIDE&CFID=98428695&CFTOKEN=58683947.

CHOREN (2010): *Launch of first BTL project in France using Carbo-V technology from CHOREN – Signature of EPC agreement for 45-MW synthesis gas plant*. Press Release, Jan. 29, 2010. http://www.choren.com/en/choren_industries/information_press/press_releases/?nid=216 (last access 5/6/2010).

Christensen, C. M. (1997): *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Harvard Business School Press.

CI – Corporate Information (2009): *Bluefire Ethanol Fuels, Incorporation, Company Snapshot*. http://www.corporateinformation.com/Company-Snapshot.aspx?cusip=09622L102 (last access 1/8/2010).

Clanton, B. (2009): *Biofuels – CEO envisions a Gulf Coast algae boom*. Houston Chronicle, Aug. 8, 2009. http://www.chron.com/disp/story.mpl/business/energy/6565247.html (last access 2/2/2010).

CleanTech Group (2009): *Clean technology venture investment reaches record $8.4 billion in 2008 despite credit crisis and broadening recession*. Jan. 6, 2009 http://cleantech.com/about/pressreleases/010609.cfm (last access 5/18/2010); CleanTech Group (2009): *Clean technology venture investment totaled $5.6 billion in 2009 despite non-binding climate change accord in Copenhagen*, The Cleantech Group and Deloitte. Jan. 6, 2009 http://cleantech.com/about/pressreleases/20090106.cfm (last access 5/18/2010).

CNN (2010): *Algenol Partners With Lee County as Commission Votes to Approve Incentive Funding for Florida-Based Biofuels and Green Chemistry Facility*. CNNMoney.com, Feb. 3, 2010. http://money.cnn.com/news/newsfeeds/articles/prnewswire/DC48946.htm; http://www.news-press.com/article/20100202/GREEN/2020356/1075/Lee-County-approves-biofuel-facility (last access 2/2/2010).

Cocke, S. (2011): *HR BioPetroleum buying Shell's shares in Cellana.* Pacific Business News, Jan. 27, 2011. http://www.bizjournals.com/pacific/news/2011/01/27/hr-biopetroleum-buying-shells-shares.html (last access 7/7/2011).

Colao, J. J. (2013): *How Bad Is It At LivingSocial? PrivCo Claims 94% Of Value Wiped Out*. Forbes, Feb. 21, 2013. http://www.forbes.com/sites/jjcolao/2013/02/21/how-bad-is-it-at-livingsocial-privco-claims-94-of-value-wiped-out/ (last access 2/23/2013).

Collins, J.; Porras, J. (1996): *Building your company's vision*. Harvard Busimess Review, September 1996, 65-77.

http://www.intenz.dk/fileadmin/user_upload/Danske/Downloads/built_to_last_-_sammendrag_paa_engelsk.pdf (last access 8/23/2010).

Conner, K. R.; Prahalad, C. K. (1996): *A resource-based theory of the firm: Knowledge versus opportunism.* Organization Science 7(5), 477-501.

Contag, P. (2008a): *The Challenge for Biofuels*. Innovation, Vol. A (1), Special Issue 2008/2009. http://www.innovation-america.org/archive.php?articleID=495 (last access 1/29/2010).

Contag, P. (2008b): *Cobalt Biofuels*. In The 21st Industry Growth Forum. Transitioning Today's Energy to Tomorrow's Clean Energy. Denver, Colorado October 28-30, 2008. http://www.nrel.gov/technologytransfer/pdfs/igf21_cobalt_biofuels.pdf (last access 1/29/2010).

Cooney, T. M. (2005): *Editorial: what is an entrepreneurial team?* International Small Business Journal 23 (3), 226-235. http://goliath.ecnext.com/coms2/gi_0199-4370493/Editorial-what-is-an-entrepreneurial.html (last access 8/5/2010), and references herein.

Coval, J. D.; Jurek, J.; Stafford, E. (2008): *The Economics of Structured Finance*. Harvard Business School, Working Paper 09-060; 2008. http://www.hbs.edu/research/pdf/09-060.pdf (last access 9/12/2011).

Cowling, M.; Murray, G.; Fryges, H.; Licht, G. (2007): *The survival and growth of "adolescent" high-tech firms in Germany and the UK, 1997-2003*. Anglo-German Foundation for the Study of Industrial Society, January 2007. http://www.employment-studies.co.uk/summary/summary.php?id=agfsis07 (last access 7/10/2009).

Cramer, B. (2008): *More start-ups using credit cards as financing*. Published Jun. 27, 2008. http://canada.creditcards.com/credit-card-news/credit-cards-startup-funds-1269.php (last access 9/15/2009).

Creditreform – KfW – ZEW (2009): *Fahrt aufnehmen in stürmischen Gewässern - Chancen und Herausforderungen in der Entwicklung junger Unternehmen (Speeding in a stormy sea – Chances and challenges of developing young firms).* KfW – ZEW Gründungspanel 2, Oct. 2009. ftp://ftp.zew.de/pub/zew-docs/gruendungspanel/KfW_ZEW_Gruendungspanel_102009.pdf (last access 7/17/2010).

Crooks, E. (2009): *Shell reins back expectations for use of biofuels*. Financial Times, Nov. 30, 2009. http://www.ft.com/cms/s/0/d963b164-dd4e-11de-ad60-00144feabdc0.html (last access 12/18/2009).

Crowley, I. F.; Trudeau, J. R. (2011):*Wernher von Braun – An Ethical Analysis*. Document of 12/20/2011. http://www.wpi.edu/Pubs/E-project/Available/E-project-121811-161339/unrestricted/von_Braun_IQP_12_20_2011_bw_final.pdf (last access 1/9/2012).

CrunchBase (2009a): *Khosla Ventures*. Last edited Dec. 5, 2009. http://www.crunchbase.com/financial-organization/khosla-ventures (last access 11/30/2009).

CrunchBase (2009b): *Solazyme*. Last edited 12/8/2009. http://www.crunchbase.com/company/solazyme (last access 1/24/2010.

CrunchBase (2009c): *Sapphire Energy*. Last edited 12/7/2009. http://www.crunchbase.com/company/sapphire-energy (last access 3/13/2010).

Cyert, R.M.; March, J. G. (1963): *A Behavioral Theory of the Firm*. Prentice-Hall, Englewood Cliffs NJ.

Dankbar, C. (2011): *Familienfirma – Preußisch Blau für Fukushima (Family firm – Prussian Blue for Fukushima).* Berliner Zeitung, Apr. 11, 2011. http://www.berlinonline.de/berliner-zeitung/berlin/339892/339893.php (last access 5/4/2011); also http://www.handelsblatt.com/technologie/forschung-medizin/medizin/ein-medikament-gegen-caesium/3980270.html (last access 3/23/2011).

Daly, J. W. (2010): *China spy scare: hypocrisy is spelled Echelon – Or, why allies spy on each other*. TechEye.net, Feb. 22, 2010. http://news.techeye.net/security/china-spy-scare-hypocrisy-is-spelled-echelon (last access 4/23/2011).

Daniel Meier Medienteam (2010): *Mikroalgen – klimafreundliche Alleskönner (Climate-friendly all-rounders*). Landesinitiative Ernährungswirtschaft, Feb. 22, 2010. http://www.ernaehrungswirtschaft.de/index.php?con_cat=49&con_art=716&con_lang=1&sid=6r1iqoqav7ap75b03dld2965v3 (last access 3/16/2010).

DAPD (2011): *Linde kauft Biomasse-Sparte von insolventer Freiberger Firma Choren (Linde purchases the biomass business of the insolvent firm CHOREN in Freiberg*). Freie Presse, Feb. 9, 2012. http://www.freiepresse.de/NACHRICHTEN/SACHSEN/Linde-kauft-Biomasse-Sparte-von-insolventer-Freiberger-Firma-Choren-artikel7900426.php (last access 2/15/2012).

Das, A. (2009): *Venture capitalists see clean-tech opportunity*. The New York Times, Jan. 9, 2009. http://www.nytimes.com/2008/01/09/business/worldbusiness/09iht-rtrinvest10.1.9096682.html (last access 11/20/2009).

Davis, A.; Russell. G. (2009): *U.S. Biofuel Boom Running on Empty*. Wall Street Journal, Aug. 27, 2009. http://online.wsj.com/article/SB125133578177462487.html (last access 8/27/2009).

De Guzman, D. (2012a): *LS9 prepares fatty alcohol sales* . ICIS Green Chemicals, Feb. 23, 2012. http://www.icis.com/blogs/green-chemicals/2012/02/ls9-prepares-fatty-alcohol-sal.html (last access 5/2/2012).

De Guzman, D. (2012b): *BASF invests in Renmatix*. ICIS Green Chemicals, Jan. 4, 2012. http://www.icis.com/blogs/green-chemicals/2012/01/basf-invests-in-renmatix.html (last access 1/ 30/2012).

De Guzman, D. (2012c): *First 2012 post: OPXBio update*. ICIS Green Chemicals, Jan. 1, 2012. http://www.icis.com/blogs/green-chemicals/2012/01/first-2012-post-opxbio-update.html (last access 2/5/2012).

De Guzman, D. (2012d): *Genomatica Withdraws IPO*. ICIS Green Chemicals, Aug. 2, 2012. http://www.icis.com/blogs/green-chemicals/2012/08/genomatica-withdraws-ipo.html (last access 17/10/2012).

De Guzman, D. (2011a): *Bio-lubes in the spotlight*. ICIS Green Chemicals, Apr. 13, 2011. http://www.icis.com/blogs/green-chemicals/2011/04/bio-lubes-in-the-spotlight.html (last access 8/13/2011).

De Guzman, D. (2011b): *BioAmber picks Ontario for new plant*. ICIS Green Chemicals, Sep. 1, 2011. http://www.icis.com/blogs/green-chemicals/2011/09/bioamber-picks-ontario-for-new.html (last access 10/23/2011).

De Guzman, D. (2011c): *Getting to know Renmatix*. ICIS Green Chemicals, Dec. 2, 2011. http://www.icis.com/blogs/green-chemicals/2011/12/getting-to-know-renmatix.html (last access 6/3/2012).

De Guzman, D. (2009): *Industrial Biotech Interview: Verdezyne*. ICIS Green Chemicals, Aug. 17, 2009. http://www.icis.com/blogs/green-chemicals/2009/08/industrial-biotech-interview-v.html (last access 9/3/2010).

Del Cardayre, S. (2009): *Introduction to LS9*. Conference Presentation, 2009. http://cleantech.com/documents/forums/2009/xxi_san_francisco/presentations/sector_leaders/LS9ConferencePresentation_gnp.pdf (last access 2/18/2010).

DeBruicker, J. (2006): *No. 13 Google: The Search Ended Here*. Business Week, Sep. 18, 2006. http://www.businessweek.com/magazine/content/06_38/b4001608.htm (last access 2/7/2008).

DeFrancesco, L. (2004): *Company founders: voices of experience – Interviews with nine leading scientists who founded startup companies*. Nature, published online Mar. 22, 2004. http://www.nature.com/bioent/2004/040301/full/bioent796.html (4/24/2008).

Della Vedova, B. (2009): *Bio-Fueling a Trade War. In Europe, protectionism passes as environmentalism.* Wall Street Journal, Aug. 3, 2009. http://online.wsj.com/article/SB10001424052970204313604574328533995657764 (last access 8/5/2009).

Den Hartigh, E.; Langerak, F.; Commandeur, H. R. (2002): *The Effects of Self-Reinforcing Mechanisms on Firm Performance*. April 2002. http://publishing.eur.nl/ir/repub/asset/200/erimrs20020517092944.pdf (last access 10/20/2010).

Dencker, J. C.; Grubery, M.; Shah, S. K. (2007): *Knowledge Acquisition Activities, Prior Knowledge and Experience & the Survival of New Firms*. In Frontiers of Entrepreneurship Research 27 (5), Chapter V – Entrepreneur Characteristics. Digital Knowledge at Babson - http://digitalknowledge.babson.edu/cgi/viewcontent.cgi?article=1011&context=fer (last access 9/21/2010).

Denk, J. E. (2012): *This Is Your Brain On The Goldberg Variations*. March 22, 2012. http://www.npr.org/blogs/deceptivecadence/2012/03/22/149148529/this-is-your-brain-on-the-goldberg-variations (last access 5/15/2013)/;
Variations in Music: http://en.wikipedia.org/wiki/Goldberg_Variations; http://en.wikipedia.org/wiki/Piano_Sonata_No._11_(Mozart).

Dew, N. (2009): *Serendipity in Entrepreneurship*. Organization Studies 30 (7), 735-753.

Dinjus, E.; Dahmen, N.; Koerber, R. (2008): *Synthetic Fuel from biomass – The bioliq process*. IFAT China 2008, Shanghai. http://media.nmm.de/34/ic08_fuelfrombiomass-thebioliq-process_dr.rainerkoerber_21062234.pdf (last access 12/18/2009).
Dahmen, N (2009): *Combining industrial scale biosynfuel production with economic*

biomass logistics. ITC-CPV, Jan. 13, 2009. http://www.biofuelstp.eu/spm2/pdfs/Nicolaus_Dahmen_Armin_Gunther.pdf (last access 12/18/2009).

DiStefano, J. N. (2009): *PhillyDeals: Solazyme gets grant for biorefinery project in Pa*. Philadelphia Business Today, Dec. 8, 2009. http://www.philly.com/philly/business/78748952.html (last access 1/23/2010).

Djokovic, D.;Souitaris, V. (2008): *Spinouts from academic institutions – A literature review with suggestions for further research*. The Journal of Technology Transfer 33 (3), 225-247.

DOE – US Department of Energy (2006): *Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda*. A Research Roadmap Resulting from the Biomass to Biofuels Workshop, December 7–9, 2005, Rockville, Maryland. Publication Date: June 2006; DOE/SC-0095. http://genomicsgtl.energy.gov/biofuels/2005workshop/b2blowres63006.pdf (last access 12/9/2009).

DOE – US Department of Energy (2009): *DOE Issues – RFI on Draft National Algal Biofuels Technology Roadmap*. Green Car Congress, Jun. 4, 2009. http://www.greencarcongress.com/2009/06/algal-roadmap-20090604.html (last access 12/23/2009); Draft: National Algal Biofuel Roadmap: https://e-center.doe.gov/iips/faopor.nsf/UNID/79E3ABCACC9AC14A852575CA00799D99/$file/AlgalBiofuels_Roadmap_7.pdf (last access 12/23/2009).

Dolan, K. A. (2008): *Mr. Ethanol Fights Back*. Forbes Magazine, Nov. 24, 2008. http://www.forbes.com/forbes/2008/1124/052.html (last access 10/24/2009).

Donner, S. (2011): *Biosprit aus Kohlendioxide (Biofuels from carbon dioxide*). Technology Review, Feb. 16, 2011. http://www.heise.de/tr/artikel/Biosprit-aus-Kohlendioxid-1190439.html (last access 11/25/2011).

Dorf, R. C.; Byers, T. H. (2007): *Technology Ventures: From Idea to Enterprise*. McGraw Hill, New York (2nd Ed. with DVD; January 11, 2007) – emphasis on information & communication technology including software and electronics.

Downing, J. (2007): *Natural entrepreneur - Her dream is creating, selling biopesticides for organic farming.* The Sacramento Bee, Jun. 17, 2007. http://www.sacbee.com/103/story/225408.html (last access 7/15/2007); http://marronebioinnovations.com/pdf/TheSacBeeJune17-2007-NaturalEnt.pdf (last access 8/17/2010).

Dröscher, M. (2008): *Chemical Entrepreneurship – New Business Development in der Industrie – Beispiel Evonik Chemicals (Chemical Entrepreneurship – New Business Development in Industry – Example Evonik Chemicals)*. Presentation Technology Entrepreneurship, Jan. 9, 2008. http://ce.ioc.KIT.edu/download/Droescher_Karlsruhe20080109.pdf.

Drucker, P. F. (1964): *Managing for Results*. New York: Harper and Row Publishers, New York.

Drucker, P. F. (1995): *Innovation and Entrepreneurship: Practice and Principles*. Reprint from 1985, Harper & Row Publishers, New York.

Drucker, P. F. (2002): *Managing the Next Society*. The Four Entrepreneurial Pittfalls, 96-103. St. Martins Press, "Truman Talley Books," 2002.
Rich Karlgaard (2004): *Peter Drucker On Leadership – Copied from Forbes with some format editing and notes added.* Forbes, Nov. 19, 2004. http://www.forbes.com/2004/11/19/cz_rk_1119drucker.html?partner=rss (last access 12/21/2010).

DTB – Deutsche Biogas AG (2011): *DTB – Deutsche Biogas AG baut Forschung und Entwicklung aus (Deutsche Biogas AG expands research and development*). http://www.presseportal.de/pm/82738/2004391/dtb-deutsche-biogas-ag-baut-forschung-und-entwicklung-aus (last access 5/23/2011).

Dziersk, M. (2008): *Design Thinking ... What is That*? Fast Company, Jul. 8, 2008. http://www.fastcompany.com/resources/design/dziersk/design-thinking-083107.html (last access 10/10/2009).

E.ON (2008): *Pilotanlage in Hamburg-Reitbrook*. E.ON Hanse, Press Release http://www.eon-hanse.com/pages/eha_de/Engagement/Mikroalgenprojekt_Hamburg/Pilotanlage_in_Hamburg-Reitbrook/index.htm (last access 1/25/2010).

Ebert, J. (2008): *Biobutanol: The Next Big Biofuel?* Biomass Magazine, May 2008. http://www.biomassmagazine.com/article.jsp?article_id=1605&q=&page=all (last access 10/30/2009).

Eckhaus, C. (2009): *Solazym*. Independent Search Consultant / Director Human Resources, Activities at Solazyme. http://www.linkedin.com/pub/christine-eckhaus/4/447/6a4 (last access 1/25/2010).

Eckmann, T. (2008): *Bootstrapping Your Start-Up*. File from 7/26/2008. http://bschool.washington.edu/cie/PDF/Bootstrapping_Your_Startup-Eckmann.ppt (last access 11/23/2009).

Ecofusion: Case Study: *Cobalt Biofuels – Introducing a New Fuel Solution*. http://www.ecofusion.com/case-studies/cobalt-biofuels.html (last access 1/28/2010).

EcoFys (2006): *Methanol plant takeover to bring bio-methanol production to Delfzijl*. Press release, Nov. 2, 2006. http://ecofys.com/com/news/pressrelease2Nov2006.htm (last access 1/19/2010).

Econo Editor WST (2007): *Bokela - Wer hat's erfunden*? *Die Karlsruher* (Who did invent it – People from Karlsruhe). Econo, 1/2007 – Dec. 29, 2006, Technologieregion Karlsruhe, page 9. http://www.econo-online.de/dynamic/bildgalerie/08_trkx5.pdf (last access 11/13/2010).

Edible Apple (2011): *From Alan Kay's Dynabook to the Apple iPad*. Edible Apple, Apr. 30, 2010. http://www.edibleapple.com/from-alan-kays-dynabook-to-the-apple-ipad/ (last access 2/17/2011).

EERE – U.S. Department of Energy – Energy Efficiency and Renewable Energy (2008): Oil *Companies, Universities Investigate Alternate Paths to Biofuels*. EERE News, Apr. 16, 2008. http://www1.eere.energy.gov/industry/distributedenergy/printable_versions/news_detail.html?news_id=11710 (last access 11/23/2009).

Effectuation.org: *About Effectuation*. http://www.effectuation.org/about-effectuation; http://en.wikipedia.org/wiki/Effectuation; http://de.wikipedia.org/wiki/Effectuation.

Efrati, E. (2013): *At 17, App Builder Rockets to Riches From Yahoo Deal*. Wall Street Journal, updated Mar. 26, 2013. http://online.wsj.com/article/SB10001424127887323605404578382243461824094.html?mod=WSJ_MostPopular_Europe (last access 3/26/2013).

Egeln, J.; Gottschalk, S.; Rammer, J.; Spielkamp, A. (2002): *Spinoff-Gründungen aus der öffentlichen Forschung in Deutschland (Spin-off foundations from public research in Germany).* Zentrum für Europäische Wirtschaftsforschung GmbH (ZEW), Gutachten für das Bundesministerium für Bildung und Forschung (Report to BMBF), Document 03/02, Nov. 2002. ftp://ftp.zew.de/pub/zew-docs/docus/dokumentation0302.pdf (last access 6/3/2010).

Egeln, J.; Falk, U.; Heger, D.; Höwer, D.; Metzger, G. (2010): *Ursachen für das Scheitern junger Unternehmen in den ersten fünf Jahren ihres Bestehens (Reasons for failure of young enterprises within the first five years of their existence).* ZEW – Zentrum für Europäische Wirtschaftsforschung, March 2010. ftp://ftp.zew.de/pub/zew-docs/gutachten/Scheitern_junger_Unternehmen_2010.pdf (last access 11/18/2010).

Eicher, C. C. (2012): *Bio hat Zunkunft (Bio has a future*). ADAC Motorwelt 6, June 2012, 45.

EIM (2009): *Study on the representativeness of business organizations for SMEs in the European Union*. EIM Business & Policy Research, Final report, May 2009. http://www.ifm-bonn.org/assets/documents/ENSR_Study_070709.pdf (last access 9/29/2010).

ElectroIQ (2011): *GE crashes CdTe party with record panels, US capacity, M&A*. Published Apr. 8, 2011. http://www.electroiq.com/index/display/photovoltaics-article-display/4741264984/articles/Photovoltaics-World/thin-film_solar_cells/cadmium-telluride/2011/4/ge-crashes_cdte_party.html (last access 5/8/2011).

EnBW (2008): *EnBW untersucht neuartige Algenzucht zur CO2-Bindung (EnBW investigates new algae culture for CO2 binding)).* Press Release, Jul. 16, 2008. http://www.enbw.com/content/de/presse/pressemitteilungen/2008/07/PM_20080716_FE_mw01/index.jsp;jsessionid=0232C3216B17114C0A0DC4B3B7C53DE2.nbw05 (last access 3/17/2010), also http://www.enbw.com/content/de/presse/pressemitteilungen/2009/07/pm_2009_07_17_enbw_subitec_cu_ys1/PM_Eutingen_EnBW_Subitec.pdf (last access 3/16/2010).

Energy Matters (2013): *Bosch To Cease Manufacturing Solar Panels*. Renewable Energy, News. http://www.energymatters.com.au/index.php?main_page=news_article&article_id=3655 (last access Mar. 28, 2013).

Engeler, G. (2008): *Finding Newer, Cleaner Ways to Meet Transportation Energy Needs*. Chevron – Global Downstream Technology, Hong Kong, Sep. 2008. http://www.hkbu.edu.hk/~hkesc/asianenergy/Session%202%20-paper%202.pdf (last access 1/23/2010).

Ensley, M. D.; Carland, J. W.; Carland, J. C. (1998): *The Effect of Entrepreneurial Team Skill Heterogeneity and Functional Diversity on New Venture Performance*.

Journal of Business and Entrepreneurship, Mar. 1998. http://www.sbaer.uca.edu/research/asbe/1998/pdf/09.pdf; http://findarticles.com/p/articles/mi_qa5424/is_199803/ai_n21417164/pg_2/ (last access 8/5/2010).

Erneuerbare Energien – Renewable Energy: *Besondere Windenergiesysteme – Vertikalachsen-Rotoren (Special wind energy systems – Vertical axis turbines)*. http://www.energyprofi.com/jo/Besondere-Windenergiesysteme.html (last access 9/10/2010).

Ernst & Young (2011): *Mittelstandsstudie von Ernst & Young – Mit Innovationen kraftvoll an die Spitze (Study of medium-sized firms of Ernst & Young*). Aachen-euregio.businesson – Das regionale Wirtschaftsportal, Jan. 28, 2011. http://www.business-on.de/aachen-euregio/young-ernst-mitarbeiter-zielen-maerkte-angebot-_id1693.html (last access 2/11/2011).

Esposito, F. (2013): *Biopolymer maker BioAmber raises $80 million in IPO*. PlasticsNews, May 17, 2013. http://www.plasticsnews.com/article/20130517/NEWS/130519929/biopolymer-maker-bioamber-raises-80-million-in-ipo# (last access 5/17/2013).

EU (2006): *Biofuels in the European Union – A vision for 2030 and beyond*. Final draft report of the Biofuels Research Advisory Council, Mar. 3, 2006. http://ec.europa.eu/research/energy/pdf/draft_vision_report_en.pdf (last access 3/31/2010).

European Biodiesel Board (EBB) (2009): *Statistics 2009*. http://www.ebb-eu.org/stats.php (last access 3/11/2009).

European Commission: SME Definition: http://ec.europa.eu/enterprise/enterprise_policy/sme_definition/index_en.htm; http://ec.europa.eu/enterprise/enterprise_policy/sme_definition/sme_user_guide.pdf (last access 7/10/2009).

European Commission – Innovation Directorate (2003): "*Breeding business success.*" Euroabstracts 41(1): 6 (published February 2003). ftp://ftp.cordis.europa.eu/pub/euroabstracts/docs/archive1-03.pdf (last access 02/15/2008); reference to European Communities. 2002. European entrepreneurship training curriculums (ISBN 92 894 3967 X), Luxembourg.

Everts, S. (2008): *Max Planck Society Moves Stateside - Germany's prestigious research society sets up shop in Florida even as it faces criticism at home*. Chemical & Engineering News 86 (9), 12-17. http://pubs.acs.org/cen/coverstory/86/8609cover.html (last access 6/1/2010).

Fahrendorf, T. (2008): *Mikroalgen zur Steigerung der Wertschöpfung an Biogasanlagen durch Aquakultur (Microalgae to increase value capture of biogas plants by aquaculture*). Novagreen Presentation, Jun. 13, 2008.http://www.3-n.info/download.php?file=pdf_files/Vortraege/080613_5-2_fahrendorf_novagreen.pdf (last access 3/16/2010).

Faltin, G. (2007): *Erfolgreich gründen – Der Unternehmer als Künstler und Komponist (Founding Successfully – The entrepreneur as an Artist and Composer)*. © DIHK – Deutscher Industrie und Handelskammertag, April 2007.

Farrell, I, (2013): *Recycling rare earth elements using ionic liquids*. Chemistry World, Mar. 15, 2013. http://www.rsc.org/chemistryworld/2013/03/recycling-rare-earth-neodymium-and-samarium-ionic-liquids (last access 3/27/2013).

Fehrenbacher, K. (2007): *10 Khosla Biofuel Bets*. Earth2tech, posted Oct. 12, 2007. http://earth2tech.com/2007/10/12/10-khosla-biofuel-bets/ (last access 11/24/2009).

Fehrenbacher, K. (2008): *Ethanol Startup Coskata Launches, Backed By General Motors and Khosla*. Earth2tech, posted Jan.13, 2008. http://earth2tech.com/2008/01/13/ethanol-startup-coskata-launches-backed-by-general-motors-and-khosla/ (last access 11/24/2009).

Fehrenbacher, K. (2009): *Cobalt Biofuels Opens Plant; Biobutanol the Next Thing?* Earth2tech, posted Jan. 12, 2010. (last access 1/28/2010).

Fehrenbacher, K. (2011): *Some red flags & numbers in Mascoma's IPO filing*. Gigaom – Earth2tech, Sep. 16, 2011. http://gigaom.com/cleantech/some-red-flags-numbers-in-mascomas-ipo-filing/ (last access 1/24/2012).

Fehrenbacher, K. (2012): *Biofuel startup Renmatix brings on BASF as backer*. Eartth2tech, Jan. 3, 2012. http://gigaom.com/cleantech/biofuel-startup-renmatix-brings-on-basf-as-backer/ (last access 1/ 30/2012).

Feldenkirchen, W.; Hilger, S. (2009): *Menschen und Marken – 125 Jahre Henkel (Men and brands – 125 years Henkel)*. File from 11/7/2009. http://www.henkel.de/de/content_data/177905_MenschenundMarken_125JahreHenkel.pdf (last access 3/18/2011).

Fergerson, W. (2007):*Using Credit Cards: Watch the Fine Print*. http://www.entrepreneurship.gov/ResourcesCenter/Topics/FinanceAndAccounting/13988.html (last access 9/15/2009).

Fertig, N. (2012): *Nanion Technologies – Von der Grundlagenforschung zum global erfolgreichen Unternehmen (Nanion Technology – From basic research to a globally successful enterprise*). Presentation Technology Entrepreneurship, Jan. 15, 2012. http://ce.ioc.KIT.edu/downloads/TH_Karlsruhe_Dr_Fertig1.pdf.

Fier, A.; Fryges, H. (1999): *Tendenz zur Internationalisierung junger Technologieunternehmen* (Tendency of Internationalization of Young Technical Enterprises). Zentrum für Europäische Wirtschaftsforschung, Mannheim. ZEW News, March 1999. ftp://ftp.zew.de/pub/zew-docs/zn/zn0399.pdf (last access 10/4/2010).

Fiet, J. O.; Clouse, V. G. H.; Norton, W. I. (2004): *Systematic Search by Repeat Entrepreneurs*. Chapter 1 in Butler, John E., Ed. (2004): Opportunity Identification and Entrepreneurial Behavior. A Volume in Researrch in Entrepreneurship and Management. Information Age Publishing, Inc. 2004.

Finfacts (2010): *US venture capitalists invested $18bn in 2009; Their European counterparts €4bn*. Finfacts, Sep. 15, 2010. http://www.finfacts.ie/irishfinancenews/article_1020572.shtml (last access 10/24/2010).

FirstMention: *Adsense 1999*. http://firstmention.com/Adsense.aspx (last access 1/29/2012).

Flaig, G.; Stadler, M. (1994): *Success breeds success. The dynamics of the innovation process*. Empirical Economics 19 (1), 55-68.

Forbes (2011): *Forbes 400 Richest Americans. Jim Breyer*. http://www.forbes.com/profile/jim-breyer/ (last access 10/30/2011).

Foss, N. J.; Klein, P. G.; Kor, Y. Y.; Mahoney, J. T. (2006): *Entrepreneurship, subjectivism, and the resource − based view: towards a new synthesis*. Working Paper. http://www.business.illinois.edu/Working_Papers/papers/06-0121.pdf (last access 9/28/2009).

Franco, A. M.; Filson, D. (2006): *Spin-outs: Knowledge Diffusion through Employee Mobility*. The Rand Journal of Economics; Winter 2006, 37 (4), 841-860. http://www.rotman.utoronto.ca/facBios/file/Rand.pdf (last access 7/20/2009).

Freundorfer, S. (2010): *Boombranche Browser-Game – Die kleinen Könige der Spielebranche (Booming browser games – The little kings of the games industry)*. Der Spiegel, Feb. 27, 2010. http://www.spiegel.de/netzwelt/games/0,1518,680100,00.html (last access 1/22/2011).

Friedman, T. (2008):*Time to Reboot America*. The New York Times, Dec. 23, 2008. http://www.nytimes.com/2008/12/24/opinion/24friedman.html?_r=1 (last access 12/23/2008).

Frishammar, J.; Florén, H.; Wincent, J. (2009)*: Patterns of Uncertainty and Equivocality during Predevelopment: Findings from Process-Based Firms.* Conference Paper, Conference: International Conference on Management of Technology, IAMOT 2009, No. 18, Orlando, United States, April 5, 2009 - April 9, 2009. https://dspace.hh.se/dspace/bitstream/2082/3388/1/Conference_paper_JF_HF_JW_IAMOT.pdf (last access 10/14/2009). (last access 10/14/2009).

Fröhlich, C. (2013): *Nick D'Aloisio verkauft App an Yahoo: Plötzlich Millionär (Nick D'Aloisio sells app to Yahoo: suddenly millionaire*). Der Stern, Mar. 26, 2013. http://www.stern.de/digital/online/nick-daloisio-verkauft-app-an-yahoo-ploetzlich-millionaer-1989636.html (last access 3/26/2013).

Fröndhoff, B. (2008): *Was Mittelständler erfolgreich* macht (What makes medium-sized firms successful). Handelsblatt, Jul. 15, 2008. http://www.handelsblatt.com/unternehmen/mittelstand/was-mittelstaendler-erfolgreich-macht/2989122.html?p2989122=all (last access 1/11/2011).

Fryges, H.; Gottschalk, S.; Licht, G.; Müller, K. (2007): *Hightech-Gründungen und Business Angels (Hightech Foundations and Business Angels).* ZEW – Zentrum fü Europäische Wirtschaftsforschung GmbH, Oct. 2007. ftp://ftp.zew.de/pub/zew-docs/gutachten/businessangel-endbericht.pdf (last access 10/12/2010).

Fuhrmans V. (2012): *Germany's New Export: Jobs Training*. Wall Street Journal, updated Jun. 14, 2012. http://online.wsj.com/article/SB10001424052702303665904577452521454725242.html?mod=WSJ_business_whatsNews (last access 6/15/2012).

Fyfe, D.; Townsend, R. (2005): *Chemical Science Spin-outs from UK Universities - Review of Critical Success Factors*. The Chemistry Leadership Council and the Royal Society of Chemistry (RSC), 2005.

http://www.rsc.org/images/ChemSciSpinOuts_tcm18-12643.pdf (last access 7/24/2010).

Galbraith, K. (2008): *Assessing the Value of Small Wind Turbines*. The New York Times, Sep. 3, 2008. http://www.nytimes.com/2008/09/04/business/04wind.html?_r=1&em (last access 9/9/2010).

Gage, D. (2012): *The Venture Capital Secret: 3 Out of 4 Start-Ups Fail*. Wall Street Journal, September 19, 2012. http://online.wsj.com/article/SB10000872396390443720204578004980476429190.html?mod=WSJUK_hpp_MIDDLEThirdNews (last access 9/21/2012).

Gangemi J. and Di Meglio, F. (2005), *Teaching the Startup Mentality*. Business Week, Oct. 25, 2005. http://www.businessweek.com/technology/content/oct2005/tc20051025_795457.htm?chan=technology_special+report+2005+-+young+entrepreneurs+of+tech (last access 05/07/2008).

Gangemi J. (2007): *A Weeklong Festival for Entrepreneurship*. Business Week, Feb. 22, 2007. http://www.businessweek.com/smallbiz/content/feb2007/sb20070222_645291.htm?chan=smallbiz_smallbiz+index+page_today%2527s+top+stories (last access 8/24/2009).

Garberson, J. (2011): *Precious Assets Hindered by Bureaucracy: Lab Scrutinized by National Academy*. The Independent, Apr. 30, 2011. http://www.independentnews.com/news/article_7a30ea08-72bd-11e0-bd4d-001cc4c002e0.html (last access 7/2/2011).

Garcia, M. L.; Bray, O. H. (1997):*Fundamentals of Technology Roadmapping*. Strategic Business Development Department, Sandia National Laboratories. Report SAND97-0665. http://prod.sandia.gov/techlib/access-control.cgi/1997/970665.pdf; file 10.1.1.31.1385.pdf accessed via Google search "Garcia Bray 'Fundamentals of Technology Roadmapping'" (last access 9/24/2010).

Garnsey, E.; Stam, E.; Heffernan, P. (2006): New *Firm Growth: Exploring Processes and Paths.* Industry and Innovation 13 (1), Mar. 2006, 1-20. http://econ.geo.uu.nl/stam/GarnseyStamHeffernan2006.pdf (last access 1/20/2011).

Gardner, T. (2009): *Virent biofuel sees financing round up to $40 million*. Reuters. http://www.reuters.com/article/idUSTRE55M6NS20090623 (last access 12/14/2009).

Garthwaite, J. (2009): *CHEAT SHEET: Heavy Hitters in Algae Fuel Deals*. Earth2tech, Jul. 14, 2009. http://earth2tech.com/2009/07/14/cheat-sheet-heavy-hitters-in-algae-fuel-deals/ (last access 1/2/2010).

Gartner, W. B. (2007): *Psychology, Entrepreneurship, and the "Critical Mess."* Chapter 14 in Baum, J. R.; Frese, M.; Baron, R. A. (eds.): The Psychology of Entrepreneurship. A Publication of the Society for Industrial and Organizational Psychology, Lawrence Erlbaum Associates, Publishers, 2007.

GBL – Green Biologics (2012): *Green Biologics Announces Merger with Butylfuel™*. Press Relase, Jan. 20, 2012. http://www.greenbiologics.com/pr-butylfuel.php (last access 4/23/2012).

Gellene, D. (2009): *A Sapphire Energy Co-Founder Sees Solutions in Algae for Drugs as Well as Biofuels*. Xconomy, Dec.2, 2009. http://www.xconomy.com/san-diego/2009/12/02/a-sapphire-energy-co-founder-sees-solutions-in-algae-for-drugs-as-well-as-biofuels/ (ast access 3/14/2010).

Gelsi, S. (2008): *Algenol takes fresh approach to ethanol production*. MarketWatch, last update, Sep. 24, 2008. https://www.sharebuilder.com/sharebuilder/Research/MarketUpdate/StockNews.aspx?GUID=%7BE36349E5-0713-4468-A8BA-FE5DBA1ADF0C%7D&Source=IndividualStock&Symbol=ADM (last access 2/2/2010).

Gelsi, S. (2009): *Exxon Mobil eyes bigger role for natural gas - Oil giant forecasts trillions for world energy projects*. MarketWatch, Dec. 8, 2009. http://www.marketwatch.com/story/exxon-sees-trillions-needed-for-energy-growth-2009-12-08?siteid=rss&rss=1 (last access 12/8/2009).

Gendron, G. (1996): *Flashes of Genius*. Inc. Magazine, May 15, 1996. http://www.inc.com/magazine/19960515/2083.html# (last access 3/23/2010).

Gergen, C.; Vanourek, G. (2009): *Fending off the Recession with “Adaptive Persistence.”* HBR Blogs Christopher Gergen and Gregg Vanourek, Apr. 7, 2009. http://blogs.hbr.org/gergen-vanourek/2009/04/fending-off-the-recession-with.html (last access 10/31/2010); Perman, S. (2008): *Intrapreneurs and Adaptive Persistence*. Business Week, Apr. 2, 2008. http://www.businessweek.com/smallbiz/content/apr2008/sb2008042_307474.htm (last access 4/30/2008).

Gevo, Inc. (2009): *Brownfield: Ag News for America – Company plans to convert ethanol plants to biobutanol*. Gevo News, Oct. 9, 2009. http://www.gevo.com/news_Ag-News_100909.php (last access 12/10/2009).

Ghaemi, N. (2008): *The psychology of ambition. The price of ambition*. Psychology Today, August 21, 2008. Blogs – Mood Swings, a Psychiatrist Surveys the Mind and the Wider World 8/7/2009. http://www.psychologytoday.com/blog/mood-swings/200808/the-psychology-ambition (last access 8/7/2009).

Giebel, H. (2013): *TimberTowers for multi-megawatt wind energy plants*. Presentation Technology Entrepreneurship, Dec. 11, 2013. http://ce.ioc.kit.edu/downloads/TimberTower_130827_KIT.pdf.

Gibson, N. (2008): *German Persistence – Our friends in Deutschland have found a mass-market gaming goldmine*. develop, Sep. 22, 2008. http://www.developmag.com/interviews/276/German-Persistence last access 9/20/2010).

Gillies, A. T. (2008): *Business In The Beltway – Taking On Congress' Favorite Biofuel*. Fortune, Mar. 12, 2008. http://www.forbes.com/2008/03/11/virent-ethanol-gasoline-biz-cz_atg_0312beltway.html (last access 12/14/2009).

Giménez, E. H. (2007): *The biofuel myths*. The New York Times, Jul. 10, 2007. http://www.nytimes.com/2007/07/10/opinion/10iht-edholt.1.6588231.html (last access 7/11/2007).

GiSeung Kim (2008): *Entrepreneurship and Self-Employment*: *The State-of-the-Art and Directions for Future Research*. New England Journal of Entrepreneurship 11 (1), Apr. 1, 2008, 39-52. http://www.sacredheart.edu/download/1924_neje_spring08.pdf (last access7/18/2009).

Gladwell, M. (2000) *The Tipping Point: How Little Things Can Make a Big Difference*. Little, Brown (Boston).

glassdoor.com (2010): *Los Alamos National Laboratory Employee Review*. glassdoot™ - an inside look at jobs and companies, Mar. 22, 2010. http://www.glassdoor.com/Reviews/Employee-Review-Los-Alamos-National-Laboratory-RVW439215.htm (last access 6/19/2010).

Glocalist (2008): *Forschung: Biokraftstoff und Wasserstoff aus Bakterien (Research: Biofuels and hydrogen from bacteria)*. Glocalist Daily News, Aug. 12, 2008. http://www.glocalist.com/index.php?id=20&tx_ttnews%5Btt_news%5D=3925&tx_ttnews%5Bcat%5D=1&cHash=2e3d1ba4d5 (last access 12/16/2009).

Gold, R. (2009a): *Size Matters: Biobutanol is Latest (Small) Biofuel Aspirant*. Wall Street Journal Blog, Sep. 30, 2009. http://blogs.wsj.com/environmentalcapital/2009/09/30/size-matters-biobutanol-is-latest-small-biofuel-aspirant/ (last access 11/9/2009).

Gold, R. (2009b): *In Energy Innovation, Everything New Is Old Again – Most Alternative Fuel Technologies Have Roots in Long-Ago Discoveries; Scarcity of 'Killer Apps' Slows Progress*. Wall Street Journal, Dec. 11, 2009. http://online.wsj.com/article/SB126048948482786623.html (last access 12/11/2009).

Golon, J. (2006): *Algae to Biomass*. Presentation, Winter 2006/2007. http://www.ecology.uni-kiel.de/~bburkhard/seminar/material6/AESA_041207_Algae.pdf (last access 3/162010).

Gompers, P. A. (2002): *Corporations and the Financing of Innovation – The Corporate Venturing Experience*. Harvard Business School and National Bureau of Economic Research. Presentation, May 3, 2002. https://www.frbatlanta.org/filelegacydocs/policy_gompers.pdf (last access 10/29/2010).

Gompers, P.; Kovner, A.; Lerner, J.; Scharfstein, D. (2008): *Performance Persistence in Entrepreneurship*. Draft, July 2008. http://www.hbs.edu/research/pdf/09-028.pdf (last access 1/24/2011).

González, Á (2008): *Weyerhaeuser, Chevron form biofuels venture*. The Seattle Times, originally published Feb. 29, 2008. http://seattletimes.nwsource.com/html/businesstechnology/2004250829_webchevron01.html (last access 11/24/2009).

Gorlick, R. (2009): *Fiese Karrierefallen – So ticken amerikanische Chefs (Nasty career traps – how American bosses proceed).* Der Spiegel, Dec. 12, 2009.

http://www.spiegel.de/unispiegel/jobundberuf/0,1518,663918,00.html (last access 04.12.2009).

Gorman, S. (2011): *U.S. Report Cites 'Persistent' Chinese, Russian Spying for Economic Gain*. Wall Street Journal, Nov. 3, 2011. http://online.wsj.com/article/SB10001424052970203716204577015540198801540.html?mod=WSJEUROPE_hpp_MIDDLEThirdNews (last access 11/3/2011).

Gottschalk, S.; Fryges, H.; Metzger, G.; Heger, D.; Licht, G. – ZEW (2007): *Start-Ups zwischen Forschung und Finanzierung: Hightech-Gründungen in Deutschland*. Mannheim, June 2007. (*Start-Ups between Research and Financing* : *Hightech Foundations in Germany. June 2007*). ftp://ftp.zew.de/pub/zew-docs/gutachten/hightechgruendungen07.pdf (last access 7/10/2009).

Gould, P.: *General History – The Steam Bus 1833-1923*. http://www.petergould.co.uk/local_transport_history/generalhistories/general/steambus.htm; http://en.wikipedia.org/wiki/Steam_bus (last access 1/6/2011).

Green Car Congress (2005): *Rentech Tracking to Startup Coal-to-Liquids Pilot Plant in Q4 2006*. Green Car Congress, Dec. 7, 2005. http://www.greencarcongress.com/2005/12/rentech_trackin.html (last access 2/20/2010).

Green Car Congress (2007a): *European Biodiesel Production Doubles in Two Years; EBB Warns on Need to Eliminate "Legislative and Standards Desert."* Published Jul. 18, 2007. http://www.greencarcongress.com/2007/07/european-biodie.html (last access).

Green Car Congress (2007b): *Range Fuels to Build First Wood Cellulosic Ethanol Plant in Georgia.* Green Car Congress, Feb. 7, 2007 (2/19/2010). http://www.greencarcongress.com/2007/02/range_fuels_to_.html.

Green Car Congress (2012): *BlueFire Renewables subsidiary and Caltex to build cellulose to sugar plant in Korea*. Green Car Congress, Feb. 15, 2012. http://www.greencarcongress.com/2012/02/clatex-20120215.html (last access 3/5/2-12).

Greene, S. (2009): *An Overview of the US Electric Bike Market*. Sperlingreene PR and Marketing Communications, Jul. 8, 2009. http://www.scribd.com/doc/17166410/Overview-of-the-Ebike-and-Electric-Bike-Market (last access 5/14/2011).

Greiner, L. E. (1998): *Evolution and Revolution as Organizations Grow*. Harvard Business Review, May-June 1998, 55-67;
Greiner, L. E. (1972): *Evolution and Revolution as Organizations Grow*. Harvard Business Review, July-August 1972, 37-46.
http://www.ils.unc.edu/daniel/131/cco4/Greiner.pdf (last access 1/31/2011).

Griesar, K. (2008): *Management von Forschung und Entwicklung (Management of Reseach and Development*). Presentation Technology Entrepreneurship, Nov. 26, 2008. http://ce.ioc.KIT.edu/downloads/Praesentation_Griesar.pdf.

Grushkin, D. (2012): *The Rise And Fall Of The Company That Was Going To Have Us All Using Biofuels.* Fast Company, Aug. 8, 2012.

http://www.fastcompany.com/3000040/rise-and-fall-company-was-going-have-us-all-using-biofuels (last access 10/4/2012).

Gruber; M.; MacMillan, I. C.; Thompson, J. D. (2008): *Look Before You Leap - Market Opportunity Identification in Emerging Technology Firms*. Management Science 54 (9), September 2008, 1652-1665.

Guardian (2008): *Biofuels: The hottest clean technology companies in Europe*. The Guardian, Sep. 18, 2008. http://www.guardian.co.uk/environment/table/2008/sep/18/cleantech100biofuels.cleantechnology100 (last access 1/6/2010).

Hamilton, T. (2009): *Dow to Test Algae Ethanol – Startup Algenol partners with Dow Chemical on a demonstration ethanol plant*. Technology Review, Jul. 16, 2009. http://www.technologyreview.com/business/23009/?nlid=2182 (last access 2/8/2010).

Handelsblatt (2012): *Die größten Solarzellenhersteller der Welt (The largest solar cell manufacturers of the world*). Handelsblatt Apr. 4, 2012. http://www.handelsblatt.com/unternehmen/industrie/solarbranche-die-groessten-solarzellenhersteller-der-welt/6127028.html (last access 4/7/2012).

Hanks S. H.; Watson, C. J.; Jansen, E.; Chandler, G. N. (1993): *Tightening the Life-Cycle Construct: A Taxonomic Study of Growth Stage Configurations in High-Technology Organizations.* Entrepreneurship: Theory and Practice, Dec. 22, 1993. http://findarticles.com/p/articles/mi_hb6648/is_n2_v18/ai_n28633506/pg_14/?tag=content;col1 (last access 1/21/2011).

Harris & Harris (2005): *Harris & Harris Group Invests in Solazyme, Inc*. Harris & Harris Group, News & Press Releases, Nov. 30, 2004. http://files.shareholder.com/downloads/TINY/828794935x0x42850/d9296dfa-a2fd-4c57-95cb-3998007c90be/TINY_News_2004_11_30_General.pdf (last access 1/25/2010).

Hauger, N.; Kaizl, M. (2010): *In virtuellen Welten* (*In virtual worlds*). Inside B Business Magazine 4, 2010, 38-41. http://www.insideb.de/upload/Files/038_039_IB_0410.pdf (last access 9/27/2011), http://www.insideb.de/upload/Files/040_041_IB_0410.pdf (last access 9/27/2011).

Hayes, T. J. (1997): *The Creative Entrepreneurs Organization: Developing Innovative Products and Businesses*. Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University. http://scholar.lib.vt.edu/theses/available/etd-111897-141039/unrestricted/TJ_s_Thesis.pdf (last access 7/8/2009).

Haynes, S. D. (2000): *The Systems Thinking Approach to Strategic Planning and Management.* CRC Press; Haynes, S. D. (2005): *The Science of Systems Thinking. The Natural Way the World Works.* http://www.stephenhaines.com/keynote/pdfs/MSST-01.pdf (last access 9/30/2009).

Headline News (2009*): Developing the Whole Biochain*. Headline News, Mar. 7, 2009. http://newsheadlinenews.blogspot.com/2009_02_09_archive.html (last access 1/22/2010).

Heathcote, M.; Fryer, C. (2008): *Alternatives to Petroleum Feedstocks : a Leading Role for Asia*. Tecnon OrbiChem Marketing Seminar at APIC 2008, The World

Chemical Industry Focuses on Asia Singapore, May 27, 2008. http://www.tecnon.co.uk/gen/uploads//rr4pcz3icabofgzuk54ocr5529052008123433.pdf (last access 1/22/2010).

Heffernan, M. (2007): *Men Dominate, Women Orchestrate.* Business Week, Small Biz, Mar. 13, 2007. http://msnbci.businessweek.com/smallbiz/content/mar2007/sb20070313_555883.htm?chan=smallbiz_smallbiz+index+page_today%27s+top+stories (last access 3/14/2007).

Heger, D.; Höwer, D.; Licht, G.; Metzger, G.; Sofka, W. (2009): High-Tech-*Gründungen in Deutschland – Optimismus trotz Krise (High-tech foundations in Germany – Optimism despite crisis*). Zentrum für Europäische Wirtschaftsforschung (ZEW) GmbH. Jul. 2009. ftp://ftp.zew.de/pub/zew-docs/gutachten/hightechgruendungen09.pdf (last access 7/17/2010).

Heiling, C. (2008):*Sriya Innovations Inc*. Wellford Energy Advisors, Lobbying Report, File of 4/14/2008. http://soprweb.senate.gov/index.cfm?event=getFilingDetails&filingID=E7B69370-1DE5-49A9-BA13-6DD88885FDDE (last access 6/4/2012).

Helmut Kaiser Consultancy (2010): *Ionic Liquid Technologies, Markets, Applications, Companies and Developments Worldwide 2008 to 2020 and 2030*. Market research report, http://www.hkc22.com/ionicliquids.html (last access 2/19/2012); http://www.prlog.org/10698069-ionic-liquids-markets-worldwide-will-reach-34-billion-us-by-2020-from-300-million-today.html (last access 6/6/2011).

Herndon, A.; Martin, C.; Goossens, E. (2011): *Total to Buy 60% of SunPower for $1.38 Billion in Solar Bet.* Bloomberg Business Week, Apr. 29, 2011. http://www.businessweek.com/news/2011-04-29/total-to-buy-60-of-sunpower-for-1-38-billion-in-solar-bet.html (last access 4/29/2011).

Herron, D. (2012): I*t's Wanxiang or bankruptcy for A123 Systems as the companies sign agreement*. Torque News, Aug. 16, 2012. http://www.torquenews.com/1075/its-wanxiang-or-bankruptcy-a123-systems-companies-sign-agreement (last access 9/3/2012).

Heskett, J. (2007): *Has Managerial Capitalism Peaked?* Harvard Business School Working Knowledge. http://hbswk.hbs.edu/item/5794.html (last access 6/20/2009).

Hess, G. (2007): *Chevron, Texas A&M Will Research Biofuels – Partnership seeks conversion of nonfood crops into renewable transportation fuel*. Chemical & Engineering News, News, May 31, 2007. http://pubs.acs.org/cen/news/85/i23/8523news5.html (last access 11/24/2009).

Hesselbein, F.; Goldsmith, M.; Beckhard, R. (Eds.), (1996): *The Leader of the Future*, foreword by Peter F. Drucker. Jossey-Bass Publishers, San Francisco.

Hewlett, W.: *The Human Side Of Management*. SMECC Vintage Electrics Vol #3 Issue #1. http://www.smecc.org/the_human_side_of_management_-_bill_hewlett.htm (last access 7/27/2010), cf. Ed Sharpe, E.: *Hewlett-Packard, The Early Years*. http://www.smecc.org/hewlett-packard,_the_early_years.htm (last access 7/27/2010).

Hiersemenzel, P. A. (2003): *Rumsfeld und Clausewitz*. Die Zeit 14/2003 – Mar. 27, 2003. http://pdf.zeit.de/2003/14/hiersemenzel2803.pdf (last access 10/9/2009).

Higgins, T.: *Casual Games as a Business*. UNITY. http://unity3d.com/support/documentation/articles/CasualGamesBusiness (last access 10/2/2011); http://en.wikipedia.org/wiki/Casual_game

Hills, G. E.; Shrader, R. C. (1998): *Successful Entrepreneurs' Insights into Opportunity Recognition.* Frontiers of Entrepreneurship Research. Wellesley, MA: Babson College. last updated January. 1999. http://www.babson.edu/entrep/fer/papers98/I/I_A/I_A_text.htm (last access 9/22/2010).

Hipple, J.; Hardy, D.; Wilson, S. A. Michalski, J. (2001): *Can corporate innovation champions survive?* Chemical Innovation 31 (11), 14-22. http://pubs.acs.org/subscribe/journals/ci/31/i11/html/11hipple.html (last access 8/12/2010).

Hitt, M., Ireland, R., and Hoskisson, R. (2005): *Strategic Management Competitiveness and Globalization Concepts*. Thompson, South-Western, 6th edition, 2005.

Hof, R. D. (2008): *How Google Fuels Its Idea Factory*. Business Week, Apr. 29, 2008. http://www.businessweek.com/magazine/content/08_19/b4083054277984.htm?chan=innovation_innovation+%2B+design_innovation+strategy (last access 9/1/2010).

Hoffman, R. (2012): *Entrepreneurs Take Intelligent Risks*. Stanford Technology Ventures Program, Entrepreneurial Thought Leaders Lecture Series, Feb. 22, 2012. http://ecorner.stanford.edu/authorMaterialInfo.html?mid=2907 (last access 4/22/2012).

Hoffman, R. (2010): *LinkedIn's Reid Hoffman: Five Lessons for Entrepreneurs*. WST Blogs, Nov. 18, 2010. http://blogs.wsj.com/tech-europe/2010/11/18/linkedins-reid-hoffman-five-lessons-for-entrepreneurs/ (last access 11/19/2010); http://en.wikipedia.org/wiki/PayPal.

Hoffman, R. (2007a): *Core Ideas for a Social Networking Company*. Stanford Technology Ventures Program, Entrepreneurial Thought Leaders Lecture, Feb. 7, 2007. http://ecorner.stanford.edu/authorMaterialInfo.html?mid=1689 (last access 9/19/2011).

Hoffman, R. (2007b): *Facing Competition through Innovation*. Stanford Technology Ventures Program, Entrepreneurial Thought Leaders Lecture, Feb. 7, 2007. http://ecorner.stanford.edu/authorMaterialInfo.html?mid=1688 (last access 8/2/2008).

Hoffmann, D. (2009): *Manfred von Ardenne – Der rote Baron (Manfred von Ardenne – The Red Baron*). FAZ, Nov. 10, 2009. http://www.faz.net/s/Rub163D8A6908014952B0FB3DB178F372D4/Doc~E842A62CD9ECB4D0BA32383FBA0DFA8B9~ATpl~Ecommon~Scontent.html (last access 11/11/2009).

Hoffritz, J. (2013): *Farben für die ganze Welt (Dyes for the whole world*). Handelsblatt, Jan. 12, 2013. http://www.handelsblatt.com/unternehmen/industrie/basf-bayer-und-co-farben-fuer-die-ganze-welt-seite-all/7611332-all.html (last access 1/20/2013); cf. also http://de.wikipedia.org/wiki/Carl_Friedrich_Wilhelm_Meister.

Hofmann, S. (2010): *Die Früchte des loyalen Ungehorsams (Fruits of loyal disobedience). Handelsblatt, Jul. 16, 2010*. http://www.handelsblatt.com/technologie/forschung/pharmakonzern-merck-die-fruechte-des-loyalen-ungehorsams;2618923 (last access 7/17/2010).

Holt, K, (2011): INFOGRAPHIC: *1 In 5 Facebook Users Play 'FarmVille,' Social Gamers Are 55% Female*. scribbal, Jun. 21, 2011. http://www.scribbal.com/2011/06/infographic-1-in-5-facebook-users-play-farmville-social-gamers-are-55-female/ (last access 10/24/2011).

Howe, J. B. (2006): *Celunol Corporation – An Introduction*. Presentation, Massachusetts Cellulosic Ethanol Workshop, Nov. 8, 2006. http://www.mass.gov/Eoeea/docs/doer/alternative_fuels/cew061108-celunol-howe.pdf (last access 12/30/2009).

Hoyos, C. (2010): *Shell to create $12bn biofuels JV in Brazil.* Financial Times, Feb. 1, 2010. http://www.ft.com/cms/s/0/7133e6a6-0f47-11df-8a19-00144feabdc0.html (last access 2/1/2010).

Huber, G. P. (1991): *Organizational learning: The contributing processes and the literatures*. Organization Science, 2: 88–115.

Humboldt Innovation (2009): *Cyano Biofuels*. SpinoffZone 2009. http://www.humboldt-innovation.de/HumboldtInnovation_spinoffdetail_de.html?mCtrl=SpinOff&mOp=View&vwflwid=2ux8cz5bvu&m_SpinOff%5BspinOffID%5D=22 (last access 12/16/2009).

ICB Americas (2004): *Technology Watch: Ionic Liquids Offer New Solutions*. ICIS, Jan. 19, 2004. http://www.icis.com/Articles/2004/01/16/549791/technology-watch-ionic-liquids-offer-new-solutions.html (last access 5/7/2005).

Iijima, S. *The discovery of carbon nanotubes – Guided by serendipity*. NEC Corp. http://www.nec.co.jp/rd/en/innovative/E1/01.html (last access 9/10/2009).

Imbler, J. *(2009): Mission: Not Impossible Successful Strategies for Cellulosic Ethanol Deployment.* Pacific Rim Summit on Industrial Biotechnology & Bioenergy, Nov. 10, 2009. http://www.zeachem.com/press/pdf/PacRim111009.pdf (last access 1/7/2010).

Ingersoll, E.; Gallagher, D. C.; Vysatova, R. A. (1998): *Industry Development Strategy for the PV Sector*. REPP - Special Report. http://www.repp.org/repp_pubs/articles/pv/2/2.html (last access 8/25/2009).

INITIAL LIGHT BULB (2009): *Small biz tech-startup: OPX Biotechnologies Inc*. WiesnerMedia, Coloradobiz, Aug. 17, 2009. http://www.cobizmag.com/articles/small-biz-tech-startup-opx-biotechnologies-inc (last access 11/11/2010).

Itim International: *An international consulting organization utilizing Prof. Hofstede's concepts, as well as those of other leading sociologists*. http://www.geert-hofstede.com/geert_hofstede_resources.shtml (last access 8/10/2009); Country Data: http://www.geert-hofstede.com/hofstede_dimensions.php (last access 8/10/2009).

ISEE – International Sustainable Energy Exchange (http://www.hart-isee.com/index.php). *Global Fuel Solutions – Fuel Technology*. http://www.hart-isee.com/index.php?page=synthetic-fuel-btl-technologies (last access 10/30/2009).

Issig, P. (2006): *Hochschulen als Unternehmerschmiede – Förderprogramm ermöglichte fast 100 Firmengründungen (Universities as forges for enterprises – Public funding facilitates almost 200 foundations*). Die Welt, Mar. 12, 2006. http://www.welt.de/print-wams/article139605/Hochschulen_als_Unternehmerschmiede.html (last access 10/1/2008).

Jacquot, J.E. (2008): *Biofuel Comparison Chart: The "Good," the Bad and the (Really) Ugly*. Treehugger – Science & Technology, May 10, 2008. http://www.treehugger.com/files/2008/05/biofuel-comparison-chart.php (last access 11/28/2009).

Jahn, D. (2007): *Firmengründungen in der Chemie (Firm's foundation in chemistry)*. Presentation Technology Entrepreneurship, Nov. 21, 2007. http://ce.ioc.KIT.edu/downloads/Praesentation_Jahn.pdf (last access 6/21/2010).

Jahn, D. (2008): *The Chemical Industry – Engine of innovation with the other industries.* Presentation VCW, Jun. 12, 2008. http://www.gdch.de/strukturen/fg/wirtschaft/vcw_va/jahn.pdf (last access 6/23/2010).

Jan, T. (2009): *Harvard workers stunned by layoffs*. The Boston Globe, Jun. 24, 2009. http://www.boston.com/news/education/higher/articles/2009/06/24/harvard_workers_stunned_by_layoffs_of_275/ (last access 6/24/2009).

John Brown: *Gustave Whitehead – Pioneer Aviator*. http://www.gustave-whitehead.com/ (last access 3/31/2013); cf. also http://www.npr.org/2013/03/19/174634237/historian-propels-connecticut-to-claim-first-in-flight; U.S. Air Force Fact Sheet – GUSTAVE WHITEHEAD: http://www.hill.af.mil/library/factsheets/factsheet_print.asp?fsID=5948&page=1; Gustave Whitehead: http://en.wikipedia.org/wiki/Gustave_Whitehead.

Johnson, J. (2011): *U.S.-Backed Solar Panel Maker Folds – Bankruptcy: Solyndra got loan guarantee but can't make a profit.* Chemical & Engineeering News 89 (36), 12. http://pubs.acs.org/cen/news/89/i36/8936notw2.html (last access 9/5/2011).

Johnson, J. (2010): *Potholes On The Road To Renewable Fuels – Corn-kernel-based ethanol hits the fast lane, but cellulosic ethanol is still stuck in first gear.* Chemical & Engineering News 37, Sep. 13, 2010. http://pubs.acs.org/isubscribe/journals/cen/88/i37/html/8837gov1.html?featured=1 (last access 9/13/2010).

Johnson, J. A. (2001): *Reconsidering the Causal Efficacy of Situations*. Invited Talk for the Biannual Kurt Lewin Institute Congress. Zeist, The Netherlands, May 11, 2001. http://www.personal.psu.edu/faculty/j/5/j5j/papers/KLI.html (last access 4/16/2010).

Johnson, K. (2009): *Brewing Biofuels: Shell, Codexis Team Up to Drive Cellulosic Ethanol Research*. WSJ Blogs – Environmental Capital, Mar. 10, 2009. http://blogs.wsj.com/environmentalcapital/2009/03/10/brewing-biofuels-shell-codexis-team-up-to-drive-cellulosic-ethanol-research/ (last access 11/24/2009).

Johnson, L. (2011): *The dismal science is bereft of good ideas*. Financial Times, Jun. 7, 2011. http://www.ft.com/intl/cms/s/0/121b216c-914a-11e0-b1ea-00144feab49a.html (last access 6/8/2011).

Johnson, W. C. *(2005): Changing Interfaces Between the Research University and , Industry.* Presentation, 2005 Engineering Research Council Workshop and Forum, Washington DC, 2/27/05. http://www.asee.org/conferences/erc/2005/upload/wayne-c-johnson.ppt (last access 6/21/2010).

Jonietz, E. (2007): *Oil from Wood – Startup Kior has developed a process for creating "biocrude" directly from biomass*. Technology Review, Nov. 9, 2007. http://www.technologyreview.com/read_article.aspx?ch=specialsections&sc=biofuels&id=19694 (last access 12/30/2009).

Kaiser, N. (2004): *Interview with Reid Hoffman, CEO of LinkedIn*. NPost, Mar. 17, 2004. http://www.npost.com/?s=hoffman (last access 11/20/2011).

Kanellos, M. (2008): *Algae: Another way to grow edible oils*. The Pulse of Technology, Jan. 25, 2008. http://www.pulseoftechnology.com/?p=4 (last access 1/12/2010).

Kanellos, M. (2009a): *Chevron Invests in LS9; Microbe Diesel by 2011*. Green Tech Media, Sep. 5, 2009. http://www.greentechmedia.com/articles/print/chevron-invests-in-ls9-microbe-diesel-possible-by-2011/ (last acess 12/11/2009).

Kanellos, M. (2009b): *GreenFuel Technologies Closing Down*. Green Tech Media, May 13, 2009. http://www.greentechmedia.com/articles/read/greenfuel-technologies-closing-down-4670/ (last access 1/2/2010).

Kaplan, J. (2003a): *Five Biggest Mistakes That Entrepreneurs Make.* Stanford Technology Ventures Program, Entrepreneurial Thought Leader Speaker Series, Oct. 1, 2003. http://ecorner.stanford.edu/authorMaterialInfo.html?mid=364 (last access 12/29/2010).

Kaplan, J. (2003b): *Five Critical Skills That Entrepreneurs Need*. Stanford Technology Ventures Program, Entrepreneurial Thought Leader Speaker Series, Oct. 1, 2003. http://ecorner.stanford.edu/authorMaterialInfo.html?mid=366 (last access 9/23/2010).

Kaplan, K.; Litoff, L.; Wright, D (2010*): Inside Zynga: Now the Creators of 'CityVille'*. ABC News, Nov. 17, 2010. http://abcnews.go.com/Nightline/inside-zynga-creators-farmville/story?id=12169767 (last access 10/5/2011).

Karlsruhe (2001): *Karlsruher Bokela erschließt sich neue Märkte (Bokela of Karlsruhe enters new markets*). Karlsruhe, Wirtschaftsförderung, Oct. 17, 2001. http://www1.karlsruhe.de/Wirtschaft/php_news/zo1_news_detail.php?auswahl=58&archiv=1 (last access 11/13/2010).

Kemna, V. (2007): *Blühende Landschaften (Flourishing landscapes).* Deutschlandfunk, Jan. 30, 2007. http://www.dradio.de/dlf/sendungen/campus/588154/ (last accesss 8/18/2010).

Kempkens, W. (2009): *Biosprit – Deutschland verpasst den Anschluss (Biofuels – Germany misses catch-up)*. Wirtschaftswoche, Apr. 28, 2009. http://www.wiwo.de/technik/deutschland-verpasst-den-anschluss-393963/ (last access (11/24/2009).

Kersting, K. (2012): *Building a startup (in ten easy steps*). Presentation Technology Entrepreneurship, Feb. 15, 2012. http:// http://ce.ioc.KIT.edu/downloads/Kersting_Vorlesung.pdf.

Keßler, A.; Frank, H.; Korunka, C.; Manfred Lueger, M. (2010): *Predicting Founding Success and New Venture Survival: A Longitudinal Study*. http://www.kmu.unisg.ch/rencontres/Renc2010/Topics_2010/C/Rencontres_2010_Topic_C_Frank_Kessler_Korunka_Lueger_f.pdf (last access 10/31/2010).

Kho, J. (2009): *The Algae Fuel Backlash: Here Come the Skeptics*. Earth2tech, Sep. 25, 2009. http://earth2tech.com/2009/09/25/the-algae-fuel-backlash-here-come-the-skeptics/ (last access 1/18/2010).

Khosla, V. (2006): *Biofuels: Think outside the Barrel*. KPCB – Experienced Team Member – Vinod Khosla., April 2006. http://www.khoslaventures.com/presentations/Biofuels.Apr2006.ppt (last access 12/7/2009).

Khosla, V. (2008a): *Emerging Energy Solutions Must Compete on Price*. Stanford Technology Venture Program, Entrepreneurial Thought Leader Lecture, Oct. 22, 2008. http://ecorner.stanford.edu/authorMaterialInfo.html?mid=2080 (last access 12/4/2009).

Khosla, V. (2008b): *The Innovation Ecosystem*. In THE BETTER WORLD REPORT PART ONE: The Art of Collaboration: The Relationships That Bring Academic Innovations to the Marketplace, 13-15. http://www.enterprise.cam.ac.uk/uploads/File/Publications/AUTM_BWR1_08.pdf (last access 12/1/2009).

Khosla, V. (2009a): *Renewable Energy – Maintech, not Cleantech*. Presentation, April 2009. http://www.khoslaventures.com/presentations/Google-4-22-09.ppt (last access 12/12/2009).

Khosla, V. (2009b): *Our portfolio – Khosla Ventures*. http://www.khoslaventures.com/presentations/Flower_Chart.ppt (last access 11/24/2009).

Kim, W. C.; Mauborgne, R. (1997): *Value Innovation – The Strategic Logic of High Growth*. Harvard Business Review, January-February 1997, 103-112; republished in 2004. HBR (July-August), 172-180. http://www.adaptive-edge.com/vi_hbr.pdf (last access 7/30/2010); http://csom.umn.edu/assets/2435.pdf (last access 1/17/2013); http://media.library.ku.edu.tr/reserve/resspring10/mktg451_AKok/kim.pdf (last access 5/17/2013).

KiOR (2012): *Annual Report 2011*. http://files.shareholder.com/downloads/ABEA-6B1XEW/1896825919x0x571270/2FFBA31D-5AB7-435B-969C-2578ACE1B273/KIOR_2011_AR.pdf (last access 5/3/2012).

Kiplinger Washington Editors (2007): *Biobutanol: On the Road to Overtaking Ethanol*. Kiplinger's Biofuels Market Alert 1 (1), 1-2, Jul. 2, 2007. http://www.biontech.com/news/print-air/KiplingerBiofuels.070702.pdf (last access 12/23/2009).

Kirchhoff, B. A.; Spencer, A. (2008):*New High Tech Firm Contributions to Economic Growth*. File of 7/22/2008. http://www.icsb.org/documents/New_High_Tech_Firms.pdf (last access 5/23/2009).

KIT (2008): *Professor and Parallel Work at Industry – Dr. Gisela Lanza is Holder of the First Shared Professorship at the KIT*. Press Release 11/2008. http://www.fzk.de/fzk/idcplg?IdcService=KIT&node=4211&document=ID_062922&lang=en (last access 7/372010).

KIT (2009): *Thin Films with a great Impact - Three Companies Are Sharing the Professorship of Thin Film Technology*. Press Release 085/2009. http://www.kit.edu/english/55_356.php (last access 7/372010).

Klann, A. R. (2007): *BlueFire Ethanol*. American Coalition for Ethanol Conference, Aug. 21, 2007. http://www.ethanol.org/pdf/contentmgmt/Arnie_Klann_BlueFire.pdf (last access 1/10/2010).

Klepper, S. (2001): *Employee start-ups in high tech industries*. Industrial and Corporate Change, 10 (3), 639–674.

Klausmann, P. (2011): *Vitracom AG – Von der Gründung zur Marktführerschaft (From Foundation to Market Leader).* Presentation Technology Entrepreneurship, Jan. 19, 2011. http://ce.ioc.KIT.edu/downloads/Praesentation_Klausmann.pdf (last access 2/1/2011).

Koenen, J. (2010): *Unternehmer? Warum nicht! (Entrepreneur? Why not?).* Presentation Technology Entrepreneurship, Jan. 27, 2010. http://ce.ioc.KIT.edu/downloads/Praesentation_Koenen.pdf (last access 7/20/2010).

Koenig, C. (2005): *Bugs waste no time*. The Oxford Times, March/April 2005. http://www.greenbiologics.com/documents/Oxford_Times_article.pdf (last access 1/28/2010).

Köhler, K. (2005): *Katja Heppe produziert mit Chitosan Wirkstoffe für Medizin und Kosmetik (With chitosan Katja Heppe produces ingredients for medicine and cosmetics).* Brikada, Oct. 25, 2005. http://www.brikada.de/cgi-bin/con.cgi?action=pub&id=557&channel=Frauen%20heute (last access 8/20/2010).

Kraft, T. E. (2005): *REVIEW The Wright Way: Seven Problem-Solving Principles from the Wright Brothers That Can Make Your Business Soar By Mark Eppler*. Journal of Industrial Teacher Education 42 (1), 67- 71. http://faculty.ksu.edu.sa/Alhassan/MAster_Students_Research_Readings/The%20Wright%20Way,%20Seven%20Problem-Solving%20Principles%20From%20the%20Wright%20Brothers%20That%20Can%20Make%20Your%20Business%20Soar.pdf (last access 4/11/2010).

Kramer, D. (2007): *Project: "Systems Biology of Cyanobacterial Biofuel Production."* http://www.forsys.net/joomla/images/partner_en/dan_kramer_eng_03-04.pdf (last access 12/16/2009);
FORSYS - *Research Units for Systems Biology in Germany*. Federal Ministry of of Education and Research (BMBF). http://www.forsys.net.

Krauter, B. (2007): *Biopesticide pioneer covers globe – Pam Marrone leads staff in finding natural solutions to big problems*. Capital Press, Oct. 5, 2007. http://www.marroneorganicinnovations.com/news/news10172007.html (last access 11/25/2007).

Krauss, C. (2009): *Ethanol, Just Recently a Savior, Is Struggling*. The New York Times, Feb. 12, 2009. http://www.nytimes.com/2009/02/12/business/12ethanol.html?ref=todayspaper (last access 11/9/2009).

Kunkel, S. W. (2001): *Toward a Typology of Entrepreneurial Activities*. Academy of Entrepreneurship Journal, January 2001. http://findarticles.com/p/articles/mi_hb6005/is_1_7/ai_n28892970/?tag=content;col1 (Last access 11/28/2010), http://home.sandiego.edu/~kunkel/articles/typent.pdf.

Kunz, M. (2008): *TV- und Atombomben-Pionier ohne Abi (TV and atomic bomb pioneer without a high-school degree*). Focus, May 26, 2008. http://www.focus.de/wissen/bildung/biografien/manfred-von-ardenne-tv-und-atombomben-pionier-ohne-abi_aid_303718.html (last access 11/11/2009); cf. also http://de.wikipedia.org/wiki/Manfred_von_Ardenne.

Kuo, I. (2011): *On the GreenBeat: Solyndra's star fades, admits to mistakes; Khosla says new biofuel IPO coming.* GreenBeat, Mar. 4, 2011.http://venturebeat.com/2011/03/04/on-the-greenbeat-solyndras-star-fades-admits-to-mistakes-khosla-says-new-biofuel-ipo-coming/ (last access 3/30/2011).

Lachmann, H. (2007): *Wir haben fünf Jahre Vorsprung (We have a Leadt Time of Five Years*). VDI Nachrichten, Oct. 19, 2007. http://www.vdi-nachrichten.com/vdi-nachrichten/aktuelle_ausgabe/akt_ausg_detail.asp?cat=3&id=35504&doPrint=1 (last access 12/17/2009).

Lachmann, L. M.: Cited in Garrison, R. W. : *From Lachmann to Lucas – On Institutions, Expectations, and Equilibrating Tendencies*. http://www.auburn.edu/~garriro/j6lachlucas.htm#N_7_ (last access 7/30/2010).

Lacy, S. (2009): *VC Markets: No Easy Answers*. Business Week, May 20, 2009. http://www.businessweek.com/technology/content/may2009/tc20090520_516821.htm?chan=technology_technology+index+page_tech+investing (last access 5/22/2009).

Lakhani, K. R.; Jeppesen, L. B.; Lohse, P. A.; Panetta, J. A. (2006): *The Value of Openness in Scientific Problem* Solving. Harvard Business School, Working Paper 07-050, October 2006. http://www.hbs.edu/research/pdf/07-050.pdf (last access 4/6/2008).

Lane, J. (2007): *Shell, HR Biopetroleum form JV to produce algae oil in Hawaii*. Biofuels Digest, Dec. 11, 2007. http://www.biofuelsdigest.com/blog2/2007/12/11/shell-hr-biopetroleum-form-jv-to-produce-algae-oil-in-hawaii/ (last access 11/24/2009); cf. also http://www.bloomberg.com/apps/news?pid=20601102&sid=ahSsmDmNPDXk&refer=uk.

Lane, J. (2008): *Cellana*. Biofuels Digest, Oct. 8, 2008. http://www.biofuelsdigest.com/blog2/2008/10/08/cellana/ (last access 12/27/2009).

Lane, J. (2009a): *BP to establish joint venture with Verenium for cellulosic ethanol; invests additional $22.5 million*. Feb. 20, 2007. http://www.biofuelsdigest.com/blog2/2009/02/20/bp-to-establish-joint-venture-with-verenium-for-cellulosic-ethanol-invests-additional-225-million/ (last access 11/12/2009).

Lane, J. (2009b): *DuPont Danisco: 50 Hottest Companies in Bioenergy candidate profile.* BioFuels Digest, Nov. 04, 2009. http://www.biofuelsdigest.com/blog2/2009/11/04/dupont-danisco-50-hottest-companies-in-bioenergy-candidate-profile/ (last access 11/20/2009).

Lane, J. (2009c): *BP to commence cellulosic ethanol production in Brazil by 2013.* BioFuels Digest, Oct. 28, 2009. http://www.biofuelsdigest.com/blog2/2009/10/28/bp-to-commence-cellulosic-ethanol-production-in-brazil-by-2013/ (last access 11/23/2009).

Lane, J. (2009d): *Gevo*. Biofuels Digest, Oct. 7, 2009. http://www.biofuelsdigest.com/blog2/2009/10/07/gevo-50-hottest-companies-in-bioenergy-candidate-profile/ (last access 12/1/2009).

Lane, J. (2009e): *Mascoma's CEO steps down as company's focus on commercialization steps up*. Biofuels Digest, Aug. 21, 2009. http://www.biofuelsdigest.com/blog2/2009/08/21/mascomas-ceo-steps-down-as-companys-focus-on-commercialization-steps-up/ (last access 12/9/2009).

Lane, J. (2009f): *Amyris raises $24.7 million in first tranche of Series C funding; aims for $62 million in total for commercialization drive*. Biofuels Digest, Aug. 24, 2009. http://www.biofuelsdigest.com/blog2/2009/08/24/amyris-raises-247-million-in-first-tranche-of-series-c-funding-aims-for-62-million-in-total-for-commercialization-drive/ (last access 12/13/2009).

Lane, J. (2009g): *50 Hottest Companies in Bioenergy: #9, Verenium*. Biofuels Digest, Dec. 28, 2009. http://www.biofuelsdigest.com/blog2/2009/12/28/50-hottest-companies-in-bioenergy-9-verenium/ (last access 12/30/2009).

Lane, J. (2009h): *BP, DuPont butanol JV, Butamax, heads for commercialization; BP = "butanol play"? How will Gevo, Cobalt counter*? Biofuels Digest, Jul. 14, 2009. http://www.biofuelsdigest.com/blog2/2009/07/14/bp-dupont-butanol-jv-is-named-butamax-heads-for-commercialization-bp-stands-for-butanol-play-how-will-gevo-cobalt-counter/ (last access 1/27/2010).

Lane, J. (2009i): *BP outlines 3-pronged biofuels strategy, says biobutanol plant will open at commercial scale in 2013*. Biofuels Digest, Nov. 6, 2009. http://www.biofuelsdigest.com/blog2/2009/11/06/bp-outlines-3-pronged-biofuels-strategy-says-biobutanol-plant-will-open-at-commercial-scale-in-2013/ (last access 1/26/2010).

Lane, J. (2009j): *50 Hottest Companies in Bioenergy for 2009/10: #3, Amyris Biotechnologies – Amyris Biotechnologies*. Biofuels Digest, Dec. 16, 2009. http://www.biofuelsdigest.com/blog2/2009/12/16/50-hottest-companies-in-bioenergy-for-200910-3-amyris-biotechnologies/ (last access 12/30/2009).

Lane, J. (2009k): *50 Hottest Companies in Bioenergy: #5, Sapphire Energy*. Biofuels Digest, Dec. 18, 2009. , http://www.biofuelsdigest.com/blog2/2009/12/18/50-hottest-companies-in-bioenergy-5-sapphire-energy/ (last access 2/10/2010).

Lane, J. (2012l): *ZeaChem and the Renewable Fuel Standard*. Renewable Energy World, Jan. 17. 2012. http://www.renewableenergyworld.com/rea/news/article/2012/01/zeachem-and-the-renewable-fuel-standard (last access 3/25/2012).

Lane, J. (2010m): *50 Hottest Companies in Bioenergy: #30, Cobalt Biofuels – Cobalt Biofuels*. Biofuels Digest, Jan. 26, 2010. http://www.biofuelsdigest.com/blog2/2010/01/26/50-hottest-companies-in-bioenergy-30-cobalt-biofuels/ (last access 2/1/2010).

Lane, J. (2010n): 50 *Hottest Companies in Bioenergy for 2009-10: #24, Algenol.* Biofuels Digest, Jan. 19, 2010. http://www.biofuelsdigest.com/blog2/2010/01/19/50-hottest-companies-in-bioenergy-for-2009-10-24-algenol/ (last access 2/10/2010).

Lane, J. (2009o): *Coskata: 50 Hottest Companies in Bioenergy candidate profile*. Biofuels Digest, Sep. 23, 2009. http://www.biofuelsdigest.com/blog2/2009/09/23/coskata-50-hottest-companies-in-bioenergy-candidate-profile/ (last access 11/30/2009).

Lane, J. (2012p): *Chain, Chain, Chain – Chain of Fuels: Mascoma, Sud-Chemie on short path to parity with gasoline*. Biofuels Digest, Mar. 2, 2012. http://www.biofuelsdigest.com/bdigest/2012/03/02/chain-chain-chain-chain-of-fuels-mascoma-sud-chemie-on-short-path-to-parity-with-gasoline/ (last access 3/21/2012).

Lane, J. (2012q): *Genomatica delays commercial-scale production to 2013*. Biofuels Digest, Feb, 14, 2012. http://www.biofuelsdigest.com/bdigest/2012/02/14/genomatica-delays-commercial-scale-production-to-2013/ (last access 2/27/2012).

Langreth, R. (2008): *Beaker Fuel*. Forbes Magazine, Nov. 24, 2008. http://www.forbes.com/forbes/2008/1124/058.html (last access 10/24/2009).

Lane, J. (2012r): *Virdia ups the ante in the Race for the New Sugars*. Biofuels Digest, Mar. 6, 2012. http://www.biofuelsdigest.com/bdigest/2012/03/06/virdia-ups-the-ante-in-the-race-for-the-new-sugars/ (last access Jun.24, 2012).

Lardon, L.; Hélias, A.; Sialve, B.; Steyer, J.-P.; Bernard, O. (2009): *Life-Cycle Assessment of Biodiesel Production from Microalgae*. Environmental Science & Technology 43 (17), 6475-6481. http://pubs.acs.org/doi/pdfplus/10.1021/es900705j (last access 1/3/2009).

Lechler, T. (2001). *Social Interaction: A Determinant of Entrepreneurial Team Venture Success*. Small Business Economics 16, June, 263-278.

Lécuyer, C. (2001): *Technology and Entrepreneurship in Silicon Valley*. Article from Dec, 3, 2001. http://nobelprize.org/nobel_prizes/physics/articles/lecuyer/index.html (last access 10/12/2009).

Lemos-Stein, M. (2009): *The Summer Of Algae*. Wall Street Journal Blog, Jul. 14, 2009. http://blogs.wsj.com/venturecapital/2009/07/14/the-summer-of-algae/ (last access 12/16/2009).

Lenk Krueger, D. (1983): *Pragmatics of dyadic decision making: A sequential analysis of communication patterns*. Western Journal of Speech Communication 47 (2), 99-117. http://www.tandfonline.com/doi/abs/10.1080/10570318309374110 (last access 9/13/2010).

LeVine, S.; Aston, A. (2009): *Betting Big on a Boom in Natural Gas*. Business Week, Oct. 8, 2009. http://www.businessweek.com/magazine/content/09_42/b4151046053399.htm (last access 10/10/2009).

Levenson, M. (2008): *Facebook, ConnectU settle dispute – Case an intellectual property kerfuffle*. The Boston Globe, Jun. 27, 2008. http://www.boston.com/business/technology/articles/2008/06/27/facebook_connectu_settle_dispute/ (last access 7/19/2009).

Levy, S. (2009): *Secret of Googlenomics: Data-Fueled Recipe Brews Profitability*. Wired Magazine, Jun. 17, 2009. http://www.wired.com/culture/culturereviews/magazine/17-06/nep_googlenomics?currentPage=all (last access 2/12/2011).

Liedtke, M. (2008): *Google is world's most powerful 10-year-old*. AP, Sep. 5, 2008. http://www.msnbc.msn.com/id/26560994/ (last access 10/6/2008).

Lieske, P. (2004): *Marktvorteil für Klötzer Alge (Market advantage for algae from Klötze*). Altmarkzeitung, Oct. 2, 2004. http://www.algomed.de/media/presse/11-45-14-25-01-2008-Kloetzer%20Rundschau%2002.10.04.pdf (last access 2/7/2008).

Locke, E. A.; Baum, J. R. (2006): *Entrepreneurial Motivation*. Chapter 5, 93-112. In Baum, J. R.; Frese, M.; Baron, R. A. (Eds.). The Psychology of Entrepreneurship. August 2006. Taylor & Francis, Inc.

Lopez, M. R. (2009): *Bio-methanol producer BioMCN receives €36 million in private equity from Waterland*. Ecoseed, Mar. 10, 2009. http://www.ecoseed.org/en/general-green-news/features/green-living/941 (last access 1/19/2010).

Loten, A. (2011): *Firms Face Hurdles Overseas – Small Companies Seek Growth Abroad, but Lack Resources of Bigger Rivals*. Wall Street Journal, Aug. 25, 2011. http://online.wsj.com/article/SB10001424053111904787404576528451448313010.html?mod=WSJEurope_hps_MIDDLE_Video_second (last access 8/25/2011).

Loui, M. C. (2009): *Ethics and Social Responsibility for Scientists and Engineers*. Friday Forum, University YMCA, Champaign, Illinois, Feb. 6, 2009. https://netfiles.uiuc.edu/loui/www/fridayforum09.pdf (last access 9/1/2012).

Lovell, N. (2011): *Gamescom Hosts Fight for Games Market*. Wall Street Journal, Aug. 17, 2011. http://blogs.wsj.com/tech-europe/2011/08/17/gamescon-hosts-fight-for-the-games-market/ (last access 8/18/2011).

Lowry, A. (2011): *Culture as a Sustainable Advantage*. Stanford Technology Ventures Program, Entrepreneurial Thought Leaders Lecture Series, Nov. 9, 2011. http://ecorner.stanford.edu/authorMaterialInfo.html?mid=2839 (last access 2/1/2012).

Luggen, M.; Tschirky, H. (2003): *A conceptual framework for technology and innovation management in new technology-based firms (NTBF)*. Management of Engineering and Technology, PICMET '03. Technology Management for Reshaping the World. Portland International Conference on; 20-24 July 2003, Page(s): 342-347.

Luggen, M.; Tschirky, H. (2004): *An Entrepreneurial Approach to Technology and Innovation Management in New Technology-Based Firms (NTBF)*. International Conference on Management of Technology, IAMOT Conference, Washington D.C. 2004. http://www.iamot.org/conference/index.php/ocs/4/paper/viewFile/958/386 (last access 7/11/2009).

Lux Research (2009): *Green Biologics Limited*. Lux Research, updated on Oct. 27, 2009. https://portal.luxresearchinc.com/research/briefing_excerpt/5577 (last access 1/6/2010).

Lux Research (2007): *Synthetic Genomics*. The Cleantech Report. http://www.luxresearchinc.com/pdf/CompanyProfile_SyntheticGenomics.pdf (last access 5/17/2010).

Luxshan (2009): *Lecture 12 –Innovation Timing & Innovation Communities*. http://luxshan.com/swi/12.pdf (last access 5/28/2010).

Mäki, K.; Hytti, U. (2008): *"Pitching Out the Lost Cases" – A Longitudinal Study of the Precedents of Non-Growth of Recent Incubator Graduates*. Paper submitted in the ICSB World Conference 2008. http://www.smu.ca/events/icsb/proceedings/entk6f.html (last access 7/10/2009).

Ma, W. (2013): *China's LDK Solar Defaults on Bond Payment*. Wall Street Journal, updated Apr. 16, 2013. http://online.wsj.com/article/SB10001424127887324030704578426241915931194.html?KEYWORDS=solar+chinese (last access 4/16/2013).

Machatschke, M. (2008): *Enercon – Vom Winde verwöhnt (Blessed by the winds)*. Manager Magazin, Dec. 8, 2008. http://www.manager-magazin.de/magazin/artikel/0,2828,586223,00.html (last access 1/15/2011).

Madrigal, A. (2009): *How Algal Biofuels Lost a Decade in the Race to Replace Oil*. Wired Science, Dec. 29, 2009. http://www.wired.com/wiredscience/2009/12/the-lost-decade-of-algal-biofuel/?utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+wired%2Findex+%28Wired%3A+Index+3+%28Top+Stories+2%29%29 (last access 1/2/2010).

Madrigal, A. (2007): *Supercrude Scum: The Algae-To-Biodiesel Battle*. Earth2tech, Oct. 3, 2007. http://gigaom.com/cleantech/supercrude-scum-the-algae-to-biodiesel-battle/ (last access 11/6/2008).

Mah, J. (2011): *Are You Building Products Customer Want?* Stanford Technology Venture Network, Entrepreneurial Thought Leaders Lecture Series, Nov. 30, 2011. http://ecorner.stanford.edu/authorMaterialInfo.html?mid=2853 (last access 6/23/2012).

Malone, T. W. (1988): *What is Coordination Theory?* Paper presented at the National Science Foundation Coordination Theory Workshop, Massachusetts Institute of Technology, Feb. 19, 1988. SSM WP # 2051-88. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.86.8170&rep=rep1&type=pdf (last access 12/5/2011).

Mandaro, L. (2007): *Monsanto, BASF in $1.5 bln genetic seeds venture*. MarketWatch, Mar. 21, 2007. http://www.marketwatch.com/story/monsanto-basf-in-15-bln-union-to-develop-seeds-for-biofuels (last access 10/30/2009).

Marine Biological Laboratory (2009). *Biofuel Displacing Food Crops May Have Bigger Carbon Impact Than Thought*. ScienceDaily, 2009. http://www.sciencedaily.com-/releases/2009/10/091022141117.htm (last access 10/25/2009).

Markman, G. D.;Gartner, W. B. (2002): *Is extraordinary growth profitable? A study of Inc. 500 high-growth companies*. Entrepreneurship: Theory and Practice – Fall, 2002. http://www.entrepreneur.com/tradejournals/article/110811955.html (last access 3/11/2011).

Marvel, M. R.; Murphy, P. J. (2007): *Human Capital and High Tech Entrepreneurial Discovery: Beyond the Search Serendipity Continuum*. Frontiers of Entrepreneurship Research 27 (5), Article 14. Available at: http://digitalknowledge.babson.edu/fer/vol27/iss5/14 (last access 9/10/2009), http://digitalknowledge.babson.edu/cgi/viewcontent.cgi?article=1097&context=fer (last access 9/10/2009).

Mascoma Corp. (2009): *Mascoma Announces Feedstock Processing and Lignin Supply Agreement with Chevron Technology Ventures*. News, Sep. 14, 2009. http://www.mascoma.com/download/Mascoma%20Chevron%20Agreement%20Release%20FINAL%20091409.pdf (last access 11/24/2009).

Marsh, P. (2008): *Prudent partnerships*. The Financial Times, Dec. 23, 2008. https://www.ft.com/cms/s/0/1d7312a6-d10b-11dd-8cc3-000077b07658,dwp_uuid=02e16f4a-46f9-11da-b8e5-00000e2511c8.html (last access 12/23/2008); http://www.cbnl.com/news/pdf/ftdotcom_231208.pdf (last access 10/30/2010).

Marsh, P. (2003): *Inside Track: Thinking big in nanoscience*. Financial Times; Jan 27, 2003. http://www.attocube.com/company/download/FT_270103.pdf (last access 1/13/2006).

Marshall, M. (2006): *Amyris gets $20M from high-profile investors to find alternative fuel*. Venture Beat, Oct. 12, 2006. http://venturebeat.com/2006/10/12/amyris-gets-20m-from-high-profile-investors-to-find-alternative-fuel/ (last access 5/6/2009).

Marshall, R. (2012): *LinkedIn considers launching intranet service for businesses*. V3.co.uk, Feb. 15, 2012. http://www.v3.co.uk/v3-uk/news/2152671/linkedin-considers-launching-intranet-service-businesses (last access 3/23/2012).

Martin, J. (2010): *Bioethanol: Cyano Biofuels setzt auf die Herstellung aus Algen (Bioethanol – Cyano Biofuels Focuses on Production by Algae).* CleanThinking, Jan. 3, 2010. http://www.cleanthinking.de/biothenaol-cyano-biofuels-algen/3789/ (last access 1/4/2010).

Martin, D.; Bloch, P. (2004): *Patent Donations and the Problem of Orphan Technologies*. A Policy Forum on The Intangible Economy. Held at the Woodrow Wilson International Center for Scholars, Washington, DC, April 14, 2004. http://www.athenaalliance.org/issuedialogue/orphan_tech.html (last access 6/11/2009).

Mauer, R.; Brettel, M. (2008): *Learning From Technology Entrepreneurs: Effectuation as a New Toolbox In Contexts of High Uncertainty*. In Iandoli, L. (2008) Technology-driven entrepreneurship – how technology shapes the way entrepreneurs start and run their businesses. 5th Inter-RENT Online Publication, European Council for Small Business and Entrepreneurship, Mar. 2008. File interrent_2008_final.pdf, created 1/8/2009 (last access 10/20/2010); search Google: “mauer brettel Effectuation toolbox pdf.”

Mayer, J. D. (1993-1994): *A System-Topics Framework for the study of personality*. Imagination, Cognition, and Personality, 13 (2), 99-123. http://www.thepersonalitysystem.org/PFAAssets/sysframework/systopics.pdf (last access 7/23/2009);
Mayer, J. D.: *Personality Psychology: A Systems Approach***.** http://www.thepersonalitysystem.org/index.htm (last access 7/23/2009); John D. Mayer**:**:*The Systems Framework for Personality in Focus.* More literature references herein. http://www.thepersonalitysystem.org/Systems%20Framework%20in%20Focus/pfasysframeandsystheory.htm (last access 7/23/2009).

MBI: Marrone, P. (Marrone Organic Innovations): *Hire People Who Share Your Values*. Business Leaders – 50 Lessons. http://www.50lessons.com/peoplefinder.asp?l=M&s=118 (last access 1/14/2010).

MBI (2007): *Marrone Organic Innovations Closes $3.75 Million Series A Financing* http://marronebioinnovations.com/pdf/MOISeriesAFinal.pdf (last access 1/14/2010).

McCann, J. E. (1991): *Patterns of growth, competitive technology, and financial strategies in young ventures*. Journal of Business Venturing 6 (3), May 1991, 189-208; available online 11 April 2002.

McCline, R. L.; Bhat, S.; Baj, P. (2000): *Opportunity Recognition: An Exploratory Investigation of a Component of the Entrepreneurial Process in the Context of the Health Care Industry*. Entrepreneurship: Theory and Practice, Winter, 2000. http://www.entrepreneur.com/tradejournals/article/74524634.html (last access 5/26/2010).

McCoy, M. (2006): *Biomass Gambit – Shell, Codexis Sign Biofuels Pact*. Chemical & Engineering News 84 (47), 21. http://pubs.acs.org/cen/news/84/i47/8447notw9.html (last access 11/24/2009).

McDermott, M.(2012): *Shell Builds Drop-In Biofuels Plant In Texas, While Revving Up Arctic Drilling Plans*. Treehugger, Mar. 1, 2012. http://www.treehugger.com/renewable-energy/shell-builds-drop-in-biofuel-plant-while-revving-oil-exploration-arctic.html (last access 5/27/2012).

McDermott, M. (2009): *BP Backs Out of Jatropha Joint Venture with D1 Oils*. Treehugger, Jul. 20, 2009. http://www.treehugger.com/files/2009/07/bp-backs-out-jatropha-joint-venture-d1-oils.php (last access 11/7/2009).

McDonald, T. (2011): E•*BOOM CAPITAL: Gevo and Amyris Take Similar Routes to Advanced Biofuel*. Energyboom, Feb. 22, 2011. http://www.energyboom.com/biofuels/e%E2%80%A2boom-capital-gevo-and-amyris-take-similar-routes-advanced-biofuel (last access 6/23/2011).

McLeod R.; Winsor, B. (2003): *3M Case Study: Entrepreneurship*. Scottish Institute for Enterprise. http://www.sie.ac.uk/File/12R0.aspx (last access 8/29//2009), http://www.venturenavigator.co.uk/content/3m_case_study?s=true (last access 8/292009).

MacMillan, D. (2013): *LivingSocial Falls to a Quarter of 2011 Value in Latest Funding*. Bloomberg News, Feb 22, 2013. http://www.bloomberg.com/news/2013-02-

22/livingsocial-falls-to-a-quarter-of-2011-value-in-latest-funding.html (last access 2/23/2013).

Meeker, M. (2001): *Technology and Internet: The Technology & Internet IPO Yearbook: 7th Edition – 21 Years of Tech Investing* Morgan Stanley Deam Witter, April 2001. http://www.morganstanley.com/institutional/techresearch/pdfs/2001ipoyb.pdf (last access 5/2/2010); Meeker, M. (2003): *Technology: Cross-Industry Insights: The Technology IPO Yearbook – 9th Edition – 23 Years of Tech Investing*. Morgan Stanley Equity Investment, Oct. 3, 2003. http://www.morganstanley.com/institutional/techresearch/pdfs/2003_tech_ipo_yearbook.pdf (last access 5/2/2010).

Melendez, L. (2009): *Green jobs may help CA out of recession*. Peninsula News, Sep. 18, 2009. http://abclocal.go.com/kgo/story?section=news/local/peninsula&id=7021996 (last access 1/25/2010).

Merton, R. K. (1968): *The Matthew effect in Science*. Science (New Series) 159 (3810), 56-63. http://www.unc.edu/~fbaum/teaching/PLSC541_Fall06/Merton_Science_1968.pdf (last access 11/3/2010).

Metzger, G. (2007): *On the Role of Entrepreneurial Experience for Start-up Financing – An Empirical Investigation for Germany*. ZEW, Discussion Paper No. 07-047, ftp://ftp.zew.de/pub/zew-docs/dp/dp07047.pdf (last access 7/11/2009).

Metzger, G.; Niefert, M.; Licht, G. (2008): *Hightech-Gründungen in Deutschland: Trends, Strukturen, Potenziale.* Mai 2008 (*Hightech Foundations in Germany: Trends, Structures, Potentials. May 2008*). ZEW. ftp://ftp.zew.de/pub/zew-docs/gutachten/hightechgruendungen08.pdf (last access 7/10/2009).

Metzger, G.; Heger, S.; Höwer, D.; Licht, G. (2010a): *High-Tech-Gründungen in Deutschland – Hemmnisse junger Unternehmen.* ZEW – Zentrum für Europäische Wirtschaftsforschung, September 2010. ftp://ftp.zew.de/pub/zew-docs/gutachten/hightechgruendungen2_10.pdf (last access 11/182010).

Metzger, G.;·Heger, D.; Höwer, D.; Licht, G. (2010b): *High-Tech-Gründungen in Deutschland - Zum Mythos des jungen High-Tech-Gründers (High-tech foundations in Germany – On the myth of the young high-tech founder)*. ZEW – Zentrum für Europäische Wirtschaftsforschung, February 2010. ftp://ftp.zew.de/pub/zew-docs/gutachten/hightechgruendungen10.pdf (last access 11/18/2010).

Meuser, F. (2011): *50 Jahre Institut für Getreideverarbeitung im Spiegel der Zeit (50 years of the Institute of Cereal Processing through the ages*). In [IGV 2011], Annual Report 2010, 38-45. http://www.igv-gmbh.de/images/stories/docs/IGV_Jahresbericht_2010_6.pdf (last access 5/8/2012).

Michel, R. (2009): *"Green gas" innovator Virent sees value in manufacturing expertise*. Manufacturing Business Technology, Jul. 29, 2009. http://www.mbtmag.com/blog/Operation_Green/20614-_Green_gas_innovator_Virent_sees_value_in_manufacturing_expertise.php (last access 12/17/2009).

Milgrom, L. (2003): *Spin doctors. Chemistry* in Britain, Jul. 2003. http://www.chemsoc.org/chembytes/ezine/2003/milgrom_jul03.htm (last access 7/31/2003).

Miller, K. (2007): *Silly Enough to Try Again?* Business Week, Jun. 1, 2007. http://www.businessweek.com/smallbiz/content/jun2007/sb20070601_336379.htm (last access 8/18/2010); *Great Advice from Serial Entrepreneurs. Pam Marrone, 50*. Business Week. http://images.businessweek.com/ss/07/06/0602_serial_entp/index_01.htm?popupWidth=770&popupHeight=660.

Mills, P. (2008): *Uncle Sam Wants U.V*. SpecialChem, Sep. 24, 2008. http://www.specialchem4coatings.com/resources/articles/article.aspx?id=10040&lr=mci08166&li=20024489 (last access 10/12/2009).

Minshall, T.; Wicksteed, B. (2005): *University spin-out companies: Starting to fill the evidence gap.* A report on a pilot research project commissioned by the Gatsby Charitable Foundation, Jan. 2005. http://www.insme.org/documents/University%20spin-out%20companies.pdf (last access 7/12/2010.

Mitchell P. C.; McKeown, A. E. (2004): *Importance of peer support and tutor involvement in entrepreneurship education for overseas Bioscience students*. BEE-j 3, May 2004. http://www.bioscience.heacademy.ac.uk/journal/vol3/beej-3-2.pdf (last access 05/07/2008).

Mitra, S.(2009): *U.S. And India's Tech Dilemma.* Forbes, Feb. 19, 2009. http://www.forbes.com/2009/02/19/india-engineer-computer-technology-enterprise-tech_india.html (last access 2/19/2009).

Molitor, J.-P. (2012): W*hite Biotech Strategies of Large Corporations: Hopes & Challenges*. SpecialChem, Jan. 30, 2012. http://www.specialchem4coatings.com/resources/articles/article.aspx?id=17704&lr=mci12337&li=20024489 (last access 2/9/2012).

Moore, G. (1999): *Solid-State Physicist William Shockley*. Time Magazine, Mar. 29, 1999. http://www.time.com/time/magazine/article/0,9171,990623-1,00.html (last access 1/7/2011).

Morais, R. (2004): *OTB-Group Makes The World Smaller*. Forbes, Apr. 23, 2004. http://www.forbes.com/2004/01/23/cz_rm_0123davosotb.html (last access 10/12/2009).

Moresco, J. (2008): *Khosla Ventures Partners With Hawaiian Utility*. Redherring, Dec. 17, 2008. http://www.redherring.com/Home/25665 (last access 12/29/2009).

Morris, M. H., Kuratko, D. F. and Covin J. G. (2008): *Corporate Entrepreneurship and Innovation: Entrepreneurial Development within Organizations* (2nd ed.). Thomson-South-Western.

Morrison, C. (2009): *Sapphire Energy gets "open checkbook" from investors for algae-based gasoline*. GreenBeat, May 29, 2008. http://green.venturebeat.com/2008/05/29/sapphire-energy-gets-open-checkbook-from-investors-for-algae-based-gasoline/ (last access 3/14/2010).

Morrissey, S. R. (2009): *High-Risk Energy Projects Get Funds. Grants: Big winners include Foro Energy, DuPont, and MIT*. Chemical & Engineering News 87 (44), 9. http://pubs.acs.org/cen/news/87/i44/8744notw1.html (last access 11/4/2009).

Moustras, M. – The Royal Society of Chemistry (2003), *Spin out companies from UK chemistry departments*. http://www.rsc.org/pdf/indusdiv/spinout.pdf (last access 02/18/2008).

MPG (2009): *Max Planck Gesellschaft – Annual Report 2008*. May 2009. http://www.mpg.de/pdf/jahresbericht2008/jahresbericht2008.pdf (last access 6/12/2010);
MPG (2010): Max Planck Gesellschaft – *Annual Report 2009*. May 2010. http://www.mpg.de/180981/Jahresbericht_2009.pdf (last access 6/12/2011).

MSFC – US Marshall Space Flight Center: *Dr. Wernher von Braun – First Center Director, Jul. 1, 1960 - Jan. 27, 1970*. http://history.msfc.nasa.gov/vonbraun/bio.html.

Mueller, S.L.; Thomas, A.S. (2001): *Culture and entrepreneurial potential – A nine country study of locus of control and innovativeness*. Journal of Business Venturing, 16 (1), 51-75.

Müller-Jung, J. (2009): *Bioenergie – Der Frühling der grünen Sonnenkollektoren (Bioenergy – The spring of green sun collectors)*. FAZNET, Apr. 7, 2009. http://www.faz.net/s/Rub80665A3C1FA14FB9967DBF46652868E9/Doc~E4E0FED18D1D14969A12DBEB846362998~ATpl~Ecommon~Scontent.html (last access 11/10/2009).

Müller-Jung, J. (2010): *Wer zaubert Biosprit aus dem grünen Topf? (Who performs magic out of the green pot?).* FAZNET, Feb. 17, 2010. http://www.faz.net/s/Rub80665A3C1FA14FB9967DBF46652868E9/Doc~E076358A5606E4CA2B741BFA3A61DE9EC~ATpl~Ecommon~Scontent.html (last access 2/17/2010).

Mugler, J. (1998): *Betriebswirtschaftslehre der Klein- und Mittelbetriebe*. Band 1, Dritte, überarbeitete Auflage, Springer Verlag Wien, New York. Kapitel: *Der Konfigurationsansatz (Business Administration for Small and Medium-Sized Enterprises* Vol. 1, Chapter: *The Configuration Approach).*

Mukhopadhyay, R. (2011a): *Biofuels: An Ethical Framework*. Chemical & Engineering News 89 (33) Web Exclusive, Aug.15,20011. http://pubs.acs.org/cen/coverstory/89/8933cover2.html (last access 8/18/2011).

Mukhopadhyay, R. (2011b): *Technology: Energy Department Offers Deep Discounts On Its Patents*. Chemical & Engineering News, May 6, 2011. http://pubs.acs.org/cen/news/89/i19/8919notw5.html (last access 5/6/2011).

Mukhopadhyay, R. (2011c): *DOE, USDA Biofuel Projects Get A Boost.* Chemical & Engineering News 89, May 10, 2011. http://pubs.acs.org/cen/news/89/i20/8920news4.html (last access 5/12/2011).

Mukhopadhyay, R. (2011d): *Clean Energy For The Military*. Chemical & Engineering News 89 (18), May 2, 2011, 8. http://pubs.acs.org/cen/news/89/i18/8918notw7.html (last access 5/4/2011).

Mukhopadhyay, R. (2011e): *Examining Biofuels Policy*. Chemical & Engineering News 89 (33), Aug. 15, 2011, 10-15. http://pubs.acs.org/cen/coverstory/89/8933cover.html?featured=1 (last access 8/17/2012).

Mullaney, T. (2011): *Why Mascoma's Shaky IPO Is Lehman's Fault*. The Motley Fool, Sep. 26, 2011. http://www.fool.com/investing/general/2011/09/26/why-mascomas-shaky-ipo-is-lehmans-fault.aspx (last access 1/23/2012).

Mullins, J. W. (2006): *What to Run BeforeYour Business Plan Course*. London Business School, 2006. http://www.stanford.edu/group/ree/archives/archive06/europe/presentations/REE_Europe_2006_JMullins.pdf (last access 5/26/2010); cf. also http://www.ieec.co.uk/2006/docs/Pre-BusinessPlanninCurricula.ppt.

Murphy, M. (2011): *Zynga Explains Method For Recording Real Revenue From Virtual Goods*. Wall Street Journal, Jul. 1, 2011. http://online.wsj.com/article/BT-CO-20110701-712257.html (last access 7/2/2011).

Murmann, J. P. (2003): *Knowledge and Competitive Advantage. The Coevolution of Firms, Technology, and National Institutions*. Cambridge University Press; The Coevolution of Industries and National Institutions: Theory and Evidence. Discussion Paper FS IV 02-14, Wissenschaftszentrum Berlin, 2002. http://skylla.wz-berlin.de/pdf/2002/iv02-14.pdf (last access 6/21/2010).

Muth, W. (2010): *Novaled AG – OLEDs for General Lighting*. Presentation, Nov. 2, 2010). http://www.rusnanoforum.ru/Document.aspx/Download/29189 (last access 2/12/2011).

Myers, S.; Majluf, N. S. (1984): *Corporate Financing and Investment Decisions when Firms have Information that Investors Do Not Have.* Journal of Financial Economics 13 (2) (June 1984), 187-221; http://en.wikipedia.org/wiki/Pecking_Order_Theory.

Nagappan, P. (2009): *Solazyme Lands U.S Navy Contracts for Algae Jet Fuel*. EnergyBoom – Biofuel Energy, Nov. 10, 2009. http://www.energyboom.com/biofuels/solazyme-lands-us-navy-contracts-algae-jet-fuel (last access 1/25/2010).

Naimark, N. M. (1995): *The Russians in Germany: A history of the Soviet Zone of occupation, 1945-1949*. The Soviet Use of German Science, p. 205-250. Harvard University Press, 1995.

Narvaes Wilmsen, E. (2006): *Colorado State Engines Lab Teams with Solix Biofuels Inc. to Mass Produce Oil from Algae as Diesel Fuel Alternative*. Colorado State University, News & Information, Dec. 7, 2006. http://www.news.colostate.edu/Release/4260 (last access 4/18/2007).

NanoScape (2002): *Nanozwiebeln bringen Styrol-Synthese auf Trab. (Nano-onions accelerate styrene synthesis*). Innovations-Report, Oct. 17, 2002. http://www.innovations-report.de/html/berichte/verfahrenstechnologie/bericht-13744.html (last access 5/5/2006).

NanoScape (2005): *Firm Profile – Design, Discovery, Development – NanoMaterialien für die Zukunft. (Firm Profile – Design, Discovery, Development – Nano-materials for* *the future*). File from 4/7/2005. http://www.nanoscape.de/pdf/History_NanoScape.pdf (last access 3/5/2006).

NASA (2003): *Remarks by NASA Deputy Administrator Gregory Centennial of Flight Commemoration.* Agency News, Dec. 17, 2003. http://www.nasa.gov/audience/formedia/speeches/fg_kitty_hawk_12.17.03_prt.htm (last access 4/11/2010).

NASDAQ (2011): *Gevo - Prospectus* - Filed Pursuant to Rule 424(b)(4), Registration No. 333-168792, Feb. 8, 2011 http://www.nasdaq.com/markets/ipos/filing.ashx?filingid=7365503 (last access 12/12/2011).

Nelson, B. (2009): *Explanation of the TVA Radar Graph.* Forbes Magazine Sep. 16, 2009. http://www.forbes.com/2009/09/08/radar-graph-explanation-entrepreneurs-finance-promising.html (last access 9/23/2010).

Nelson, J. W.(2002): *Color Me With Good Fortune*. Molecular Interventions 2 (3), 186-187 (June 2002). http://molinterv.aspetjournals.org/content/2/3/186.full (last access 2/18/2010).

NEnA: *Katja Heppe – Ich lebe für meine Idee* (*Katja Heppe* – I live for my idea). Nano-Entrepreneurship-Academy. http://www.nano-4-women.de/content/view/50/104/lang,en/ (last access 8/16/2010).

Neubauer, U. (2006): *Forscher in geheimer Mission (Researchers with secret mission)*. Nachrichten aus der Chemie 54, 759-761. http://www.gdch.de/taetigkeiten/nch/inhalt/jg2006/forscher.pdf (last access 8/25/2010).

Neutraceuticals World (2009): *B&D Nutritional Ingredients Partners with Solazyme*. Published Dec. 1, 2009. http://www.nutraceuticalsworld.com/contents/view/15110 (last access 1/24/2010).

New York Times (1997): *Manfred von Ardenne, 90, Dies; Was German Nuclear Physicist*. The New York Times, May 29, 1997. http://www.nytimes.com/1997/05/29/world/manfred-von-ardenne-90-dies-was-german-nuclear-physicist.html (last access 3/24/2011).

NewNet – New Energy World Network: *NewNet Innovator Profile: Rick Wilson, Cobalt Biofuels*. NewNet, Oct. 12, 2009. http://www.newenergyworldnetwork.com/clean-energy-investor-profiles/newnet-innovator-profile-rick-wilson-cobalt-biofuels.html (last access 1/26/2010).

Newton D. (2001): *Using Credit Cards to Finance Your Startup. Think of it as a temporary solution*. Jun. 18, 2001. http://www.entrepreneur.com/money/financing/financingcolumnistdavidnewton/article41520.html (last access 9/15/2009).

Nicolaou, N.; Shane, S.; Cherkas, L.; Hunkin, J.; Spector, T. D. (2008): *Is the Tendency to Engage in Entrepreneurship Genetic?* Management Science 54 (1), January 2008, 167-179; cf. also
Nicolaou, N.; Shane, S.; Cherkas, L.; Hunkin, J.; Spector, T. D. (2007): *Is the Tendency to Engage in Entrepreneurship Genetic?* http://wsomfaculty.cwru.edu/shane/ge/GE1.pdf (last access 6/18/2009).

Niefert, M., Metzger, G.; Heger, D.; Licht, G. (2006): *Hightech-Gründungen in Deutschland.* Endbericht, Mannheim, Juni 2006. (*Hightech Foundations in Germany*. Final Report, Mannheim, June 2006). ZEW. ftp://ftp.zew.de/pub/zew-docs/gutachten/hightechgruendungen.pdf (last access 7/10/2009).

NNFCC (2009): *Review of Technologies for Gasification of Biomass and Wastes*. Final Report, NNFCC Project 09/008, Jun. 2009. NNFCC final report E4tech 090609[1].pdf; access via Google search "Review of Technologies for Gasification of Biomass and Wastes" (last access 2/202010).

Nonnast, T. (2006): SAP – *Langsam, aber gewaltig (SAP – slow but colossal).* Handelsblatt, Apr. 7, 2006. http://www.handelsblatt.com/sap-langsam-aber-gewaltig;1061581 (last access 7/29/2010.

NVCA (2009): *Venture Impact – The Economic Importance of Venture Capital-Backed Companies to the U.S. Economy*. The National Venture Capital Association (NVCA). http://www.nvca.org/index.php?option=com_content&view=article&id=255&Itemid=103; NVCA_venture_impact_5th_ed.pdf (file last access 10/10/2010).

NVCA: *Venture Capital 101 – What is Venture Capital*. Venture_Capital_101.pdf from www.NVCA.org; (file last accessed 10/11/2010).

O'Brien, J. M. (2007): *Meet the PayPal mafia*. Forbes Magazine, Nov. 26, 2007. http://money.cnn.com/2007/11/13/magazines/fortune/paypal_mafia.fortune/index.htm (last access 7/1/2011); http://en.wikipedia.org/wiki/PayPal_Mafia.

Obituary (1956): *Thomas J. Watson Sr. Is Dead; I.B.M. Board Chairman Was 82*. The New York Times, On this Day, Jun. 20, 1956. http://www.nytimes.com/learning/general/onthisday/bday/0217.html (last access 1/25/2011).

Oilgae Blog (2008): *Vinod Khosla Feels Algae Are not Yet Ready for Primetime?* October 31, 2008. http://www.oilgae.com/blog/2008/10/vinod-khosla-feels-algae-are-not-yet.html (last access 2/18/2010).

Ohff, H. (1981): *Karl Friedrich Schinkel – Preußische Köpfe (Prussian Heads).* Stapp Verlag, Berlin 1981; cf. also http://en.wikipedia.org/wiki/Karl_Friedrich_Schinkel; http://de.wikipedia.org/wiki/Karl_Friedrich_Schinkel; http://de.wikipedia.org/wiki/Christian_Peter_Wilhelm_Beuth.

Oilgae Blog (2009): *Biofuels Digest released summary of US venture capital investment in biofuels*. Posted on January 25, 2009 by GURU @ 8:23 PM. http://www.oilgae.com/blog/2009/01/biofuels-digest-released-summary-of-us.html (last access 10/24/2009).

Olson, P. D. (1986): *Entrepreneurship: opportunistic decision-makers*. Journal of Small Business Management, 11 (2), 25-31. Google cache - http://www.allbusiness.com/human-resources/employee-development-problem-solving/102133-1.html (last access 7/8/2009).

Oneal, M. (2006): *Entrepreneur putting his chips on ethanol*. Chicago Tribune, Oct. 13, 2006. http://www.chicagotribune.com/news/nationworld/chi-0610130129oct13,0,2550074.story (last access 2/20/2010).

Onuoha G. (2007): "*Entrepreneurship*" AIST International Journal 10:20-32 cited in Wikipedia (http://en.wikipedia.org/wiki/Entrepreneurship, last access 7/8/2009).

Openshaw, E.; Pentland, A. (2012): *Making Visible the Invisible: Meaning, Not Content, Matters in Social Data.* All Things, Sep. 28, 2012. http://allthingsd.com/20120928/making-visible-the-invisible-meaning-not-content-matters-in-social-data/ (last access 10/5/2012).

OPXBio (2011): *Dow and OPXBIO Collaborating on Renewable Route to Acrylic Acid*. News, Apr. 11, 2011. http://www.opxbiotechnologies.com/press/Dow_and_OPXBIO_Collaborating_on_Renewable_Route_to_Acrylic_Acid.php (last access 4/29/2011).

ORNL – Oak Ridge National Laboratory (2010): *DNP Green Technology, Inc. Exclusively Licenses Patents Invented at Argonne National Laboratory and Oak Ridge National Laboratory*. ORNL, Mar, 9, 2010. http://www.ornl.gov/adm/partnerships/success_stories/dnp.shtml (last access 3/4/2012).

Osterath, B.; Guggolz, E. (2013): *Wir waren immer kurz vom Abschuss (We were always just before the shooting down*.) *Interview with key researcher Ludwig Pohl*. Nachrichten aus der Chemie 61, 758-761.

Ozgen, E.; Baron, R.A. (2007): *Social sources of information in opportunity recognition: Effects of mentors, industry networks, and professional forums*. *Journal* of Business Venturing 22, 174-192.

Page, L.; Schmidt, E. (2002): *Video – Innovate in Technology and Business: The Founding of Google*. Innovate in Technology and Business: The Founding of Google Entrepreneurial Thought Leader Speaker Series, May 1, 2002. http://ecorner.stanford.edu/authorMaterialInfo.html?mid=1074 (last access 7/2011).

Pasztor, A. (2012): *Private Space Run Makes History*. Wall Street Journal, May 25, 2012. http://online.wsj.com/article/SB10001424052702304840904577426042171703270.html?mod=WSJEurope_hpp_LEFTTopStories (last access 5/26/2012); cf. also Andresen, T. (2012): *Elon Musk - Der Elektroauto-Pionier, der auf den Mars will (Elon Musk – The electrocar pioneer who want to reach the Mars*). Handelsblatt. May 25, 2012. http://www.handelsblatt.com/unternehmen/management/koepfe/elon-musk-der-elektroauto-pionier-der-auf-den-mars-will/6671546.html (last access 5/25/2012).

Patrashkova-Vozdolska, R. (2005): *Modeling teams: A general systems theory approach*. PhD Thesis, University of Massachusetts Amherst, 2005, 228 pages; AAT 3193932). http://gradworks.umi.com/31/93/3193932.html (last access 7/27/2010); Presentation with some details. http://home.kelley.iupui.edu/tatikond/webpage/AoM2005StudentPresentations/PatrashkovaPresentation.ppt.

PBS – Public Broadcasting Service (2009): *Timeline: History of the Electric Car*. Now on PBS, Week of Oct. 30, 2009. http://www.pbs.org/now/shows/223/electric-car-timeline.html (last access 5/28/2010).

Peach S. (2011): *Current Technology Could Reduce Global Energy Demand by 85%*. Chemical & Engineering News, Jan. 19, 2011. http://pubs.acs.org/cen/news/89/i04/8904scene1.html (last access 1/20/2011).

Peer, M. (2013): *Netzwirtschaft – Deutsche Gründer erobern Asien (Net economy – German founders conquer Asia*). Handelsblatt, published on Apr. 2, 2013. http://www.karriere.de/karriere/deutsche-gruender-erobern-asien-165593/ (last access 3/6/2013); cf. also http://www.crunchbase.com/company/lazada.

Perlin, J. (2003): *From Space to Earth. The Story of Solar Energy*., http://www.californiasolarcenter.org/pdfs/rahus/Panels_1-10_poster.pdf (last access 8/25/2009); also http://www.californiasolarcenter.org/fste/fste.html (last access 8/25/2009).

Perman, S. (2006): *Is There a Gene for Business?* Business Week, Oct. 30, 2006. http://www.businessweek.com/smallbiz/content/oct2006/sb20061030_540336.htm (last access 7/19/2009).

Phuong Le (2008): *Algae fuel science chalks up federal, private funding*. Lubbock Online, Nov. 5, 2008. http://www.lubbockonline.com/stories/110508/bus_352191682.shtml (last access 12/12/2009).

Pienkos, P. T. (2008): *Historical Overview of Algal Biofuel – Technoeconomic Analyses*. DOE Algal Biofuels Workshop, Dec. 9, 2008. http://www.nrel.gov/docs/fy09osti/45622.pdf (last access 12/23/2009).

Pienkos P. T.; Darzins, A. (2009): *The promise and challenges of microalgal-derived biofuels*. Biofuels, Bioprod. Bioref. 3, 431–440 (2009); DOI: 10.1002/bbb). http://www.afdc.energy.gov/afdc/pdfs/microalgal_biofuels_darzins.pdf (last access 12/23/2009).

pipeline (2008): *pipeline™ Exclusive – Fermentation Technology Developer Eyes £3.5 Million*. Clean Technologies & Renewable Energy II (27), 4-5 (25 November – 01 December 2008). http://www.mountroyalventures.com/assets/pdfs/VB%20Research%20Ingeligence%20Report.pdf (last access 1/28/2010).

Pisano, G. (2006): *Don't Wait Around for the Next Amgen*. Business Week, Dec. 20, 2006. http://www.businessweek.com/technology/content/dec2006/tc20061220_865132.htm?chan=technology_technology+index+page_science (last access 8/23/2010).

Pleschak, F.; Werner, H. (1998): *Technologieorientierte Unternehmensgründungen in den neuen Bundeländern – Wissenschaftliche Analyse und Begleitung des BMBF-Modellversuchs (Technology-oriented firms' foundation in the new federal states – Scientific analysis and accompanimentof the BMBF pilot)*. Physica-Verlag, Heidelberg.

Poliakoff, M.; Howdle, S.; Lathbury, D. (2009): *Ten things chemical engineers should know about chemists*. Chemistry World, January 2009. http://www.rsc.org/chemistryworld/Issues/2009/January/Comment.asp (last access 7/1/2011).

Porretto, J. (2009): *Exxon makes first big investment in biofuels*. Forbes, Jul. 14, 2009. http://www.forbes.com/feeds/ap/2009/07/14/ap6650792.html (last access); also http://www.google.com/hostednews/ap/article/ALeqM5jORvy4DeZKdWvIkiC0ewOYFEnmhQD99E5HS03.

Prahalad, C.K.; Bettis, R.A. (1986): *The dominant logic: A new linkage between diversity and performance*. Strategic Management Journal, 7: 485-501.

PresseBox (2012): *PURPLAN GmbH wird Preisträger 2012 – Einmaliges Know-how (PURPLAN GmbH awarded in 2012 – A unique know-how*). Pressemeldung BoxID 535224, Sep. 8, 2012. http://www.pressebox.de/pressemeldungen/oskar-patzelt-stiftung/boxid/535224 (last access 10/23/2012).

PrivCo (2013): *Fisker's Road to Bankruptcy/Ruin*. Research Note, Apr. 4, 2013; Breaking News, Apr. 22, 2013; Breaking News, Apr. 23, 2013; Breaking News, Apr. 26, 2013; Breaking News, Apr. 29, 2013.

Procter, C. (2008): *Solix Biofuels hopes to generate green from algae*. Denver Business Journal, Jan. 25, 2008. http://www.bizjournals.com/denver/stories/2008/01/28/story4.html?page=all (last access 11/6/2008).

Pruitt, A. (2009a): *Gevo, Inc. Develops Revolutionary Butanol Biofuel*. EnergyBoom, Biofuel Energy, Nov. 25, 2009). http://www.energyboom.com/biofuels/gevo-inc-develops-revolutionary-butanol-biofuel (last access 1/11/2010).

Pruitt, A.; Kalish, A. (2009b): *U.S. Census data showing new and young firms as the primary source of new jobs come at a critical time for policymakers*. Kauffman Foundation, Nov. 5, 2009. http://www.kauffman.org/newsroom/kauffman-foundation-analysis-emphasizes-importance-of-young-businesses-to-job-creation-in-the-united-states.aspx (last access 3/23/2010).

Purac (2011): *BASF and CSM explore a bio-based Succinic Acid joint venture*. Purac, Press Release, Aug. 1, 2011. http://www.purac.com/EN/Biobased_chemicals/News/Press-release-BASF-and-CSM-explore-a-joint-venture.aspx (last accss 9/23/2011).

Pure Energy Systems (PES) Network: *Wind Turbine Systems for Home Power Generation.* http://peswiki.com/index.php/Directory:Home_Generation:Wind_Turbine (last access 9/9/2010).

Quon, K. (2012): *Solazyme: An Undervalued Investment With A Hidden Identity*. Seeking Alpha, May 24, 2012. http://seekingalpha.com/article/614271-solazyme-an-undervalued-investment-with-a-hidden-identity (last access 5/25/2012).

Quatar Airways (2009): *World's First Commercial Passenger Flight Powered By Fuel Made From Natural Gas Lands In Qatar*. Media Room, Oct. 12, 2009. http://www.qatarairways.com/global/en/newsroom/archive/press-release-12Oct09-2.html (last access 12/11/2009); cf. also 12/11/2009 http://www.qatarairways.com/global/en/newsroom/archive/press-release-12Oct09-2.html.

Radiomuseum: *History of the radio manufacturer Leybold und von Ardenne Oszillografengesellschaft*. http://www.radiomuseum.org/dsp_hersteller_detail.cfm?company_id=7507 (last access 9/12/2012).

Raice, S.; Ovide, S. (2012): *Groupon Investors Give Up*. Wall Street Journal, Aug. 20, 2012. http://online.wsj.com/article/SB10000872396390443989204577599273177326912.html (last access 8/120/2012).

Raice, S.; Smith, R. (2011): *Groupon IPO Cheers Valley*. Wall Street Journal, Nov, 5, 2011. http://online.wsj.com/article/SB10001424052970203716204577017773545604142.html?KEYWORDS=groupon+ipo (last access 11/6/2011).

Ramey, D. E. (2007):*Butanol: The Other Alternative Fuel*. In NABC 19: Agricultural Biofuels: Technology, Sustainability and Profitability. South Dakota State University, Conference May 22 – 24, 2007, 137-147. http://nabc.cals.cornell.edu/pubs/nabc_19/NABC19_5Plenary2_Ramey.pdf (last access 12/23/2009).

Ramsey, M. (2012): *China's New Target: Batteries*. Wall Street Journal, Aug. 8, 2012. http://online.wsj.com/article/SB10000872396390443991704577576881949308486.html (last access 8/8/2012).

Rapier, R. (2011): *What Happened at Choren?* The energy collective, posted Jul. 9, 2011. http://theenergycollective.com/robertrapier/60963/what-happened-choren (lass access 11/14/2011); Consumer Energy Report, Jul. 8, 2011. http://www.consumerenergyreport.com/2011/07/08/what-happened-at-choren/ (last access 8/3/2011).

Rapier, R. (2010): *Broken Promises from Range Fuels*. Consumer Energy Report, Feb. 23, 2010, update 8/18/2010. http://www.consumerenergyreport.com/2010/02/23/broken-promises-from-range-fuels/ (last access 11/25/2010); Rapier, R. (2010): *Diminishing expectations from Range Fuels*. Forbes, Feb. 25, 2010. http://www.forbes.com/sites/energysource/2010/02/25/diminishing-expectations-from-range-fuels/ (last access 3/1/2010).

Rapier, R. (2009a): *Vinod Khosla at Milken Institute: Part II*. R-Squared Energy Blog Pure Energy, May 1, 2009. http://robertrapier.wordpress.com/category/cilion/ (last access 12/9/2009).

Rapier, R. (2009b): *GreenFuel Bites the Dust*. R-Squared Energy Blog, May 15, 2009. http://i-r-squared.blogspot.com/2009/05/greenfuel-bites-dust.html (last access 1/2/2010).

Rapier, R. (2009c): *Book Review: Green Algae Strategy: End Oil Imports And Engineer Sustainable Food And Fuel* by Mark Edwards. The Oil Drum, posted on Jun. 8, 2009. http://www.theoildrum.com/node/5465 (last access 1/12/2010).

Rapier, R. (2006): *Cellulosic Ethanol vs. Biomass Gasification*. R-Squared Energy Blog, Oct. 22, 2006. http://robertrapier.wordpress.com/2006/10/22/cellulosic-ethanol-vs-biomass-gasification/ (last access 2/19/2010).

Ravenstijn, J. (2011): *Switched on to biopolymers*. In Biowerkstoff Report – Report on Bio-based Plastics and Composites. Edition 8, March 2011. File 11-03_Biowerkstoff-Report_8.pdf. http://www.nova-institut.de/download/bwr8_2011 (last access 6/5/2012).

RedHerring (2010): *Cleantech Venture Bleak as a Smoggy Day*. RedHerring, Podcast on 30 September 2010. http://www.redherring.com/Home/26444 (last access 10/7/2010).

Reinhold, R.: *Understanding the MBTI ® and Personality Type – Type Dynamics: Interpreting the Myers Briggs MBTI ®Personality Type Code*. PersonalityPathways; Reinhold Development – Marketing & Internet Development for Small Business Daniel Laufenberg – Laufenberg Economic Quarterly. http://www.personalitypathways.com/article/type-dynamics.html (last access 8/12/2010).

Reisch, M. S. (2006): *Start-up Firms Pursue Biofuels – Entrepreneurs invigorate search for economical biomass-based fuels.* Chemical & Engineering News 84 (47), Nov. 20, 2006. http://pubs.acs.org/cen/coverstory/84/8447cover3a.html (last acces 2/20/2010). Reisch, M. S. (2006): *Fuels Of The Future – Chemistry and agriculture join to make a new generation of renewable fuels*. Chemical & Engineering News 84 (47), 30-32. http://pubs.acs.org/cen/coverstory/84/8447cover3.html (last access 11/11/2009).

Reisch, M. S. (2007a): *Suits and Lab Coats – Industry draws on academic know-how to help develop specialty chemicals and other new materials*. Chemical & Engineering News 85 (47), 15-20. http://pubs.acs.org/cen/coverstory/85/8547cover.html (last access 12/20/2007).

Reisch, M. (2007b): *BASF Commits $20 Million To Harvard Research – Five-year program will draw on Harvard's School of Engineering and other departments.* Chemical & Engineering News 85 (45), Oct. 29, 2007 http://pubs.acs.org/cen/news/85/i45/8545news1.html (last access 6/21/2010).

Reisch, M. S. (2010): *French chemical firm ramps up effort to commercialize acrylic acid based on glycerin*. Chemical & Engineering News, 88 (21), May 24, 2010, 20-21.

Reisch, M. S. (2011a): *Instrumental Efforts – Entrepreneurs take big risks to bring the latest scientific tools to market.* Chemical & Engineering News 89 (32), 14-19. http://pubs.acs.org/cen/coverstory/89/8932cover.html?featured=1 (last access 8/9/2011).

Reisch, M. (2011b): *Investors Bet On Cleantech*. Chemical & Engineering News 89 (43), Oct. 24, 2011, 9. http://pubs.acs.org/cen/news/89/i43/8943notw9.html (last access 10/27/2011).

Reisch, M. S.(2012): *A123 Systems Goes Bankrupt*. Chemical & Engineering News 90 (43), 8. http://cen.acs.org/articles/90/i43/A123-Systems-Goes-Bankrupt.html (last access 10/29/2012).

RenewableEnergyWorld.com Editors (2010): *Solyndra Feeling the Pressure*. RenewableEnergyWorld.com, Nov. 5, 2010. http://www.renewableenergyworld.com/rea/news/article/2010/11/solyndra-feeling-the-pressure (last access 3/30/2011).

Rensselaer Polytechnic Institute (2007): *Beyond Batteries: Storing Power in a Sheet of Paper.* Rensselaer Research Review Fall 2007. http://www.rpi.edu/research/magazine/fall2007/batteries-1.html (last access

7/21/2009). Rensselaer Polytechnic Institute. *Serendipity and the Paper Battery*. http://www.rpi.edu/research/biotechnology/report/battery.html (last access 7/21/2009).

Reportlinker (2011): *Virtual Goods in Social Networking and Online Gaming*. PRNewswire, Jun. 6, 2011. http://www.kfvs12.com/story/14845327/virtual-goods-in-social-networking-and-online-gaming?clienttype=printable (last access 7/4/2011).

Reuter, B. (2011): *Unternehmenspleite - Aus für den Holzdiesel (Company insolvency – Stop for the wood diesel*). Wirtschaftswoche, Jul. 15, 2011. http://www.wiwo.de/unternehmen/unternehmenspleite-aus-fuer-den-holzdiesel/5307676.html (last access 11/17/2011).

Reuters (2010): *Venture capital money drops to 1997 levels – report*. Reuters, Jan. 22, 2010. http://www.reuters.com/article/idUSN2213491820100122 (last access 1/22/2010).

RFA – Renewable Fuels Association: Statistics, *Historic U.S. fuel, Ethanol Production.* http://www.ethanolrfa.org/pages/statistics (last access 5/5/2012).

Ritch, E. (2010): *Solix shipping algae oil biofuel from demo plant*. Cleantech, Jan. 5, 2010. http://cleantech.com/news/5460/solix-shipping-algae-oil-biofuel-de (last access 10/2/2010).

Riddell, L. (2012): *Solazyme's IPO filing revealed*. San Francisco Business Times, Mar. 15, 2011. http://www.bizjournals.com/sanfrancisco/blog/2011/03/solazymes-ipo-turns-up-interesting.html (last access 4/1/2012).

Riddell, L. (2011): *Amyris, Total create joint biofuels venture*. San Francisco Business Times, Dec. 1, 2011. (last access 1/10/2012).

Riegler, A. (2002): *When Is a Cognitive System Embodied?* Cognitive Systems Research 3 (3), 339-348. http://pespmc1.vub.ac.be/riegler/papers/riegler01embodiment(old).pdf (last access 4/16/2010).

Riley, C. (2013): *Major Chinese solar company goes bankrupt*. CNNMoney Mar. 21, 2013. http://money.cnn.com/2013/03/21/news/suntech-solar-bankruptcy/index.htm (last access 4/16/2013).

Ripplinger, P (2009): *Industrial production of microalgae biomass with flat-panel airlift photobioreactors.* Presentation, ALGAE 2009, Hamburg. http://global.subitec.com/pdf/Subitec_ALGAE_2009.pdf (last access 3/17/2010).

Ritchey, T. (2011): *General Morphological Analysis – A general method for non-quantified modelin*g. File from 4/1/2011. Adapted from the paper "Fritz Zwicky, Morphology and Policy Analysis," presented at the 16th EURO Conference on Operational Analysis, Brussels, 1998. http://www.swemorph.com/pdf/gma.pdf; http://www.swemorph.com/ma.html (last access 8/19/2011).

Rittel, H.; Webber, M. (1973): *Dilemmas in a General Theory of Planning*. Policy Sciences (4), 155-169. Elsevier Scientific Publishing Company, Inc., Amsterdam. http://www.uctc.net/mwebber/Rittel+Webber+Dilemmas+General_Theory_of_Planning.pdf (last access 11/16/2009).

Ritter, S. K. (2011): *Small-Business Award: BioAmber, Minneapolis*. Chemical & Engineering News 89, Jun. 27, 2011. http://pubs.acs.org/cen/news/89/i26/8926notw1c.html (last access 7/2/2011).

Ritter, S. K. (2004): *Biomass or Bust – Technology to use plant-derived sugars to produce chemical feedstocks is ready ... and waiting*. Chemical & Engineering News 82 (22), 31-34. http://pubs.acs.org/email/cen/html/060804150713.html (last access 11/3/2009).

Roberts, E. B. (1989): *Initial capital for the new technological enterprise.* MIT Working Paper, No 2103-1-89, September 1989. http://dspace.mit.edu/bitstream/handle/1721.1/2235/SWP-2603-20912627.pdf?sequence=1 (last access 10/14/2010).

Robinson, S. (2009): *Second-generation biofuels need work – Fuel trek: the next generation*. ICIS, Feb. 24, 2009. http://www.icis.com/Articles/2009/02/24/9195433/second-generation-biofuels-need-work.html (last access 11/9/2009).

Roe, W. (2009): *Coskata – The Leader in Feedstock Flexible Ethanol*. US DOE - Biomass 2009. http://www1.eere.energy.gov/biomass/pdfs/Biomass_2009_Adv_Biofuels_I_Roe.pdf (last access 2/19/2010).

Rogers, W. S.; Mead, J. L. (2011): *The next small step for mankind – nanotechnology's journey to commercialization*. File from 4/29/2011. http://www.daypitney.com/news/docs/dp_3562.pdf (last access 5/18/2011).

Rooney, B. (2011): *Bigpoint In $350 million Deal*. Wall Street Journal, Apr. 26, 2011. http://blogs.wsj.com/tech-europe/2011/04/26/bigpoint-in-350-million-deal/ (last access 4/26/2011).

Rosenfeld, E. (2007*): Credit Cards: A Small Business Financing Tool*. http://www.entrepreneurship.gov/ResourcesCenter/Entrepreneur/13500.html (last access 9/15/2009).

Ross Range, P. (2012): *Vorbild Deutschland – Ein Amerikaner entdeckt das deutsche Industriewunder (Model Germany – An American discovers the German industrial miracle*). Handelsblatt, Aug. 7, 2012. http://www.handelsblatt.com/politik/konjunktur/nachrichten/vorbild-deutschland-ein-amerikaner-entdeckt-das-deutsche-industriewunder/6966492.html (last access 8/8/2012).

Ruch, E. (1975): *The Diagram Lattice as Structural Principle*. Theoretica Chimica Acta 38, 167-183.

Ruhm, K. H.(2008): *Dynamic System in the Steady State Condition – State Space*. Internet Portal "Measurement Science and Technology"; Document d0000881; rev00. ETH Zurich, Switzerland, Institute for Dynamic Systems and Control, First Edition 12/11/2008.http://www.mmm.ethz.ch/dok01/d0000881.pdf; http://www.mmm.ethz.ch/dok01/d0000321.pdf (last access 5/6/2011).

Rumelt, R. (1996): *The Many Faces of Honda.* California Management Review 38 (4), 103-111– citation on page 110. cf. also http://www1.ximb.ac.in/users/fac/dpdash/dpdash.nsf/pages/BP_Honda (last access 6/3/2009).

Runge, W. (2006): *Innovation, Research and Technology Intelligence in the Chemical Industry – Integrated Business, Technical and Systems Approaches*. Fraunhofer IRB Verlag, Stuttgart, 2006.

Runge, W. (2006a): *Patentbewertung und Patentanalysen – Zweck, Adressaten, Kontext, Methoden and Technik (Patent Assessment and Patent Analyses – Purpose, Addressees, Context, Methods, and Technology*). In: Conference Proceedings PATINFO 2006, Schramm R. und Milde, S. (Eds) 2006, 269 – 287.

Runge, W.; Bräse, S. (2008): *Education in Chemical Entrepreneurship: Towards Technology Entrepreneurship for and in Chemistry-Related Enterprises*. Karlsruhe University (TH). http://ce.ioc.KIT.edu/download/Chem_Entrepreneurship_Paper.pdf.

Runge, W. (2010): *Mit einer Idee zum Technologieführer (From an Idea to a Leader of Technology).* An Overview on Nanopool GmbH Based on a Guest Lecture and Literature for Technology Entrepreneurship. PresentationTechnology Entrepreneurship, Dec. 9, 2009. http://ce.ioc.KIT.edu/downloads/Praesentation_Schwindt.pdf (last access 7/19/2010).

Russo, A. (2001): *Five Myths About Entrepreneurs. Understanding How Businesses Start and Grow*. National Commission on Entrepreneurship (of the US), March 2001. http://www.publicforuminstitute.org/nde/sources/reports/2001-five-myths.pdf) (last access 11/23/2007); http://www.renderx.com/~renderx/myths/en/art_letter.pdf (last access 10/23/2012).

RWE (2009a): *Das RWE Algenprojekt (The RWE Alga Project)*. RWE Power AG in Bergbau 2, 64 – 66, 2009 http://www.bergbau-zeitschrift.de/zeitung09/09-02-64-66.pdf (last access 3/15/2010), cf. also http://www.rwe.com/web/cms/de/213188/rwe-power-ag/klimaschutz/innovationszentrum-kohle/algenprojekt/ (last access 3/14/2010), http://www.rwe.com/web/cms/mediablob/de/2374/data/213188/1096/rwe-power-ag/klimaschutz/innovationszentrum-kohle/algenprojekt/brosch-algenprojekt.pdf.

RWE (2009b): *Klimafreundliche CO2-Nutzung: Algen binden Kohlendioxid problemlos in Biomasse ein (Climate-firiendly CO2 Utilization – Algae capture carbon dioxide in biomass without problems).* RWE Power, Sep. 11, 2009. http://www.rwe.com/web/cms/de/2320/rwe-power-ag/pressemitteilungen/?pmid=4003947 (last access 3/16/2010).

RWE (2010): *RWE Power, BRAIN join forces in white biotech: co-operation on CO2 as raw material for new products*. RWE Power, Jan. 4, 2010. http://www.rwe.com/web/cms/de/2320/rwe-power-ag/pressemitteilungen/?pmid=4004370 (last access 3/16/2010).

Sanderson, K. (2009): *The Great Beyond. Biofuel woes.* Posted by Katharine Sanderson on October 23, 2009. http://blogs.nature.com/news/thegreatbeyond/2009/10/biofuel_woes.html (last access 10/25/2009).

SAP-1: *Geschichte der SAP: Mehr als 37 Jahre im Business mit dem E-Business History of SAP – More than 37 years in business with e-business).* http://www.sap.com/germany/about/company/geschichte/index.epx (last access

7/302010); cf. also Dietmar Hopp: http://www.whoswho.de/templ/te_bio.php?PID=1187&RID=1; Hasso Plattner: http://www.whoswho.de/templ/te_bio.php?PID=1181&RID=1; Klaus Tschira: http://www.whoswho.de/templ/te_bio.php?PID=2563&RID=1.

SAP-2: SAP Tutorial and Guide – SAP Definition and Brief History. http://saptutorial.net/sap-definition-and-brief-history/ last access 7/29/2010); cf. also http://en.wikipedia.org/wiki/SAP_AG; http://de.wikipedia.org/wiki/SAP.

Sasiadek, S. (2004): *Entrepreneurship Versus Intrapreneurship*. July 4, 2004. http://drsusansasiadek.com/yahoo_site_admin/assets/docs/Entrepreneurship_Versus_Intrapreneurship.86181859.htm (last access 7/13/2009).

Say, J.-B. (1803): Traité d'économie politique, ou simple exposition de la manière dont se forment, se distribuent, et se consomment les richesses – *A Treatise on Political Economy; or the Production, Distribution, and Consumption of Wealth*. Translated from the Fourth Edition of the French, By C. R. Prinsep, M. A. with Notes by the Translator. New American Edition. Containing a Translation of the Introduction, and Additional Notes by Clement C. Biddle, LL. D. Member of the American Philosophical Society. Philadelphia: Claxton, Remsen & Haffelfinger 624, 625, & 628 Market Street 1880; Batoche Books, Kitchener 2001. http://socserv.mcmaster.ca/econ/ugcm/3ll3/say/treatise.pdf (last access 6/19/2009).

SBDC – Minnesota Small Business Development Centers (2012): *MetroSpec Technology.* Annual Report 2010, 10. File of 1/9/2012. http://www.positivelyminnesota.com/About_Us/Goals_Results/Our_Progress/Program_Results/Small_Business_Development_Centers_2010_Annual_Report.pdf (last access 3/1/2012).

Schedl, H. L.; Vola, M. (2007): *Hidden Champions of the 21st Century – Presentation for the Conference "Top management: Challenges and Limits of Competition."* Minsk, Nov. 30 2007. http://www.krconsult.org/download_files/confa3/shedl_hidden_champions_presentation_minsk.pdf (last access 10/8/2010).

Scheffler, S. (2009): *Biosprit – Warum Bill Gates auf Algensprit setzt (Biofuels – Why Bill Gates Bets on Algae)*. Handelsblatt, Apr. 4, 2009. http://www.handelsblatt.com/technologie/energie_technik/warum-bill-gates-auf-algensprit-setzt;2232435 (last access 9/3/2009).

Schibilsky, M. (2008): *Treibstoff aus Algen – Energiewunder der Erdgeschichte (Fuel from Algae – The Energy Wonder of the Earth's History).* RBB Broadcast – Ozon aus Wissenschaft und Umwelt, Mar. 17, 2008. http://www.orb.de/ozon/beitrag/2008/treibstoff_aus_algen.html (last access 1/4/2010).

Schild, R. (2009): *Business & Change in VON ARDENNE*. MBA Alumni Event, Sep. 15, 2009. http:// mbaurv.oasi.org/bd/business_and_change_in_von_ardenne1.pdf (last access 11/23/2009).

Schneider, J. J. (2010): *Akademia-Industrie-Austausch – ein Schuss Neugier und Offenheit (Academia-industry-exchange – a little bit of curiosity and openness*). Nachrichten aus der Chemie 58 (7/8), 838-839.

Schonfeld, E. (2009a): *Interview: Vinod Khosla Is On The Hunt For Great Technologies*, TechCrunch, Sep. 12, 2009. (last access 12/8/2009).

Schonfeld, E. (2009b): *Khosla Ventures Raises $1.1 Billion. It's For More Than Just Clean Tech*. TechCrunch. http://www.techcrunch.com/2009/09/01/khosla-ventures-raises-11-billion-its-for-more-than-just-clean-tech/ (last access 11/24/2009).

Schrage, M. (2010): *The Delicate Art of Unauthorized Innovation*. Harvard Business Review, Mar. 24, 2010. http://blogs.hbr.org/schrage/2010/03/the-delicate-art-of-unauthoriz.html (last access 8/25/2010).

Schramm, C. (2006a): *The Entrepreneurial Imperative.* Philanthropy Magazine, Sep. 25, 2006 http://prt.timberlakepublishing.com/article.asp?article=1416&paper=0&cat=149 (last access 3/2/09).

Schramm, C. (2006b): *Entrepreneurial Capitalism and the End of Bureaucracy – Reforming the Mutual Dialog of Risk Aversion*. http://www.aeaweb.org/annual_mtg_papers/2006/0107_1015_0304.pdf (last access 6/20/2009 as html.

Schürmann, H. (2007): *Den Klimawandel bekämpfen: Mikroalgen retten die Umwelt (Fighting climate change – Microalgae to save the world*). Handelsblatt, Nov. 12, 2007. http://www.handelsblatt.com/technologie/umwelt-news/mikroalgen-retten-die-umwelt;1350492 (last access 2/14/2010).

Schubert, T. (2008a): *Unternehmensgründung in der Chemiebranche – Ein Erfahrungsbericht (Firm's Foundation in the Chemical Industry – A Report of Experiences*). Presentation Technology Entrepreneurship, Jan. 23, 2008. http://ce.ioc.KIT.edu/download/Schubert_Karlsruhe20080123.pdf (particularly slide 31).

Schubert, T. (2008b): *IOLITEC – A Material Supplier for the PV Industry*. 2nd International Conference on Solar PV Investments 19th & 20th February, Frankfurt (Germany). http://investments2008.epia.org/Files/PDF/WS_080220_3A-06_TSchubert.pdf (last access 3/10/2011).

Schubert, T. (2006): *IoLiTec – Ihr Partner für ionische Flüssigkeiten (Your Partner for Ionic Liquids*). 2nd Partnering-Event Chemie Start-ups, Frankfurt am Main, 9/22/2006. http://events.dechema.de/index.php?id=1052&suffix=pdf&nonactive=1&lang=de&site=events_media (last access 5/3/2007).

Schubert, T. (2005): *A brief history of IoLiTec*. Company Newsletter, Ionic Liquds Today, 1/05, Mar. 3, 2005.

Schubert, T. (2004): *IoLiTec*. File 4-IoLiTec.ppt as pdf-from 7/6/2004, particularly slide 5 (last access on the Web 4/30/2010).

Schuetzle, D.; Tamblyn, G.; Tornatore, F.; MacDonald, T. (2007): *Range Fuels has BioConversion Technology as a partner for the Georgia plant*. In *Alcohol Fuels from Biomass – Assessment of Production Technologies*. Report Draft, Mar. 27, 2007, page 67. ASSESSMENT-BIOALCOHOL-tech[1].pdf, Google search "Alcohol Fuels from Biomass – Assessment of Production Technologies" (last access 2/20/2010).

Schuler, T. (1999): *Verrat unter Freunden (Betrayal among friends).* Die Zeit, 1999. http://www.zeit.de/1999/40/199940.nsa_2_.xml (last access 8/30/2010); poor English translation: Schröm, O. (2009): *Betrayal among friends*. http://groups.google.com/group/sci.geo.meteorology/msg/1617cdd82eedfcd3 (last access 3/16/2011).

Schumpeter, J. A. (1942): "*Creative Destruction*." http://transcriptions.english.ucsb.edu/archive/courses/liu/english25/materials/schumpeter.html (last access 6/2/2011). From:
Joseph A. Schumpeter Capitalism, Socialism, and Democracy. New York: Harper, 1942, pp. 82-85.

Schumpeter, J. A. (1911): *Theorie der wirtschaftlichen Entwicklung*. Duncker and Humblot, Leipzig. (Translated by R. Opie. Cambridge: Harvard University Press, 1934. The Theory of Economic Development: An inquiry into profits, capital, credit, interest and the business cycle.

Schumpeter, J. (1939): *Business Cycles*. MacGraw-Hill, New York.

Schwartz, D. (2010): *The A.I.M Interview - Sapphire Energy's Tim Zenk*. Algae Industry Magazine, Feb. 9, 2010. http://www.algaeindustrymagazine.com/tim-zenk/ (last access 3/13/2010).

Schwedt, G. (2009): *Goethe – Der Manager (Goethe – The Manager*). Wiley-VCH, Germany.

Schweinsberg, M. (2007): *SusTech GmbH & Co. KG – Erfolg durch Public-Private-Partnership (SusTech GmbH & Co. KG – Success through Public-Private-Partnership).* In VDI: Identifizierung von Innovationshemmnissen in der Werkstoffforschung und –entwicklung. Ergebnisse des Workshops am 20.09.2007 in Bonn (Identification of innovation barriers for materials research and developments. Results of a workshop on 9/20/2007 in Bonn). http://www.techportal.de/uploads/publications/572/Workshopbericht_Innovationshemmnisse.pdf (last access 7/3/2010).

Scully, V. (2007): *Effects of the Biofuel Boom*. Business Week, Aug. 27, 2007. http://www.businessweek.com/investor/content/aug2007/pi20070824_143619.htm?chan=technology_technology+index+page_top+stories (last access 11/2/2009).

SearchEngineWatch (2003): *Google Buys Applied Semantics*. SearchEngineWatch.com, Apr. 24, 2003. http://searchenginewatch.com/article/2047715/Google-Buys-Applied-Semantics (last access 2/12/2011).

SEC (2009)**:** *SEC-Filing Bluefire***.** 10-K 1 f10k2008_bluefire.htm 2008 ANNUAL YEAR END REPORT. http://www.sec.gov/Archives/edgar/data/1370489/000121390009000636/f10k2008_bluefire.htm.

SEC (2010): *Amyris Biotechnologies, Inc.* United States – Securities and Exchange Commission, FORM S-1, REGISTRATION STATEMENT. http://www.sec.gov/Archives/edgar/data/1365916/000119312510085595/ds1.htm (last access 4/25/2010).

Seelye, K. Q. (2009): *What Happens to the American Dream in a Recession*? The New York Times, May 8, 2009. http://www.nytimes.com/2009/05/08/us/08dreampoll.html?_r=1&hp (last access 5/8/2009).

Seidler, C. (2009): *Alles auf Alge* (*Bet on Algae*). Der Spiegel, Dec. 16, 2009. http://www.spiegel.de/wissenschaft/natur/0,1518,665958,00.html (last access 16/12/2009.

Senge, P. M (1990): *The Fifth Dimension: The Art and Practice of the Learning Organization*. Doubleday, New York, NY.

Senge, P. M. (2006): *The Fifth Discipline – The Arts and Practice of the Learning Organization*. Second revised ed., Random House Business Books, 2006.

Seraphim, P. G. (2009): *Brazil's Ethanol-Enhanced History*. Ethanol Producer Magazine, September 2009. http://www.ethanolproducer.com/article.jsp?article_id=5906&q=&page=all (last access 10/30/2009).

Seymour, R. (2000): *Ms. versus Mr. Who is the Better Boss*? The Magazine for Canadian Entrepreneurs. V. 19, 1-2. http://www.profitguide.com/w100/2000/related.asp?ID=857 (last access 12/5/2002).

Shah, D. (2007): The *Dark Side of Startups: 5 Corrosive Co-Founder Conflicts*. OnStartups, posted Aug. 21, 2007. http://onstartups.com/tabid/3339/bid/2148/The-Dark-Side-of-Startups-5-Corrosive-Co-Founder-Conflicts.aspx (last access 12/17/2011).

Shane, S. (2000): *Prior Knowledge and the Discovery of Entrepreneurial Opportunities*. Organization Science (4), July-August 2000, 448-469.

Shell (2007): *Shell Hydrogen and Virent Energy Systems to Manufacture Hydrogen Using Biomass*. Press Release, May 24, 2007. http://www.shell.de/home/content/usa/aboutshell/media_center/news_and_press_releases/archive/2007/virent_biomass.html (last access 1/26/2020).

Shelley, C. E.; Zhou, J. (2008): *Organizational Creativity Research – A Historical Overview*. In Handbook of Organizational Creativity, Jing Zhou, Christina Shalley (Eds.), Chapter 1. Lawrence Erlbaum Associates New York 2008 (subsidiary of the Taylor & Francis Group, LLC).

Sheridan, C. (2009): *Making green*. Nature Biotechnology 27, 1074–1076. http://www.nature.com/nbt/journal/v27/n12/full/nbt1209-1074.html (last access 3/21/2010).

Sherman, E. (2011): *How LinkedIn Turns a Profit when "Users" Don't Use the Site*. CBS Money Watch, Aug. 5, 2011. http://www.cbsnews.com/8301-505124_162-43452177/how-linkedin-turns-a-profit-when-users-dont-use-the-site/?tag=bnetdomain (last access 8/12/2011).

Short, P. L. (2009a): *Tight Focus Helped German Clusters Compete*. Chemical & Engineering News 87 (3), Jan. 19, 2009. http://pubs.acs.org/cen/business/87/8703bus2a.html (last access 1/26/2009).

Short, P. L. (2009b): *Clustering In Heidelberg – German region wins competition to anchor one of five national R&D clusters*. Chemical & Engineering News 87 (3), Jan. 19, 2009. http://pubs.acs.org/cen/business/87/8703bus2.html (last access 1/26/2009).

Short, P. L. (2006): *Out of the Ivory Tower*. Chemical & Engineering News 84 (17), 15-21. http://pubs.acs.org/cen/coverstory/84/8417ionicliquids.html (last access 6/23/2006).

Shrader, R.; Siegel, D. S. (2007): *Assessing the relationship between human capital and firm performance: evidence from technology-based new ventures*. Entrepreneurship: Theory and Practice 31 (6), 893-908. http://www.entrepreneur.com/tradejournals/article/170729964.html (last access 10/14/2008).

Shubnikov, A. V.; Koptsik, V. A. (1974): *Symmetry in Science and Art*. Plenum Press, New York, 1974.

Sierra Angels (2008): *Astia Honors Pam Marrone with Clean Tech Innovator Award*. San Francisco, Nov. 17, 2008. http://www.sierraangels.com/news-111708-marrone-organic/ (last access 1/14/2010).

Simon, H. (1955): *A Behavioral Model of Rational Choice*. Quarterly Journal of Economics 69 (1) (February 1955), 99-118.

Simon, H. (1956): *Rational Choice and the Structure of the Environment*. The Psychological Review 63 (March 1956), 129-138.

Simon, H. (2008): *Hidden Champions des 21. Jahrhunderts: Die Erfolgsstrategien unbekannter Weltmarktführer (Hidden Champions of the 21st century – Success Strategies of Unknown Global Market Leaders*). Presentation, RKW-Forum 2008, Nov. 20, 2008. http://www.rkw-bw.de/pdf/RKW-Organisation/RKW-Forum2008_VortragProfSimon.pdf (last access 10/8/2010); http://www.businessconnect.com.au/Documents/Content/Hermann_Simon%20_HiddenChampions.pdf (last access 10/8/2010).

Simon, H. (2007): *Hidden Champions des 21. Jahrhunderts : Die Erfolgsstrategien unbekannter Weltmarktführer (Hidden Champions of the 21st century – Success Strategies of Unknown World Market Leaders*). Campus, Frankfurt a. M., 2007;
Simon, H. (2009): *Hidden Hidden Champions of the 21st – Success Strategies of Unknown World Market Leaders*. Springer, New York, 2009.

Simon, H. (1996): "*Hidden Champions – Lessons from 500 of the World's Best Unknown Companies"* Harvard Business School Press, Massachusetts, 1996.

Skyttner, L. (2001): *General Systems Theory – Ideas and Applications*. World Scientific Publishing Company, Hackensack, NJ, USA;
General Systems Theory – Problems Perspectives Practice. World Scientific Publishing Company, Singapore. 2nd ed 2005.

Smith, M. R. (1985): *Military Enterprise and Technological Change – Perspectives on the American Experience*. MIT Press 1985.

Smith, R.; Raice, S. (2011): *Groupon Shares Backpedal*. Wall Street Journal, Nov. 23, 2011.

http://online.wsj.com/article/SB10001424052970203710704577054613912424388.html (last access 11/23/2011).

Smith, R.; Grocer, S. (2011): *Wall Street Cools to Groupon*. Wall Street Journal, Dec. 15, 2011. http://online.wsj.com/article/SB10001424052970204026804577098804223481254.html (last access 12/15/2011).

Smith-Hunter, A.; Kapp, J.; Yonkers, V. (2003): *A psychological model of entrepreneurial behavior*. Journal of the Academy of Business and Economics , April, 2003. FindArticles.com. 08 Jun, 2009. http://findarticles.com/p/articles/mi_m0OGT/is_2_2/ai_113563670/.

Snyder, M. (2010): *3 Charts That Prove We Are Living In The Biggest Debt Bubble In The History Of Our World*. The Economic Collapse, Nov. 3, 2010. http://www.businessinsider.com/charts-of-the-debt-bubble-2010-11 (last access 11/3/2010).

Sonnete, D. (2011): *Lecture 5: The Tipping Point and Epidemics – of innovations and entrepreneurial successes*. D-MTEC Chair of Entrepreneurial Risks. Swiss Federal Institute of Technology Zurich, file of 5/20/2011. http://www.er.ethz.ch/teaching/Lect5_Tipping_point_epidemics_11-2.pdf (last access 10/28/2011).

SpecialChem (2012): *Enerkem Begins Production of Cellulosic Ethanol at its Québec Facility*. SpecialChem, Jun. 12, 2012. http://www.specialchem4adhesives.com/resources/latest/displaynews.aspx?id=5976&lr=mas12195&li=10030139 (last access 6/20/2012).

SpecialChem4Coating (2011): *The most important factor that enables to develop new products & solve technical problems.* SpecialChem, Jan. 1, 2011. http://www.specialchem4coatings.com/community-pulse/community-insight.aspx?id=15117&lr=wpc11606&li=20024489 (last access 2/8/2011).

Specialchem4polymers (2011): *LANXESS Plans to Commercially Produce EPDM from Bio-based Ethylene by End of Year*. SpecialChem, Sep. 30, 2011. http://www.specialchem4polymers.com/resources/latest/displaynews.aspx?id=6505&lr=wpa11107la15&li=70056708 (last access 10/15/2011).

Spiewak, M.; Thuswaldner, G. (2009): *US Hochschulen – In Harvard wird gespart (US Universities – Harvard has to save money).* DIE ZEIT, Jan. 8, 2009. (last access 1/9/2009).

St. John, J. (2009): *Mascoma Starts Up Cellulosic Ethanol Demo Plant*. Green Tech Media, Feb. 25, 2009. http://www.greentechmedia.com/articles/read/mascoma-starts-up-cellulosic-ethanol-demo-plant-5790/ (last access 12/28/2009).

St. John, J. (2008): *LS9 Seeks Up to $100M Under New CEO*. Green Tech Media, Oct. 8, 2008. http://www.greentechmedia.com/articles/read/ls9-seeks-up-to-100m-under-new-ceo-1550/ (last access 12/11/2009).

St. John, J. (2011): *Oil Giant BP Backs Biofuel Startup Verdezyne*. Earth2tech, May 9, 2011. http://gigaom.com/cleantech/oil-giant-bp-backs-biofuel-startup-verdezyne/ (last access 6/23/2011).

Stack, J.; Balbach,, J.; Epstein, B.; Hanggi, T. (2007): *Cleantech Venture Capital: How Public Policy Has Stimulated Private Investment*. Environmental Entrepreneurs and Cleantech Venture Network LLC, May 15, 2007. http://www.e2.org/ext/doc/CleantechReport2007.pdf (last access 10/31/2009).

Stam, E.; Garnsey, E. (2007): *Entrepreneurship in the Knowledge Economy*. File from 5/8/2007. http://www.dur.ac.uk/resources/dbs//faculty/centre_entrepreneurship/publications/ResearchPaper018.pdf (last access 1/15/2011);
Stam, E.; Garnsey, E. (2006) *New Firms Evolving in the Knowledge Economy; Problems and solutions around turning points*. In: Dolfsma, W. & Soete, L. (Eds.), Understanding the Dynamics of a Knowledge Economy, 102-128. Cheltenham, Edward Elgar.

Stangler, D. (2010): *High-Growth Firms and the Future of the American Economy*. Kauffman Foundation Research Series: Firm Formation and Economic Growth, March 2010 .http://www.kauffman.org/uploadedfiles/high-growth-firms-study.pdf (last access 3/11/2011).

Startup Life (2007): *Ubiquitous Startups and the VC – Biofuel Investment Jumps 4000%*. Posted on Wednesday, March 21, 2007. http://sookman.blogspot.com/2007/03/biofuel-investment-jumps-4000.html (last access 10/20/2009).

Stewart, C. (2006): *The CODA Genomics executives*. The Orange County Register, Jun. 26, 2006. http://www.ocregister.com/articles/favorite-40767-professor-school.html (last access 2/4/2011).

Steyer, C.-D. (2007): *Von Tempo-Erbsen bis Kosmetik-Algen (From speed-up peas to cosmetics algae*). Der Tagesspiegel, Oct. 26, 2010. http://www.tagesspiegel.de/berlin/Brandenburg;art128,2407052 (last access 2/14/2010).

Stone, B. (2008): *Judge Ends Facebook's Feud With ConnectU*. The New York Times, Jun. 26, 2008. http://bits.blogs.nytimes.com/2008/06/26/judge-ends-facebooks-feud-with-connectu/ (last access 7/19/2009).

Stone, B. (2009): *ConnectU's 'Secret' $65 Million Settlement With Facebook*. The New York Times, Feb.10, 2009. http://bits.blogs.nytimes.com/2009/02/10/connectus-secret-65-million-settlement-with-facebook/ (last access 7/19/2009).

Strategy Analytics (2007): *Games Industry Transformed As One-Third of Games Software Revenues will be Generated Online by 2011*. Strategy Analytics, Sep. 10, 2007. http://www.strategyanalytics.com/default.aspx?mod=PressReleaseViewer&a0=3569 (last access 9/26/2011).

Streb, J. (2002): *Internationale Zusammenarbeit und nationale Alleingänge: Die Entwicklung der Synthesekautschukindustrie in Deutschland und den USA vor und während des Zweiten Weltkriegs. (International cooperation and national independence initiative – The development of the synthetic rubber industry in Germany and the USA before and during the Second World War).* http://www.uni-tuebingen.de/uni/wwl/streb-ht.doc (last access 2/24/2010).

Streb, J. (1999): *How to win Schumpeterian Competition. Technological Transfers in the German Plastics Industry from the 1930s to the 1970s*. Yale University - Economic Growth Center, Center Discussion Paper No. 811, Sep. 1999. http://www.econ.yale.edu/growth_pdf/cdp811.pdf (last access 2/23/2010).

Stromeyer, E. B. (2009): *Pathway to Clean Energy – LS9 Inc. Innovates with UltraClean Technology*. Suite 101, Jul. 23, 2009. http://oil-energy-companies.suite101.com/article.cfm/pathway_to_clean_energy (last access 12/30/2009).

Stroud, S. (2010): *Cobalt teams up with Fluor*. Sustainable Industries, Aug. 26, 2010. http://sustainableindustries.com/articles/2010/08/cobalt-teams-fluor (last access 5/11/2011).

Süd-Chemie (2010): *Süd-Chemie to build Germany´s largest plant for the biotechnological production of biofuels from straw*. Press Release, Jul. 21, 2010. http://www.sud-chemie.com/scmcms/web/page_en_7566.htm (last acces 8/22/2010).

Süd-Chemie (2009): *Süd-Chemie and Linde launch production of climate-friendly biofuels*. Press Release. May 7, 2009. http://www.sud-chemie.com/scmcms/web/content.jsp?nodeIdPath=2991,6599,7362,7440&lang=en (last access 8/22/2010).

succidia AG: *Prof. Dr. Dr. hc. Otto Pulz*. Labor&more. http://www.laborundmore.de/research/6538/Prof.-Dr.-Dr.-h.-Otto-Pulz.html (last access 5/2/2013).

Sugarcaneblog (2009):*Brazil’s CTC and BASF to develop Biotech Sugarcane*. Posted on Aug. 6, 2009. http://sugarcaneblog.com/2009/08/06/brazils-ctc-and-basf-to-develop-biotech-sugarcane/ (last access 10/30/2009).

Sull, D. N.; Wang Y. (2005): *The Three Windows of Opportunity*. Harvard Business School – Working Knowledge, Jun. 6, 2005. http://hbswk.hbs.edu/archive/4835.html (last access 4/21/2010).

Sullivan, D. (2004): *Google IPO To Happen, Files For Public Offering*. SearchEngineWatch.com, Apr. 29, 2004. http://searchenginewatch.com/3347471 (last access 2/22/2011).

Sullivan, D. (2003): *What’s Behind Google’s Purchase of Applied Semantics*? ClickZ, Apr. 30, 2003. http://www.clickz.com/clickz/column/1699604/whats-behind-googles-purchase-applied-semantics (last access 2/12/2011).

Sutton, R. I. (2007): *Extraordinary Contempt and Defiance Beyond the Normal Call of Engineering Duty*. Bob Sutton Work Matters http://bobsutton.typepad.com/my_weblog/2007/04/extraordinary_c.html (last access 8/25/2010)

Sutton, R. I. (2004): *Two Weird Ideas That Work*. Entrepreneurial Thought Leader Speaker Series, Stanford University, STVP, Oct. 27, 2004. http://edcorner.stanford.edu/authorMaterialInfo.html?mid=1190 (last access 8/25/2010).

Svoboda, E. (2008): *Fueling The Future*. Fast Company Magazine 122, Feb. 1, 2008. http://www.fastcompany.com/magazine/122/fueling-the-future.html (last access 10/30/2009).

Tajeddini, K.; Mueller, S. L. (2009): *Entrepreneurial characteristics in Switzerland and the UK: A comparative study of techno-entrepreneurs.* Journal of International Entrepreneurship 7 (1), 1-25.

Tam, P.-W. (2010): *Venture-Capital Firms Caught in a Shakeout*. The Wall Street Journal, Mar. 9, 2010. http://online.wsj.com/article/SB10001424052748703915204575104221092909884.html?mod=WSJEUROPE_hpp_sections_tech (last access 3/10/2010).

Tam, P.-W.; Bensinger, G.; Sherr, I. (2012): *Startups Adjust to Web's Down Cycle*. Wall Street Journal, Dec. 23, 2012. http://online.wsj.com/article/SB10001424127887324296604578177541652032424.html (last access 12/16/2012); cf. also http://en.wikipedia.org/wiki/LivingSocial.

Tam, P.-W.; Ante, S. E. (2010): *Super Angels' Alight – No Longer Flying Solo, Big Investors Attract Others to Juice Start-Ups*. The Wall Street Journal, Aug. 16, 2010. http://online.wsj.com/article/SB10001424052748703321004575427840232755162.html (last access 10/27/2010).

Tamásy, C.; Otten, C. (2000): *Unternehmensgründungen aus Hochschulen – welche Faktoren begünstigen die Gründungswahrscheinlichkeit und den Gründungserfolg? (University-based start-ups – which factors favour the probability and success of new enterprises?).* BMBF – exist, Jan. 2000; 7- 11. http://www.bmbf.de/pub/EXIST-D.PDF, English version http://www.bmbf.de/pub/EXIST-EN.PDF (last access 4/1/2010).

Taylor, P. (2010): *Biosuccinic acid ready for take off?* Chemistry World, Jan. 21, 2010. http://www.rsc.org/chemistryworld/News/2010/January/21011003.asp (last access 3/9/2010).

Taylor, W. C. (2009): *MBAs vs. Entrepreneurs*. Harvard Business Online May 5, 2009. http://www.businessweek.com/managing/content/may2009/ca2009055_933788.htm (last access 5/3/2010).

Tech Crunchies (2010): *Google Profit And Revenues Timeline*. Go rumors, posted: Mar. 3, 2010. http://gorumors.com/crunchies/google-ad-revenue-profit-timeline/ (last access 8/6/2010).

TECH{dot}MN: *MetroSpec Technology – FlexRad*. http://tech.mn/directory/companies/metrospec-technology/ (last access 3/12/2012).

Technology Park Adlershof (2008): *Lebenswissenschaften im Adlershof Focus – Wirkstoffe aus blauen Bakterien und molekulare Angeln (Life science in focus of Adlershof – Bio-active compounds from blue algae and molecular hooks).* Adlershof News, Aug. 27, 2008. http://www.adlershof.de/newsview/?no_cache=1&tx_ttnews%5Btt_news%5D=3660 (last access 2/16/2010).

Technology Park Adlershof (2009): *Over the Pond*. Adlershof News, Nov 2. 2009. http://www.adlershof.de/newsview/?no_cache=1&L=2&tx_ttnews%5Btt_news%5D=7717&klTyp=0 (Lats access 1/4/20010).

Teresko, J. (2005): *From Confusion To Action*. IndustryWeek, Sep. 1, 2005. http://www.industryweek.com/ReadArticle.aspx?ArticleID=10650 (last access 7/26/2009).

Thayer A.. M. (2011): *Top Instrument Firms*. Chemical & Engineering News 89 (17), 13-19. http://pubs.acs.org/cen/coverstory/89/8917cover.html?featured=1 (last access 5/16/2011).

Thayer, A. M. (2008): *Building Businesses – Turning university research into products takes time, money, and initiative as four nanotechnology companies' experiences show.* Chemical & Engineering News 86 (13), 10-15. http://pubs.acs.org/cen/coverstory/86/8613cover.html (last access 7/7/2010).

The Energy Blog (2006): *Solix Biofuels/Colorado State Deleloping Novel Algae Production System*. The Energy Blog, Dec. 28, 2006. http://thefraserdomain.typepad.com/energy/2006/12/solix_biofuelsc.html (last access 4/18/2007).

The Economist (2011): *Fail often, fail well*. Economist.com/blogs/schumpeter, The Economist, Apr. 14, 2011. http://www.economist.com/node/18557776 (last access 12/9/2011).

The Kirton Adaption-Innovation Inventory: http://www.kaicentre.com/ (last access 8/12/2010); *Publications and Current Work Using – Adaption-Innovation Theory*. http://www.kaicentre.com/PubList.doc (last access 8/13/2010).

The Myers & Brigg Foundation: *MBTI® Basics*. http://www.myersbriggs.org/my-mbti-personality-type/mbti-basics/ (last access 8/12/2010); *The 16 MBTI® Types*. http://www.myersbriggs.org/my-mbti-personality-type/mbti-basics/the-16-mbti-types.asp (last access 8/12/2010); *Understanding MBTI® Type Dynamics*. http://www.myersbriggs.org/my-mbti-personality-type/understanding-mbti-type-dynamics/ (last access 8/12/2010); cf. also http://en.wikipedia.org/wiki/Myers-Briggs_Type_Indicator.

The New York Times (2009): *Do Women Make Better Bosses?* Editors of The New York Times, The New York Times, Aug. 2, 2009. http://roomfordebate.blogs.nytimes.com/2009/08/02/do-women-make-better-bosses/ (last access 8/3/2009).

Theil, S. (2005): *The Next Petroleum*. Newsweek, Aug. 8, 2005. http://www.newsweek.com/id/56334 (last access 10/30/2009).

Thurm, S.; Raice, S.; Emos, T. (2012): *Social-Media Frenzy Fizzles*. Wall Street Journal, updated Jul. 27, 2012. http://online.wsj.com/article/SB10000872396390443477104577553431459135876.html (last access 7/28/2012).

Thurm, S.; Tam, P.-W. (2012): *Prominent Investors Miss Web IPO Payoff*. Wall Street Journal, Jun. 18, 2012. http://online.wsj.com/article/SB10001424052702303836404577474422342954922.html?mod=WSJEUROPE_hpp_MIDDLESecondNews (last access 6/19/2012).

Tidd, J.; Bessant, J.; Pavitt, K. (2001): *Managing Innovation – Integrating Technological, Market and Organizational Change* (2nd Ed.). John Wiley, Chichester [3rd Edition 2005].

Thomas, A. (2010): *Peter Thiel: From Frankfurt to the World of Global Markets*. aTrader, Jun. 17, 2010. http://www.atrader.com/manager-profile/11-peter-thiel-frankfurt-world-global-markets (last access 7/1/2011).

Tozzi, J. (2009): *Think Twice About Being First to Market*. Business Week, May 19, 2009. http://www.businessweek.com/smallbiz/content/may2009/sb20090519_306313.htm?chan=smallbiz_smallbiz+index+page_getting+started (last access 5/23/2010).

Tracey, J. (2009): In Kohler, C. (2009): *The 15 Most Influential Games of the Decade*. Wired, Dec. 24, 2009. http://www.wired.com/gamelife/2009/12/the-15-most-influential-games-of-the-decade/ (last access 9/24/2010).

Tuckman, B. W. (2001): *Developmental sequence in small groups*. Psychological Bulletin 63 (6), 384-99 (1965). Copyright International Association of Facilitators Spring 2001. Provided by ProQuest Information and Learning Company. All rights Reserved FindArticles.com. 07 Jul, 2011. http://findarticles.com/p/articles/mi_qa3954/is_200104/ai_n8943663/?tag=mantle_skin;content (last access 7/7/2011).

Tullett, A. D. (1997): *Cognitive Style - Not Culture's Consequence*. European Psychologist 2 (3), 258-267.

Tullo, A. H. (2011): *Breaking In The New*. Chemical & Engineering News 89 (38), Sep. 19, 2011, 10-14. http://pubs.acs.org/cen/coverstory/89/8938cover.html?featured=1 (last access 9/23/2011).

Tullo, A. H. (2010): *Amyris Files For IPO – Industrial Biotechnology: Firm is devising biomass-based routes to chemicals, fuels*. Chemical & Engineering News, Apr. 21, 2010. http://pubs.acs.org/cen/news/88/i17/8817news2.html (last access 4/24/2010).

Tullo, A. H. (2009): *Two Companies Eye Renewable Polymers – Green Chemistry: Braskem and Novomer have big plans for polymers based on renewable resources*. Chemical & Engineering News, Dec. 15, 2009. http://pubs.acs.org/cen/news/87/i51/8751news6.html (last access 12/20/2009).

TVA - The Venture Alliance: *Fundability Assessment*. http://www.tvausa.com/fundability_assessment.html (last access 9/23/2010).

UC Davis (2006): *Chevron to Fund Major Biofuel Research Projects at UC Davis*. UC Davis News & Information, Sep. 19, 2006. http://www.news.ucdavis.edu/search/news_detail.lasso?id=7873 (last access 11/24/2009).

Ucbasaran, D.; Wright, M.; Westhead, P.; Busenitz, L. W. (2003): *The Impact of Entrepreneurial Experience on Opportunity Identification and Exploitation – Habitual and Novice Entrepreneurs*. Advances in Entrepreneurship, Firm Emergence and Growth 6, 231-263.

Ucbasaran, D.; Westhead, P.; Wright, M. (2004):*The focus of entrepreneurial research – contextual and process issues*. File modified Aug. 10, 2004. http://ibis.nott.ac.uk/uniei/papers/paper1.doc (last access 9/15/2010).

UFOP - Union zur Förderung von Oel- und Proteinpflanzen e.V. (2007): *BASF und DBE planen gemeinsame Biodieselanlage (BASF and DBE plan a joint biodiesel plant).* UFOP-Marktinformation Ölsaaten und Biokraftstoffe, January 2007. http://www.ufop.de/downloads/RZ_MI_0107.pdf (last access 10/30/2009).

Ulrich, K. T.; Eppinger, S. D. (2000): *Product design and development*. McGraw-Hill, 2000; Exhibit 14-12 shown by
Thonemann, U. W. (2005): *Lecture – Product Development*. University of Cologne, File from 11/4/2005. http://s3.amazonaws.com/zanran_storage/www.wiso.uni-koeln.de/ContentPages/42419587.pdf (last access 7/12/2010).

US Bureau of Labor Statistics (2011): *International Comparisons of Annual Labor Force Statistics, Adjusted to U.S. Concepts, 10 Countries, 1970-2009 - Employment by sector, 1970 and 2009.* http://www.bls.gov/fls/intl_labor_force_charts.pdf; http://www.bls.gov/fls/flscomparelf/employment.htm#table2-4.f.na (last access 3/11/2011).

Utsch, A.; Rauch, A.; Rothfuss, R.; Frese, M. (1999). *Who becomes a small scale entrepreneur in a post-socialist environment: On the differences between entrepreneurs and managers in East Germany*. Journal of Small Business Management, 37 (3), 31-42. http://www.allbusiness.com/management-companies-enterprises/291539-1.html (last access 4/25/2009).

Van Gigch, J. P. (1974): *Applied General Systems Theory*. Harper & Row, Publishers, New York.

Van Noorden, R. (2009): *Editorial*: *Sustainable connection*. Chemistry World, January 2009. http://www.rsc.org/chemistryworld/Issues/2009/January/Editorial.asp (last access 3/25/2009).

Van Noorden, R. (2008): *Biobutanol enters battle of the alcohols*. Chemistry World, Feb. 2008. http://www.rsc.org/chemistryworld/Issues/2008/February/BiobutanolEntersBattleAlcohols.asp (last access 3/8/2009).

Van Zanten, M. (2007): *Persoonlijke aansprakelijkheid wordt in grote bedrijven geschuwd (Personal liability is avoided in large companies)*. In: Topmanagers op eigen benen (Top managers on their own feet). Management Scope, Oct. 26, 2007. http://managementscope.onzetestomgeving.nl/magazine/artikel/271-topmanagers-eigen-benen (last access 1/19/2010).

Vanden Plas, J. (2008): *Alternative energy Visions: Virent looks for a successor to Apfelbach.* Wisconson Technology Network – WTN News, Oct. 6, 2008. http://wistechnology.com/articles/5094/ (last access 12/15/2009).

VentureBeat: *Green Biologics Overview*. Venture Beat Profiles. http://venturebeatprofiles.com/company/profile/green-biologics (last access 1/5/2010).

Vercipia (2010): *Consolidated Financial Statement – Vercipia Biofuels – Highlands Ethanol LLC*.

http://www.myflorida.com/audgen/pages/nonprofit_forprofit%20rpts/2009%20highlands%20ethanol%20dba%20vercipia%20biofuels.pdf (last access 4/2/2012).

Verganti, R. (2010): *Having Ideas versus Having a Vision*. Harvard Business Review Blog – The Conversation, Mar. 1, 2010. http://blogs.hbr.org/cs/2010/03/having_ideas_versus_having_a_vision.html (last access 3/30/2010).

Verser, D. (2008): *Will we really have $1.50 Non Food Ethanol? An Interview with Zeachem's EVP R&D, Dan W. Verser*. Alternative Energy Blog, posted on Apr. 12, 2008. http://www.alternativeenergy.com/profiles/blog/show?id=1066929%3ABlogPost%3A26030 (last access 1/5/2010).

Verser, D. (2009): *Dan Verser – Co-Founder – ZeaChem*. Entrepreneur Trek – Stanford, Mar. 21, 2009. http://www.slideshare.net/EntrepreneurTrek/dan-verser-cofounder-zeachem (last access 1/5/2010).

Viering, K. (2009): *Die Treibstoff-Züchter (The Fuel Breeders*). Berliner Zeitung, Nov. 20, 2009. http://www.berlinonline.de/berliner-zeitung/archiv/.bin/dump.fcgi/2009/1120/mutmacherjetztundhier/0443/index.html (last access 12/16/2009).

Villanueva, J.; Forbes, D.; Zellmer-Bruhn, M.; Sapienza , H. (2005): *The Entrepreneurial Intentions of Academic Scientist-Inventors*. Babson Frontiers of Entrepreneurship Research 2005; to be published in Journal of Business Venturing. http://www.babson.edu/entrep/fer/2005FER/chapter_xxii/paper_xxii3.html (last access 7/8/2009).

Vitols, S. (2001): *The Origins of Bank-Based and Market-Based Financial Systems: Germany, Japan, and the United States*. Discussion Paper FS I 01 – 302, Wissenschaftszentrum Berlin für Sozialforschung, Jan. 2001. http://bibliothek.wz-berlin.de/pdf/2001/i01-302.pdf (last access 8/15/2010).

Vlasic, B. (2013): *Breaking Down on the Road to Electric Cars*. The New York Times, Apr. 23, 2013. http://www.nytimes.com/2013/04/24/business/fisker-broke-down-on-the-road-to-electric-cars.html?pagewanted=all&_r=0 (last access 4/25/2013).

Voigt, K.-P. (2008): *Mikroalgen aus der Altmark mindern CO2-Aufkommen (Micro-algae from the Altmark reduce CO2 rise*). Mitteldeutsche Zeitung, Aug. 15, 2008. http://www.mz-web.de/servlet/ContentServer?pagename=ksta/page&atype=ksArtikel&aid=1218774013904 (last access 5/9/2011).

Voith, M. (2009a): *Dow Plans Algae Biofuels Pilot – Project will test a process to turn CO2 into ethanol.* Chemical & Enfineering News 87 (27), 10. http://pubs.acs.org/cen/news/87/i27/8727notw5.html.

Voith, M. (2009b): *Up From The Slime - Start-up companies see algae as the new renewable fuel source*. Chemical & Engineering News 87 (4), 22-23. http://pubs.acs.org/cen/email/html/cen_email_cen_87_i04_8704bus1.html (last access 1/2/3/2010).

Voith, M. (2010a): *A Slowdown For Start-Ups*. Chemical & Engineering News 88, Oct. 18, 2010. http://pubs.acs.org/cen/news/88/i43/8843news2.html (last access 10/20/2010).

Voith, M. (2010b):*Cleantech Funding Falls*. Chemical & Engineering News 88 (41), 10. http://pubs.acs.org/cen/news/88/i41/8841notw6.html (last access 10/21/2010).

VON ARDENNE:*The life's work of Manfred von Ardenne*. http://www.vonardenne.biz/VON_ARDENNE/Company/Company/Manfred-von-Ardenne/Introduction.html; in German: http://www.vonardenne.biz/VON_ARDENNE/UNTERNEHMEN/VON-ARDENNE/Manfred-von-Ardenne/Einleitung.html; cf. also http://en.wikipedia.org/wiki/Manfred_von_Ardenne.

Von Bertalanffy, L. (1968). *General System Theory: Foundations, Development, Applications*. George Braziller; New York.

Von Hoerner, H. (2008): vH&S – *Ein mittelständiges Unternehmen erfolgreich auf dem Gebiet der Raumfahrt seit 1971 (vH&S – A medium-sized enterprise successful in arerospace since 1971)*. Presentation Technology Entrepreneurship, Jan. 16, 2008. http://ce.ioc.KIT.edu/downloads/Praesentation_vonHoerner.pdf, http://ce.ioc.KIT.edu/59.php (last access 6/8/2011).

Vosmek, S.(2009): *Marrone Bio Introduces Innovative iPhone Application*. Astia, Nov. 16, 2009. http://astianotes.blogspot.com/2009/11/marrone-bio-introduces-innovative.html (last access 1/14/2010).

Wadhwa, V. (2006a): *Venture Capital: The Good, Bad, and Ugly*. Business Week, Jul. 18, 2006. http://www.businessweek.com/print/smallbiz/content/jul2006/sb20060717_402629.htm (last access 10/21/2010).

Wadhwa, V. (2006b): *15 Things You Need to Score VC Funding*. Business Week, Aug. 1, 2006. http://www.businessweek.com/smallbiz/content/aug2006/sb20060801_119338.htm (last access 11/5/2010).

Wadhwa, V. (2009): *Why Less Is More for Startups*. Business Week, Jun. 23, 2009. http://www.businessweek.com/smallbiz/content/jun2009/sb20090623_890999.htm (last access 11/10/2009).

Wadhwa, V.; Aggarwal, R.; Holly, K. "Z"; Salkever, A. (2009): *The Anatomy of an Entrepreneur – Family Background and Motivation*. Kauffman Foundation Report, July 2009. http://www.kauffman.org/uploadedFiles/ResearchAndPolicy/TheStudyOfEntrepreneurship/anatomy-of-entrepreneur-family-background-and-motivation.pdf (last access 7/27/2009).

Wald, M. L. (2009a): *E.P.A. Says It Expects to Raise Amount of Ethanol Allowed in Fuel Blends to 15%*. New York Times, Dec. 2, 2009. http://www.nytimes.com/2009/12/02/business/energy-environment/02ethanol.html (last access 12/2/2009).

Wald, M. L. (2009b): *Industry Built From Scratch*. The New York Times, Oct. 15, 2009. http://www.nytimes.com/2009/10/15/business/energy-environment/15biofuel.html?_r=1 (last access 11/30/2009).

Walker, J. (2011): *For Tech's Elite, Mobile Gaming Is a Big Play*. Wallstreet Journal, Nov. 15, 2011. http://online.wsj.com/article/SB10001424052970204323904577038462736751448.html?mod=WSJEUROPE_hpp_MIDDLEThirdNews (last access 11/15/2011).

Wallace, A. (2012): *Boulder's OPX Biotechnologies reaches 'scale-up' milestone*. The Denver Post, Mar. 27, 2012. http://www.denverpost.com/business/ci_20267474/boulder-opx-biotechnologies-reaches-milestone-bioacrylic (last access 3/31/2012).

Waltz , E. (2009a): *Algae Energy Orgy*. Mother Jones, September/October 2009 Issue. http://motherjones.com/politics/2009/09/algae-energy-orgy (last access 1/26/2010).

Waltz , E. (2009b): *Biotech's green gold*? Nature Biotechnology 27, 15-18. http://www.nature.com/nbt/journal/v27/n1/full/nbt0109-15.html (last access 2/2/2010);
Waltz, E. (2009b): *Box 1 The economics of closed bioreactors: a back-of-the-envelope calculation*. Nature Biotechnology 27, 15-18. http://www.nature.com/nbt/journal/v27/n1/box/nbt0109-15_BX1.html (last access 2/2/2010).

Wang, U. (2011): *Report: Range Fuels to Shut Down Plant*. Earth2tech, Jan. 14, 2011. http://gigaom.com/cleantech/report-range-fuels-to-shut-down-plant/ (last access 3/17/2011).

Wang, U. (2008): *Cobalt to Build Pilot Biobutanol Plant in 2009*. Green Tech Media, Oct. 21, 2008. http://www.greentechmedia.com/articles/read/cobalt-to-build-pilot-biobutanol-plant-in-2009-5037/ (last access 11/9/2009).

Wasch, M. (2010): *Bokela setzt auf China-Geschäft (Bokela focuses on business in China)*. Badische Neueste Nachrichten (BNN), Nov. 14, 2010.

Wasik, J. F. (2007): *Forget the Ethanol Myth – Avoid Biofuel Bubble*. Bloomberg New, Jul. 23, 2007. http://www.bloomberg.com/apps/news?pid=20601039&refer=columnist_wasik&sid=aOS8e5kvDESE (last access 10/7/2007).

Watzlawick, P.; Beavin, J.; D. Jackson, D. D. (1967): *Pragmatics of Human Communication. A Study of Interactional Patterns, Pathologies, and Paradoxes*. W. W. Norton and Co, New York;
Watzlawick, P.; Beavin, J. H.; Jackson, D. D. Jackson (1969): *Menschliche Kommunikation. Formen, Störungen, Paradoxien*. Verlag Hans Huber, Bern, Stuttgart, Wien.

Waters, R. (2011): *Technology: the Internet bubble*. Financial Times, Jun. 20 2011. http://www.ft.com/intl/cms/s/0/6fd71904-9b69-11e0-bbc6-00144feabdc0.html (last access 6/21/2011).

Watson, W. E.; Ponthieu, L. D.; Critelli, J. W. (1995): *Team interpersonal process effectiveness in venture partnerships and its connection to perceived success*. Journal of Business Venturing 10, (5), 393-411.

Weber, R. (2002): *Managing growth to achieve efficient coordination in large groups*. Carnegie Mellon University, Aug. 8, 2002. http://www.casos.cs.cmu.edu/publications/papers/GrowNew.pdf (last access 9/6/2010).

Weernink, J. (2009): *Product development efforts*. SpecialChem, Jul. 31, 2009. http://www.specialchem4coatings.com/community-pulse/community-insight.aspx?id=11754 (last access 7/31/2009).

Weidemann, T. (2009): *Free to Play Games – Essentials*. Consultant Online Entertainment, file last access 11/20/2009. http://kapitalrejsen.dk/sites/kapitalrejsen.dk/files/dokumenter/FREE%20Teut%20Weidemann%20f2p%20Market%20Foundations.pdf (last access 10/22/2011).

Weishaupt, G. (2012): *Solarbranche – Nur die Giganten dürfen sich sonnen (Solar industry – Only the giants may sunbathe*). Handelsblatt, Apr. 4, 2012. http://www.handelsblatt.com/unternehmen/industrie/solarbranche-nur-die-giganten-duerfen-sich-sonnen/6475028.html (last access 4/4/2012).

Wellsphere (2009): *BlueFire Wants to Be Algae's Sugar Daddy***.** Posted May 27, 2009. http://stanford.wellsphere.com/green-living-article/bluefire-wants-to-be-algae-s-sugar-daddy/687352 (last access 12/23/2009).

Wernher von Braun – http://en.wikipedia.org/wiki/Wernher_von_Braun; http://de.wikipedia.org/wiki/Wernher_von_Braun.

Wesoff, E. (2009): *The Elephant in the Room*. Green Tech Media, Jun, 30, 2009. http://www.greentechmedia.com/green-light/post/algenol-the-elephant-in-the-room/ (last access 2/2/2010).

Wheeler, T. B. (2009): *Algae Power – Researchers In A Baltimore Lab Work To Tap The Energy Potential Of A Bacterium*. The Baltimore Sun, May 8, 2009. http://articles.baltimoresun.com/2009-05-08/news/0905070142_1_blue-green-algae-ethanol-carbon-dioxide (last access 2/5/2010).

Wheelwright, S. C.; Clark K. B. (1992): *Revolutionizing product development: quantum leaps in speed, efficiency, and quality. Free Press*, 1992. Figures shown on page 13 by Thonemann, U. W. (2005): Lecture – Product Development. University of Cologne, file from 11/4/2005. http://s3.amazonaws.com/zanran_storage/www.wiso.uni-koeln.de/ContentPages/42419587.pdf (last access 7/12/2010).

Wiele, J. (2011): *Facebook und die Folgen – Gesichtsverlust (Facebook and the consequences – Loss of face).* FAZ, Sep. 29, 2011. http://www.faz.net/aktuell/feuilleton/medien/facebook-und-die-folgen-gesichtsverlust-11373614.html (last access 9/30/2011).

Wikinvest (2009): *Bluefire Ethanol (BFRE).* http://www.wikinvest.com/stock/Bluefire_Ethanol_(BFRE) (last access 12/27/2009); Wikinvest (2013):

http://www.wikinvest.com/stock/Bluefire_Ethanol_(BFRE)/Data/Income_Statement (last access 12/27/2009).

Wilder, B. (2004): *Pushing for alternative fuel – Blacklick company's butanol production process seeks investors to grow*. Columbus Business Journal, Sep. 3, 2004. http://columbus.bizjournals.com/columbus/stories/2004/09/06/smallb1.html (last access 8/25/2008).

Wilson, L. (2008): *Kelp wanted: Biofuel firms turn to algae, Solazyme doubles space in South S.F*. San Francisco Business Times, Mar. 26, 2007. http://sanfrancisco.bizjournals.com/sanfrancisco/stories/2007/03/26/story11.html?i=76479&b=1174881600%5E1436302 (last access 1/12/2010).

Wintzenburg, J. B. (2009): *Erfolgreiche Frustgründung (Foundation resulting from frustration).* Der Stern, . Jun. 7, 2009. http://www.stern.de/wirtschaft/news/unternehmen/gruender-trotzen-wirtschaftskrise-die-unternehmenslustigen-705563.html (last access 2/7/2011); Deutscher Gründerpreis - *Purplan GmbH aus Wallenhorst gehört zu in Deutschland (German National Founders' Award – Purplan GmbH from is one of the Top-Climbers in Germany)*. Weser-Ems Business-on, Jun. 3, 2009. (last access 2/7/2011); http://www.deutscher-gruenderpreis.de/owx_medien/media17/1735.pdf (last access 2/7/2011).

Wirth (2009): *Prozessfiltration: schnelle Umsetzung akademischen Wissens in den Filterapparatebau (Process filtration – fast transfer of academic knowledge into construction of filter apparatuses*). ChemManager, Feb. 12, 2009. http://www.chemanager-online.com/news-opinions/interviews/prozessfiltration-schnelle-umsetzung-akademischen-wissens-den-filterapparat (last access 6/10/2010).

Witt, P. (2006): *Unternehmensgründer als ehrbare Kaufleute (Entrepreneurs as honest businesspersons).* http://www2.wiwi.hu-berlin.de/institute/im/publikdl/Witt.pdf (file created on 10/11/2006).

Witzmann, R.- P. (2006): *Kooperation zwischen FH Lausitz und IGV auf dem Gebiet der phototrophen Biotechnologie (Cooperation between FH Lausitz and IGV in the field of phototrophic biotechnology*). Innovations-Report, Nov. 13, 2006. http://www.innovations-report.de/html/berichte/biowissenschaften_chemie/bericht-73868.html (last access 3/28/2010).

WOC - World of Chemicals (2012): *BASF to invest $30 million in Renmatix*. World of Chemicals News, Jan. 3, 2012. http://www.worldofchemicals.com/media/basf-to-invest-30-million-in-renmatix/2076.html (last access 2/4/2012).

Wolcott, R. C.; Lippitz, M. J. (2007): *The Four Models of Corporate Entrepreneurship*. MIT Sloan Management Review 49 (1), 74- 82. http://www.business.ualberta.ca/mlounsbury/techcom/readings/wolcott.pdf (last access 7/21/2009).

WolframMathWorld: *Fibonacci Number*. http://mathworld.wolfram.com/FibonacciNumber.html; cf. also http://en.wikipedia.org/wiki/Fibonacci_number; *Fibonacci Numbers in Nature*: http://britton.disted.camosun.bc.ca/fibslide/jbfibslide.htm; Welcome to the Fibonacci Project: http://www.fibonacci-project.eu/.

Wong, V. (2009a): *How to Nurture Future Leaders*. Business Week, Sep. 30, 2009. http://www.businessweek.com/innovate/content/sep2009/id20090930_806435.htm?chan=innovation_innovation+%2B+design_top+stories (last access 10/10/2009).

Wong, V. (2009b): *How Business Is Adopting Design Thinking*. Business Week, Sep. 30, 2009. http://www.businessweek.com/innovate/content/sep2009/id20090930_853305.htm?chan=innovation_design+index+page_special+report+--+design+thinking (last access 10/10/2009).

Woods, P. (2009a): *Paul Woods on Algenol Biofuels*. Clean Skies News, Aug. 3, 2009. http://www.cleanskies.com/videos/paul-woods-algenol-biofuels (last access 2/2/2010).

Woods, P. (2009b): *Algenol Biofuels – Integrated Biorefinery for Producing Ethanol from Hybrid Algae*. Presentation, Dec. 4, 2009. File of 9/29/2009. http://lee.ifas.ufl.edu/AgNatRes/Sustainability/Algenol_Lee_county_climate_change_2009.pdf (last access 2/2/2010).

Woods, P. (2009c): *Algenol Biofuels – Integrated Biorefinery for Producing Ethanol from Hybrid Algae.* Presentation, The University of Florida, IFAS, Dec. 4, 2009. File of 11/17/2009. http://lee.ifas.ufl.edu/AgNatRes/Sustainability/Algenol_Lee_county_climate_change_2009.pdf (last access 2/11/2010).

Woo, C.Y.; Daellenbach, U.;Nicholls-Nixon. C. (1994): *Theory Building in the Presence of Randomness – The Case of Venture Creation and Performance*. Journal of Management Studies, 31 (4), 507-524.

Woopidoo: *Larry Page Biography (Lawrence E. Page): Google Cofounder*. http://www.woopidoo.com/biography/larry-page/index.htm (last access 1/21/2011).

Worthen, B. (2012): *Newest Tech IPO Doubles on Day One*. Wall Street Journal, Apr. 19, 2012. http://online.wsj.com/article/SB10001424052702303513404577353891795293210.html?mod=WSJEUROPE_hpp_MIDDLEFourthNews (last access 4/20/2012).

Wuttke, K. (2008): *Sächsische Firma entwickelt ethisch-ökologisch unbedenklichen Biosprit (Company from Saxony develops ethicics- and ecology-compliant biofuel*). Deutschlandfunk, May 2, 2008. http://www.dradio.de/dlf/sendungen/firmen/778008/ (last access 12/20/2009).

Wüst, C. (2007): *Thanksgiving in the gas tank – New technologies from the former East Germany*. Der Spiegel, May 1, 2007. http://www.spiegel.de/international/world/0,1518,479922-5,00.html (last access 12/21/2009).

Yang, W.; Kiron, D. (2010): *Cambridge NanoTech*. Harvard Business Review Case 9-610-083, May 14, 2010. http://www1.hbr.org/product/cambridge-nanotech/an/610083-PDF-ENG?Ntt=cambridge%2520nanotech.

Yin, R. (1994). *Case study research: Design and methods* (2nd ed.). Beverly Hills, CA: Sage Publishing.

Zakaria, F. (2009): *Is America Losing Its Mojo?* Newsweek, Nov. 14, 2009. From the magazine issue dated Nov. 23, 2009. http://www.newsweek.com/id/222836 (last access 11/21/2009).

Zakaria, F. (2008): *There Is a Silver Lining*. Newsweek, Oct. 20, 2008. http://www.newsweek.com/id/163449/output/print (last access 10/21/2008).

Zbikowski, F.; Brandkamp, M. (2013): *Start-ups sind flexibler, schneller und risiobereiter (Start-ups are more flexible, faster and more ready to take risk*). Nachrichten aus der Chemie 61, 982-985; http://www.high-tech-gruenderfonds.de/, http://www.en.high-tech-gruenderfonds.de/.

Zeller-Silva, G. (2007): *Zu schnell zu groß (Too fast too large*). Die Zeit Online, Feb. 27, 2007. http://www.zeit.de/online/2007/08/Solarenergie-Aktien (last access 2/27/2007).

Zentner, B. (2004): *Merseburger sieht in Klötze grün (Person from Merseburg sees green in Klötze)*. Mitteldeutsche Zeitung, Oct. 2, 2004. http://www.algomed.de/media/presse/11-46-52-25-01-2008-MZ%20Artikel%20Merseburg.pdf (last access 5/12/2012).

Zezima, K. (2009): *Harvard Slows Its Growth in a Boston Neighborhood*. The New York Times, Feb. 18, 2009. http://www.nytimes.com/2009/02/19/us/19harvard.html?ref=us (last access 2/18/2009).

Zhao, Y. (2009):*Young Tableaux and the Representations of the Symmetric Group*. Student Article, MIT, File from 4/4/2009. http://web.mit.edu/yufeiz/www/papers/youngtab-hcmr.pdf (last access 3/21/2012).

Zolin, R.; Kautonen, T.; Kautonen, A. (2008):): *The Devil You Know? The Potential Downside of Strong And Weak Ties for Entrepreneurial Team Formation*. Swinburne University of Technology, Regional Frontierts 2008 – Conference Paper, AGSE 2008, 325-337. http://www.swinburne.edu.au/lib/ir/onlineconferences/agse2008/000059.pdf (last access 8/5/2010).

ZoomInfo (2008): *Solazyme , Inc. – Company Profile*. http://www.zoominfo.com/Search/CompanyDetail.aspx?CompanyID=104890649&cs=QGGQIEZIE (last access (1/12/2010); http://www.yatedo.com/p/Christine+Eckhaus/normal/dc5f4cc12f98ec1f1bed1272034d417c (last access 2/11/2011).

Zuber-Knost, E. (2009): *Hydrogen from Microalgae – Scientists Work on Highly Efficient Processes – KIT Coordinates Joint Project*. KIT Press Release 141/2009. http://www.kit.edu/english/55_604.php?PHPSESSID=37c3fa1b957025a2de2f590a0ecf7876 (last access 2/12/2010).

Zynga (2011): *Zynga, Inc*. S-1 Filing S-1 Filing, PROSPECTUS (Subject to Completion), Issued Jul. 1, 2011. http://www.sec.gov/Archives/edgar/data/1439404/000119312511180285/ds1.htm (last access 9/22/2011).

NOTES

1. Technology Entrepreneurship: http://ce.ioc.KIT.edu.
2. Webster's Online Dictionary: Entrepreneurship.http://www.websters-online-dictionary.org/definition/entrepreneurship (last access 7/12/2009).
3. Spin-out: http://en.wikipedia.org/wiki/Spin_out.
4. http://en.wikipedia.org/wiki/Leadership (last access 7/14/2009).
5. http://en.wikipedia.org/wiki/Political_economy (last accesss 9/11/2009).
6. Trade-off: http://en.wikipedia.org/wiki/Trade-off (last access 6/6/2011).
7. Supply chain: http://en.wikipedia.org/wiki/Supply_chain (last access 12/3/2010).
8. BOS (Balance-of-System) Cost:
   A term for the parts of a solar electric system besides the actual solar panels. It includes batteries, cables, inverter, safety and monitoring equipment, and the mounting racks that hold the panels;
   it may also represent costs of all components other than the PV modules including design, land, site preparation, system installation, support structures, power conditioning, operation and maintenance, batteries, indirect storage, and other related costs.
9. Click'n'vote: http://www.omnexus4adhesives.com/community-pulse/pastclicknvote.aspx?id=72 (last access 6/7/2011).
10. MSN Encarta: Utilize is more common in technical contexts. The device utilizes a special plug-in connection. It can also refer to using things in unusual or unintended ways, as a more formal equivalent of "make use of." http://encarta.msn.com/dictionary_/utilize.html; The Free Dictionary by Farlex: http://www.thefreedictionary.com/utilize.
11. "Kein Operationsplan reicht mit einiger Sicherheit über das erste Zusammentreffen mit der feindlichen Hauptmacht hinaus.
    Nur der Laie glaubt in dem Verlauf eines Feldzuges die konsequente Durchführung eines im Voraus gefassten, in allen Einzelheiten überlegten und bis ans Ende festgehaltenen, ursprünglichen Gedankens zu erblicken.......Es kommt darauf an, in lauter Spezialfällen die in den Nebel der Ungewissheit gehüllte Sachlage zu durchschauen, das Gegebene richtig zu würdigen, das Unbekannte zu erraten, einen Entschluss zu fassen und dann kräftig und unbeirrt durchzuführen."
12. Jack Welsh: *Clausewitz in Business*. http://www.clausewitz.com/business/index.htm; on the Clauswitz Homepage http://www.clausewitz.com/index.htm (last access 10/1/2009).
13. Magnetfeldtechnik Resonanz GmbH: http://www.deutscher-gruenderpreis.de/resonanz (last access 10/13/2009).
14. Experience: http://en.wikipedia.org/wiki/Experience (last access 6/10/2011).

15. Society for Organizational Learning (SOL): http://www.solonline.org/, http://www.solonline.org/organizational_overview/ (last access 10/21/2011).

16. http://en.wikipedia.org/wiki/Experience_curve_effects; http://en.wikipedia.org/wiki/Learning_curve (last access 11/4/2010).

17. Capitalism: http://en.wikipedia.org/wiki/Capitalism; http://en.wikipedia.org/wiki/Financial_capitalism.

18. Capitalism: http://www.websters-online-dictionary.org/definition/capitalism.

19. OECD: Glossary of Statistical Terms – Marketing Innovation. http://stats.oecd.org/glossary/detail.asp?ID=6871 (last access 4/10/2010).

20. Carl Benz (1910): "Aufgrund der beschränkten Verfügbarkeit von Chauffeuren wird es niemals mehr als 5000 Automobile geben." http://www-pu.informatik.uni-tuebingen.de/users/klaeren/sprueche/805.htm (last access 7/24/2009); Gottlieb Daimler ((1834-1900): "Die weltweite Nachfrage nach Kraftfahrzeugen wird eine Million nicht überschreiten – allein schon aus Mangel an verfügbaren Chauffeuren." http://manager-lounge.com/testimonials/mercedes/index.php (last access 7/24/2009).

21. Exchange value: http://en.wikipedia.org/wiki/Exchange_value (last access 6/14/2011).

22. Intangible assets: http://en.wikipedia.org/wiki/Intangible_asset (last access 6/14/2011).

23. Herd behavior: http://en.wikipedia.org/wiki/Herd_behavior (last access 6/14/2011).

24: Entry barrier: http://en.wikipedia.org/wiki/Barriers_to_entry; Exit barrier: http://en.wikipedia.org/wiki/Barriers_to_exit (last access 6/14/2011).

25. Business cycle: http://en.wikipedia.org/wiki/Business_cycle, http://en.wikipedia.org/wiki/Economic_downturn, http://en.wikipedia.org/wiki/Economic_bubble. (last access 6/11/2011).

26. An-Institute: http://de.wikipedia.org/wiki/An-Institut (last access 6/18/2011).

27: BMWi (2010): Jahresbericht 2010 | 2011 – Die Initiative Kompetenznetze Deutschland im Überblick (Annual Report 2010 | 2011 – Overview of the Initiative Competence Networks). http://www.kompetenznetze.de/service/bestellservice/medien/jahresbericht2010.pdf (last access 6/18/2010), Kompetenznetze Deutschland: http://www.kompetenznetze.de/.

28. Innovationsallianz: http://www.bmbf.de/pub/flyer_innovationsallianz.pdf (last access 6/19/2011).

29: CRADA: http://www.usbr.gov/research/tech-transfer/crada/whatcrada.html (last access 6/19/2011).

30. Nanosys data: http://www.hoovers.com/company/Nanosys_Inc/rfsffri-1.html (last access 6/19/2011).

31. In Germany (Austria and Switzerland) a "habilitation" (leading to the degree Dr. habil.) is usually one prerequisite to become a professor in a science discipline at a university.

32: *Inc.* is a monthly US magazine written for the people who run growing companies. The magazine publishes an annual list of the 500 (and also 5000) fastest-growing private companies in the US, the "*Inc.* 500" list.

33: German High-Tech Gründerfonds: conditions – requires founder's own contributions (up to 20 percent); up to €500,000 in a first round of funding, purchases 15% shares with a nominal value and provides a subordinated shareholder loan. In addition, the Fund keeps a further €500,000 for follow-on financing. The loan has a term of 7 years.
http://www.high-tech-gruenderfonds.de/finanzierung/finanzierungskonditionen/.

34: SBA: http://en.wikipedia.org/wiki/Small_Business_Administration (last access 6/23/2011).

35: Venture Capital: http://en.wikipedia.org/wiki/Venture_capital;
http://de.wikipedia.org/wiki/Risikokapital (last access 6/23/2011).

36: Limited Partnership (LP): http://en.wikipedia.org/wiki/Limited_partnership;
General Partnership (GP): http://en.wikipedia.org/wiki/General_partnership (last access 6/23/2011).
GP is similar to the German GbR (Gesellschaft bürgerlichen Recht). GbR is the basic form of partnership based on an agreement (or contract) of at least two persons intending to achieve a common goal. For any liabilities of the partnership the partners are liable personally and with all their wealth and assets. Liability cannot be limited in principle.

37: Penny stocks: http://en.wikipedia.org/wiki/Penny_stock
http://en.wikipedia.org/wiki/Pink_Sheets.
Pink Quote, informally known as the Pink Sheets, is an electronic quotation system operated by Pink OTC Markets that displays quotes from broker-dealers for many over-the-counter (OTC) securities. These securities tend to be inactively traded stocks, including penny stocks and those with a narrow geographic interest.

38. Locus of control: http://en.wikipedia.org/wiki/Locus_of_control (last access 6/27/2011).

39. August Horch: http://de.wikipedia.org/wiki/Audi,
http://de.wikipedia.org/wiki/August_Horch; http://en.wikipedia.org/wiki/Audi;
http://en.wikipedia.org/wiki/August_Horch.

40. Volition: the capability of conscious choice and decision and intention; an act of will.

41. Samuel Moore "Sam" Walton: http://en.wikipedia.org/wiki/Sam_Walton;
http://www.fastcompany.com/magazine/77/walmart.html.

42. The Kirton Adaption-Innovation Inventory: http://www.kaicentre.com/ (last access 6/29/2011); The Myers & Brigg Foundation: http://www.myersbriggs.org/ (last access 6/29/2011)

43. Gedanken experiment: http://en.wikipedia.org/wiki/Gedanken_experiment. (physics) A hypothetical (“thought”) experiment which is possible in principle and is analyzed (but not performed) to test some hypothesis. Also known as thought experiment.

44. “dm” and Götz Werner”: Blocked careers or business ideas as the origin of entrepreneurship is all over. For instance, in Germany Götz Werner was employed with a large drugstore organization. In Germany a drugstore is a retail store featuring basically no drugs and medicines, but miscellaneous items for the home, such as household and baby care, personal care and cosmetics, hygiene and cleaning products, food additives and nutraceutials etc. After a reorganization of the sales unit he suggested to introduce the concept of a discount drugstore chain combined with competent advising services. This idea was rejected and, after leaving his employer, he founded in 1973 his own discount drugstore called “dm-drogerie markt GmbH + Co. KG” (dm is Drogerie Markt in German) as the kernel of the currently leading German discount drugstore chain. For 2009/2010 revenues were €5,6 billion with ca. 30 percent outside Germany and ca. 36,000 employees. ttp://de.wikipedia.org/wiki/G%C3%B6tz_Werner.

45. Group dynamics: http://en.wikipedia.org/wiki/Group_dynamics (last access 7/4/2011).

46. Ernst Werner von Siemens: http://www.ask.com/wiki/Werner_von_Siemens?qsrc=3044; Johann Georg Halske: http://www.ask.com/wiki/Johann_Georg_Halske?qsrc=3044.
Johann Georg Halske (1814 – 1890) was a German master mechanic who started his own workshop in Berlin in 1844, which he ran together with his partner F. M. Böttcher.
In 1847 Halske co-founded the Siemens & Halske Telegraph Construction Company together with Werner von Siemens (1816– 1892). Siemens took over the role of the developer, Halske focused on finishing and production of the telegraphs. Halske was particularly involved in the construction and design of electrical equipment such as the press which enabled wires to be insulated with a seamless coat of gutta-percha, the pointer telegraph and the morse telegraph and measuring instruments. In 1867 he withdrew from the company.
Siemens left school without finishing his education, but joined the Prussian army to undertake training in engineering, in mathematics, physics, chemistry and ballistics. He is known world-wide for his advances in various technologies, and chose to work on perfecting technologies that had already been established.

47. Enercon GmbH: http://en.wikipedia.org/wiki/Enercon; http://www.windsofchange.dk/WOC-usaturb.php (last access 7/12/2011).

48. Theoria – expectation: Wikipedia: http://en.wikipedia.org/wiki/Theoria; http://en.wikipedia.org/wiki/Praxis_(process); http://www.merriam-webster.com/dictionary/theory; en.wikipedia.org/wiki/Expectation_(epistemic).

49. Best practice: http://en.wikipedia.org/wiki/Best_practice.

50. Bootlegging: http://en.wikipedia.org/wiki/Bootleg.

51. Idea: http://www.merriam-webster.com/netdict/idea.

52. ConnectU.com lawsuit: http://en.wikipedia.org/wiki/Criticism_of_Facebook.

53. Electric vehicles: http://en.wikipedia.org/wiki/Electric_vehicle; http://en.wikipedia.org/wiki/Electric_car; http://de.wikipedia.org/wiki/Elektroauto; http://en.wikipedia.org/wiki/La_Jamais_Contente (last access 7/19/2011).

54. Gestalt: http://en.wikipedia.org/wiki/Gestalt_psychology.

55. Clarence Birdseye: http://en.wikipedia.org/wiki/Clarence_Birdseye, http://web.mit.edu/invent/iow/birdseye.html, http://www.usatoday.com/money/industries/technology/maney/2004-07-14-frozen_x.htm.

56. Drucker Quotes: http://www.1-famous-quotes.com/quote/927861.

57. First-Mover Advantage: Encyclopedia of Management, http://www.enotes.com/management-encyclopedia/first-mover-advantage (last access 7/24/2011); http://en.wikipedia.org/wiki/First-mover_advantage.

58. Kondratiev waves: http://en.wikipedia.org/wiki/Kondratiev_wave.

59. Environmental Entrepreneurs: http://www.e2.org/.

60. Lux Research: THE CLEANTECH REPORT™. http://www.luxresearchinc.com/cleantech.php; CleanTech Group: Cleantech definition. http://cleantech.com/about/cleantechdefinition.cfm (last access 5/18/2010).

61. Orphan drug: http://en.wikipedia.org/wiki/Orphan_drug.

62. Switching cost: http://en.wikipedia.org/wiki/Switching_barriers.

63. Critical success factor (CSF): http://en.wikipedia.org/wiki/Critical_success_factor.

64. SWOT analysis: http://en.wikipedia.org/wiki/SWOT_analysis.

65. Screwdriver: http://en.wikipedia.org/wiki/Screwdriver (last access 9/6/2011).

66. Technology trajectory: http://en.wikipedia.org/wiki/Technology_trajectory.

67. Paradigm: http://en.wikipedia.org/wiki/Paradigm.

68. Hybrid power plant: https://www.enertrag.com/projektentwicklung/hybridkraftwerk.html, https://www.enertrag.com/download/prospekt/hybridkraftwerk_kurzinfo_090417.pdf.

69. Massively Multiplayer Online Games (MMOGs): http://en.wikipedia.org/wiki/Massively_multiplayer_online_game; http://de.wikipedia.org/wiki/Massively_Multiplayer_Online_Role-Playing_Game; http://en.wikipedia.org/wiki/MUD.

70. Widget application: http://en.wikipedia.org/wiki/Software_widget.

71. AAA game: The gaming press tends to use AAA to mean a really high quality game. Marketing folks will use it to refer solely to the advertising budget (i.e. the actual quality of the game is irrelevant). Producers usually will use it to mean both (i.e. is high quality and has a big marketing budget).

72. Generally Accepted Accounting Principles (GAAP): http://en.wikipedia.org/wiki/Generally_Accepted_Accounting_Principles; http://en.wikipedia.org/wiki/Generally_Accepted_Accounting_Principles_(United_States).

73. Ambiguity: http://en.wikipedia.org/wiki/Ambiguity.

74. Scenario: http://en.wikipedia.org/wiki/Scenario.

75. Currency Volatility: http://sdw.ecb.europa.eu/quickview.do?SERIES_KEY=120.EXR.M.USD.EUR.SP00.A (last access 12/2/2011).

76. William Shockley: http://en.wikipedia.org/wiki/William_Shockley.

77. Intel: http://en.wikipedia.org/wiki/Intel.

78. Fairchild Semiconductor: http://www.fairchildsemi.com/company/history/.

79. Hanks et al. [1993] derived empirically a taxonomy of growth stage architectures in a 1988 sample of 126 high-technology organizations (R&D intensity on average 3.1%) reflecting a situation in 1987/1986. The firms represent 14 industry groups, have mean sales of $5,530,783, and employ a mean of 125 employees. Industries represented in the sample include computer software, electronic and communications equipment, chemicals, pharmaceuticals, aerospace equipment, lasers and optics, and analytical and measuring devices. The study allowed to characterize states of the young firms in terms of age and organizational features. Other variables were defined as follows.

    Structural form, or basis of organization, was self reported by respondents based on brief descriptions and coded as follows: simple structure, 1; by function, 2; by divisions, 3; and other, 4.

    Centralization was measured by giving respondents a list of five decision issues. They were then asked to indicate the level of management that must approve the decision before legitimate actions may be taken.

    Formalization was operationalized using a scale of eleven items. The first ten items used a 7-point Likert-type scale, ranging from strongly agree to strongly disagree. The eleventh item measured the formalization of the decision-making process in the organization. Typical formalization include accounting and financing.

80. Targeted Selection: http://www.pacificu.edu/offices/hr/training/interview/pdfs/TargetedSelection.pdf (last access 2/19/2011).

81. NanoGate AG: Runge, W.: *Technology Entrepreneurship Curriculum – Course Material*. Handout Lectures 0-4, page 37. http://ce.ioc.KIT.edu/downloads/Chem_Entrepreneur_0_4.pdf; Handout Lectures 5-9. page 34. http://ce.ioc.KIT.edu/downloads/Chem_Entrepreneur_5_9.pdf; Handout Lectures 10-13, pp. 9, 14, 17. http://ce.ioc.KIT.edu/downloads/Chem_Entrepreneur_10_13.pdf.

82. Resource-Based View (RBV): http://en.wikipedia.org/wiki/Resource-based_view.

83. Financial Bootstrapping: http://en.wikipedia.org/wiki/Entrepreneurship.

84. Ashby Memory: “Thus, suppose I am in a friend’s house and, as a car goes past outside, his dog rushes to a corner of the room and cringes. To me the behaviour is causeless and inexplicable. Then my friend says, “He was run over by a car six months ago.” The behaviour is now accounted for by reference to an event of six months ago. If we say that the dog shows “memory” we refer to much the same fact – that his behaviour can be explained, not by reference to his state now but to what his state was six months ago. If one is not careful one says that the dog “has” memory, and then thinks of the dog as having something, as he might have a patch of black hair. One may then be tempted to start looking for the thing; and one may discover that this “thing” has some very curious properties. Clearly, “memory” is not an objective something that a system either does or does not possess; it is a concept that the observer invokes to fill in the gap caused when part of the system is unobservable.” [Ashby 1957:117]

85. Molecular Excited States: This is similar to issues of physical chemists or chemical physicists who study electronically excited states of molecules by ultraviolet (UV) absorption spectroscopy of circular dichroism (CD) spectroscopy in solution (wavelength: ca. 300 nm – 200 nm) or the gas phase (wavelength ca. 190 nm – 120 nm). The spectra are analyzed in terms of spectral bands and the band peaks corresponds to energies of particular molecular excited states. Overlapping bands sometimes show only up as shoulders of very strong bands or not at all; theoretical curve resolution (assuming bell-shaped Gaussian bands) may reveal more bands. Whereas UV spectroscopy exhibits only positive bands, for certain molecular configurations CD spectroscopy (using linearly polarized light) exhibits positive and negative bands and thus supports band resolutions or even may reveal very weak bands which cannot be observed with UV spectroscopy.
(cf. the author’s list of publication:
http://www.riscnet.de/Files/Publications_WR.htm).

86. Heyl GmbH & Co. KG: Capture radioactive cesium-through Radiogardase-Cs® capsules which are produced by the firm Heyl Chemisch-Pharmazeutische Fabrik GmbH & Co. KG (Berlin). The firm was founded in 1734 as a trading company and became a paint factory and chemical wholesale firm in 1765. Particularly, Heyl focused on Prussian (Berlin) Blue which was developed in Berlin in 1704 (http://www.heyl-berlin.de). Currently one business of Heyl operates in a niche that focuses on drugs and medicaments which remove radioactive elements and compounds from the body. It has approval in Germany, Japan and the US (FDA) [Runge 2006:398-401].

87. Nanogate AG: [Runge 2006:550]; Runge, W.: Technology Entrepreneurship – Course Material. Slide Numbers 3.7 (http://ce.ioc.KIT.edu/55.php), 7.8 (http://ce.ioc.KIT.edu/downloads/Chem_Entrepreneur_5_9.pdf), 10.18, 10.28, 10.33 (http://ce.ioc.KIT.edu/downloads/Chem_Entrepreneur_10_13.pdf).

88. Microsoft – Revenues and Numbers of Employees (last updated on October 4, 2011): http://www.thocp.net/companies/microsoft/microsoft_company.htm (last access 8/3/2010).

89. Cisco Systems – Revenues and Number of Employees:
http://www.icmrindia.org/casestudies/catalogue/Business%20Strategy2/Cisco-

Acquisition-Strategy.htm (last access 2/8/2011); http://www.referenceforbusiness.com/history2/83/Cisco-Systems-Inc.html (last access 1/3/0/2011); http://www.icmrindia.org/casestudies/catalogue/Business%20Strategy2/Cisco-Acquisition-Strategy.htm (last access 2/8/2011); http://newsroom.cisco.com/dlls/corpinfo/corporate_overview.html.

90. The German Renewable Energy Act: http://en.wikipedia.org/wiki/Renewable_energy_in_Germany; http://en.wikipedia.org/wiki/Feed-in_tariffs_in_Germany.

91. Chernobyl disaster: http://en.wikipedia.org/wiki/Chernobyl_disaster.

92. Silicon Cycle: BizEsp – Solar Power – The Market 2nd May 2007: http://www.bizesp.com/uploads/SolarPower2.05.07.pdf (last access 3/14/2011).

93. Solarbuzz Reports World Solar Photovoltaic Market Grew to 18.2 Gigawatts in 2010, Up 139% Y/Y. Mar. 15, 2011. http://www.solarbuzz.com/our-research/recent-findings/solarbuzz-reports-world-solar-photovoltaic-market-grew-182-gigawatts-20 (last access 4/5/2011).

94. Google: http://en.wikipedia.org/wiki/Google.

95. AdSense: http://en.wikipedia.org/wiki/AdSense.

96. Acquisition of Applied Semantics: Press release, Apr. 23, 2003. http://www.google.com/press/pressrel/applied.html (last access 1/29/2012).

97. Biorefinery funding: http://www1.eere.energy.gov/biomass/financial_opps_news.html?sol_id=254; https://www.fedconnect.net/FedConnect/?doc=DE-FOA-0000096&agency=DOE; Federal Biomass Policy - Federal Legislation - The Energy Independence and Security Act of 2007, http://www1.eere.energy.gov/biomass/federal_biomass.html (last access 3/25/2010).

98. The 1970s oil crises: http://en.wikipedia.org/wiki/1973_oil_crisis; http://en.wikipedia.org/wiki/1979_energy_crisis; http://en.wikipedia.org/wiki/Price_of_petroleum.

99. Methanol: http://en.wikipedia.org/wiki/Methanol_fuel; http://de.wikipedia.org/wiki/Holzvergasung, http://de.wikipedia.org/wiki/Methanol.

100. Crude oil formation: http://en.wikipedia.org/wiki/Crude_oil#Formation.

101. NELHA: Natural Energy Laboratory of Hawai'i Authority Annual Report 2008. http://www.nelha.org/pdf/ARnelhaFY2008.pdf (last access 1/2/2010).

102. HR BioPetroleum: Shell and HR BioPetroleum build facility to grow algae for biofuel. News, Nov. 12, 2007 http://www.hrbp.com/News/121107.html; HR BioPetroleum: HR BioPetroleum, Alexander & Baldwin, Hawaiian Electric and Maui Electric to Develop Algae Facility for Biodiesel on Maui. News, Jul. 15, 2008. http://www.hrbp.com/News/071508.html; HR BioPetroleum: Pilot Facility. http://www.hrbp.com/Facilities/Pilot.html; http://investing.businessweek.com/research/stocks/private/person.asp?personId=4172513 Edward T. Shonsey.

103. Solazyme, Inc.: http://en.wikipedia.org/wiki/Solazyme.

104. Hydrothermal carbonization (HTC): http://www.dw-world.de/dw/article/0,,2071791,00.html (last access 3/18/2010); http://en.wikipedia.org/wiki/Hydrothermal_carbonization; http://www.rsc.org/Publishing/Journals/dt/News/b804644cpersp.asp.

105. Prof. Steinberg Produktions- und Vertriebs GmbH & Co KG and Algomed in Klötze/Sachsen-Anhalt: http://www.algomed.de/; http://www.algomed.de/index.php?op=algenfarm; http://www.algomed.de/index.php?op=algenfarm_anlage http://www.algomed.de/?op=presse&id=9 etc. (last access 5/10/2012).

106. Prof. Dr. Karl-Hermann Steinberg: http://www.algomed.de/index.php?op=algenfarm_koepfe (last access 2/8/2008).

107. Range Fuels: http://www.rangefuels.com/range-fuels-technology.html (last access 1/12/2010).

108. An Altenews Interview with Mark Emalfarb, Founder and CEO of Dyadic (Symbol: DIL), and Dr. Glenn Nedwin, PhD, Dyadic's Chief Science Officer. http://www.altenews.com/Dyadic%20Interview.pdf (last access 2/2/2010).

109. ButylFuel, LLC: Home Page http://www.butanol.com/, http://butanolc.startlogic.com/page7.html and http://butanol.com/docs/Weizman-Terre_Haute.doc, http://butanol.com/docs/SciAm_7-27.doc.

110. Samuel Morse: http://en.wikipedia.org/wiki/Samuel_Morse.

111. Biofuel: http://en.wikipedia.org/wiki/Biofuel; http://en.wikipedia.org/wiki/Cellulosic_ethanol; http://en.wikipedia.org/wiki/Cellulosic_ethanol_commercialization.

112. Compounding: The goal of compounding is to modify the properties of a basic raw materials for particular applications. Compounding means preparing mixtures or blends of pure-grade raw materials, where additionally fillers, reinforcing agents (e.g. fibers) or other functional additives (e.g. stabilizers, plasticizers, flame retardants etc.) are added in small amounts. A solution of the individual components will not take place. Hence, by compounding at least two materials are joined together (in a molten state) to form a homogeneous mixture. The special challenge is to avoid a possible separation of the compound over time.

113. Nylons-Srikanth, P. (Ed.) (2011): *Handbook of Bioplastics and Biocomposites Engineering Applications*, p. 411. John Wiley and Scrivener Publishing.

114. William Henry Perkin, FRS (1838 – 1907) http://en.wikipedia.org/wiki/William_Henry_Perkin; http://www.answers.com/topic/william-perkin.

115. Faraday Effect: The rotation of the plane of polarization of either a plane-polarized light beam passed through a transparent isotropic medium or a plane-polarized microwave passing through a magnetic field along the lines of that field. Also called Faraday rotation.

116. Catalysis Research Lab (CaRLa): http://www.carla-hd.de/.

117. InnovationLab GmbH (iL): http://www.innovationlab.de/en/homepage/.

118. HP – Innovation Research Program: http://www.hpl.hp.com/open_innovation/irp/index.html.

119. Young diagrams: http://en.wikipedia.org/wiki/Young's_lattice.

120. PayPal Mafia: http://en.wikipedia.org/wiki/PayPal_Mafia.

121. Yelp: http://en.wikipedia.org/wiki/Yelp,_Inc.

122. Feasibility: http://en.wikipedia.org/wiki/Feasibility_study.

123. Sunk cost: http://en.wikipedia.org/wiki/Sunk_costs.

124. Contingency theory: http://en.wikipedia.org/wiki/Contingency_theory.

125. http://en.wikipedia.org/wiki/Price_of_petroleum.

126. http://en.wikipedia.org/wiki/Methanol_fuel; http://de.wikipedia.org/wiki/Holzvergasung, http://de.wikipedia.org/wiki/Methanol.

127. Elon Musk: http://en.wikipedia.org/wiki/Elon_Musk.

APPENDIX A

A.1 Entrepreneur, Company and Market Cases

A.1.1 The Biofuels Bubble and the Related Outburst of Entrepreneurship and Intrapreneurship

In the new century industrialized countries ran into a biofuels boom by demanding ambitious renewable-fuel targets set by policy and legislation (“mandates”). For instance, biofuels were to provide 5.75 percent of Europe’s transport power by 2010 and 10 percent by 2020. US Federal fuel standards increased the volume of renewable fuel required to be blended into gasoline from 9 billion gallons in 2008 to 36 billion gallons by 2022. (Box I.1).

In essence, the *biofuels market* has been created by policy and, together with other effects, became the origin of a *boom*. It is a *policy-driven market* (Table I.15). The following biofuel bubble effect is particularly striking for the US, though structurally similar events can be observed around the world including Germany.

Public policy has not only stimulated increased public funding of research and development but stimulated also huge private investment. Governmental grants, subsidies and loan guarantees as well as private investment were swamping universities and public research institutions. Government spurred also with grants the construction of new biofuel plants, and also with big per-gallon subsidies. Furthermore, dynamics was generated by hordes of startups and their quest for venture capital financing (Figure I.34). It was estimated that in the US blending mandates alone would provide over $33 billion in tax credits to the biofuels industry from 2009 through 2013 [Davis and Russell 2009].

Contrary to an investment in a software or Internet company, for a “*research-to-manufacturing*” startup one has to finance heavy in investments upfront in large scale plants and product introduction will take years. Thus for VCs the favorite business model is to get an industrial partner (corporate venturing) on board prior to the capital intensive investment stage and who eventually will take over the company years later.

The current description and discussion of entrepreneurship and intrapreneurship in biofuels will focus on the period 2000 – 2008/2009 and looks at significant developments after the Great Recession in 2007–2009. Concerning new technology ventures there are two fundamental orientations related to technology and type of NTBF:

1. The thermochemical and catalytic routes are preferentially followed by *engineering-type firms*, often with well experienced founders (“veterans”) and often further developing a century old technology;

2. The biotechnology and bioengineering route is preferentially followed by *research-based startups* (RBSUs).

A.1.1.1 The Origins and the Drivers

The starting situation around 2000 for an industry was focused on *first generation biofuels*. It was characterized by a core of some well established food firms, giant to small, engaged in sugar, corn or soybeans and "*corn ethanol*" and vegetable oils-based biodiesel taking advantage from the big *incentive-driven opportunities*. That let farmers shift to crops to meet growing demand for vegetable-based fuels (biodiesel) and sugar-based fuels (bioethanol – *corn ethanol*). And farmers who bought shares in nearby ethanol facilities became wealthy, thanks to corn prices increasing by 65 percent in just two years, and the skyrocketing value of existing ethanol plants.

The US Department of Energy (DOE) expected in 2004 that ethanol could eventually supply 30 percent or more of US transportation fuel needs [Ritter 2004]. For instance, in the US it took ten years from 1980 to 1990 to increase the volume of corn ethanol for fuel five-fold (1980: 175 – 1990: 900 mio. gallons) [RFA]. But from 2000 (1,630 mio.) to 2008, with billions of dollars flooding into new facilities, the absolute volume shot up to 9,000 mio. gallons based on an ever increasing number of new plants or capacity extensions of existing plants.

Also food and agricultural giants like Archer Daniels Midland (AMD) and Cargill in the US (both large suppliers of bioethanol and biodiesel) or Südzucker in Germany [Runge 2006:188] which is Europe's largest producer of sugar and sugar products jumped onto the band-wagon now called bioethanol. ADM, the largest US (and global) grain processor, then got 25 percent of its operating profit from biofuels, including both ethanol and biodiesel, and its shares were being increasingly seen as an energy, as well as an agriculture, play [Scully 2007].

In 2007 ethanol production accounted for about 20 percent of the US corn crop [Scully 2007]. Similarly, in Europe in 2002, 2003 and 2004 biodiesel production rose already by a 30-35 percent rate. But there was a 65 percent record growth in 2005 over 2004. And production of biodiesel in Europe jumped 54 percent in 2006 to 4.89 million tons (about 1.5 billion gallons), up from 3.184 million tons (about 961 million gallons) in 2005 [Green Car Congress 2007a]. Total EU27 biodiesel production for 2008 was over 7.7 million metric tons, an increase, but significantly reduced growth rate in relation to previous ones, of 35.7 percent from the 2007 figures [European Biodiesel Board 2009].

In that line chemical giants like the German BASF and DuPont or Monsanto in the US which for decades have produced agricultural chemicals for plant and crop protection (pesticides, insecticides etc.) or genetically modified seeds to achieve resistance against pests entered the scene. For instance, BASF formed joint ventures with Monsanto [Mandary 2007] and partnered with the Brazilian Sugarcane Technology

Center (CTC) [Sugarcaneblog 2009] to develop genetically modified corn, soybean or sugarcane to increase crop yields. And additionally in 2007 BASF started together with DBE Deutsche Bioenergie AG to build a biodiesel plant [UFOP 2007].

As *crude-oil prices continually rose*, the arguments for alternative fuel sources grew stronger. With global oil prices shooting up from $40-50 per barrel by September 2004 to achieve $77 in July 2006 and, finally to peak at $147 by July 2008, public and private investments was flooding into the development of biofuel technology and facilities to produce it – just to counteract the exploding energy cost and the dawning end of the petro-oil age. [125]

The *sky-high energy prices* induced some far-reaching effects centering on the deep belief, short- to medium-term, biofuels to become an economically competitive power alternative to petro-fuel [Scully 2007]. And, furthermore, there was corroboration by a related success story for bioethanol. In the mid-1970s the world had been hit by two oil price explosions, caused by production restraints in OPEC countries, and oil prices soared from a few cents per gallon to a couple of dollars per gallon. Through *initiation by a governmental program Brazil* strove to have so-called flex-fuel cars which run on ethanol.

In 2003 *flexible fuel vehicles* (FFVs) appeared on the market which have engine systems that are able to run with a mix of gasoline and ethanol. Currently all major automotive firms of the world manufacture these FFVs for use in Brazil. And a growing fleet of new-generation (flex-fuel) cars can run on straight ethanol. Ethanol accounts for more than 50 percent of the whole consumption of light car fuels in the country [Seraphim 2009].

In the late 1990s, Brazil dropped its alcohol subsidies and now made biofuel so competitive that (in 2005) it could trump gasoline at $25 a barrel [Theil 2005]. Brazil, which produces 7 billion gallons of ethanol per year, has 15 million ethanol-based or flex-fuel cars [Lane 2009c].

It is interesting to note that in the US a fuel blend called E85, which is 85 percent ethanol and 15 percent gasoline, is being made available in many states. For instance, in California, there were more than 300,000 flex-fuel vehicles in 2006 that were designed to use E85, but because the E85 distribution system has not developed as fast as the vehicle fleet, most are operating on gasoline [UC Davis 2006]. Globally, General Motors produced more than 5 million flex-fuel vehicles by 2009. In the US alone, there were more than 3.5 million GM flex-fuel cars and trucks on the road: For the 2010 model year, there were seventeen E85-capable flex-fuel vehicles from the Chevrolet, Cadillac, Buick and GMC brands [Coskata 2009.].

Since around 2004 *too much loose cash has found its way into biofuels* as a special area of the big *policy-driven* market of renewable energy (Figure I.34). Expectations grew dramatically. Many people in the venture capital industry were betting huge amounts of money on the sector. And they expected to make a 10-to-1 return [Das

2009]. “There are so many people that this almost feels like the oil land rush of the mid-1800s” in the US” [Langreth 2008].

Venture capitalists backing clean technology entrepreneurs sensed that opportunity, in particular, with regard to *second generation biofuels*. And entrepreneurship was additionally associated with a number of *“me too” firms’ foundation*. In 2006 in the US already 48 new ethanol plants and eight expansions of existing plants were under construction [Reisch 2006]. And there may have been the dream that someone is going to be the next Exxon of biofuels.

Basically, however, there is not enough suitable land for corn growing to make a significant dent in America’s voracious energy needs. Even if every bushel of US corn, wheat, rice and soybean were used to produce ethanol, it was estimated that it would only cover about 4 percent of US energy needs on a net basis [Wasik 2007]. Yet that did not stop ethanol investors or a wave of irrational exuberance from Wall Street to Brazil. Venture capital investment in biofuels increased from less than $1 million in 2004 to $20.5 million in 2005 [Startup Life 2007] and in 2007 venture capitalists poured $637 million into biofuels.

As part of the 2005 Energy Act, the US Department of Energy granted six cellulosic facilities special financing of up to $385 million to help build their first production facilities that, in aggregate, should reach 130 million gallons per year [Stack et al. 2007]. For 2008, VCs poured $680.2 million into US biofuels, including $437 million for cellulosic ethanol, $175.9 million in microalgae, $42 million in butanol and 25.3 million into systems and infrastructure providers [Oilgae Blog 2009].

The rapid capitalization and concentration of power within the biofuels industry was extreme. Behind the scenes giant oil, chemical, agricultural, auto corporations and large enzymes and genetic engineering companies were forming partnerships and joint ventures, and they were consolidating the research, production, processing and distribution chains of food and fuel systems under one industrial roof.

The names of giants then showing up in the game included Shell, BP, Chevron, and at last ExxonMobil, ADM, Cargill, BASF, Bayer, DuPont, Dow Chemical, Monsanto, Syngenta, VW, Daimler, Ford and General Motors and large enzyme companies like Danish Novozymes and Danisco (with its US subsidiary Genecor; Danisco A/S was recently acquired by DuPont) and the US firm Diversa [Runge 2006:872-873]. Biofuels was estimated to “be a $150 billion industry” [Langreth 2008]. But, “*the industry is still pretty much a government creation.*” [Carey 2009]

When farm products were increasingly being converted to biofuels, the offered biofuels do act like energy products. As corn and other crops become increasingly important raw materials for biofuels, the companies that make and process them were starting to act more like energy companies.

But, the most powerful players to enter the scene was "*Big Oil*," not just because of the issues of oil supply and prices, but the perceived danger to loose control of the multi-trillion-dollar transportation fuel industry (cars, trucks, trains, ships and airplanes) not just to food and agricultural industries, but also to electricity providers through the push to electrocars – also initiated by governments. Royal Dutch Shell, BP and chemical giant DuPont were leading the industry's heavy counterattack (Table I.83) – though experts said biofuels will not replace all petroleum-derived gasoline or diesel. Instead, biofuels will only extend fossil fuel supplies.

For instance, Royal Dutch Shell, Europe's second biggest energy group, formed a $12bn joint venture with Cosan, the big Brazilian sugarcane processor, that will bring together the operations of sugar, ethanol and the distribution and marketing of fuels in Brazil. The joint venture will be the world's largest bioenergy operation. Both partners will contribute retail stations and fuel retail stations and establish a network of ca. 4,500 retail sites. Shell's deal followed that of BP, its closest European rival, which saw BP providing half the $1bn investment in two ethanol plants being prepared by Tropical BioEnergia, a venture it entered with Grupo Maeda, a Brazilian agribusiness group, and Santelisa Vale, a Brazilian sugar and ethanol producer [Hoyes 2010].

There is *a bewildering array of technologies for biofuels* (Figure I.184), pushed by startups and NTBFs which are often spin-outs from universities and public research institutes and funded by governmental grants and subsidies as well as venture capital. After second generation biofuels (bioalcohols) the next biobased input for biofuels turned to algae ("*third generation biofuel,"* Figure I.34).

Following these developments the *"heavyweights" from oil* were hedging their bets taking fundamental ethical, technical and commercial disadvantages of first generation biofuels into account (Box I.1) and established differentiated strategies relying often on genetically modified objects (GMOs) and genetic engineering or chemical and process engineering to transform non food-related input into biofuels. As their innovation strategies c*orporate investors* have been drawn to invest in or acquire biofuels companies that fit neatly into their value chains or long-term strategies. But also giant automotive firms, such as VW, Daimler and General Motors, entered the scene in a corresponding move (Table I.83).

Already in 2005 [Theil] the question was: "*will biofuels be able to take hold without tax credits and subsidies, especially if oil prices head downward*? Then there is the politics of global trade." By mid of 2008 the biofuel bubble began to burst, at least with respect to agricultural first generation biofuels. Those who bet exclusively on bioethanol often suffered the same fate as those investors who took the plunge on the Internet dot.com companies around 2000. Awareness spread that the goals lawmakers set for the biodiesel and ethanol industry are in serious jeopardy.

However, misaligned political incentives are not sufficient to explain the bubble (and its burst). The *Great Recession* with its global credit crisis, a glut of capacity, lower oil prices by crushed fuel demand and delayed government rules changes on fuel mixes (blending mandates postponed) were threatening the viability of biodiesel and second-generation fuels derived from feedstocks other than food. Low oil prices had a numbing effect on consumers and their interest in this area.

“Ethanol, the largest biofuel sector, was also in financial trouble, although longstanding government support will likely protect it to a certain degree.” Plans were lagging for a new generation of factories that were supposed to produce ethanol from substances like wood chips and crop waste, overcoming the drawbacks of corn ethanol. But that nascent branch of the industry conceded it has virtually no chance of meeting political production mandates that kick in soon [Theil 2005].

Many biodiesel companies started operating in the red. Even ethanol producers, which have enjoyed government subsidies and growing federal requirements to blend it into gasoline, were operating at a loss over 2008. Numerous established producers in the US filed for Chapter 11 bankruptcy-court protection. By mid of 2009 two-thirds of US biodiesel production capacity were sitting unused.

GreenHunter Energy Inc., operator of the largest US biodiesel refinery, stopped production and in June 2009 said it may have to sell its Houston plant, only a year after politicians presided over its opening. GreenHunter’s business model hinged on selling to a government-guaranteed buyer [Carey 2009].

Until the mandate kicked in, GreenHunter and other biodiesel makers counted on exporting their output to Europe, a much bigger user of diesel. GreenHunter opened in June 2008 as oil prices skyrocketed. By then, soybean oil prices were soaring, too. Dozens of other new biodiesel plants, which make a diesel substitute from vegetable oils and animal fats, stopped operating because biodiesel production was no longer economical. The European Union dealt the final blow when it slapped a tariff on US biodiesel, killing what had been the industry’s main sales outlet [Davis and Russell 2009].

Furthermore, the shift in power to Big Oil was already showing effects in the traditional corn ethanol business in 2008, where low prices led to the idling of more than 20 percent of capacity. VeraSun Energy, one of the largest US ethanol companies, filed for Chapter 11 (bankruptcy) in October 2008 [Carey 2009].

The situation in 2009: “The ethanol industry is on its back despite the billions of dollars they have gotten in taxpayer assistance, and a guaranteed market.” There were overcapacities due to reduction in blending and/or production mandates. It was estimated that of the 150 ethanol companies and 180 plants in the US, 10 or more companies have shut down 24 plants during the last quarter of 2008. That idled about 2 billion gallons out of 12.5 billion gallons of annual production capacity. Furthermore, it was estimated that a dozen more companies were in distress [Krauss 2009].

And there was consolidation. As ethanol producers teeter on the brink of bankruptcy – slammed by high corn prices and low gasoline demand – larger refiners were looking for opportunities to buy their assets on the cheap. For instance, Valero Energy bought seven of VeraSun Industries' ethanol plants. VeraSun owned 16 biorefineries with the total capacity to produce 1.4 billion gallons of ethanol annually, or about 13.0 percent of the total US capacity [Ackerman 2009].

As a *typical response* to such difficulties of a policy-driven market interference by the corn ethanol industry association occurred and requested a change of the blending mandate in favor of corn ethanol, in the US from E10 to E15 [Wald 2009a].

In Germany, the Federal Environment Ministry announced plans to reduce the biofuels target by 2020, because of "changes in circumstance." The German blending target was 6.25 percent in 2009, and the government said that lifting the E10 mandate (blending 10 percent of biofuel into conventional gasoline) in the market meant that the 2009 quote would have to be lowered to 5 percent.

Already by mid of 2008 27 percent of German oilseed mills had shut down production entirely and 36 percent were running on less than 50 percent of capacity. In Germany, the biodiesel industry was additionally facing a new extinction threat as federal government carried forward with its plan to increase biodiesel taxes by 40 percent. The tax hike, from 15 Euro cents to 21 cents per liter, was part of a based increase of green fuel taxes until they are the same as conventional fuel taxes. A previous tax hike removed the price advantage of biodiesel over conventional diesel and resulted in a massive decline in biodiesel output. All this became finally effective in 2009. Increasing the blending proportion from 5 to 6.25 percent was postponed to 2011 [Biofuels Digest 2008]. Correspondingly, in the US in 2009 biodiesel plants started to be idled due to the expiration of the biodiesel tax credit.

One often hears "explanations" for the tough times for biofuel startups during the Great Recession, for instance:

> "We are closing doors. We are a victim of the economy," said a venture capitalist at Polaris Venture Partners, which invested in the algae firm GreenFuel [Kanellos 2009b], but the point is:
> we are going to be hearing "victim of the economy" every time one of these "hypesters" runs out of money. It is the convenient excuse [Rapier 2009b].

In the end biofuel carcasses were everywhere and it was an open question in how far governmental stimulus programs in CleanTech to ease the Great Recession will help survival of biofuel firms which came under scrutiny with regard to new studies on greenhouse gas emissions by second generation biofuels (Box I.1) [Carey 2009].

But irrespective of the mass of "biofuel firm deaths" there was an emerging algae biofuel boom with a lot of startups – as third generation biofuels based on algae obviously could be a response to lifting greenhouse gas emissions by second generation biofuels (A.1.1.4). Over the 2004-2010 period a large horde of biofuel startups exposed very many smart ideas. But “the winners likely will be Shell, BP, DuPont, and other majors” [Carey 2009] and ExxonMobile.

Finally and, in particular, with regard to “energy independence” of a country, one has to consider *biofuels in the context of the overall “energy mix,”* the various contributions of the different energy sources of a country. And for the US there is an indication that this will change, at least for the medium term markedly. There was an orientation in the US from oil-based fuels and coal towards natural gas [Gelsi 2009; LeVine and Ashton 2009].

In the US, but also Australia, massive natural-gas discoveries heralded a big shift in the energy landscape of the US – for power supply, heating, the petrochemical industry and also transportation fuel. After an era of declining production, the US is now swimming in natural gas. And 98 percent of the natural gas consumed in the US is produced in North America [Casselman 2009]. This will finally have effects on people’s attitudes and behavior and thus on the biofuels scene. Furthermore, the distribution (via ships, railroads or trucks) of natural gas as “*liquefied natural gas*” (LNG) will induce a changed economy [Runge 2006:124].

And there is another key factor which may have an influence on biofuels policy. After, in early 2010 the US government provided several drilling permissions for oil in the Gulf of Mexico, the “Deepwater Horizon catastrophe” occurred which put drilling on hold and thus affected “energy independence” efforts of the US. Offshore drilling has been put forward by the Obama administration as one prong of a multi-prong approach to ending the foreign oil dependence. The Transocean Deepwater Horizon oil rig related to oil giant BP as the operator exploded, sank and masses of oil were leaking from the well. It triggered the worst oil spill in US history and seriously damaged the economy and the environment of the Gulf States. According to Obama “BP is responsible for this leak. BP will be paying the bill.”

The Deepwater Horizon environmental catastrophe in the US was assumed to may exert an influence on societal attitudes and new political initiatives with regard to boosting renewable energy and, in particular, biofuels.

As a summary, the jumping-off situation for the biofuel bubble and the policy-driven market is described in Box I.1 and its structural layout is illustrated in Figure I.34. Its discussion requires a systems approach and, for entrepreneurship and intrapreneurship, an emphasis on the related value system and approaches to problem-solving of technical and commercial as well as cost issues. In the following we shall not discuss the issue whether sufficient land, for instance, in the US or Germany, is available to meet the quantitative requirements or mandates set by policy.

Companies, NTBFs and startups had to adapt themselves also to different legislation and the rest of realities of the sector, such as second and third generation biofuels, hybrids, prices of raw materials and petro-oil prices, margins and the increase in fuel demand in China and India.

Last but not least, companies will have to deal with governmental initiatives, incentives, subsidies and pressure which should guarantee energy security throughout diversification and local production. Finally, according to venture capitalist Vinod Khosla [2008a], "if a technology doesn't meet the '*Chindia test*' – meaning that it is cheaper than the current status quo in China and India – then it is not a viable, scalable, and cost-effective long-term alternative. Anything that will uproot the global reliance on oil or coal must be less expensive; else it will never gain traction in the global marketplace."

> Only the companies able to face those challenges will survive. The key factors to determine failure or success for these companies are – apart from concurrence and balance with food crops for biofuels, their ability to guarantee their raw materials, their collection, storage and distribution management as well as their cost efficient conversion to energy/power sources and the energy storage and their fit into existing or currently built energy distribution systems, and the approval of legislation in favor of biofuels to reduce CO2 emissions – in short, the value system of the transportation fuel segment and related technical and commercial hurdles (Figure I.171).

Interpreting the Chindia test as measure of price of products based on the same or a generic technology, also the policy-driven boom/bust developments of photovoltaic and solar cells markets, the Chindia effect and the Great Recession encountered extreme problems for once "shining" NTBFs in Germany and the US (ch. 4.3.5.2).

A.1.1.2 The Technologies and Products' Situation

Ultimate goals of the biofuels key players are either commercial large-scale production of biofuels and distribution into the transportation fuel market segments defined roughly by type of vehicle, usage for short- or long-distance transportation and the power source of the vehicles (Figure I.171) or to provide a platform for "*biorefineries*" [Runge 2006:849-873] targeting production of biobased fuel and additional biobased materials ("co-products", A.1.1.6). The essential classes of biofuel products comprise

- Biodiesel, where its production process may also provide glycerin (also named glycerol) and special biosolvents
- Bioethanol, first- and second-generation ethanol (also called corn and cellulosic ethanol), which can be used also for solvents or other basic chemicals
- Biobutanol, which can be used as a full replacement of (at least) petro-fuel for cars and simultaneously can be used for an important solvent or intermediate for the chemical industry and is currently produced by petrochemical processes

- Biogasoline, which is a mixture of hydrocarbon molecules like those produced at a petroleum refinery and can be used as gasoline, diesel fuel, and jet fuel in blending with or as a replacement of petro-fuel.

Some comparisons and differentiators of bioethanol, biobutanol and biogasoline are given in Table I.82. Here, in particular, for the butanol case it must be considered that (branched chain) isobutanol has even better energy efficiency as a transportation fuel than normal (straight chain) n-butanol.

Even though the commercial opportunity appears vast, the constraints within which biofuel producers must operate are extremely tight (Figure I.171). The biofuel industry is essentially characterized by *competition* related to

- *End-products* as well as *application* areas (where biobutanol additionally is overlaid by an n-butanol versus isobutanol or mixture of isomeric butanols competition),
- Corresponding *production technologies* and *raw materials input*, as expressed in the corn ethanol versus cellulosic ethanol positions and the types of biomass (various plant and waste-related biomass versus algae),
- Access to *financial and human resources*,
- The market segments, financial and political power of players and
- Corresponding political interferences in the policy-driven market through legislative, subsidizing and national protection measures which may affect the various types of products and the financial resources allocated to them differently.

For instance, in the US there is not only a quantitative setting for the overall biofuels market, but even a "supplier constraint" in terms of type of biofuels. The Energy Independence and Security Act of 2007 mandates the use of 36 billion gallons of biofuels by 2022. Some 15 billion of those gallons must come from corn-based ethanol. The rest falls under the category of "advanced biofuels." Within the latter category, 16 billion gallons of the mandate were reserved for fuels derived from cellulosic biomass, such as wood chips, straw and wheat. One billion gallons must be biomass-based diesel [Gillies 2008].

The emphasis on corn-ethanol and corn as an input reflects a *country-specific feature for directions of innovation and entrepreneurship by the country's "natural resources"* [Runge 2006:287]. Discussing entrepreneurship in biofuels in a global context one has to consider the relevance of national resources. This is for the US farmland, corn, soybean and cereals resources and the related economy of the US "Corn Belt" – and political implications – and forests' wood [Runge 2006:287]. Sugar as a natural resources has been discussed above for Brazil.

This means, national advantages in natural resources and traditional industries can be fused with related competencies in broad technological fields and thus provide the basis for technological advantages in new product fields and often new and strong and innovative companies. As a corollary, this situation often induces strong political effects of the particular industry through lobbying on the federal and state level.

With respect to *end-use of transportation biofuels* innovative and entrepreneurial activities are also to a large extent *country-specific*. For instance, considering cars in the US there is a preference for gasoline combustion engines and little use of Diesel engines and gas-powered engines. With regard to blending with bioethanol there is no broad use of FFVs, partly due to lacking infrastructure, whereas in Brazil FFVs dominate. Also for gas-powered engines infrastructure is lacking in the US. But in Europe and particularly Germany Diesel engines are broadly used and even gas-powered cars can rely on a relatively well distributed infrastructure.

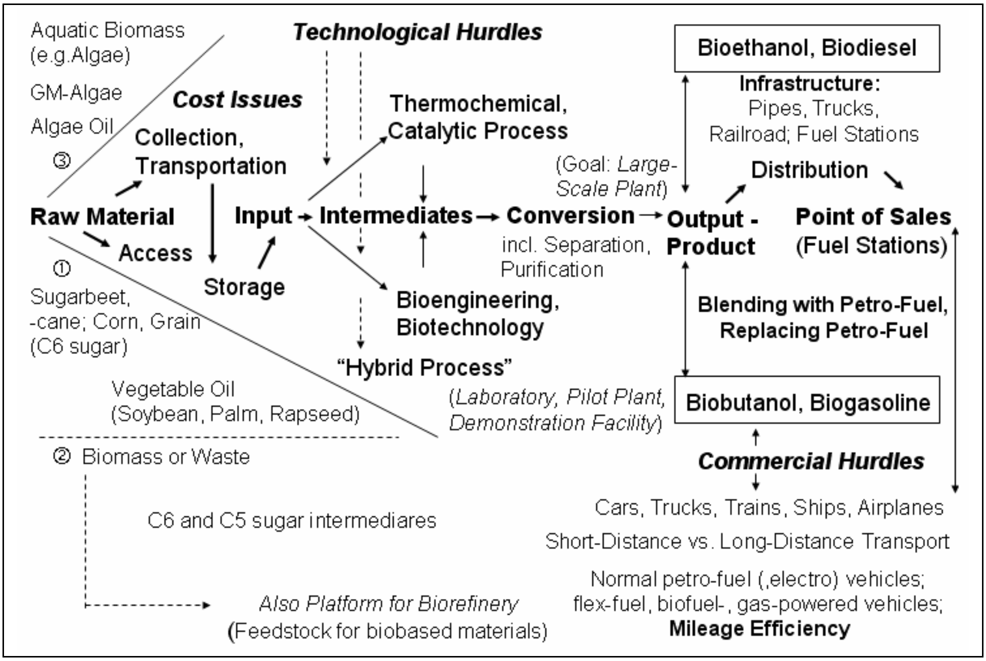


Figure I.171: The biofuels industry: The segments and technical and commercial hurdles for the race across the value system.

Concerning input (raw material and intermediates) in terms of the above discussions one might assume that the least expensive and most energy dense feedstock would be used to increase return on investment? No, it is not only the challenges to think about the logistics of the feedstock, but to consider the cost components and their mutual balances in the overall system. In tackling the competition with petro-fuel one must *carefully weigh all the costs before settling on a business model*.

Think of all your inputs including transportation, costs for equipment and operations, process design (for instance, recycling energy from other parts of the process), needs for license-in technologies, ultimate products and co-products etc. And, finally, know what the competition can offer in terms of price, quantity and quality. Furthermore, try to use the current fuel infrastructure. The problem is that British Petroleum and Exxon and Shell might not agree with the "newcomer." These have to ask themselves: Who owns the infrastructure, and can we cooperate with them, with or without a government role?

The input-to-output path in Figure I.171 can essentially be broken down into the steps from raw material to output of a firm's value chain (Figure I.7) and involves the scale-up process displayed in Figure I.8. Relating a particular raw material basis to be "harvested" (dry or wet) from a given area of land ("point of collection" of a particular region) to the economic effects of the produced biobased transportation fuel (Figure I.171) provides an expression (Equation I.20) which makes "Land Productivity of Biomass/Waste" proportional to the key performance measures of the agriculture/"farming," biofuels and automotive industries.

Equation I.20:

$$\underbrace{\begin{pmatrix}\text{Land Productivity}\\ \text{of Biomass/Waste}\\ \text{(miles/ac/yr)}\end{pmatrix}}_{} \propto \overset{\textbf{Input}}{\begin{pmatrix}\text{"Farm"}\\ \text{Yield}\\ \text{(BDT/ac/yr)}\end{pmatrix}} \times \overset{\textbf{Conversion}}{\begin{pmatrix}\text{Conversion}\\ \text{Yield}\\ \text{(gal/BDT)}\end{pmatrix}} \times \overset{\textbf{Output Performance}}{\begin{pmatrix}\text{Mileage}\\ \text{Efficiency}\\ \text{(miles/gal)}\end{pmatrix}}$$

BDT = Bone Dry Tons, ac = acres, yr = year

With regard to the overall goals of saving energy and reducing CO2 emission one has also to consider, where both, farm and conversion yields, contribute through these efficiencies to the overall energy and climate balances. The target would be to compete with cost of \$85-\$100 per barrel mineral oil without public subsidies. Hence, considerations of the following kind may be associated with intentions to start a biofuels firm.

> Our operating costs are lower than more traditional technologies, and as our technology is realizing higher yields and utilizing biomass more efficiently it can economically take biomass from a wider radius and capture economies of scale with larger production capacities. We can compete with \$85-\$100 mineral oil (unsubsidized cost between \$2 and \$3 per gallon). We can make that possible through use of 100-ton railroad cars of biomass instead of using trucks because we have a compression technology for biomass to make rail cost effective.

As production and distribution of first-generation biofuels can follow largely established input provision, production processes and other "beaten tracks" (no technical hurdles, "normal" commercial conditions, but acceptance and ethical issues discussed in Box I.1) the value system given in Figure I.171 will only focus on second- and third-generation biofuels with a number of hurdles to be overcome – and on the plenty of technical opportunities and myriad solutions to problems for entrepreneurship and intrapreneurship.

From a general economic point of view biofuels may just represent a major component for a "*biorefinery*" concept embedded in the concept of a "biobased economy" [Runge 2006:565-570, 578-585, 849-873]. In so far, any economic activities related to biofuels can view biofuels as a dedicated segment of transportation fuels or as a part of the broader concept of a biorefinery.

In line with the last "hierarchy" in the US within the biomass program there is a "*Recovery Act – Demonstration of Integrated Biorefinery Operations*" which provides funding opportunities also for biofuels. [97] A number of biofuels startups to be discussed below achieved financing via the biofuels mandate or DOE funded biorefineries (for instance, BlueFire Ethanol, Range Fuels, Mascoma, Verenium Biofuels Corporation).

As a conclusion, *biofuels are proving expensive in terms of upfront capital*. Disregarding end-product competition or substitutive potential, respectively, between types of biofuels among each other (Table I.82) and with respect to petrofuels, the economy of biofuels production for NTBFs and other involved firms is determined by local cost minima along the value system from "raw material" to "output" (Figure I.171, Equation I.20). The *final metrics* is "*capital cost per gallon (liter) capacity*."

Local minima depend on the following major parameters:

- Feedstock: Type of biomass or waste, respectively (plant- and waste-based versus aquatic biomass like algae), cost of feedstock when cost of input increases due to increased demand for biofuel production;
- Cost of planting, growing, harvesting/collecting the biomass where the location plays a role (national or international; for instance, BioMCN (Table I.87), GBL (Table I.95), BP/Verenium-Vercipia (Table I.84), Amyris (Table I.99);
- Transportation, storage and pre-treatment of the biomass (Bioliq, Figure I.173);
- The fundamental process cost – thermochemical, bioengineering, or biothermal "hybrid" process – with various cost reduction options, such as utilizing known overall processes (Fischer-Tropsch syngas, Figure I.174), utilizing lego-type existing technologies (BlueFire, ZeaChem – Table I.86,Table I.88.), genetically modified microbes or enzymes to increase yield/output or finding the "best" naturally occurring objects for fermentation, particular process step energy efficiency;
- Increasing process efficiencies by various means, such as energy efficiency by processing intermediates and co-products which can be fed back into the process, minimizing water use;

- Separation and purification of end-products which again means issues of energy efficiencies (Cobalt, Table I.96);
- Co-financing biofuels production by simultaneous co-manufacturing marketable products, the “biorefinery model.”

Moreover, continuous R&D is needed to improve conversion yields and also engineering has to follow a continuous improvement process to increase process efficiency.

According to Figure I.171 in the end biofuels for transportation addresses the issues of *blending petro-fuels with biofuels or replacing petro-gasoline*. Therefore, it is important to be aware of players and ownerships in the current petroleum value system. The oil industry supply chain (Figure I.172) comprises upstream crude oil exploration and production, and downstream refined products manufacturing.

Refining can be associated with oil firms. However, there are also independent oil refiners. These oil refiners can also serve as blenders, for instance, blending gasoline with additives like octane boosters or with biofuels – bioethanol or biodiesel.

This is followed by Wholesale product distribution from refineries (blenders) to primary distribution terminals and Retail delivery to final customers (end-users) with the automotive industry interfering technically and government politically with the refinery/blending stage. Figure I.172 depicts the sectors of the petroleum industry and shows that the oil industry is largely integrated across the whole value system.

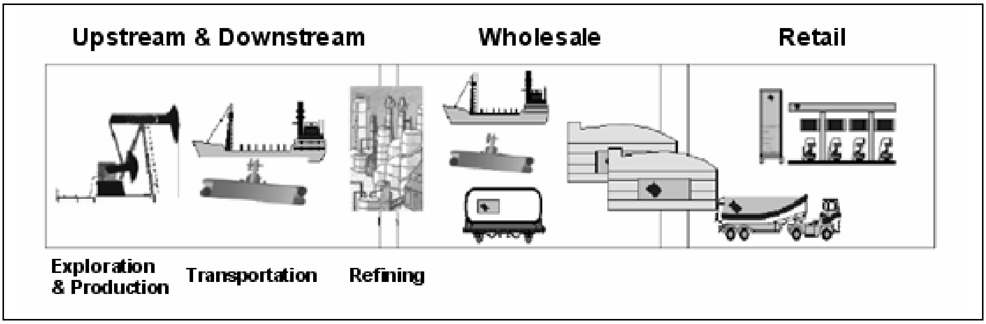


Figure I.172: The petroleum (oil industry) supply chain.

Generic Factors Triggering the Current Biofuels Orientation

The actual biofuel focus and related innovative and entrepreneurial activities occured as an additional peak of a progression cascading for more than one hundred years and triggered by parameters which are induced by comparable events or initiatives, respectively.

The current situation exhibits some sort of “déjà vu” when Germany strove for synthetic fuel during the 1920-1940 period [Runge 2006:271-272]. In comparison to previous ones the current step of the cascade is enforced essentially by four additional factors:

- Societal “green” attitudes in developed societies and climate change issues inducing political actions;
- The “decentralization megatrend” (in particular, for energy);
- The new biotechnological options of genetic modifications of microorganisms (and plants);
- Additional (specific) financing options for technology and entrepreneurship in the biofuels sector by the venture capital industry.

The current main political drivers for the biofuel industry in Europe and particularly the US are:

1. Fight climate change, use environmentally friendly, “renewable” energy, reduce the “carbon footprint,” which is the total amount of greenhouse gases produced to directly and indirectly support human activities, usually expressed in equivalent tons of carbon dioxide (CO2).
2. Dramatically reduce, or even end, dependency on foreign petro-oil; in the US the focus is to reduce dependency on imported petro-oil, Germany looks at changing its power mix in favor of “renewable energy sources” (RESs).
3. Spur the creation of a domestic bioindustry emphasizing concepts of a bio-based economy and biorefineries. A special origin of this direction is the widespread belief that petro-oil oil supply will cease “soon.”

The new biotechnology options for biofuels occurred in line with scientific/technical progress for the bio-agricultural field. On the other hand, the second and third drivers are interwoven. These drivers initiated corresponding technical innovations in Germany and the US which are still the basis for current biofuel developments. What has changed essentially is the variability of the raw material input.

For Germany, immediately before World War I and then until the WWII for aggression *self-sufficiency (“autarky”)* became a characteristics of *national security policy*. Areas of interest were formulated as interests to the national administration and the military, many of them being chemical areas for civilian and military purposes: hydrogenation of coal (*synthetic fuel*), more *efficiency* for use of German coal, fertilizers, artificial fibers, *synthetic rubber, fermentation technology* to release Germany from imports of alcohol etc. Striving for self-sufficiency peaked just before and during the two world wars.

Additionally, over the past 150 years, geologists and other scientists have regularly predicted that the world’s oil reserves would run dry within a few years. Particularly, in 1922 the US Geological Survey predicted that the US only has energy oil supply to last 20 years which spurred innovation and cooperation activities in and between German and US firms [Runge 2006: 424, 564-565].

Currently, there is again a public discussion when oil fields will dry up, that global oil production is about to peak (“peak oil”) and that there is an absolute end of cheap oil mainly by ever increasing demand from China and India. The bioindustry orientation occurred parallel with the 1920s "oil issue" in terms of the "Chemurgy Movement" in the US, which can be seen as a bottom-up entrepreneurial approach, and the German plant-based "Ersatzstoff"-approach which was largely driven by government [Runge 2006:565-566].

Generally, in Germany (and the US) the emphasis was on the involvement of huge companies with the financial power to master the challenge for synthetic fuel and rubber [Runge 2006:270-272]. Rubber brings in aspects of the current "biorefinery" concept. The German synthetic rubber "BUNA S" was produced in Germany and the US. But, in both countries governmental guarantees for price and sales quantities were needed. In the US additionally governmental financing of related plants were necessary to start large-scale industrial production on BUNA S.

In this context, industry and academia interactions and "technology transfer" in the US for developing the synthetic rubber between DuPont and the University of Notre Dame is notable. Notre Dame's most famous effort in *technology transfer* was Father Julius Nieuwland's groundbreaking work with polymerized-2-chloro-1,3-butadiene, which led to two patents and the development of Neoprene in 1931 by the DuPont chemical company. That particular bit of "intellectual property" was very good fortune for the Notre Dame University – some $2 million when the royalty payments ceased in 1948 [Streb 2002, Runge 2006:272, 692].

The 1973 first oil crisis started when the members of Organization of Arab Petroleum Exporting Countries or the OPEC (consisting of the Arab members of OPEC, plus Egypt, Syria and Tunisia) proclaimed an oil embargo "in response to the U.S. decision to re-supply the Israeli military" during the Yom Kippur War. It lasted until March 1974. For the most part, industrialized economies relied on crude oil, and OPEC was their predominant supplier. With the US actions seen as initiating the oil embargo, the long-term possibility of embargo-related high oil prices, disrupted supply and recession occurred. Correspondingly, in the industrial countries there was a strong movement to become independent from OPEC oil.

> Due to expensive oil the energy crisis led to greater interest in *renewable energy* and *spurred university and other publicly funded research in solar power and wind power*. It also led to greater pressure to exploit North American oil sources, and increased the West's dependence on coal and nuclear power. Notably, already at that time, the Brazilian government implemented a very large project called "Proálcool" (pro-alcohol) that ultimately led to blend gasoline with ethanol for automotive fuel (for FFVs). This project, which produces ethanol from sugar cane, continues and has reduced oil imports and decreased the price of fuel [Seraphim 2009].

The 1973 "oil price shock," along with the 1973–1974 stock market crash, has been regarded as the first event since the Great Depression to have a persistent economic effect. The second (1979) oil price crisis in the US occurred in the wake of the Iranian

Revolution. In 1980, following the Iraqi invasion of Iran, oil production in Iran nearly stopped, and Iraq's oil production was severely cut as well. However, after 1980, oil prices began a six-year decline that culminated with a 46 percent price drop in 1986. This was due to reduced demand and over-production, which caused OPEC to lose its unity.

> In 1979 US President Jimmy Carter outlined his plans to *reduce oil imports* and *improve energy efficiency* in his "Crisis of Confidence" speech. Acting as an example he had already installed solar power panels on the roof of the White House and a wood-burning stove in the living quarters. [98]

Correspondingly, again several governmental research programs, initiatives and pilot projects started worldwide with regard to "renewable energy," adding hydrogen and algae options (see below).

Around 2000 the idea of a "biobased economy" emerged with the "biorefinery" as a central concept [Runge 2006:849-873]. Not only biofuels, but many other CleanTech areas occurred in the spot, such as photovoltaic (PV; solar cells) and solarthermics (solar thermal energy), fuel cells and batteries, and wind turbines (ch. 4.3.5.2). And related innovative and entrepreneurial activities relied considerably on governments and further developments and refinements on several decades old or century old scientific insights and technologies.

A.1.1.3 Intrapreneurship and Entrepreneurship in Biofuels: The Biomass-to-Biofuels Boom

For biofuels for the transportation sector the economic realities for startups show up as an exertion of power and resources as well as the streamlined utilization of financial and infrastructural resources of incumbents. Apart from corporate-internal activities, the theme is *innovation of (mostly) giant companies by means of interrelating to NTBFs and other firms* (Table I.83; Figure I.41, Figure I.51) following rather common New Business Development (NBD) approaches given below [Runge 2006:722-730].

- Corporate sponsorship and funding of external basic and applied research in universities and public research organizations;
- Joint research and/or development alliances (JRAs, JDAs) with startups and NTBFs; special cooperation by which big firm will receive R&D samples from NTBFs for tests;
- Joint ventures with related firms or investing directly or indirectly in startups through "corporate venturing," preferentially in startups/NTBFs in a later stage of development (ch. 1.2.7.2); on the other hand, interrelated NTBFs have access to the resources of the firm's stakeholders, for instance, get help, advice and consulting for process and plant engineering and biofuel analytics (cf. Shell, BP);
- License-in from startups and NTBFs;

- "Cherry picking" (picking "winners") from the masses of early- and late-stage startups in the world fitting their current value chain and long-term strategy rather than doing own research and intrapreneurship;
- Utilizing the firms' capabilities to tap to their advantages into the various financial resources and other aids of policy to fuel inventions and technology developments.

Some of the giant firms had already technical/commercial footsteps in biofuels. For instance, Shell and BP had already large mix-in of ethanol and experiences in processing and plant engineering; Dupont synthesized successfully the alcohol 1,3-propanediol by fermentation.

From Table I.83 and further related text one may extract the following specifics concerning intrapreneurship of giant companies from the oil, chemical and automotive industries in biofuels.

- There is pronounced sponsoring/funding of universities and public research organizations by BP, DuPont and Chevron. BP, for instance, provided $500 million over ten years to establish a dedicated biosciences energy research laboratory attached to a major academic center in the US; the Energy Biosciences Institute (EBI) is led by Berkeley and with Lawrence Berkeley National Laboratory and the University of Illinois at Urbana-Champaign.

There are numerous alliances and cooperations of oil and chemical giant firms with investments in startups and "later-stage" NTBFs to tackle different technologies and/or developments targeting different steps of the value system (Figure I.171).

Shell was said to have over 70 research alliances in biofuels [Kanellos 2009a]. And also large firms that were around 20 years in corn ethanol like privately held US firm Poet LLC set up alliances to enter cellulosic ethanol. Poet had a network of 26 plants in seven US states producing ca. 1.25 billion gallons of ethanol annually (revenues of $4 billion in 2008).

- JVs and other forms of alliances show also up for oil/chemical giants with other large firms.
  For instance, there are the DuPont's connections with Genencor (a unit of Denmark's Danisco, now belonging to DuPont) and Poet LLC emphasizing cellulosic ethanol and also Shell's connections with the Canadian firm Iogen in cellulosic ethanol [Runge 2006:858; Gold 2009].
  Poet's research discovered an enzyme and designed a process that allows converting the starch from corn kernels into sugar and fermenting it without using heat. The process for cellulosic ethanol, which Poet commissioned to Danish industrial biotech giant Novozymes to develop, shall reduce energy consumption and increase its yield of ethanol in the fermented mix [Dolan 2008].

- By 2008 a new emphasis on algae emerged as a raw material for biofuels (biogasoline and biodiesel).
  In particular, its late entry into biofuels suggests that ExxonMobile bets on photosynthetic algae to be a viable, long-term candidate raw material for various types of biofuels. BP seemed to give it a try and also Shell and DuPont. And chemical giant Dow Chemical planned an algae biofuels pilot. The joint project with the firm Algenol (A.1.4, Figure I.179) should test a process to turn CO2 into ethanol [Voith 2009a].
- It seemed that Shell's "biogasoline" ("normal gasoline" and diesel) versus DuPont/BP's cellulosic ethanol and biobutanol (and biodiesel) emerges as the heavyweight fight for the future of the gas tank.
  Recently, French oil giant Total also joined the biobutanol option [Gold 2009a] through an investment in the startup Gevo, Inc. (Table I.99)
- Automotive companies "synchronized" their developments with developments in biofuels through investments in selected NTBFs.
  For instance, not only Shell had stakes in the German firm CHOREN Technologies, but also the German automotive giants VW and Daimler had ones [Runge 2006:254-255; Kempkens 2009]. Correspondingly, Mascoma (Table I.99) snagged $100 million in funding from General Motors (GM), Marathon Oil and other investors plus millions more in government grants, and aimed to produce cellulosic ethanol from wood chips using genetically engineered bacteria [Langreth 2008].

GM and Coskata (Table I.99) said their partnership will enable them to work together on ethanol research and development, as well as to build the infrastructure needed to commercialize the biofuel. GM said it will utilize the fuel from the demonstration facility, and will also provide some of its carbon-based waste, like old tires, as a feedstock for Coskata [Fehrenbacher 2008]. And Virent Energy's investor Honda was testing Virent's fuels in engines [LaMonica 2009].

The JV of Chevron with Weyerhaeuser (Catchlight Energy) was remarkable in that the JV would study "*not only the technology, but also the commercial implications of creating a viable business*. It should *devise a sustainable business model* "from the forest lands to the fuel." That involves harvesting timber, transporting it, breaking technological ground to process it into biofuel, and finding ways of transporting and distributing the fuel [González 2008].

The BP/DuPont partnership, Butamax Advanced Biofuels, should focus on developing a technology program to produce biobutanol from many different types of feedstock and was expected to license the technology to produce biobutanol to other biofuel producers. It would work closely with Kingston Research Ltd., another JV between BP and DuPont. Kingston Research would be constructing a biobutanol demonstration plant in the UK. [Lane 2009h; Lane 2009i]. Biobutanol can be blended with any fuel – gasoline, diesel or ethanol – or can be used as a bio-alternative to chemicals.

Butamax can be characterized (business model, strategy; status 2009) as follows [Anonymus 2008; Lane 2009h]:

- Develop and commercialize biobutanol targeting advanced *metabolic pathways for 1-butanol* as well as other *higher octane biobutanol isomers*;
  develop biocatalysts to produce 1-butanol as well as 2-butanol and isobutanol – the higher octane biobutanol isomers that are of increased interest and utility from a fuels perspective ("high octane biobutanol"),
  develop a genetically-modified microbe, or "ultimate bug," as the catalyst for new technology to significantly improve the conversion ratio in processing feedstock into biobutanol, boosting fuel yield and concentration [Chase 2006];
  have a strong intellectual property position in the butanol areas of greatest interest through patents covering the higher octane isomers as well as the previously announced 1-butanol patents;
- Not only *improve the bio-process to produce commercial volumes* of biobutanol, but also pursue an *integrated commercialization strategy* that incorporates building pilot and commercial scale facilities, a complete fuel evaluation, and a full environmental life cycle analysis,
  work with fuel blenders and distributors globally to introduce biobutanol into the fuels market;
- *License the technology* to produce biobutanol to other biofuel producers;
- Deliver by 2010 a *superior biobutanol manufacturing process* with economics equivalent to ethanol and commercially produce biobutanol in 2013 [Lane 2009h].

Three other (new) ventures, advanced in their routes towards commercial production and working on butanol-based solutions, are in the US, ButylFuel (below text), Cobalt Biofuels (Table I.96) and Gevo (Table I.99) and in the UK Green Biologics (Table I.95).

"*Cellulosic ethanol*," as opposed to sugar or starch-based (corn) ethanol, broadens the choice of feedstock without impacting food supplies. But bioethanol – whether from corn or new sources – runs into something called the "*blending wall*." Right now much of the gasoline in the US (and Germany) contains 10 percent ethanol (E10), which works fine in today's cars and trucks. However, automakers worry that higher levels will damage engine components. So they will void the warranties of most vehicles running on richer ethanol blends. But there is more (Table I.82), if performance of different biofuels is compared [Kiplinger Washington Editors 2007].

Table I.82: Comparing the biofuels bioethanol, biobutanol, biogasoline and their fit with existing infrastructure and vehicle compatibility.

Properties, Features	**Bioethanol (EtOH)**	**Biobutanol (BuOH)**	**Biogasoline**
Energy Efficiency; Mileage Efficiency	70 percent of the mileage of petro-gasoline ("hydro-carbons")	88 percent of the mileage of petro-gasoline; lower vapor pressure – less volatile (than EtOH), more comparable octane number with petro-gasoline, especially if also *isobutanol* is in place	Comparable with petro-gasoline, has ca. 50 percent more BTUs (British thermal units) per gallon than EtOH does
Water content	Attracts water, separating EtOH from water in the production is energy-intense	Does not attract water like EtOH, can be transported in existing pipelines and is less sensitive to colder temperatures.	Negligible
Other Features		Very important chemical solvent and intermediate	
Blending with Petro-Gasoline	Restricted blending with petro-gasoline: "Blending Wall" E10 (max. 10%)	Blending with petro-gasoline (in higher concentration than EtOH) or replacing (100%)	To any extent; replacing petro-gasoline
Transportation, Fuel Station Infrastructure	Need for separate ethanol infrastructure; damage (corrosion) by high water content (trucks, trains, barges and pipelines)	Can be transported in existing pipelines and is less sensitive to colder temperatures.	Compatible with existing petroleum-based infrastructure

Table I.82, continued.

Performance in Vehicles	Needed "flux fuel vehicles" (E85); damages "normal" combustion engines	No need to retrofit vehicles; shown that cars can run on pure biobutanol	Compatible with existing vehicle (combustion engine) operation

The data in this table reveal one central *issues of biofuels legislation*. It is bioethanol and biodiesel oriented. But what is more serious is the fact that usually governmental incentives and tax credits are done on a volume (per-gallon) basis. In essence, in the US ethanol is getting an unusually large credit, considering that it got ca. 20 percent less energy per gallon than biobutanol and more than 50 percent less than biogasoline. Although large volumes of cellulosic ethanol may be used in the coming decade and beyond, its long-term technical feasibility has been questioned because of its low energy density.

To put the level of development of biofuels into perspective with regard to have a full commercial large-scale plant (Figure I.171) consider Iogen Energy partnering with Royal Dutch Shell on a demonstration-scale cellulosic ethanol plant that sold its output in 2009 at a single station in Ottawa, Canada. Emphasizing the *demand* side, the plant produced about 40,000 liters a month (10,560 gallons). By way of comparison, Canada drank 30.2 million gallons of gasoline every day in 2008 and the US guzzled 377.6 million gallons daily. In 2008 in the US ca. 140 billion liters were consumed, in Germany 45 billion liters [Seidler 2009].

In 2009 some new firms already were building – or contemplating building – industrial scale facilities, for instance, CHOREN Industries in Germany (below text) or Verenium (Table I.84) in the US [Gold 2009a].

Scaling-up (Figure I.8) to produce biofuels on a commercial scale is the tricky part for related startups or NTBFs. That has been the hard part for all of the cellulosic ethanol startups. But it was the big oil companies that were perceived to may help these companies eventually reach commercial scale.

Key intrapreneurial and innovative activities of oil and chemical giants in biofuels during the period 2005-2009 are summarized in Table I.83.

One business model for startups for rapidly expanding to commercial-scale operations focuses on collaborations being formed between biofuel startups and "Big Energy" which are comparable to the partnerships formed between biotech startups and big pharmaceutical companies. For US Codexis the Shell deal reflects a desire to apply its biotechnology to markets beyond pharmaceuticals. Alan Shaw (then CEO of Codexis) said Codexis will soon be forming a new business to further its efforts in the bioindustrial field [McCoy 2006].

Shell's deal with microbe/enzyme producer Codexis strikes at the heart of the big challenges standing in the way of biofuel's coming of age: How to economically turn starches into sugars. Once cellulosic material like wheat stalks and corn stovers are broken down, they can be fermented just like corn and turned into ethanol. The problem so far has been finding a way to cheaply, quickly, and massively break down huge amounts of agricultural or municipal waste and having microorganisms that convert efficiently not only C6, but also C5 sugars into ethanol. Basically, converting biomass to biofuels requires breakthrough developments in three areas:

- chemical preparation of the cellulosic biomass (*pre-treatment*) and separation of the cellulose and hemicellulose parts from the lignin,
- conversion of pretreated cellulosic biomass to fermentable sugars (degrading the chemical bonds of the cellulose/hemicellulose) by combinations of enzymes (*saccharification*),
- and the development of novel microorganisms to ferment the sugars to ethanol or other fuels (*fermentation*).

Table I.83: Oil and chemical giants' key activities in biofuels 2005 – 2009.

Company (Remarks)	**Alliance [1] / JV**	**1st Generation Bioethanol**	**2nd Generation Bioethanol**	**Biobutanol**	**Biodiesel**	**Biogasoline**	**"Algae Biofuel"**
British Petrol (BP) for blending in 2005, BP purchased 590 mil. gallons of bioethanol (575 mil. gallons in the US) and 70 mil. gallons of biodiesel 2) BP emphasizes producing cellulosic ethanol through its partnership with Verenium in the US and on sugarcane and ethanol in Brazil, and on biobutanol [McDermott 2009]	a) "*Butamax Advanced Biofuels*" (see below): JV with DuPont b) *Verenium* (formerly Diversa) c} *Verenium* BP has invested additionally $22.5 mil. in Verenium and formed a JV called Vercipia – now BP Biofuels Highlands [Lane 2009a] d) *Universities* BP to spend $500 mil. over the next ten years to establish a dedicated biosciences energy research labora-	a) Retrofitting an ethanol plant to produce biobutanol	c) BP's $112.5 mil. total investment in Verenium is the largest by an oil major in an advanced biofuels company; funding is the basis for a commercial scale cellulosic ethanol plant, will pursue to globally license technology of Verenium as well as developing the commercial scale plant, a team comprised of employees from both BP and Verenium, the 1.4 mil. gallon-per-year (MGY)	a) With DuPont (see also DuPont) first phase of the DuPont-BP venture will consist of using existing technology to convert sugar beets into 30,000 tons, or 9 mil. gallons, of biobutanol annually at British Sugar's facility, second phase of the venture involves developing a genetically-modified microbe, or "ultimate bug," as the catalyst for new technology to significantly improve the con-	e) D1-BP Fuel Crops Limited, to accelerate the planting of Jatropha curcas – a drought resistant, inedible oilseed bearing tree which does not compete with food crops for good agricultural land or adversely impact the rainforest – in order to make more sustainable biodiesel feedstock available on a larger scale, both firms intend to invest around $160 mil. over the next five years [BP 2007]		f) Martek, specializes in engineering fuel and other products from algae, fungi and other microbes [Associated Press 2009a]

	tory attached to a major academic center [BP 2006]; BP funding for the Energy Biosciences Institute (EBI) is led by Berkeley and with Lawrence Berkeley National Laboratory and the University of Illinois at Urbana-Champaign [Birgeneau 2007]; $35 mil. from BP biofuels research center at UC Berkeley (as annual budget) [Langreth 2008] e) *JV with D1 Oils* to develop Jatropha biodiesel feedstock f) *BP and*		cellulosic ethanol plant in Jennings, LA is the first true demonstration-scale plant in US capable of producing ethanol from non-food cellulosic biomass sources, [Lane 2009a] BP to commence cellulosic ethanol production in Brazil by 2013 [Lane 2009c]	version ratio in processing feedtocks into biobutanol, boosting fuel yield and concentration; UK provides fuel station infrastructure and test field, "By getting it out in the pump, letting consumers buy it ... I think that will help government get behind it" [Chase 2006]	D1 Oils will buy out BP a mere £500,000 (ca. $823,000), even though the joint venture was valued at more than £7 mil. ($11.5 mil.) over its two-year lifetime. [McDermott 2009] f) Martek "we believe *sugar-to-diesel* technology has the potential to deliver economic, sustainable and scaleable biodiesel supplies," fuel will be created from biomass; microbes will convert the biomass into lipids, which will then be turned into		

	Martek Biosciences form algae biodiesel partnership, BP will contribute up to $10 mill. [Associated Press 2009a]				fuel		

1. Company, University or Public Research Institute/Center.
2. http://www.bp.com/genericarticle.do?categoryId=2012968&contentId=7018719 (last access 11/10/2009).
3. http://www.shell.com/home/content/aboutshell/our_business/previous_business_structure/oil_products/fuels/biofuels/biofuels.html (last access 11/22/2009).
4. http://www.virent.com/MeetVirent/our_story.html, http://www.virent.com/News/press/03-26-08_Shell_Virent_Biogasoline_Collaboration.pdf.

Table I.83: continued.

Company (Remarks)	**Alliance [1] / JV**	**1st Generation Bioethanol**	**2nd Generation Bioethanol**	**Biobutanol**	**Biodiesel**	**Biogasoline**	**"Algae Biofuel"**
DuPont with sugar producer Tate & Lyle already produced the di-alcohol propanediol (PDO) for polymers by fermentation [Runge 2006:583]	a) BP and British Sugar; the two companies have applied for more than 60 patents in the areas of biology, fermentation processing, chemistry and end uses for biobutanol, those patents cover the higher octane isomers as well as the previously announced 1-butanol. According to Anonymous, this places the BP/DuPont partnership in a strong intellectual property position [Ebert 2008; Anonymus	c) Converts an existing Broin ethanol plant into a biorefinery (cost of $220 mil.), upgraded facility would operate on both corn and stover instead of on corn alone [Reisch 2006]	a) Together with BP and British Sugar built $400 mil. bioethanol plant [Van Noorden 2008]; b) switchgrass feedstock supplied by Genera Energy and corn cobs supplied by Sun Grant, $140 M funding from parents. 90 scientists from DuPont and Danisco dedicated to project. State of Tennessee has granted $40 mil. towards the demonstration plant [Lane 2009b]	a) Converts the UK's first ethanol fermentation plant to produce biobutanol [Chase 2006], a) by using traditional methods, such as the ABE fermentation process to create biobutanol [ISEE] e) DuPont and BP have developed catalysts to produce 1-butanol (a four-carbon chain with the alcohol group at one end), 2-butanol (a four-carbon chain with the alcohol group bonded to a			d) Produces biobutanol from seaweed (macro-algae, a potentially sustainable and scalable new source of biomass) [Morrissey 2009]

	2008]; b) partnership (JV) with enzyme company Genencor (a unit of Denmark's Danisco, recently acquired by DuPont) [Dolan 2008]; c) with corn ethanol producer POET [Reisch 2006]; d) gets $9.0 mil. for a partnership with the biofuel startup Bio Architecture Lab from the US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E). [Morrissey 2009]			carbon atom in the middle of the chain), and isobutanol (a branched chain with the alcohol group on one end). Isobutanol and 2-butanol have higher octane ratings, making them better fuels, the companies found that gasoline blends containing 16% high-octane butanols deliver fuel performance similar to blends with 10% ethanol (E10) [EERE 2008]			

Table I.83: continued.

Company (Remarks)	**Alliance [1] / JV**	**1st Generation Bioethanol**	**2nd Generation Bioethanol**	**Biobutanol**	**Biodiesel**	**Biogasoline**	**"Algae Biofuel"**
Royal Dutch Shell Shell Biofuels: Shell currently buys, trades, stores, blends and distributes (essentially Brazilian sugar cane) bioethanol. It is the world's largest distributor – more than 6 bil. liters in 2008 – and continues to build its capability 3) It is said that Shell has five (corn) "ethanol hubs" in the US, providing the distribution infrastructure for 30% of US ethanol [BioFuelWatch 2009]	a) With Canadian company Iogen Corp it has a stake in [Runge 2006:858] b) with the German firm CHOREN Industries it had a stake in [Porretto 2009; Runge 2006:254-255], gave up its minority stake in Nov. 2009; wanted to continue to support CHOREN c) with Codexis it has a stake in, development agreement renewed in 2009 [McCoy 2006; Johnson		a) Produces cellulosic ethanol from wheat straw c) speeds up development of super enzymes that can chew through starchy plants and break them down more quickly, cellulosic material like wheat stalks and corn stovers [Johnson 2009]		b) Develops and produces biodiesel from wood residue ("BtL process") [Runge 2006:254-255]; plans a 200,000 tons per year biodiesel plant costing €800 mio. [Kempkens 2009]; d) will construct with HR BioPetroleum an algae-oil production facility to produce feedstocks for biodiesel ("second-generation biodiesel") [Lane 2007]	e) A thermochemical catalytic process ("Bio-Forming") to convert sugars into hydrocarbons, the chemicals found in petroleum; claimed: sugars are converted directly into gasoline and gasoline blending through a catalytic process, new "biogasoline" molecules have higher energy content than ethanol (or butanol) and deliver better fuel efficiency, Virent's unique cata-	d) To build a pilot facility for growing marine algae and producing algal oils that can, in turn, be used to make biofuels; Cellana, completed construction on the Kona coast of the big island of Hawaii, and the demonstration facility is now operating [Bigelow 2009]; expands the 2.5-hectare (269,000 square foot) pilot project (2007) to a 1,000-hectare facility after two years and later to a full-

Said earlier in 2009 it would scale back large investments in wind and solar in favor of next-generation biofuels [Porretto 2009]; continues to be close to familiar businesses	2009] d) JV (named Cellana) with HR BioPetroleum [Lane 2007] e) with Virent Energy Systems joint research and development effort [EERE 2008; Carey 2009] 4}					lytic process uses a variety of biomass-derived feedstocks to generate biogasoline at competitive costs, sugars can be sourced from non-food sources like corn stover, switch grass, wheat straw and sugarcane pulp, in addition to conventional biofuel feedstock like wheat, corn and sugarcane 4)	scale commercial 20,000-hectare plant, grows only non-modified, marine microalgae species in open-air ponds using proprietary technology. Algae strains used will be indigenous to Hawaii; once the algae are harvested, the vegetable oil will be extracted; expectation: 60 tons of oil per hectare

Table I.83: continued.

Company (Remarks)	**Alliance [1] / JV**	**1st Generation Bioethanol**	**2nd Generation Bioethanol**	**Biobutanol**	**Biodiesel**	**Biogasoline**	**"Algae Biofuel"**
ExxonMobile photosynthetic algae appears to be a viable, long-term candidate for biofuels [Porretto 2009]	*Synthetic Genomics Inc. (SGI);* has so far done early work on algae strains; with $300 mil. designated for research and development at Synthetic Genomics; planned to build a greenhouse and biofuels test facility in San Diego to test different strains of genetically engineered algae and methods of commercial biofuels production [Bigelow 2009a]					Algae-based gasoline/biodiesel [Porretto 2009]	2009: $600 mio. to develop algae-derived biofuels; "commercializing algae-based biofuels will cost billions of dollars more" [McCoy 2009] SGI has plans to build a greenhouse and biofuels test facility to test different strains of genetically engineered algae and methods of commercial biofuels production

Table I.83: continued.

Chevron, has a special emphasis on research and development alliances, studies ways of producing and converting specially grown non-food crops into ethanol and other biofuels, will address the vast range of variables – from genetics to thermo-chemical reactions to economics	a) Biofuels development agreement with the National Renewable Energy Laboratory (NREL) [McCoy 2006] b) agreement with Texas A&M University (four-year period), formed research arrangements with Georgia Tech; the University of California, Davis; and the Colorado Center for Biorefining & Biofuels, which is a consortium of the Energy Department's National Renewable Energy Laboratory, three major Colorado		a) Converts biomass such as forestry and agricultural waste into ethanol and renewable fuel [Reisch 2006] c) converting cellulose and lignin – the compounds plants are made of – into biofuels; the venture will study "not only the technology, but also the commercial implications of creating a viable business there," devises a sustainable business model "from the forest lands to the fuel," Weyerhaeuser is one of the largest producers of pulp		b) Chevron says its large-scale biodiesel plant in Galveston, Texas, is fully operational, has a 22% equity position in the plant [Hess 2007] said it will be able to prove it can make diesel from designer microbes and sugar economically by 2011 [Kanellos 2009]	f) Getting biodiesel from algae	a) Working with NREL on a five-year project to research transportation fuels from algae f) getting biodiesel from algae

	universities, and other private companies [Hess 2007; UC Davis 2006]; c) JV (Catchlight Energy) with timber behemoth Weyerhaeuser [González 2008] d) with Mascoma a feedstock processing and lignin supply agreement [Mascoma Corp. 2009] e) investment in LS9 f) biodiesel feedstock development and testing agreement with Solazyme		and timber in the world. [González 2008]; d) Chevron will supply feedstock that Mascoma will convert to cellulosic ethanol, a by-product of that conversion is energy-rich lignin, which Mascoma will then provide Chevron to evaluate whether it can be turned into transportation fuel.				

The investment of BP in Verenium (Table I.84; itself created from Celulol and Diversa; Table I.99) and finally in their JV, Vercipia Biofuels, emerged as an exemplary bio-engineering-oriented route of a biofuel innovation path of a large (giant) company (Table I.83, Table I.84): Starting with corporate venturing and ending with acquiring the whole ligno-cellulosic biofuels *business* of Verenium which is now run under the name BP Biofuels Highlands. Main features and innovative characteristics of Verenium are given in Table I.84, additional details for Verenium are found with Lane [2009g].

Table I.84: Verenium targeted by BP focusing on its biofuels business. *)

Company (Foundation) Remarks	**Major Funding**	**CEO, Other Executives, Key Researchers; Technology Protection**
Verenium Corporation, Cambridge, MA Formed in 2007 by a merger of Diversa and Celulol (Table I.99). Headquartered in Cambridge, MA, has research and operations facilities in San Diego, CA; Jennings, LA (Verenium Biofuels, LLC) and Gainesville, FL. Organizational Units: Biofuels Business, Specialty Enzyme Business, R&D (complementary components of biofuels). Markets Served: Biofuels, Industrial Processes, Health & Nutrition Annual Revenues and Losses	As of March 31, 2007 had cash, cash-equivalents and short-term investments on hand of ca. $125.5M; together with approximately $20M [Childs 2007]. In 2008, the Jennings Facility was selected for an award under a $240M federal program, operated by the US Department of Energy, to support the development of up to nine small-scale biorefineries in the US. BP's $112.5 million total investment is one of the largest by an oil major in an advanced biofuels company, BP has invested an additional $22.5M in Verenium and formed a joint venture Vercipia [Lane 2009a]. BP put up $90M to	Carlos A. Riva President and CEO; Riva joined Celunol as CEO in 2006, prior to joining Celunol, from 2003 to 2005; Riva served as Executive Director of Amec PLC, a major global construction and engineering company based in UK; from 1995 to 2003; Riva served as CEO of InterGen, a joint venture between Shell and Bechtel that developed more than 18,000 megawatts of electric generating capacity; William H. Baum Executive VP Business Development since 2007 after the merger of Diversa Corporation and Celunol Corporation; joined Diversa in 1997 as VP Sales and Marketing, then Senior VP Business Development and to Executive VP Chemical, Agriculture, and Industrial Enzymes Business; Gregory Powers Executive VP, Research and Development with Verenium since 2008; before joining Verenium, Dr. Powers was VP of Global Engineering at United Technologies Corporation's Carrier Division, (responsible for all engineering activity and strategy development supporting core innovation for the company), held various positions with the General Electric Company; Janet Roemer Executive VP Specialty Enzymes Business Unit; prior to joining Verenium, Ms. Roemer held several positions with BP Group, e.g. chief executive of a $1.7 billion North American chemical business; Has a substantial intellectual property position,

($, mio.): 2008: 57, (26) 2009: 49, (15) 2010: 52, (14) 2011: 61, (6.5) (FORM 10-K (Annual Report of 03/05/2012) For Vercipia: Net losses: $10,353,177 (2009), $6,251,816 (2008) [Vercipia 2010]	develop "low-cost, environmentally sound cellulosic ethanol production facilities in the US." Through a second deal, BP agreed to provide additionally $45 mil. and to form a JV with Verenium for construction of a cellulosic ethanol production plant near Tampa, FL., estimated to cost close to $400M; the JV has sought federal loan guarantees to cover 80 percent of that pricetag [Bigelow 2009a]	including more than 250 issued patents and more than 350 patent applications, as of March 2009 [Lane 2009g], in September 2010, Verenium completed a *sale of its ligno-cellulosic biofuels business to BP*, refocusing the company on its historical strength in enzyme development (FORM 10-K Annual Report of 03/05/2012).
Technology, Goals Business Model: Rely on alliances/JV; Has a strong IP position (patents), and holds exclusive rights to commercialize University of Florida technology for cellulosic ethanol production License-out and technology transfer Biomass from nearby sources Announced plans to build first commercial cellulosic ethanol plant in Highlands County, Florida, with a target	Emphasis on cellulosic ethanol; Verenium is a vertically-integrated firm in the biofuels industry through the combination of assets, technologies and personnel. Verenium claims to be the only company to offer fully integrated, end-to-end capabilities in pre-treatment, novel enzyme development, fermentation, engineering and project development [Childs 2007], "full range of 'field-to-pump' capabilities," has combination of enzyme discovery and enzyme evolution platforms. Enables conversion of nearly all of the sugars found in cellulosic biomass, including both five-carbon and six-carbon sugars, Uses a combination of microorganisms and specialty enzymes to convert up to 95% of available sugars in biomass feedstocks into fuel ethanol. The Jennings 1.4 million gallons-per-year (MGY) demonstration plant will draw on locally grown sugarcane bagasse and specially bred energy cane; in 2009 optimizing its 1.4 million-gallon-per-year demonstration-scale facility. Verenium has established the Jennings site as a permanent cellulosic ethanol "Center of Excellence," where future plant operators will be trained for roles in other commercial sites; the Jennings technology was transferred to BP's plants in Brazil after operations commenced at the US facility [Lane 2009c].	

capacity of up to 36 mil. gallons per year (MGY)	In addition, the Company's process technology has been licensed by Tokyo-based Marubeni Corp. and Tsukishima Kikai Co., Ltd. and has been incorporated into BioEthanol Japan's 1.4 million liter-per-year cellulosic ethanol plant in Osaka, Japan; Verenium and Marubeni are continuing to advance the commercialization of cellulosic ethanol projects utilizing Verenium's proprietary technology in Asia with the opening of a three million-liter-per-year plant in Saraburi, Thailand Verenium's goal: from a cost standpoint to be producing ethanol that is competitive with (today's) grain ethanol (~$2/gal) [Lane 2009g]. *Business Model Biofuels* [Lane 2009g]: Develop integrated solutions for the emerging cellulosic ethanol industry for use in production facilities that the firm owns and operates, individually or jointly with partners, as well as those of third-party licensees; develop novel, high-performance enzymes and to advance technology and process development capabilities, together with BP, at the pilot and demonstration-scale plants in Jennings, Louisiana, and the first planned commercial facility in Highlands County, Florida (36 MGY facility is expected to begin commercial production in 2012); exploit opportunities in the developing market for the production of cellulosic ethanol; incorporate scientific and engineering skills into the production facilities; achieve increased product sales and profit margins to support the future growth and profitability of the firm's portfolio of products sold directly by Verenium and by partners. The BP/Verenium JV Vercipia Biofuels JV planned the first commercial-scale cellulosic ethanol facility in Highlands County, Florida and expected to break ground on that site in 2010. The estimated construction cost for this 36 million gallon-per-year facility is between $250 and $300 million. Production from this plant was expected to begin in 2012 [BP 2009]. Another cost estimate: the project will cost close to $400 million, and the joint venture has sought federal loan guarantees to cover 80 percent of that pricetag [Bigelow 2009a; BP 2009]. Verenium will pursue distribution, research, marketing or production partnerships or alliances

*) From the firm's Web site if not stated otherwise by a reference;
firm's status: early 2010.

Shell's approach to biogasoline and biodiesel for transportation is essentially reflected by the interconnections with the German CHOREN Industries and Virent Energy Systems (Table I.85) and with HR BioPetroleum (Table I.89) focusing on biogasoline (including biodiesel).

Table I.85: Virent Energy Systems as a target of Shell regarding biogasoline and hydrogen. *)

Company (Foundation) Remarks	**Major Funding**	**CEO, Other Executives, Key Researchers; Technology Protection**
Virent Energy Systems, Inc. Madison, WI (2002) Founded by Dr. Randy Cortright and Prof. James Dumesic to commercialize the Aqueous Phase Reforming (APR) process, a technology the two invented and patented while at the University of Wisconsin-Madison. Started as Virent Energy Systems LLC. Employees: 2003: 5 2004: 12 2007: 54 2008: 68 2009: 75. Revenues: 2007: $4M (top line) 2008: $11M [Gillies 2009]. Having received prestigious government and industry recognition, Virent will seek to manufacture, and not just license technology,	2003: wins a competitive Advanced Technology Program (ATP) grant. 2004: grants awarded by the US Department of Energy to further advance Virent's hydrogen research; $2.2M in Federal funding, $550k in State funding, and raised $300k of private equity seed money. 2006: $2M grant from the US Department of Agriculture and Department of Energy for development of converting glycerol (co-product of biodiesel production) into renewable propylene glycol. 2007: $11M in federal funding including a second Advanced Technology Program grant from the National Institute of Standards and Technology. 2007: raised over $30M in equity financing. By 2009: raised about $70M, some	Lee Edwards President & CEO; Edwards brings 25 years of global energy leadership and petroleum industry experience to Virent; was President and CEO of BP Solar, a global solar technology provider; Edwards held a range of executive positions; Eric Apfelbach President and CEO; was replaced in 2008 by a person "likely to have experience in energy markets" (Edwards). Dr. Randy Cortright Founder & Chief Technical Officer; is experienced in the field of catalytic processing of biomass-derived feedstock into chemicals and fuels, is the co-inventor of Aqueous Phase Reforming (APR), the innovative pathway to biofuels and bioproducts used by the BioForming® technology platform. His background includes research and development, process design, start-up, and operations of large scale industrial catalytic processes at UOP LLC, a provider of petroleum and petrochemical process technologies. After leaving UOP, Dr. Cortright earned his PhD in Chemical Engineering, from the University of Wisconsin. In academia, he specialized in catalytic systems for the clean manufacturing of fuels and petrochemicals. He holds seven issued patents. 2008: Virent owns or holds the exclusive rights to 17 pending or issued patents in the US and 41 pending or issued patents in other countries; 6 issued US patents, 2 US patent applications, and 25 foreign patent and patent applications are the subject of exclusive and irrevocable licenses from the Wisconsin Alumni Research Foundation (WARF). Virent is the only source for liquid conversion of sugar-based feedstock into hydrogen and

boils down to "continuous improvement." In March 2010 Virent and Shell started up a demonstration plant at its facilities in Madison, Wisconsin, as part of the development deal that Virent and Shell started in 2008.	\$40M from corporate investors and government grants and \$30M in venture capital arms of Honda, Cargill and other companies; expected to raise \$25 million to \$40 million [Gardner 2009, LaMonica 2009]	alkanes. Hydrogen is also a key interest of Shell.
Technology, Goals Technology demarcation point in terms of cost competitiveness: crude oil will remain above the \$60 per barrel mark. *Business Model:* Biorefinery orientation for own production; technology licensing; retrofitting existing ethanol plants to Virent's process. Partnering with major energy (Shell) and agricultural (Cargill – supply chain) companies; is building a 10,000 gallon per year plant, to build a 100 million gallon per year plant by 2015 [Gardner 2009].	Started to commercialize the Aqueous Phase Reforming (APR) process by which hydrogen is generated from sugar. Technology has evolved into the BioForming™ process, which enables the production of renewable products: Liquid Biofuels ("biogasoline") Chemicals (e.g. propylene glycol) Fuel Gases (hydrogen – H_2) The BioForming™ process is thermochemical. 2006: expanding the BioForming technology to convert plant sugars into hydrocarbon molecules ("biogasoline"). Virent's BioForming *platform technology* employs *low temperature* aqueous-phase reforming and solid state catalyst (rather than microbes) to convert plant sugars into hydrocarbon molecules. Focuses on catalyst composition, reactor design, and reaction conditions. The BioForming process can economically utilize many types of biomass and carbohydrates from cellulosic and biomass-derived feedstock: Glycerol (also named glycerin; by-product of biodiesel production from vegetable or animal oil); Glucose and Sucrose (from sugar crops); Starches (glucose containing polysaccharides); Long-chained glucose contained in cellulose (plant cell walls); C5 and C6 sugars, such as xylose, arabinose, and glucose contained in hemicellulose (part of the protective covering around cellulose). Is already processing mixed sugar streams. Looked at what is a long-term, sustainable way to get biomass feedstock into the process. Thinks sugarcane and the plant that the sugar cane comes from are going to be the cheapest, most scalable feedstock	

	on a global basis for quite a while. Virent's pitch is explicitly *anti-ethanol*. Around a quarter of existing ethanol production capacity is of the wet mill type which could be converted to low temperature catalytic BioForming technology for biogasoline production at significantly lower capital costs than would be needed for new Virent plants. Hopes to license its fuel process [Gardner 2009]; is building its own full-scale production refinery to reap maximum margin from end products and gain a direct feedback loop for improvement of its process. Finally, in 2007 Shell Hydrogen LLC and Virent set up a five-year joint development agreement to develop further and commercialize Virent's BioForming technology platform for hydrogen production (worldwide market for distributed and centralized hydrogen is estimated at approximately 45 million tons each year) [Shell 2007].

*) From the firm's Web site if not stated otherwise by a reference; firm's status: end of 2009; for more information cf. "Virent-Story-Through-2011.pdf" provided on its Web site.

Virent's business model is not focused on biofuels alone, but emphasizes a "*biorefinery model*" which is directed toward biofuels, biochemicals and biomaterials [Runge 2006:849-866] and adds a specialty (fuel cell grade) hydrogen gas which finds also applications in semiconductor manufacturing, ammonia production or in gas chromatography analytics (as a carrier gas). Correspondingly, Virent has a joint agreement with Shell Hydrogen, a subsidiary of Shell Oil Co., to produce hydrogen from renewable glycerol and sugar-based products [Vanden Plas 2007].

The development of Virent's BioForming® technology platform is supported through strategic partners including Cargill, Coca-Cola, Honda and Shell, as well as 80 employees (by 2013) based in Madison, Wisconsin. Virent recently signed agreements with the Coca-Cola Company to provide the technology and biobased chemical Paraxylene to create 100 percent plant-based, renewable PlantBottle® packaging.

The company has received several grants from the US Departments of Commerce, Energy and Agriculture and has been recognized with many honors, including the World Economic Forum Technology Pioneer award and the EPA's Presidential Green Chemistry Challenge Award.

The fundamental process Virent is relying on is one hundred years old and was developed in Germany. In the early 1900s, research on the extraction of chemicals and energy from coal in Germany was focused on two primary approaches [Runge 2006:424-425].

- Direct liquefaction under pressure by converting coal into liquids with the help of hydrogen and heavy oils (Bergius process; Coal-to-Liquids, CtL), and
- Indirect liquefaction by first gasifying coal and then converting the resulting gas into liquids through the process of the Fischer-Tropsch (FT) synthesis (Gas-to-Liquids (GtL)). The process converts a mixture of carbon monoxide (CO) and hydrogen (H_2) called “synthesis gas” (“syngas”) to liquid hydrocarbons using, for instance, iron and cobalt catalysts. A special, currently very economic route of the GtL process uses *natural gas*.

Over time the FT process has been subjected continuously to modifications, became an established technology and is still applied on a large scale. Currently, two companies have commercialized their FT technology, Shell (in Malaysia) and Sasol (several plants in South Africa), using *natural gas* and *coal* as feedstock to produce the syngas, respectively. In South Africa CtL is used on a large scale to produce automotive fuels from coal.

In the US Bioconversion Technology, LLC, (BCT) founded in 2003 and essentially led by Robert E. “Bud” Klepper and Kenneth L. Klepper, started with an emphasis on gasification (“anaerobic thermal conversion”). Bud Klepper was the inventor (and patent holder) of a gasification process capable of processing 25-35 tons per day of coal to *synthesis gas*. Bud Klepper’s *engineering company* generated syngas from coal, coal slurry, coal fines, but also other biomass feedstock. The gasification technology is called the Klepper Pyrolytic Steam Reforming Gasifier (PSRG) with a Staged Temperature Reaction Process (STRP). A separate Klepper Ethanol Reactor catalytically converts syngas into ethanol.

According to a comparative evaluation of such systems the Klepper system has the highest energy efficiency of any system and the highest syngas energy content of any thermochemical biomass conversion system that has been developed for biomass inputs of less than 1,000 tons/day [Green Car Congress 2005; Green Car Congress 2007b]. BCT created revenues by licensing its technology globally.

BCT was later transformed into Kergy, Inc. and then Range Fuels by Khosla Ventures, LLC (Table I.99). And the BCT original thermal converter was upgraded to a so-called K2 modular system [Rapier 2006; Schuetzle et al. 2007]. Obviously, Kergy also looked to “optimize an existing and a novel catalyst or catalyst combinations for the conversion of syngas to alcohols.” [Reisch 2006]

Gasification of biomass to produce biofuels as a well known approach for more than twenty years is just a capital-intensive process that has the problem of competing against lower cost (but unsustainable) gasification options [NNFCC 2009, Schuetzle et al. 2007; Rapier 2006].

Similarly to the CtL process, and in line with current biofuel efforts, Bergius also succeeded in 1930 in Germany to convert wood into cellulose and treating the biomass with hydrochloric acid to get (biobased) synthetic sugar via saccharification and fermentation. The product was similar to beet sugar in taste and application. And in 1938 building a plant was started that should become operational in 1939 to convert 400,000 m3 of wood per year into sugar [Runge 2006:566].

The Israel-based recent startup HCL CleanTech (now named Verdia, Table I.99) acknowledges Bergius when they wrote on their Web site: "Innovative HCL Recovery Process Revolutionizes the 1930 Bergius Technology for Converting Cellulosic Materials into Fermentable Sugars." HCL CleanTech "has developed a proprietary full HCL (hydrochloric acid) recovery process, which makes an old, industrially-proven German cellulosic to fermentable sugars and ethanol process economically very attractive."

Similarly in the US, Arkenol/BlueFire further developed the acid hydrolysis process (here with concentrated sulfuric acid) [BlueFire Ethanol 2004, Klann 2007] to make it economically viable through the use of new technology like flash fermentation and membrane distillation and purification, modern control methods, and newer materials of construction and focusing on a special type of biomass.

BlueFire Ethanol Fuels (Table I.86) follows a "veterans approach" and biorefinery orientation [Runge 2006:849-866] with a management team of people having 25+ years of experience in project finance, technology commercialization and project development. BlueFire's *biorefineries will be located near markets with high demand for ethanol* and will *use locally available biomass*. It is a cellulose-to-ethanol company with demonstrated production of ethanol from urban trash (post-sorted municipal solid waste – MSW), rice and wheat straws, wood waste and other agricultural residues. By weight, post-sorted MSW is more than 70 percent cellulose.

Bluefire's favorite input is municipal waste, because it can build its refineries on landfills, cutting feedstock transportation costs and using methane emitted from decomposing waste to help the plant generate 70 percent of its own electricity.

The BlueFire process licensed from Arkenol uses naturally-occurring yeast, which has been specifically cultured by a proprietary method to ferment mixed (C6 and C5) sugars (actually, NREL developed *rec. Z. mobilis* (licensed by BlueFire) and *S. cereviscae* yeast) to produce ethanol at 95 percent [BlueFire 2004]).

Arkenol can license its technology to qualified entities for their own project development. However, Arkenol prefers to offer more than just a license. With its team members, Arkenol can provide turnkey engineering, procurement, construction, and operations services. Arkenol will work with developers around the world to license its technology and on an individual project, a corporate or a regional basis. Notably, BlueFire and Arkenol share the same president and CEO (Table I.86).

> Decision-making and action in new biofuels firms is often by a management team with members providing large "science, technology, management and policy experiences and connections."

An entrepreneurial "*veterans approach*" can often be assumed to be founded and run by an "*old boys network*," which is an exclusive informal network linking members of a social class or profession or organization in order to provide connections and information and favors (especially in business or politics), often indicated by current or past affiliations to the same organization.

Table I.86: BlueFire Ethanol Fuels showing an engineering-type approach to innovation and entrepreneurship. *)

Company (Foundation) Remarks	**Major Funding**	**CEO, Other Executives, Key Researchers; Technology Protection and Position**
BlueFire Ethanol Fuels, Inc. Irvine, CA (2006) New name: **BlueFire Renewables, Inc** An over-the-counter (OCT) publicly traded stock company. Revenues (from consulting, DOE Grant/ Reimbursement, in 2009 selling ethanol to Solazyme, Inc.): 2007: $49,000, 2008: $1.075 mil., 2009: $4.32 mil. 2010: $669k [Wikinvest 2009]. Employees 2008: 12 [CI 2009], 2011: 6 full time employees and three part time employees.	2007: Securities Purchase Agreement, Quercus Trust acquired shares of common stock and warrants for total proceeds of $15M, strategic investment (Quercus Trust shares of voting common stock 34.4%); 2007: Department of Energy (DOE) provides grant of $40M for the first of two stages of its second US commercial ethanol production using cellulosic wastes diverted from landfills in Southern California (ca. 17 million gallons per year); has been invited	Experienced Management Team specializing in project finance, technology commercialization and project development: Arnold R. Klann – Chairman - President – CEO; CEO for BlueFire Ethanol, Arkenol, Inc., and ARK Energy; prior to founding ARK Energy, he launched three businesses and managed complex teams for project development and operation; Arkenol is a technology and project development company; ca. 30 years experience in corporate management, project finance, engineering, design, construction, start-up, environmental permitting, driving force behind the research and development effort leading to the commercialization of the Arkenol technology; BS (electrical engineering); (shares of voting common stock 49%); John E. Cuzens – SVP CTO; has been with ARK Energy and Arkenol and is the co-inventor of seven of Arkenol's eight US foundation patents for the conversion of cellulosic materials into fermentable sugar products using a modified strong acid hydrolysis process, experience of 20+ years of project management, experience punctuated frequently with engineering or R&D management assignments; B.S. Chemical Engineering; (shares of voting common stock 6.1%) Necy Sumait – SVP – Director; Senior Vice President for BlueFire Ethanol and for Arkenol, Inc., background in the development of energy projects from inception through financial closing, commissioning, and operations. She has broad experience in siting, regulatory compliance, governmental and community relations and legislative affairs (of federal, state and local agencies); (shares of

Business plan developed in conjunction with Booz Allen Hamilton, in particular, use waste to produce ethanol and put the production near to end users.	to submit a formal application for a DOE loan guarantee to assist in the financing of ethanol production facilities; approved for California Energy Commission Grant of $1M 2009: DOE increased funding to $81.1M for Phase II construction of the cellulosic ethanol biorefinery planned for Fulton, MS, in addition to the previously announced Phase I funding of ca. $7M for development of the Fulton plant (goal 19 mil. gallons) [Wikinvest 2009]; has received a $3.8 mil. reimbursement from the US DOE to be used for preconstruction activities for its second planned biorefinery in Fulton, MS. NOTE: In Dec. 2013 the firm	voting common stock 6.2%) William Davis – VP Project Management; 30+ years of experience; he has served as advisor to the Governor of California for energy conservation and renewable energy policy; additionally he has worked for several Fortune 500 companies managing their energy development activities. Notably: William A. Farone – Technical Advisor for Arkenol, Inc.; 30+ years of technical research experience in the alternative energy, chemical and biotechnology industries, managed the Arkenol Technology Center focusing on the development of new chemical technology and biotechnology, and the optimization of existing chemical processes. Dr. Farone is the chief scientist and technical expert for all equipment application, feedstock processing and product development activities at the Arkenol Acid Hydrolysis Pilot Plant and co-inventor of Arkenol's US foundation patents for the conversion of cellulosic materials into fermentable sugar products. BlueFire Ethanol Inc. has formed a technology development services agreement with William Farone. Farone is president and CEO of Applied Power Concepts Inc. (APC), a producer of higher-value sugar-based chemicals. Under the new agreement, Farone and Applied Power Concepts Inc. will work with BlueFire to continue advancement of the technology. BlueFire will conduct development work at the APC facility [Austin 2009]. *Staff and majority shareholders have been involved in technology development since 1992* as Arkenol. Research and development work completed, patent protections in place, pilot-scale process successfully completed, bioethanol commercial plant projects currently in various stages of development. Bluefire is the *exclusive North American licensee* of "Arkenol Technology," may also utilize certain biorefinery related rights, assets, work-product, intellectual property and other know-how related to nineteen ethanol project opportunities originally developed by ARK Energy; from 1994-2000, a test pilot biorefinery plant was built and operated by Arkenol in Orange (CA) to test the effectiveness of the Arkenol Technology; results fed into another test pilot biorefinery plant in Izumi, Japan, built

	got notice from the DOE indicating that the DOE would no longer provide funding under the firm's DOE grant for developing its cellulosic waste facility in Fulton, due to inability to comply with certain deadlines for informing the DOE on future financing the Fulton Project a)	and operated by engineering firm JGC Corporation (Arkenol retained the rights to the Arkenol Technology while the operations of the facility were controlled by JGC); in 2002 JGC was awarded a contract by the New Energy and Industrial Technology Development Organization (NEDO) of the Japanese Government for the implementation and commercialization of cellulosic ethanol production technology; *the Izumi facility enabled to verify Arkenol's technology as being commercially viable via an unrelated third party*, setting the stage for the rollout of this technology in the US; design and engineering of BlueFire's facilities in North America by established engineering firms can rely on use the Arkenol Technology and utilize JGC's operations knowledge [SEC 2009, BlueFire Ethanol 2004]; JGC exclusive licensee for SE Asia
Technology, Goals, Strategy Vision: Build/ develop biorefineries focused initially on bioethanol; Mission: Become a world-class *producer and supplier of renewable liquid fuels* by the production of ethanol from opportunistic sources; Create a business that *develops and owns* state-of-the-art ethanol biorefineries that are the *lowest cost producers* of ethanol.	The process [Klann 2007:6] is cellulose/hemicellulose to mixed sugars using Arkenol's concentrated (sulfuric) acid hydrolysis to provide ethanol and open routes to other biobased products, such as biobutanol, to become a *biorefinery*. It is an incremental innovation ("improvement") of an old technology developed in Germany in 1930 ("Bergius process") centered on input selection and plant and process engineering. Claimed: The only cellulose-to-ethanol company worldwide with demonstrated *production of ethanol from urban trash* (post-sorted MSW), but also rice and wheat straws, wood waste and other agricultural residues; Bluefire can use the landfill to power its refining process; combined with the use of lignin, a by-product from the Arkenol process; the capture of methane from a nearby landfill allows Bluefire's refineries to be 70% self-powered. Strategy: Equity and debt funding for the BlueFire projects will be done on the project level, not the Corporate level, which means little or no dilution to current shareholders [Klann 2007]. Targeting specific geographic areas with the highest demand for ethanol fuels (e.g. California) and available feedstock supply; BlueFire will be project lead and equity owner in projects utilizing their technology; Bluefire positions its production facilities right on landfills, in order to exploit certain cost advantages: input is from municipal waste cuts feedstock transportation costs and can use methane emitted from decomposing waste to help the plant generate 70% of its own electricity [Wikinvest 2009]; as a broad spectrum of biomass can be used for the process, targeted regions are large urban areas where waste disposal is a problem and landfill	

Projections of 20 biorefineries to be in commercial production within the next 7 years in North America.	disposal alternatives are important and areas adjacent to National Forests where there is a pressing (and long-term) need to dispose of dead or diseased vegetation. The plan is, concurrent with the development of its own facilities, to deploy the technology, form associations with a group of companies selected on the basis of well-defined criteria (Joint Venture Development Partnerships with qualified and experienced regional developers throughout the US and Canada); that is the desire to create a portfolio of strategic partnerships. BlueFire's product selling revenue orientation has materialized by an alliance with algal biofuel company Solazyme, Inc. (Table I.90) which purchases and tests BlueFire sugars. Solazyme directly feeds the algae sugar rather than relying on light [Wellsphere 2009].
Risk, Risk Mitigation	Bluefire competes with many other biofuels manufacturers, though its closest competitors are cellulosic (and corn) ethanol companies. Targeting a biorefinery model would allow lifting dependency on just one offering in the future – bioethanol – through downstream processing. BlueFire is well beyond the research and development stage of its business plan and the *technology has been in actual production for over five years* in NEDO's pilot plant in Japan. Without government grants Bluefire's facilities would have no hope of being profitable, illustrating the company's dependence on government aid to be feasible and legislative support to achieve profitability: Federal and state governmental funding to build its refinery helps to offset the hefty installation cost of $5.00 per gallon for a 55 million gallon per year facility. Without such funding, it would be very difficult for Bluefire to make ethanol cost-competitive with other fuels, much less turn a profit [Wikinvest 2009]. According to BlueFire's plan sub $1.00/gal production costs are feasible for facility 2 through 20 [Klann 2007]. Further risk mitigation would require a shift in the auto industry to accommodate for higher blending (cf. the E15 thrust) and/or to build the missing infrastructure for still relatively few FFVs in the US that would allow E85. "Bluefire is Dependent on Legislative Support to Achieve Profitability." [Wikinvest 2009]

*) From the firm's Web site if not stated otherwise by a reference; firm's status: end of 2009;
a) cf. also Jim Lane's article "Being solid and liquid: The screwy, upside-down world of renewable fuels financing" in Biofuels Digest of Oct. 6, 2013.

By the end of November 2011, BlueFire Renewables formed a wholly owned subsidiary, SucreSource, LLC, that will manufacture cellulosic sugars from biomass and will use BlueFire's patented Arkenol Acid Hydrolysis Technology. SucreSource will capitalize on BlueFire's existing process design packages, providing either a 34,000 tons per year or 163,000 tons per year source of cellulosic sugars.

SucreSource was riding a wave shifting the paradigm for energy sources and was created to meet the market's increasing demand for cellulosic sugars not just for biofuels, but also for bioplastic and specialty chemical markets (A.1.1.6). BlueFire claims to be the only cellulose-to-fuel company worldwide with demonstrated production of biofuels from urban trash (post-sorted MSW), rice and wheat straws, wood waste and other agricultural residues. BlueFire received an increase to its Grant totaling $88 million under the American Recovery and Reinvestment Act in December of 2009 [Lane 2011h].

SucreSource is actively pursuing partnership opportunities to deploy the technology. Early in 2012 SucreSource signed agreements with GS Caltex – a joint venture between GS Holdings and Chevron, and a leading Korea-based petroleum company to build a cellulose-to-sugar plant in Korea.

The facility will process 2 tons of construction and demolition debris per day into cellulosic sugar, which will be converted into a high value chemical by GS Caltex's proprietary technology. The facility will be owned and operated by GS Caltex with SucreSource providing the process design package, equipment procurement and technical and engineering support. If the initial facility is validated, SucreSource will work with GS Caltex to develop and build larger commercial scale facilities in Korea and throughout the world [Green Car Congress 2012].

If in the well established Fischer-Tropsch (FT) process syngas is obtained from biomass, the process is referred to as a BtL (Biomass-to-Liquid) which has been developed and was utilized by CHOREN Industries GmbH in Germany to produce SunFuel für Otto engines und SunDiesel® for Diesel engines [Runge 2006:254-255], the last one being used as a blend in Shell's premium "V Power Diesel" fuel in Germany and Austria. CHOREN, founded in 1998, ultimately acted as a holding.

The biomass spectrum for BtL includes wood chips from forest timber or from rapid turnover plantations, straw briquettes, energy, crops or recycled wood (from houses). According to its Web-site CHOREN became a group with several subsidiaries. The number of employees of the CHOREN Group was around 300. Some subsidiaries were already profitable in 2009, but overall CHOREN remained in the red (Capital employed: > €180M with €100M invested in the Beta-Plant).

Revenues for 2007 of more than €4M were reported [Lachmann 2007]. About 20 percent of the Beta-Plant investment was by the federal government and local state government [Wuttke 2008]. As an LLC CHOREN had eight partners including two corporate investors (automotive firms VW and Daimler) with minority stakes and a private businessman with a majority stake [Lachmann 2007]. The key founder Bodo Wolf left CHOREN as a partner in 2008, but stayed connected as a consultant to the firm [Wuttke 2008]. Shell Deutschland Oil GmbH had sold its shares in CHOREN Industries GmbH to all the remaining CHOREN shareholders.

By 2009 CHOREN produced 15,000 tons/year biodiesel (ca. 4.8 million gallons) and planed for a €800 million plant for 200,000 tons/a ("Sigma-Plant") which would correspond to 0.7 percent of the then demand of diesel fuel in Germany where diesel is much more used for cars than in the US. However, the prerequisite for building was that after 2015 in Germany biofuels continue to get a tax exempt [Kempkens 2009].

Simultaneously, there was a European research project OPTFUEL comprising European car manufacturers and led by VW (with a minority stake in CHOREN) to drive large-scale production of 2nd generation biofuels which will be based on CHOREN's Carbo-V®-process. A part of the research funds would be used for the development of economically and ecologically viable concepts for supplying a large-scale plant with biomass (cf. Figure I.173), such as CHOREN's Sigma-Plant.

Apart from own production, product selling and licensing CHOREN's business (revenue) model was based on its proprietary Carbo-V gasification process and on engineering core competence which includes a wide range of services for design, installation and operation for Carbo-V biomass combined heat and power plants in line with the common service offerings of an *engineering company*, specializing in *mechanical engineering and plant engineering* – similar to BlueFire's offerings.

- Concept development for the construction of industrial-scale production units including or integration of the process into existing energy supply configurations
- Advice to and support of companies in organizing biomass supply concepts and the relevant processing technology, or even organization of the complete biomass management, including the securing of long-term raw material provision as main supplier
- Process engineering design for the project
- Permit engineering for the entire plant
- Basic and detail engineering for the Carbo-V section
- Design, construction, delivery and installation of the main process equipment
- Assistance during installation, start-up and commissioning, training of operating personnel
- Technology transfer.

In 2010 CHOREN and the French group CNIM (Constructions Industrielles de la Méditerranée SA) signed an EPC agreement (engineering, procurement and construction). The agreement covered the design and construction of a synthesis gas production facility using biomass feedstocks, whereas CHOREN provides extensive engineering and other technical services [CHOREN 2010].

For CHOREN *about half of the production cost resulted from type and procurement of biomass* (Figure I.171, Figure I.173). A strategic option would be *production in countries where biomass is cheaper*. The other alternative, type of biomass, can be related to the technical bottleneck of the process: The actually used biomass provides too little hydrogen to the syngas of the FT process [Lachmann 2007].

Correspondingly, in November 2009 CHOREN USA LLC reported on a two-year bioenergy cooperative project with the energy crop company Ceres, Inc. which was funded in part by a grant from the US Department of Energy and Agriculture. Ceres would evaluate the *composition* of a broad range of switchgrass and willow plants, and provide biomass samples to CHOREN for thermochemical processing.

The results should be used to identify the most relevant compositional traits and later, to select the plants and traits that improve conversion and maximize fuel yields. Additionally, it was said that CHOREN USA will use the results of the work to help the company selecting its initial US project site. But generally, the C/H proportion from biomass is inferior to that from fossil energy sources. This suggests adding hydrogen from other renewable sources which would give Virent's process a flavor. Further questions for the gasification of biomass were the use of dry versus wet biomass and consistency of the biomass composition.

> Whether it is cosmetics, chemicals or other applications, for the relevant natural product, such as chitosan (cf. Heppe Medical Chitosan GmbH, ch. 2.1.2.4) or here biomass using "biological" ("renewable") stuff as raw material, intermediate or other input for technical processes, the *composition* of the natural, renewable material and also the material's *composition consistency*, which may be sourced from different regions and/or at different seasons, are crucial for technical processes and may interfere with scale-up efforts and quality and purity requirements.

Among other factors, the above issues were also reasons why CHOREN went bankrupt in Germany by mid of 2011. Most of the 290 employees lost their jobs [Rapier 2011; Reuter 2011]. In early 2012 the giant German engineering conglomerate Linde (Linde Engineering Dresden) took over the biomass business of CHOREN saving in Germany 65 jobs [DAPD 2012] and took over the Carbo-V® Technology. More details are given by Rapier [2011]:

In 2009, the author dealing with what happened to CHOREN [Rapier 2011] accepted a job as Chief Technology Officer for the man who was at that time the largest shareholder of CHOREN (which was not his only investment). Both persons shared a belief that oil prices are inevitably headed much higher, and in that case they both believed the CHOREN process would be ultimately economically viable.

In 2009 CHOREN started commissioning the gasification section for its process. That was the beginning of a long process of running for a period of time, and then shutting down and making adjustments. One of the biggest challenges with the gasification was that there was no blueprint; nobody had run a gasifier like this at this scale on a biomass feedstock. Hence, the plant had to work through many new technological challenges, and with a staff of 290 employees, the time it took to work through the issues was costly.

As CHOREN had elected to forgo government funding, private investors have borne the development costs over the past few years. Several of those investors – including Shell – exited at various points due to the time and cost it was taking to work out the technical issues. Ultimately, the largest shareholder was largely funding the ongoing operations of CHOREN from his pocket.

While the plant made good progress, commissioning took far longer than expected. Rapier had in fact warned that it would take at least a year to start up the plant once it was mechanically complete, but it was taking even longer than expected. It finally got to the point that all investors decided to stop funding development, because all of the technical bugs had not been worked out. *It was not that there were any technical show-stoppers, it was just that the timing of how long it would take to work through the issues was uncertain.*

CHOREN Industries and its four engineering-oriented founders, in particular, Bodo Wolf, provide a representative case for a rise of entrepreneurial spirit and private initiative in 1990 almost immediately after the Berlin Wall was teared down and the former German Democratic Republic (GDR) ceased to exist.

The four persons immediately initiated self-employyment by setting up an engineering office [Ahrens 2005] which developed into CHOREN Technologies GmbH. The team started in the biofuels field years before it became a huge wave, with a pilot plant ("Alpha") to test their Carbo-V process in 1998 and a pilot production plant ("Beta") in 2003. Bodo Wolf, after having left CHOREN in 2008, acted as an angel investor for the German startup SunCoal GmbH (B.2) which focuses on BtC – Biomass-to-Coal.

With regard to the FT (GtL) and CtL processes the first to benefit from them was Germany during World War II. Germany, rich in hard and brown coal, built enormous liquefaction plants. After the war, the GDR, to secure its resources, operated the German Fuel Institute (DBI), a center for coal processing in the mining town of Freiberg.

After the German Reunification the DBI left behind a group of highly specialized scientists and engineers who were highly specialized in a field abandoned by the West (after oil-based industries took over coal-based ones) that offered a key to a more efficient way of using biomass. The key persons of the DBI were the engineer Bodo Wolf, Eckard Dinjus (see below) and Bernd Meyer, each of them having their own technological approach to the field.

Dinjus became professor and head of a "BtL Division" (later Institute for Chemical Engineering - Division of Physicochemical Processes) at the Karlruhe Research Center (Forschunszentrum Karlsruhe – FZK, a German National Research Center; now part of the Karlsruhe Institute of Technology – KIT). Meyer became a director at the Technical University of Freiberg. The two professors would rather see more research done on BtL before it makes the transition to general industrial use. Indeed, when they testified as experts at an official hearing, they advised the government against providing CHOREN with loan guarantees [Wüst 2007].

This particular constellation for the BtL-case represents a further example of the key issues of technology transfer, namely that *effective technology transfer of complex industrial processes depends highly on "people transfer," knowledge and experience (know how) bound to people* ("subject matter expert" – SME – providing "tacit technology"), as has been shown by several historic cases.

- Manufacturing of porcelain in the 1700s: after defeating Saxony in a war, winner Prussia transferred many of the Meissen (near Dresden, Saxony) workmen of the porcelain production site to Berlin and Berlin afterwards became a famous competitive manufactory [Runge 2006:405].
- In 1927 US Standard Oil (now ExxonMobil) and German I.G. Farben (see [Runge 2006:271-272]) agreed to cooperate technically in the further development of synthetic oil and fuel by coal liquefaction via the Bergius process [Runge 2006:424]. Standard Oil and I.G. Farben set up the "Joint American Study Company" (JASCO) to work on synthetic oil. JASCO should push commercialization of technologies. Therefore, both partners sent scientific and technical employees as the "carriers of people-based knowledge" into JASCO.
  After WW II captured German scientists continued to work on synthetic fuels in the US.
- The biggest corresponding know-how and technology transfer occurred in the 20th century after WW II when the US and Soviet Union each caught the top 100+ German scientists and engineers who developed the V2 missiles or the world's first jet fighter, the Messerschmidt 262 jet, and moved them to their respective countries. No such technologies existed in the world outside Germany and the German specialists rebuilt the missiles and jets to educate and train Americans or Russians in the technologies [Runge 2006:405]. And German scientists transferred to the USSR also contributed to building the Russian atomic bomb (ch. 2.1.2.8).

Collecting biomass and getting enough of it in one place to make a difference is a key problem in the biomass world. "Trucking costs can become exorbitant. You want to preprocess it at the farm and then ship a high-density, high-energy intermediate to processing plants." [Jonietz 2007]

Focusing particularly on the issues of economical collection, procurement and transportation, the first part of the biofuel value system (Figure I.173), Dinjus of the KIT developed a BtL process called "Bioliq," through stepwise projects together with the engineering firm Lurgi GmbH (now a subsidiary of Air Liquide) as an industry partner. By November 2009 the third of four steps for a pilot plant had been funded with €11 million by the German federal and related state governments. Bioliq aims at the production of biofuels (and industrial chemicals like propylene, ethylene or acrylic acid; Figure I.174) via the FT and methanol/dimethylether (DME) route [Runge 2006:851-852, 858]. In May 2011 there was the topping-out ceremony for the related €60 million Bioliq plant.

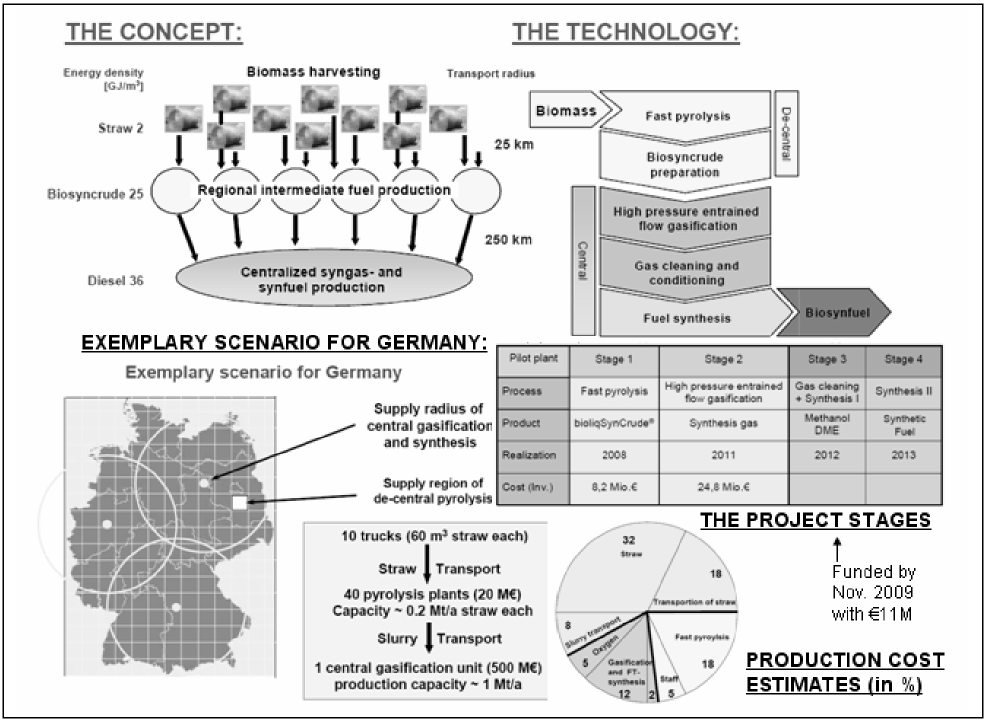


Figure I.173: The KIT – Lurgi Biofuel BtL Project Bioliq emphasizing the input – biomass collection and transportation and proportions of overall production cost.

The overall *systems-oriented* project focuses on the necessary infrastructure for raw material (straw) collection through a *decentralized* stepwise approach. Raw material is collected and transported over short distances (less than 25 km) to mini-plants. Here a “fast pyrolysis” converts the biomass to a mixture of an “oil” and a “coke” which are combined into a suspension.

This “slurry” (“*biosyncrude*”) is of such a “high energy density” that its transportation to the actual BtL plant is economically viable. The BtL plant then provides “syngas” which can be further processed [Dinjus et al. 2008]. Transportation of biomass beyond short distances would quickly cost more BTUs (British thermal units) than the biomass fuel would yield. Having or building an infrastructure to collect and store the biomass, hence, is *the* serious cost concern.

Systems thinking concerning biofuels and biomass and “commercially successful” entry into the transportation area brings about further considerations – the *economics will change* upon success of the biofuels firms.

> Rising biofuel production, or the burning of biomass to generate electricity, will drive up demand and prices for the raw material, just as production of corn ethanol helped raise the price of that crop. Biomass is cheap right now because no one wants it. As firms want it, it will become more expensive.
>
> Furthermore, and more important, the laws of supply and demand mean that replacing a significant amount of (petro-)gasoline with biofuels would drastically lower the demand for gasoline. That, in turn, would cause the price of gasoline to plunge, making biofuels less competitive.

The only notable activities concerning cellulosic ethanol in Germany are observed for Süd-Chemie (Box I.3) which was recently acquired by Swiss specialty chemicals firm Clariant. It is a company with €1.225 billion sales (in 2010; employs some 6,500 people) operating on a worldwide scale. Its business units, Functional Materials and Catalysis & Energy, offer products and technical solutions for numerous industrial sectors to facilitate effective use of resources in customer value chains. The Catalysts Division offers solutions for the chemical, petrochemical and refinery industries, for energy storage and hydrogen production, as well as off-gas purification

In 2009 Süd-Chemie opened a pilot plant at the firm’s Research Center in Munich supported by the Bavarian Minister of Economics, Infrastructure, Transport and Technology and the EU to produce bioethanol from lignocellulosic biomass. The pilot plant will be using cereal straw to manufacture up to two tons of bioethanol fuel annually.

The process developed by Süd-Chemie and German gases and engineering giant Linde allows biofuels, such as ethanol, to be extracted from biomass, for instance wheat straw or maize (corn) straw, with the aid of enzymes created using biotechnological methods. The partners in this alliance offer complementary competencies. Whereas Süd-Chemie´s expertise lies in the sectors of biocatalysis and bioprocess engineering, Linde’s subsidiary, Linde-KCA-Dresden, offers extensive experience in implementing chemical and biotechnological processes on a commercial scale [Süd-Chemie 2009] – and now owns also the rests of CHOREN and its Carbo-V® Technology.

Süd-Chemie´s sunliquid® process uses not only the cellulose contained in plants, but also the so-called hemicellulose. Both can be converted into ethanol, making it possible to increase ethanol production by up to fifty percent compared with conventional technology.

Planned for 2012 a large-scale demonstration plant was started by mid of 2010, located in the immediate vicinity of the new Bavarian BioCampus in Straubing, that will produce up to 2,000 metric tons per year (670,000 US gallons) of bioethanol fuel from agricultural waste, such as wheat straw or maize (corn) straw, bagasse from sugar cane or so-called energy crops [Süd-Chemie 2010].

In July 2012 Clariant inaugurated the new cellulosic ethanol pilot. The plant – the biggest of its kind in Germany – will start producing produce around 1,000 tons/year of cellulosic ethanol, using around 4,500 tons/year of locally sourced agricultural waste as a feedstock. Clariant said studies show Germany potentially has around 22 million tons of straw that could be used for energy production without compromising essential soil regeneration, which would be sufficient to cover around 25 percent of Germany's current gasoline requirements.

Süd-Chemie´s demonstration plant will represent a scaled-down version of the entire integrated manufacturing process. The total project had a volume of altogether €28 million ($35 million) and comprised an investment volume of some €16 million and accompanying research projects amounting to approximately €12 million. These and additional related research projects were subsidized by the Bavarian State Government and Germany's Federal Ministry of Education and Research (BMBF) with approximately €5 million respectively [Süd-Chemie 2010]. The pilot plant represents the interim stage necessary prior to erecting production plants with annual capacities of 50,000–150,000 tons of bioethanol.

The current situation at Süd-Chemie shows that CAPEX (capital expenditures) is radically lower than for other bioethanol plants. Their system is designed to ultimately cost less than $100 million for a 20 million gallons (60,000 ton) plant, and is expected to have OPEX (operating expenditures) that is competitive with first generation (corn) ethanol. The company is on the road transforming the economics of cellulosic ethanol, to compete at parity with gasoline and was expected to commence licensing in 2012 [Lane 2012p].

According to Süd-Chemie and its Unique Selling Proposition (USP) "We are one of the few companies worldwide that have process development and enzyme development under one roof. We are independent from enzyme supply, because we make our own during the process itself, using only a small fraction of pretreated feedstock. We have optimized enzymes for feedstock and operating conditions." "We will deliver the complete technology." "The basic engineering package, also include all biotech software, microorganisms for producing enzymes, downstream processing, for producing the ethanol, and also help with the start up." [Lane 2012p]

Summarizing some aspects of innovation and intrapreneurship in biofuels considered so far the following emerges.

> Research, innovation and commercialization progress in the biofuels area require tremendous capital investments. Startups and NTBFs might have the technology, but they lack the capital to build the (pilot and demonstration)

plants and other infrastructure required to fully prove it. Hence, they need very strong partners and giant oil (and automotive) firms play a key role.

Federal and state governments play a very important role for financial support in terms of tax credits, subsidies, and research support (grants and cooperation with public research organizations; Figure I.34).

But, looking at oil firms as partners, one must be aware of Big Oil's contribution into perspective. For instance, for ExxonMobil, the world's largest publicly traded oil company, the biofuels investment (in a $600 million partnership with biotech company Synthetic Genomics Inc. [Lux Research 2007] over five to six years!) is tiny compared with its spending to find new supplies of crude oil and natural gas [Porretto 2009]. Capital spending of a giant oil company is $20 – $30 billion per year. *Exxon Mobil made $142 million in profit each day of 2008*. Correspondingly, the financial risk of the investments for these firms does not weight very strongly.

It seems that concerning performance data of ethanol (Table I.82), its carbon footprint (Box I.1) and "without a Shift in the Auto Industry, Cellulosic Ethanol is No More Than a Good Idea." [Wikinvest 2009]

In short, assessments of biofuels' roles referring to Shell Chief Executive Officer Peter Voser turned to the statements that *advanced biofuels will not be in widespread use until about 2020* and that it would take "quite a number of years" before there is a commercially proven plant. The company has also been forced to acknowledge that it has been *over-optimistic* about when these ventures will start to pay off [Crooks 2009].

In line with this statement corporate and capital investors were plagued by promises of startups/NTBFs concerning the start date of production by commercial plants which deviate by years from reality. For instance, the following projections were made during the 2007-2009 period on commercial production or generating notable revenues:

- Cobalt Biofuels (Table I.96), founded 2006, planned: a $25 million GPY plant for 2012; for 2015 jumpstart revenue in the chemicals market; claim to first commercial sales of biobutanol in 2011 and "multiple facilities" by 2014; according to its recent fact sheet: Demo-scale plant expected to be operational in 2011; 1.5 million GPY facility operational in 2012;
- LS9, Inc. (Table I.99) founded in 2005, would not reach commercial production levels until 2013;
- Solazyme (Table I.90), founded in 2003, would be at parity with $80 oil by 2012/13.

But often there are associated other concerns with statements about the time of entry into large-scale production, for instance, with regard to Range Fuels [Rapier 2010] and Coskata [Admin 2011a] (Table I.99).

For Range Fuels Rapier [2010] provided firstly common wisdom and advice. Learn to be conservative with claims, because failing to deliver can have far-reaching impacts. Plus, a pattern of over-promising and under-delivering will ultimately destroy your credibility, and thus your ability to get anything done.

He then secondly turned to “Range Fuels: Years of Broken Promises.” And he presented a timeline from October 2006 to February 2010 to show the remarkable evolution of their “progress” that has gone largely unreported and emphasized the “highlights.”

The key point is that in May 2009, while Range Fuels stopped issuing so many press releases, replaced CEO Mitch Mandich was quoted in the New York Times admitting that “the soup’s not quite cooked yet.”

The known amount of money by 2010 that has been poured into this firm (Table I.99) – beyond Khosla and company’s initial investment – is $158 million in VC money, $76 million of DOE money in 2007 to finance the Georgia plant, $80 million from the USDA (a loan guarantee of $80 million, and that allowed the company to secure an $80 million bond in 2010 to fund the plant’s construction in 2010), and $6 million from the state of Georgia. Further, they asked for more DOE money, but were turned down. That turned out to be more than $320 million to build 4 million gallons of methanol capacity.

Rapier [2010] could refer to and cite a US EPA report:

“As for the Range Fuels plant, construction of phase one in Soperton, GA, is about 85% complete, with *start-up planned for mid-2010*. However, there have been some *changes to the scope of the project* that will *limit the amount of cellulosic biofuel that can be produced in 2010*. The *initial capacity has been reduced from 10 to 4 million* gallons per year. In addition, since they plan to *start up the plant using a methanol catalys*t they are *not expected to produce qualifying renewable fuel in 2010*. During phase two of their project, currently slated for mid-2012, Range plans to *expand production at the Soperton plant* and *transition from a methanol to a mixed alcohol catalyst.* This will allow for a greater alcohol production potential as well as a greater cellulosic biofuel production potential.” (Emphases added)

And Rapier concluded: “So taxpayers funded a **40 MGY** wood-based **ethanol** plant and they are instead getting a **4 MGY** wood-based **methanol** plant.”

In line with this, in 2011 Bud Klepper, who is not only Range Fuels’ technical advisor but also the original founder of the company that became Range Fuels, announced that Range Fuels is laying off most of its employees at its plant near Soperton, Ga, after it makes a single batch of ethanol, and the company will shut down the plant while it tackles technical problems and raises more money [Wang 2011].

Some remarkable conclusions of R. Rapier [2010] were as follows.

- Range Fuels' "people had been in the habit of promising the moon to secure ever more funding."
- Investors seem to proceed "how Silicon Valley innovates." "The thing is, the energy industry is full of very smart people who went to the same schools the people in Silicon Valley attended."
- Failure tars an entire renewable industry as being hopelessly unrealistic.

A similar situation in different context can be described for Coskata (Table I.99), founded in 2006. In 2010/2011 biofuel companies, many without revenues or commercial products, continued to shoot for IPOs. Filing for an IPO in the *industrial biotech* boom, which began with a successful listing on the NASDAQ by Codexis in 2010 was followed by IPOs of Amyris, Gevo, KiOR (all in Table I.99) and Solazyme (Table I.90). Then, PetroAlgae, Mascoma (Table I.99), BioAmber and Genomatica (A.1.1.6) have also filed S-1 registrations for proposed IPOs, as did Coskata (Table I.99) in December 2011 when it looked for a $100 million IPO.

In 2010 Coskata lost $28.7 million while recording $250K in revenues and $23.3 million for the nine months ended September 30, 2011. They expected these losses to continue for the foreseeable future. A recent summary of its S-1 registration culminated in a revealing overview entitled "The Risks, Translated from SEC-speak." [Admin 2011] Below are some cited examples of that exercise concerning credibility, execution and delivery.

In SECSpeak:	**In English**
"In place of the plasma gasifier that we used at our Lighthouse facility, we expect to integrate an indirect biomass gasifier with our syngas cleaning technology, which have never been tested together for fuels production. While biomass gasifiers are a proven technology, they have only been used commercially on a limited basis and have experienced operational reliability issues."	Uh, we didn't actually use our proposed gasification machine, a/k/a/ Old Unreliable, because in the demonstration that we did, we decided to demonstrate something else. (a/k/a = also known as)
"*We have entered into an MOU with a lender for $87.9 million of debt financing to fund a portion of the cost of constructing Phase I of our planned Flagship facility. We have also received a conditional commitment from the USDA relating to a 90% guarantee of such debt financing…The process for finalizing the definitive documentation with the lender and the USDA may take longer than expected or may not happen at all."* (MOU: Memorandum Of Understanding)	Your investment dollars may become, er, marooned (i.e "into the Valley of Death rode the six hundred"), if we don't close this loan.

"*A disruption in our supply chain for components of our proprietary nutrient package could materially disrupt or impair our ability to produce renewable fuels and chemicals*."	If Rumplestilskin the Magic Coskata Microorganism doesn't get his vitamins, he won't spin our straw into gold.
"*Although we currently intend to use the net proceeds from this offering in the manner described in "Use of Proceeds," we will have broad discretion in the application of the net proceeds*."	If we spend all this money on, say, golf memberships, the only ethanol we'll see will be at the 19th Hole.

Overall one can say that opinions about the developments and future of biofuels are split reduced to the question "Advanced Biofuels: pipedream or solid investment?" [Bomgardner 2011b].

The industry partly blamed the credit crisis (Great Recession) for its slow pace, but acknowledged that *getting the conversion techniques to work is the biggest problem* [Wald 2009b]:

- "It's certainly turned out to be more complicated technically than people thought it would be," said Brian Foody, the president and chief executive of Iogen (working with Shell).
- BP America also acknowledged slow progress in its company's joint venture with Verenium, in Louisiana. "We aren't seeing fundamental technology issues; it's more a matter of optimizing the engineering of the pots and pans we use to do the cooking, so to speak."

Experiences of the average duration of scale-up from the laboratory to a high-volume commercial plant from the chemical industry could be used as an indicator for estimating that time. Scale-up after laboratory work for the polymers/plastics area (polyethylene, Nylon or Perlon, Kevlar, Biomax/Ecoflex) by thermochemical processes took 6 – 8 years [Runge 2006:655] and probably more than 10 years for bioengineering processes. Evonik Industries (previously Degussa) reported 13 years for an industrial biocatalytic process [Runge 2006:577].

A model for the biofuels industry following the thermochemical path could be the Izumi Biorefinery (a US/Japan cooperation, in operation since 2002 in Japan) which uses Arkenol's concentrated acid hydrolysis technology for the conversion of biomass to ethanol. It took 9 years from completion of base technology developments to deployment, 12 years from ideas and R&D to "demo" deployment [BlueFire Ethanol 2004].

As engineers know, scale-up proceeds in a series of steps, and the scale-up between steps can range from a factor of, say, 10x in the case of a conservative play, to as much as 150x in a single step.

Correspondingly, cellulosic ethanol production has not grown as fast as the industry or the federal US government had hoped it would. An investment firm predicted that cellulosic ethanol companies will be able to supply only 28.5 million gallons by 2010, short of the federal government's 100 million gallon goal [St. John 2009]. The industry acknowledged that it will make a few million gallons of the advanced fuel in 2010, at most, and could fall even further behind the 2011 quota, 250 million gallons [Wald 2009b].

Shell's emphasis on its core competency with regard to the process engineering and particularly the FT-process and the large variety the intermediate syngas provides to produce other commercial industrial products on a large scale referring to existing, proven sub-processes (Figure I.174) represents a strong directional effect for the realities of the future of bioethanol.

Specifically, Shell demonstrated the world's first commercial passenger flight powered by a fuel made from natural gas [Quatar Airlines 2009] after developing and producing jet fuel using a 50-50 blend of synthetic GtL kerosene ("*GTL Jet Fuel.")* and conventional oil-based kerosene fuel.

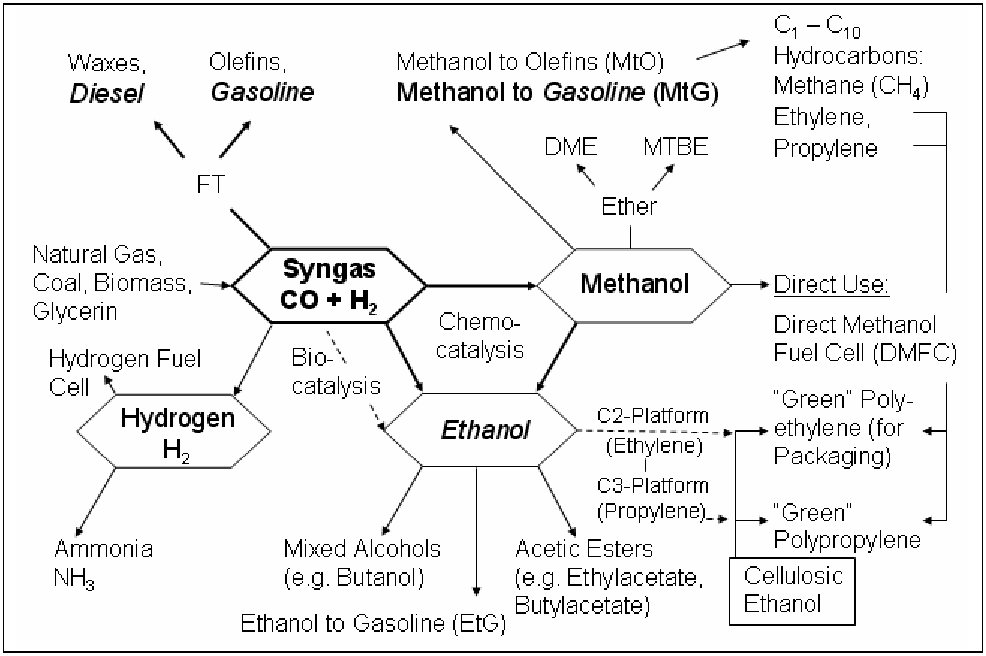


Figure I.174: Syngas routes to selected high value products and applications (DME = dimethylether, MTBE = Methyl-tertiary-butyl-ether, a gasoline additive – "octane-booster").

The flight was the latest step in over two years of scientific work carried out by a *consortium consisting of Airbus, Qatar Airways, Qatar Petroleum, Qatar Science & Technology Park, Rolls-Royce, Shell and WOQOD.* Much of this work was being undertaken at the Qatar Science & Technology Park in Doha. Shell and Quatar Petroleum started building a commercial plant (project Pearl) which should open in 2012 and deliver 1 million tons/a of *GTL Jet Fuel*.

The simplest alcohol (bio)methanol can also be used as a chemical building block for a range of future-oriented biobased products, including bio-MTBE, bio-DME, bio-hydrogen and synthetic biofuels (synthetic hydrocarbons). Furthermore, biomethanol can represent the input for so-called “Direct Methanol Fuel Cells” (DMFCs), as offered successfully by German NTBF Smart Fuel Cell AG (now SFC Energy AG) [Runge 2006:328-335, 623].

Europe and particularly Germany, has a very long history of synthetic methanol. Currently it is produced, for instance, through pyrolysis via syngas (Figure I.174). The first patent to produce methanol via syngas was granted to the chemical giant BASF in 1913; its first large-scale commercial plant started production in 1923 [99].

For centuries, methanol was first produced from pyrolysis of wood, leading to its common English name of wood alcohol or wood spirit (in German Holzspiritus or Holzgeist). Today, China is the largest producer and consumer of methanol in the world. And in 2008 it utilized 3 million tons of methanol (of a total of 45 million tons consumed worldwide) as a fuel blend. [126] Methanol usage in China for other products is: formaldehyde (38 percent), MTBE (20 percent), acetic acid (11percent), fuel use (4 percent), other uses (27 percent) [Engeler 2008].

In China (contrary to the US or Germany) methanol has been approved in 2009 for use as a motor vehicle fuel and as a renewable fuel for transportation. Like ethanol in Brazil and the US, China now permits methanol to be added to pure gasoline so that it can make up to 85 percent of the mixture for use in flex fuel cars (FFVs). As the US has E85, China has M85. However, among alcohols as biofuels methanol has the lowest energy content and stoichiometric air fuel ratio meaning that fuel consumption (on a volume or mass basis) will be higher than other alcohol or hydrocarbon fuels (Table I.82).

Similar to the US, to become (more) independent from crude oil imports, China promotes biomethanol as a biofuel – and also biobutanol (cf. Green Biologics, Table I.95) [Blanco 2009]. In the 1980s in Germany there was a large field test of M15 and M85 fuels sponsored by a German ministry which involved more than 1,000 vehicles and all German automotive firms, the mineral oil industry and many research institutes. [126] But there was no significant follow-up. [126]

More importantly, for biomethanol entrepreneurs, methanol plays a key role as an alternative to petroleum feedstock for the petrochemical industry (MtO, Figure I.174), which brings in the names of chemical giants like German BASF and US Dow Chemical. In particular, there is a strong emphasis on methanol-to-ethylene (MtE) and methanol-to-propylene (MtP) (Figure I.174) processes. Also here China plays a leading role [Heathcote and Fryer 2008]. And recently already the concept of a "methanol economy" has been put forward [Bullis 2006].

Based on gasification of largely municipal waste to syngas the primary focus of the Canadian firm Enerkem (headquartered in Montreal) is the commercial production of cellulosic ethanol. However, its three step process first requires the production of methanol as a chemical building block for the production of ethanol (Figure I.174). Enerkem can sell its methanol as an end-product, or use it as a key intermediate to produce other renewable chemicals.

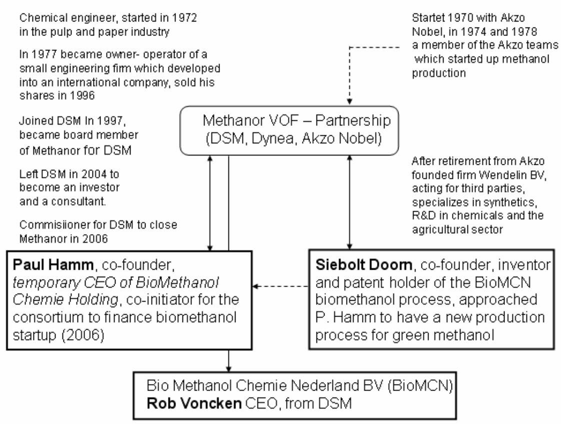
Enerkem announced in 2012 the initial production of cellulosic ethanol from waste materials at its demonstration facility in Westbury, Québec. Its technology has been developed and tested during the past 11 years. Enerkem has already produced cellulosic ethanol at its smaller scale pilot laboratory facility. The newly installed equipment for the conversion of Enerkem's methanol into cellulosic ethanol is now used in combination with the larger methanol equipment already in operation at Westbury [SpecialChem 2012].

With Europe's strong orientation towards biodiesel as a biofuel and its by-product glycerin as a cheap raw material it was almost natural that entrepreneurial ideas are generated around glycerin as a basis for biofuels and other biobased feedstock materials following a biorefinery approach as a commercialization model.

And, indeed, in the Netherlands Bio-Methanol Chemie Nederland BV (BioMCN) introduced a *glycerin-to-syngas* process to produce biomethanol (Table I.87). It is a typical engineering, biorefinery approach to entrepreneurship of founders with profound experience in business and technology ("veterans approach") taking advantage from pre-work of an industrial partnership.

Table I.87: BioMCN showing an engineering-type approach to innovation and entrepreneurship. *)

Company (Foundation) Remarks	**Major Funding**	**CEO, Other Executives, Foundation, Key Researchers; Technology Protection and Position**
Bio Methanol Chemie Nederland BV (BioMCN), Delfzijl, The Netherlands (Nov. 2006) BioMCN claimed to be the first company in the	Main shareholder: the European private equity firm Waterland; remaining shares owned by management and some of the original founders, the Japa-	Rob Voncken CEO; before joining BioMCN fulfilled several positions at Dutch chemical firm DSM in the areas of business development, marketing & sales, general management; was responsible for the management of several outsourcing, divestment and acquisition projects; Siebolt Doorn, co-founder; inventor of the BioMCN technology and co-founder of BioMCN [Ecofys 2006]

world to produce and sell industrial quantities of bio-methanol and the largest 2nd generation biofuels producer in the world. Employees: 2009: 80 Sales (in €): 2007: 101 mio. (net profit €5.7 mio.), 2008: 85 mio. (Net loss 12.9 mio.); Capex 2007: €3.4 mio. Capex 2008: €26 mil., majority on the construction of the commercial bio-methanol plant [BioMCN 2008; BioMCN 2009]. Since March 2008 producing biomethanol in a 20,000 tons pilot plant; in July 2009 successful start-up of a 200,000 tons per year bio-methanol plant. October 2008: winner of the European Responsible Care Award	nese chemical firm Teijin and Dutch investment company NOM [BioMCN 2009]; in 2009 received from Waterland €39M to fund the expansion of the facility to double production capacity to 400,000 tons by 2010 [Lopez 2009]. EOS Demo (Energie Onderzoek Subsidies - Energy Research Subsidy) and IBB-subsidies (Innovatieve BioBrandstoffen) granted total investment subsidies for an amount of €.8.2M; first amount of €0,7M received in 2008; in October 2007 extra financing facility of in total €30M on top of existing subordinated loan (€10M) already granted in 2006.	Paul Hamm, co-founder; co-initiator of the consortium and temporary CEO of BioMethanol Chemie Holding [Ecofys 2006; Van Zanten 2007]. Foundation approach (Figure): technology veterans sharing previous firm affiliations and serial entrepreneurs; a quasi management buyout (MBO); team acquired a natural gas-to-methanol plant with two lines of 330,000 tons per year capacity jointly owned by Dutch firms DSM, Akzo Nobel, and Dynea (Figure) and retrofitted the existing lines; November 2006 – The new owner of the methanol plant is BioMethanol Chemie Holding (BV), a consortium of Econcern, NOM, Oakinvest,. S. Doorn and P. Hamm. Fundamental European patent (EP1897851) represented an *improvement of a known glycerin-to-syngas process*, where liquid glycerol droplets – in a stream of inert gas or steam – are introduced into a catalyst bed; leads to significant carbon deposition on the catalyst and catalyst deactivation; the improvement is that glycerin is not introduced into the catalyst bed as a liquid, but is fed to the catalyst bed as a vapor, together with the necessary amount of steam this results in significantly diminished carbon deposition on the catalyst. **Figure:** BioMCN foundation and founders' interconnections. 

Technology, Goals, Strategy	The innovative and patent-protected process converts crude glycerin, a residue from biodiesel production, into biomethanol via syngas ("glycerin-to-syngas"). The key steps of the process: purifying crude glycerin and then converting it into bio-syngas. Syngas is sent to a methanol converter to produce crude biomethanol, the crude biomethanol is purified by distillation. Continuous improvement of the process on lab scale and pilot plant scale, e.g. regeneration procedure to remove carbon from the catalyst. By using biomass instead of natural gas as a feedstock means supplying the market with a "green" product that has a higher market value. Flex fuel cars can run on any mixture from 100% gasoline up to 85% bio-methanol (M85). Actually, it was a *retrofitting* approach: BioMCN acquired in 2006 a natural gas-to-methanol plant. Methanol to be used as a feedstock in the sense of a *biorefinery* approach for downstream producing, for instance, formaldehyde or acetic acid. Even though Delfzijl is located in the very North of The Netherlands, it can be considered an ideal location due to excellent road, rail and water links. Also, 15% of Dutch chemicals are produced in Delfzijl. The global methanol market was believed to be around 35 – 38.000 kt of which some 20 – 25% is sold in Europe [BioMCN 2009]. Business focus was mainly on Europe as the primary market for BioMCN. In Europe BioMCN claims to have a market share of 5% in the existing methanol markets. Commercialization/revenue model: owner-operator, BioMCN will spend several years concentrating on the production of bio-methanol from glycerin "We are aiming to expand into biorefining but that is a long-term concept which will not be realized for 10 years." [Headline News 2009] It is assumed that most of the revenues currently come from selling biomethanol as an input for the petro-gasoline octane booster MTBE (to oil companies for blending with petro-gasoline).

*) From the firm's Web site if not stated otherwise by a reference; firm's status: early 2010.

BioMCN showed healthy further development. In 2011 BioMCN and the Investment and Development Agency of North Netherlands (NOM) have, together with Visser & Smit Hanab and German giants Linde and Siemens, formed a consortium to build a large scale biomass refinery. This refinery will be built next to the biofuel plant that BioMCN opened in Delfzijl in 2010. This consortium asked the Ministry of Economic Affairs, Agriculture and Innovation (EL&I) for a subsidy. The proposed refinery will be the largest of its kind. The biomass refinery can process approximately 1.5 million tons of residual wood, which will yield more than 500 million liters of second generation bio-methanol [BioMCN 2011].

In line with the historic production of methanol from pyrolysis from wood (via syngas) also acetic acid (as a key component of "wood vinegar" – Holzessig in German) can be obtained from wood pyrolysis. [99, 126] This leads almost directly to ZeaChem, Inc.'s biofuel process.

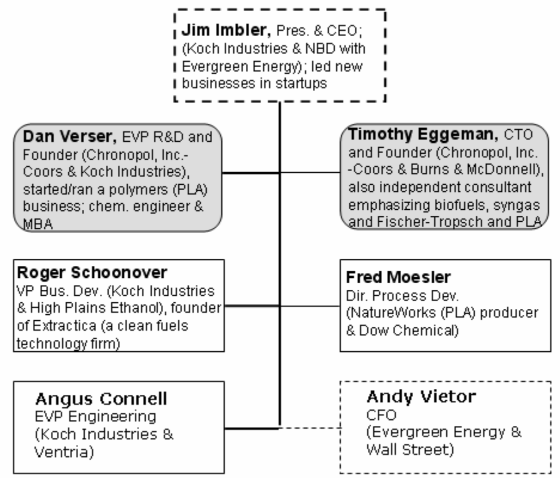
Whereas the bioengineering route usually converts (C6 sugars or C6 and C5 sugars) to bioethanol or biobutanol, Zeachem's bioengineering patented process relies on lignin separation and converts the fermentable sugars into acetate (ethyl acetate, which is the ethanol ester of acetic acid; CH3CO-OC2H5) and then gasifies the remainder, tough lignin and all other, into hydrogen before mixing the two streams in a reaction called "hydrogenolysis" (a chemical reaction whereby a carbon-carbon or carbon-heteroatom single bond is cleaved or undergoes "lysis" by hydrogen) to produce ethanol.

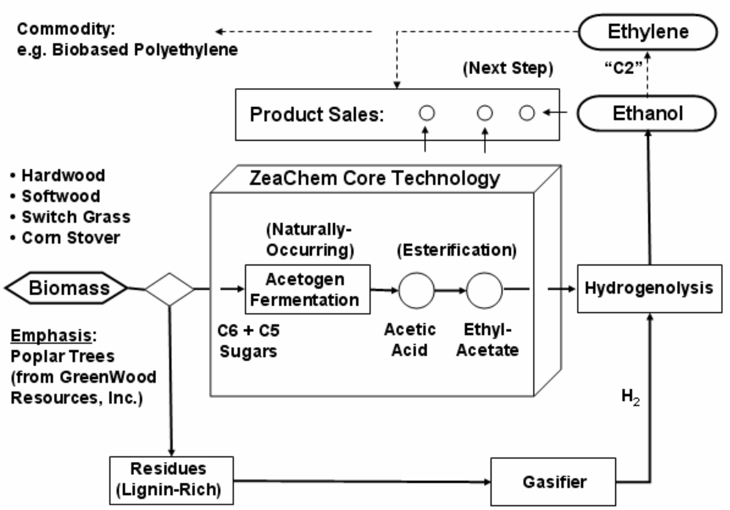
There are two remarkable points: 1) a big refinery rather than oil company appears as an investor; and 2) ZeaChem Inc. did not invent anything. "There's no new bugs, no new equipment. We're taking things that already exist." [Verser 2009] A Lego-type process is followed; only *commercial-off-the-shelf (COTS) components* are used, no unproven technology.

The lessons from ZeaChem entrepreneurship is the focus on people (team), building on experience (what you can do best), timing and persistence. There is a very structured engineering-type approach to financing and risk mitigation. And, as in case of BioMCN, the human component comprises a people's network of shared company affiliations which brings in trust and stability.

Table I.88: Zeachem showing an engineering-type approach to innovation and entrepreneurship using only proven technology. *)

Company (Foundation) Remarks	**Major Funding**	**CEO, Other Executives, Key Researchers; Technology Protection**
ZeaChem, Inc. Lakewood, CO (2002); Incorporated in 2002, founded 1998 – "Two guys in a pickup" [Verser 2009]. Headquarter in Lakewood, (CO)	Funding together with profit from service contracts and grant funding $34M Series B (2008), several VCs and Valero Energy Corp., the largest pe-	According to its EPC services Burns & McDonnell ZeaChem has 30 employees, half of whom work in the ZeaChem R&D facility in Menlo Park, Calif., where scientists and engineers conduct laboratory-scale research to prove the theoretical chemical viability of each step of manufacturing. **Figure 1**: ZeaChem Management Team – experienced persons ("veterans"} with interpersonal relationships (and co-working).

and R&D laboratory facility in Menlo Park (CA). 2009 employee number: 25 [Verser 2009] Series A financing for proved out technology at lab scale, Series B financing for demo plant	troleum refiner in the US; $6M Series A (2006). $25M grant from the US Department of Energy (DOE) as support for construction of the first cellulosic biorefinery with capacity of 250,000 gals per year (GPY); should be online by the end of 2010; more DOE grants (e.g. no. DE-FG36-03GO13010 of 2002/2003)	 Unique balance of knowledge and experience in plant engineering, refining, biological, chemical and ethanol process. Strong backgrounds regarding business management, project and capital deployment, chemicals/energy production and risk management Numerous process patents mainly by T. Eggeman and D. Verser
Technology, Goals, Strategy Addresses existing deep markets; Flexible product platform, bioethanol just one product; Bioerefinery-approach: Start with ethanol and C2 platform, expand to C3 chain (Figure I.174); Use known microbes, equip-	"We do not depend on any new scientific input ... they all have been done at very large scale." [Verser 2008] Claims: The patented process they utilize offers the highest yield at the lowest costs, with the lowest fossil carbon footprint of any known biorefining method. ZeaChem uses *naturally occurring bacteria*, an acetogen, in its fermentation process. There is no genetic modification to the bacteria. A key strategy for ZeaChem is to co-locate its biorefineries with dedicated energy crops. Contracted with Greenwood Resources of Oregon to supply hybrid poplar trees for their feedstock (integrating the process with the forestry industry), a tree farm with a radius of five miles, that is about 50,000 acres, and that would supply one ethanol plant of roughly 100 million gallons (per year); will begin construction of its Oregon demo facility by the end of 2009. Has selected CH2M HILL as the Engineering, Procurement and Construction (EPC) contractor for its first biorefinery. ZeaChem's technology is *a parallel hybrid system* of gasification and	

ment, processes; Focus on management team with execution on technical and commercial level; Have strategic support; Recurrency: Expand technology into other products and repeat; Maintain the option of awarding direct licenses to qualified parties. ZeaChem has a number of potential business segments that will necessarily involve strategic partners	fermentation: a Lego-type “hybrid” fermentation esterification hydrogenolysis process. (“indirect” ethanol fermentation and chemically high efficient, well established hydrogenolysis) – current products and future C2-platform products. A differentiator: ZeaChem’s ability to produce a range of cellulosic biobased products to serve a variety of market sectors; produce many chemicals and fuels within various carbon chain product groups; production facilities will be capable of producing the products that will yield the best margin – should market conditions change, a ZeaChem facility will have the option of changing the products produced. **Figure 2:** The ZeaChem Proceess.  Revenue Model: 1. Able to produce ethanol at <$1/gal 2. License technology for early plants, 3. Sell products, and monetize markets and geographies. Moving forward by combinations: 1. Strategic investors. 2. Government support Partnerships: Strategic – Valero Energy Corp. (acts also as investor), Feedstock: Greenwood, VC: such as MDV. Reduce risk by alliances along entire value chain Feedstock supply, Technology (successful demo plant for core technology, warrantees from

	non-core technology vendors)
Risk Mitigation: [Imbler 2009] Bottom-Line: Have more money than you need Once technology established, utilize traditional project finance	**Risk** / **Mitigation Strategy** Demo. Capital Cost: Freeze design; provide explicit project definition Scale-up: Establish clear performance goals for each level of scale-up; design for process flexibility Integration: Use Lego block deployment if possible to minimize potential of integration issues Technology: Keep plant #1 based on known technology and processes where possible (remember risks are multiplicative) Engineering: Use experienced knowledgeable EPC, but maintain tight supervision on daily basis Operations: Evaluate partnering with experienced operator Economics: Fix feedstock costs and sellout production from plant to 3rd party credit worthy entity Funding: Ensure business has adequate funding accessing a variety of different sources

Risk	Mitigation Strategy
Demo. Capital Cost	Freeze design; provide explicit project definition
Scale-up	Establish clear performance goals for each level of scale-up; design for process flexibility
Integration	Use Lego block deployment if possible to minimize potential of integration issues
Technology	Keep plant #1 based on known technology and processes where possible (remember risks are multiplicative)
Engineering	Use experienced knowledgeable EPC, but maintain tight supervision on daily basis
Operations	Evaluate partnering with experienced operator
Economics	Fix feedstock costs and sellout production from plant to 3rd party credit worthy entity
Funding	Ensure business has adequate funding accessing a variety of different sources

*) From the firm's Web site if not stated otherwise by a reference; firm's status: early 2010.

Zeachem's "indirect" ethanol fermentation which combines a thermochemical and a bioengineering (fermentation) approach to bioethanol corresponds to a "*hybrid*" process based on syngas as schematically outlined in Figure I.175.

By the end of 2011 ZeaChem launched its 250,000 gallon per year core process, at their Boardman, Oregon, biorefinery. "'We came in on schedule and significantly under budget," reflected ZeaChem CEO Jim Imbler. "We had a guaranteed maximum price, but in this case we received a rebate check. One of our long-term VCs said to me I've seen a lot of things, but I have never seen a check come back." "It came down, we think, to the choice we made to use known processes, known vendors."

ZeaChem integrates feedstock from a portion of GTFF's residual fiber with local agricultural residue suppliers to achieve feedstock costs 50 percent less compared to Brazilian sugar cane and 80 percent less, compared to corn based processes [Lane 2012l].

In Colorado, Zeachem has received a conditional commitment for a $232.5 million loan guarantee from the US Department of Agriculture's 9003 Biorefinery Assistance Program [Biofuels Digest 2012]. Development of the first commercial biorefinery is already underway. The facility is expected to have capacity of 25 million or more GPY, and is expected to be competitive, upon completion, with $50 oil, with a targeted $1.96 operating cost per gallon. Its first commercial plant will be located adjacent to

ZeaChem's 250,000 GPY integrated demonstration biorefinery in Boardman, which is a logistics and transportation hub for the Columbia River system through the Port of Morrow and is projected to be operational by late 2014. Under the conditional commitment, ZeaChem must meet specified conditions before the 60 percent loan guarantee can be completed, and must also source the loan. Silicon Valley Bank was the bank of record for the project.

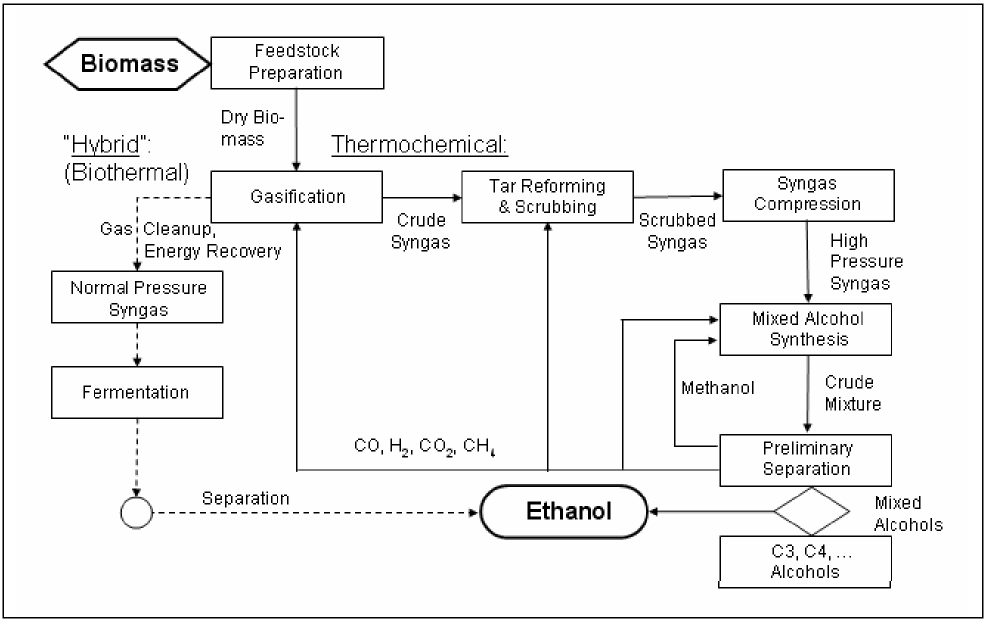


Figure I.175: Flow diagram of the thermochemical and a "linear hybrid" approach to bioalcohols.

The total project cost for the 25 million gallon per year biorefinery is estimated to be $390.5 million, and the remainder of the project cost shall be covered through equity contributions by ZeaChem and its investment group [Biofuels Digest 2012].

The news of ZeaChem's startup came at a time of significant blow-back for the cellulosic biofuels movement and sector, after the US EPA waived down the scheduled 500 million gallon mandate for cellulosic ethanol, first proposed back in 2007 when the current Renewable Fuel Standard (RFS) was developed, down to 10.45 million gallons for 2012.

The overall mandates for 2012, under the Renewable Fuel Standard, are as follows expressed in ethanol-equivalent gallons (actual volumes in parentheses)

- Biomass-based diesel: 1.5 billion gallons (1.0 bil. gal)
- Advanced biofuels: 2.0 billion gallons (1.3–1.5 bil. gal)
- Cellulosic biofuels: 10.45 million gallons (8.65 mio. gal)
- Renewable fuels: 15.2 billion gallons (14.5–14.7 bil. gal).

A.1.1.4 The Special Algae-to-Biofuels Boom

As for the biomass-to-biofuel movement the same occurs for the third-generation biofuels. For the emerged boom of algae-to-biofuels, "*everything new was old again*." In the US the National Renewable Energy Lab (NREL) in Golden (CO) led a $25 million study of algae from 1978 to 1996, before money dried up and government research shifted to ethanol [Gold 2009b; DOE 2009]. DOE canceled the program in 1996, saying *the process could not be made cost-competitive with petroleum refining* [Voith 2009b]. Similar research programs and experiments were persued in Germany, also with no promising results and corresponding endings.

Furthermore, all kinds of research avenues were explored, but when the funding shriveled during later years, knowledge, experts and know-how were lost. Programs that started during the late 1970s and early 1980s were stopped in the years of low energy prices that followed. In the US, now, there was all this biofuel work going on, and they are all going back to that public domain research. In the context of the biofuel boom interest in algae-based biofuels also exploded and venture capital and corporate money flowed also into this field. It is estimated that over 75 percent of the companies who had algal aspirations in the1980s and 1990s no longer exist [Rapier 2009c].

A notable difference to bioalcohols and biogasoline, however, is that past efforts with algae focused essentially on research rather than development and demonstration [Pienkos 2008; Pienkos and Darzins 2009]. The 18 years of research at the National Renewable Energy Laboratory (NREL) yielded a lot of knowledge, but it resulted in nothing resembling a commercial product or process. In the best-case scenario, when all is said and done, algal biofuel could cost $50 per barrel. But that will not happen anytime soon, and it could take a decade [Madrigal 2009; 2007].

There are about 30,000 species of algae. "100 are well known and between 15 and 20 are used for production." [Robinson 2009]. Hence, there is plenty of scope for competition. But the diversity of algae also meant that there is scope to produce niche algae for different conditions. And it is unlikely that there will be a single type of algae that work well in the cold climates, the tropics, salt and fresh water.

Furthermore, there is no parallel agricultural enterprise equivalent for cultivating algae at a similar scale. "We don't have the infrastructure yet to grow literally thousands of acres, maybe millions of acres of algae," NREL's researcher Darzins said. In short, the science of algae cultivation (algaeculture), agronomy-for-algae, does not exist.

“Algae growers” are still learning how to protect their fragile crop from predators and invasive species.

It was thus clear that a significant basic science and applied engineering R&D effort including a rigorous techno-economic and life-cycle analysis (LCA) will be required to fully realize the vision and potential of algae [DOE 2009]. In this regard, a recent publication [Lardon 2009] reported algal biofuels would not have a positive energy balance; in other words, you had have to put more energy in than you would get out.

Algae constitute single-celled or simple multi-cellular photosynthetic organisms. They produce their own food by using energy from sunlight to synthesize complex molecules from carbon dioxide and water – both in sea and fresh water. Algae range in size from microscopic organisms to giant seaweeds some hundred meters in length (micro- versus macro-algae). They contain chlorophyll and other pigments which give them a variety of colors. They manufacture their food by photosynthesis (Figure I.177). Inside their mushy cells, algae contain up to 50 percent vegetable-oil-like lipids by dry cell weight. Genetic engineering claims it can tailor the oil composition, productivity, and other traits of the algae.

> Algae are very interesting: they created the oxygen (Figure I.178) in our atmosphere, and also oil, both essential as a basis of our existence.

The close connections of algae to petro-oil are as follows. “Geologists view crude oil and natural gas as the product of compression and heating of ancient organic materials (i.e. kerogen) over geological time. Today’s oil formed from the preserved remains of prehistoric zooplankton and algae, which had settled to a sea or lake bottom in large quantities under anoxic conditions. Over geological time the organic matter mixed with mud, and was buried under heavy layers of sediment resulting in high levels of heat and pressure (known as diagenesis). This caused the organic matter to chemically change, first into a waxy material known as kerogen which is found in various oil shales around the world, and then with more heat into liquid and gaseous hydrocarbons in a process known as catagenesis.” [100]

In principle, for biofuels algae offer many advantages over traditional oilseed crops, such as corn, soybeans or rapeseed.

- Better Yield:
  Algae yield far more oil than traditional oil seeds. Up to 50 percent of an algae’s body weight is comprised of oil, whereas oil-palm trees – currently the largest producer of oil to make biofuels – yields approximately 20 percent of their weight in oil. Although many different parts of plants may yield oil, in actual commercial practice oil is extracted primarily from the seeds of oilseed plants.
  The draw is that algae have the potential to produce up to ten times more oil per acre than traditional biofuel crops such as oil palm [Waltz 2009b].

- Rapid Growth:
  Algae grow up to 15 times faster than oilseed crops grown on land. According to a rule of thumb, bacteria will divide once an hour and algae once every day.
- Better Use of Land:
  Algae can be grown in marginal lands in places away from the farmlands and forests, thus minimizing potential stresses to our food chain and ecosystems.
- Reduced Pollution:
  Algae can reduce pollution by utilizing via photosynthesis large amounts of potentially harmful CO2 from industrial emissions to grow rapidly.
- Frequent Harvests:
  Daily harvesting diminishes the risk of crop failures in comparison to terrestrial plants.
- Algae may produce directly bioethanol (sugars to ethanol, Figure I.178) or other fuels by fermentation.

Algae provide carbohydrates, proteins, and lipid oils, essentially triglycerides (Figure I.178) which may be converted to fatty acid methyl esters (FAMEs) and biodiesel. Considerable research has focused on using algae for the production of hydrogen gas (H_2, Table I.92). As a target for commercialization and production of biofuels the algae focus so far was on the following:

- Food and feed applications: after extracting the algae oil the remaining protein-rich algae biomass can used for food and feed;
- Nutritional additives and fine chemicals: fine chemicals for pharmaceuticals and cosmetics or, for instance, astaxanthin pigments as adding color to the flesh of farmed fish or as antioxidants. Fatty output that makes algae a cosmetic ingredient can also be used for biodiesel. Nutritional and health care additives are produced as capsules, tablets and correlative;
  food- and probably also cosmetics-related products may encounter acceptance issues in various societies if genetically modified objects are used
- Sequestration of carbon dioxide (CO2): CO2 is absorbed by algae, CO2 is the feed for algae (Figure I.177)
- Raw material for biogas plants: algae biomass can serve as a raw material for power generation in combined heat and power (CHP) plants; anaerobic digestion is a series of processes in which microorganisms break down biodegradable material in the absence of oxygen, here to biogas.

For most of these applications rather than open cultivation ponds (or algae enclosed in plastic tubes) that are exposed to the sun closed photobioreactor systems with various layouts and shapes are used. This prevents any exposure to heavy metal contamination or dust, sand or microbiological contaminations (voracious microbes that feed on algae “like a pack of jackals at a buffet”) and guarantees consistent and reliable supply of algae. Their use in health care requires the products to be free from pesticides and herbicides.

Bioreactors allow controlling the growth of algae through feeding and control of algae exposure to radiation.

The below Figure I.176 illustrates qualitatively the market value of the various algae products in relation to their market volumes or anticipated volumes, respectively, for a state of commercial scale offerings of biofuels. However, it must be considered that increasing value is or may be associated with increasing concern about genetically modified objects as components of the products. For the highest value offerings it will be the consumer (of a particular society) who decides upon the purchase. High value products can fetch high prices, but some of these markets already have strong players.

Cultivating algae in open ponds or other open systems may encounter similar problems as agriculture do, namely the weather in terms of variations in temperature and sunshine as well as wind or storm which may bring dirt, dust and pollution to the algae.

With regard to biofuels, how to grow algae cheaply on a large scale is one of the biggest challenges facing the industry. When cultivating algae difficulties may be encountered when trying to *scale-up*. In large numbers, the organisms sometimes *crowd* one another out and emit toxic waste that halts the production process. That means, even if you can do it in a test tube, getting the same kind of quality on a large scale could be an issue.

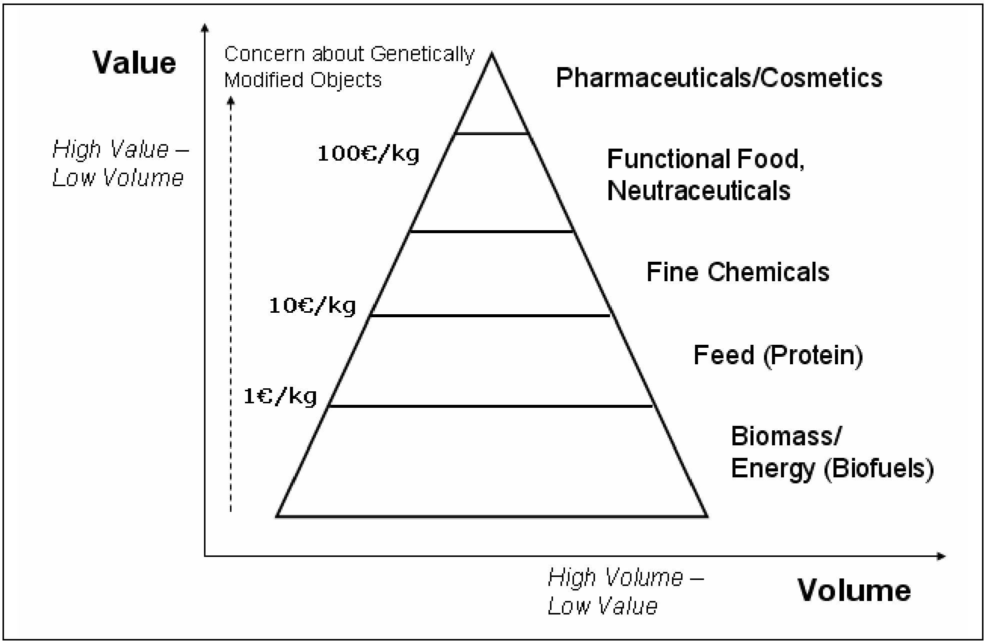


Figure I.176: The algae value ladder for different offerings.

Also related to crowding in open ponds there is the issue of the necessary *radiation exposure* (from sun light above): In a crowded algal assembly only the layers nearest to the surface will get sufficient light (“self-shading”) which limits productivity.

Finally, one approach for NTBFs targeting biofuels from algae would be to focus also on the high value-low volume part of algae (Figure I.176) as co-products that can be an additional source of revenue and can improve the overall economics of a biofuel process.

To overcome the problems of scale, cost and price competitiveness with petro-oil companies will be working with a different combination of inputs, conversion methods, extraction techniques, and outputs (Figure I.177). Algae have been sampled from local sources, extreme environments, and genetics labs. They are grown in sunlight and in the dark, in high-tech tanks (bioreactors) and low-tech ponds.

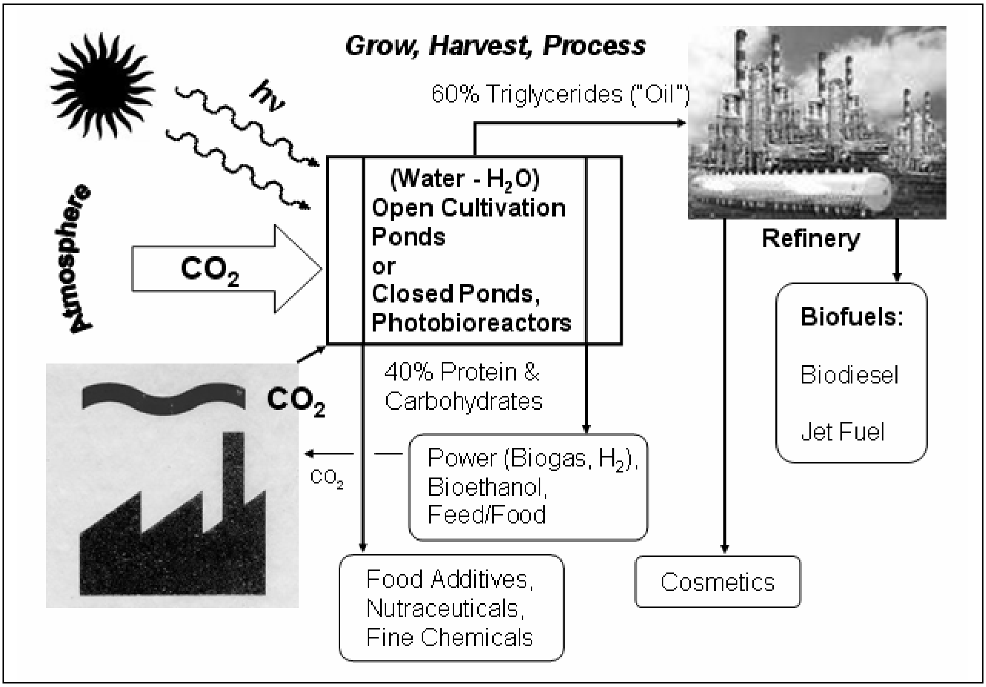


Figure I.177: Algal biomass output streams based on (sun) light and carbon dioxide (CO2) from the atmosphere or a nearby CO2-emitting plant as algae feed and major products and applications.

Today, there is no commercially viable algae approach to biofuels. Production costs need to come down by about a factor of 10. For instance, when the algae first must be harvested, the open-pond method gets expensive and a cost-effective dewatering process must be put into place. On the other hand there is a capital cost ladder associated with lowest cost for open ponds, then closed ponds and highest capital costs with closed photobioreactors.

It was estimated in 2009 that the best process and strategy will take three to five years to reach commercialization [Voith 2009b]. According to NREL researcher Darzin it will take at least five or ten years before anyone finds a way to produce commercial quantities [Wheeler 2009].

Algae as a biomass input exhibits generally a broad versatility depending upon whether algae oil or whole algae is used for further processing. It is also possible to use algae as input for a gasification route to biofuels (Figure I.175). Biogas produced from algae contains essentially methane (CH4) and carbon dioxide. And when methane is used for power generation a closed loop for CO2 is generated (Figure I.177).

Algae grow in freshwater or seawater (salt water). During its growth they produce freshwater (2 gallons of seawater to make 1 gallon fresh water) according to Figure I.178.

In the context of bioethanol, it is interesting to note that cyanobacteria, formerly called blue-green algae, also produce ethanol which is the basis for the entrepreneurial operations of Algenol Biofuels (Table I.91). Genetic manipulation transformed each cell into a small "ethanol factory.

There are notable firms, one being an NTBF, which are successfully active in the high value nutritional additives and fine chemicals algae business. In the US (in Kailua Kona, Hawaii) there is Cyanotech Corp., incorporated in Nevada in 1983, with Common Stock trading on the NASDAQ Capital Market. Cyanotech (revenues $13.9 mio. in 2009, $17.0 mio. in 2011) claims to be the world's largest producer of natural Astaxanthin for human consumption.

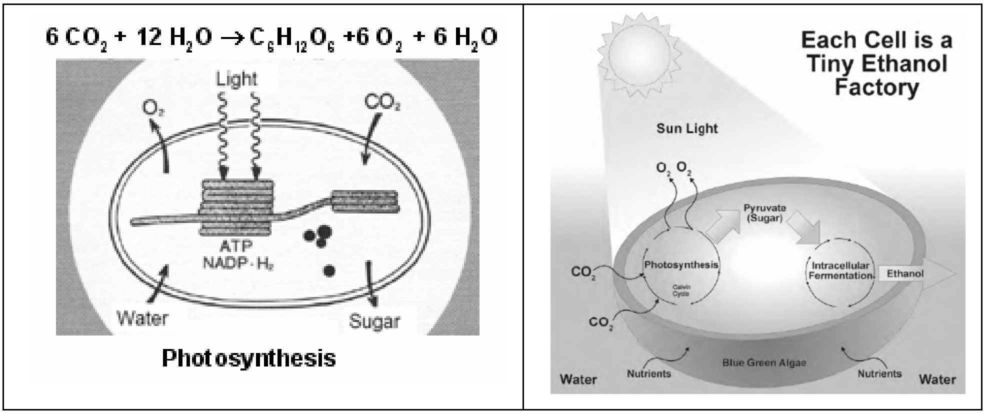


Figure I.178: How algae produce directly bioethanol: Direct To Ethanol® technology (Source – Right: [Woods 2009a; Ahlm 2012:2]).

In Germany, BlueBioTech GmbH [Runge 2006:577], founded in 2000, is rather successful in commercializing algae as food additives and for functional food and cosmetics. It specializes in research, development, production and sales of microalgae as well as natural dietary supplements, feed additives and aquaculture feed. It also provides custom manufacturing services. Further directions target co-operation with industrial partners to develop and produce microalgae and/or extracts, for instance, as active pharmaceutical ingredients (APIs). It sells branded food additives (BluBio® brand) to consumers in capsules, tablets and correlative directly via its Web shop or through common distribution channels.

BlueBioTech GmbH has a group structure. In 2002 BlueBioTech International GmbH was founded as a hub for marketing and distribution activities with partners around the globe. It has several locations in Germany. Particularly, R&D is located in Germany as well as plants for processing algae powders.

BlueBioTech appeared as the sole manufacturer, with German expertise and technology, of microalgae in China. The capacities of the facilities in Germany were not large enough to fulfill the great market demand. Therefore, BlueBioTech International produces larger amounts of powders of *Spirulina* and *Chlorella* (the names of the most important microalgae species) through a joint venture in China on a Chinese sun island. Here there is no farming or industry. "The climatic conditions at the certified algae farm are excellent. The water, in which the algae grow, comes from a depth of 120 meters. It can't be any purer!" Currently, ca. 400 metric tons are produced per year.

As a private firm (LLC) BlueBioTech keeps a low level about their revenues. It is known that the firm expected revenues of €5 million in 2003 and the founder confirmed €6 million. Hence, one would estimate revenues of €10 to €15 million in sales for 2009.

Concerning algae for biofuels and the role of startups and Big Oil a situation emerged similar to that for biomass-to-biofuels: We see alliances of startups or NTBFs with giant oil companies, such as Shell, ExxonMobile or Chevron, or chemical giants DuPont (Table I.83) and Dow Chemical or with other large companies. Others active in the algae-biofuels industry said *ExxonMobile's investment validated the sector.*

The oil industry's view is reflected by ExxonMobile's view of the area, as expressed by a vice president at ExxonMobil Research and Engineering Co. (Emil Jacobs, italics added):

> "Growing algae does not rely on fresh water and arable land otherwise used for food production. And lastly, *algae have the potential to produce large volumes of oils* that can be *processed in existing refineries* to manufacture fuels that are *compatible with existing transportation technology and infrastructure*."

> "This is not going to be easy, and *there are no guarantees of success*." The project (with SGI; Table I.83) involves *three critical steps*: identifying algae strains that can produce suitable types of oil quickly and at low costs, determining the best way to grow the algae and developing systems to harvest enough for commercial purposes [Porretto 2009].
>
> "We *pulled together a pretty high-powered team* ("think tank approach") to look at alternative energy sources and we *looked at all biofuels*." After examining for ability to scale-up "meaningfully," technical challenges, environmental impact and economics, ExxonMobil arrived at algae, Jacobs said [Lemos-Stein 2009].

Also Chevron seemed to think that algae will provide the biofuel of the future [Scheffler 2009]. Similar to ExxonMobile, also Dow Chemical made excessive due diligence [Woods 2009a] before it announced plans to build together with Algenol Biofuels a $50 million pilot plant at Dow's huge industry complex in Freeport that will test Algenol's technology on a large scale.

The project was focused with regard to several important implications. It could point the way to a more sustainable path for making ethanol. It also could help determine the feasibility of using biofuels not just to power cars, but to produce common building block chemicals (Figure I.174) currently derived from fossil fuels. This means it emphasizes the biorefinery concept (Table I.91).

Royal Dutch Shell established a joint venture in 2007 with HR BioPetroleum to build a pilot facility for growing marine algae and producing algal oils that can, in turn, be used to make biofuels. HR BioPetroleum Inc., incorporated in the State of Delaware and headquartered in the State of Hawaii, is a developer of large-scale microalgae production technology. It is a University of Hawaii, School of Ocean and Earth Science and Technology based company. [102] It offers algae products, such as algae oil, biodiesel, and animal feed proteins; carbohydrates for the production of ethanol and petroleum-based products; and military jet fuel. The joint venture was called Cellana LLC and Shell took the majority share.

Cellana sees itself possibly best positioned in the race to algae biofuels. *As for cellulosic alcohols, to be of any significance, algae technology needs to be scaled-up. Any aspiring algae company needs to find a route to mass markets. One route is to do this with a global partner, big enough to handle the technology risk.* For an algae company to be attractive for a large partner (or, to attract funding from any other source), it needs to have the right competences, and have structured and solid programs as part of its business plan (Table I.89).

Cellana should construct an algae-oil production facility to produce feedstock for biodiesel. The 3 MGY pilot plant was next to the Maui Electric power plant at Maalaea

(Hawaii) on the Kona coast of Hawaii Island. It would make the Maui Electric plant's CO2 emissions as feedstock for the algae [Lane 2008].

Assuming everything occurs successfully as planned the first phase of the commercial facility was envisioned to be in operation by 2011. The site, leased from the Natural Energy Laboratory of Hawaii Authority (NELHA) [101] , is near existing commercial algae enterprises, primarily serving the pharmaceutical and nutrition industries. The facility would *grow only non-modified, marine microalgae species in open-air ponds using proprietary technology*.

An academic research program supported the project, screening natural microalgae species to determine which ones produce the highest yields and the most vegetable oil. The program included scientists from the Universities of Hawaii, Southern Mississippi and Dalhousie, in Nova Scotia, Canada. This demonstration plant would be an important test of the technology and critically of commercial viability. [102]

Table I.89: Innovation architecture and business plan components for the Shell – HR Biopetroleum joint venture Cellana, LLC. *)

Professional, experienced management („veterans approach")	Edward T. Shonsey, CEO and Director, HR BioPetroleum, Inc. served e.g. as Executive VP, Internal Development of Verenium Corp. and as its Interim CEO and also CFO; also President and CEO of Syngenta Seeds Inc. C. Barry Raleigh co-founded HR Biopetroleum, Inc. in 2004; served as its Chairman and President; he is an experienced manager of large research organizations.
Top (experienced) algae scientists („veterans approach") Technology has been validated in production of algae oil and antioxidants/carotenoids such as astaxanthan, at pilot operation located in Kona. Over a period of several years, Dr. Mark Huntley, CSO and a co-founder of HR Biopetroleum has utilized a proprietary two-stage algae cultivation system at this site; he overcame a number of key challenges – namely, open-pond contamination and low productivity.	Mark Huntley Chief Science Officer, co-founded HR Biopetroleum, Inc. in 2004, is a thought-leader in marine biological sciences generally and algae cultivation technologies specifically; has been active in algae-related research and development for more than 20 years; held research faculty positions at both the Scripps Institution of Oceanography and the University of Hawaii. Huntley held also a senior management role for 10 years in a special program; as an entrepreneurial CEO he took Aquasearch Inc., a marine biotechnology company focused on the production of astaxanthan and other value-added products from cultivated marine microalgae, from startup to a public market valuation of $200 million in four years; is skilled at organizing interdisciplinary R&D programs.

Algae production experience The key advancement made by Huntley and his co-inventor, Redalje, was to couple the continuous, large-scale production of a pure culture of algae in the sterile, controlled photo-bioreactors with the larger-capacity open ponds used for large-scale production	Dr. Donald Redalje co-founder and Member of Scientific & Technical Team, co-founded HR BioPetroleum Inc. and served as a Member of its Scientific & Technical Team; is a leading expert in microalgae physiology and biochemistry; He holds numerous patents in the area of marine biotechnology and is a co-inventor of the ALDUO™ process.
Structured programs	Strain selection, cultivation development, extraction, scale-up, product development
Strong partners: a) Scientific and b) commercial	a) Cellana has an academic research program including scientists from the Universities of Hawaii, Southern Mississippi and Dalhousie, in Nova Scotia, Canada b) capacity to take technology risk, professional execution, professional culture (Shell)
Location, pilot facility, Proximity to scientific and commercial partners	Will make the nearby Maui Electric Powerplant's CO2 emissions as feedstock for the algae; the "Kona Demonstration Facility" (KDF) on the Kona coast of Hawaii Island was leased by Cellana from the Natural Energy Laboratory of Hawaii Authority (NELHA); was also near existing commercial algae enterprises, primarily serving the pharmaceutical and nutrition Industries.
CO2 feed for algae	Access and permits to operate, piping etc. from Maui Electric plant to the adjacent algae facility; non-modified, marine microalgae species in open-air ponds
Sales contracts	Vegetable oil and protein/carbohydrates
Commercial roll-out plan	?

*) From the firm's Web site if not stated otherwise by a reference.

However, as observed for German CHOREN, in 2011 Shell withdrew from the project set up according to best practice and endowed with many resources (cf. also the approach of venture capitalist Vinod Khosla; Table I.98). H R BioPetroleum acquired Shell's shareholding in Cellana in January 2011; HRBP became the sole owner of Cellana, including its six-acre demonstration facility in Kona, Hawaii. Shell provided an undisclosed amount of short-term funding for Cellana during the transition. In 2011, it was one of the most advanced operational demonstration facilities among algae-to-biofuel organizations and companies in the US.

The envisioned first phase of the commercial facility to be operational by 2011 did not materialize. Still in the research and development stage, the company had been working toward developing a commercial facility on Maui by 2013. Obviously, there again was the issue of scaling-up. But, the focus on breeding and growing only non-modified, marine microalgae species and strain selection introduced another obstacle.

HRBP commented: “We will continue to operate Cellana’s Kona demonstration facility and to continuously improve the economics for growing marine algae using HRBP’s patented process.” “Based on HRBP’s and Cellana’s results to date, we believe this technology holds great potential for the economical production of algae and algae-derived products for applications within the aquaculture and animal feed markets, as well as for the production of algal oil for conversion into biofuels.” [Cocke 2011; Algae Industry Magazine 2011]

Biofuels Entrepreneurship Related to Algae in the US and Germany

In 2009 in the US there were about 100 startups [Voith 2009b] and worldwide there were an estimated 200 algae companies [Waltz 2009]. In this technologically highly risky field the American GreenFuel Technologies was the first high profile algal concern to go under, but it would not be the last. The prominent startup GreenFuel, which grew out of Harvard University and MIT research (founded in 2001, staff of 50 in early 2009 [Kanellos 2009b]), went bust early in 2009 after blowing through $70 million [Madrigal 2009].

Greenfuel raised millions of dollars for R&D, had a bioreactor development arrangement with the German firm IGV (Institut für Getreideverarbeitung) [Schibilsky 2008] and landed a high-profile deal in Spain to erect test facilities for an algae farm project. The multi-year deal in Spain was worth $92 million to build greenhouses that grow algae, which can be harvested for vegetable oil to make biodiesel or to make animal feed. The project developer was Spain’s Aurantia; the algae would be fed sunlight and carbon dioxide from the Holcim cement plant near Jerez, Spain.

Processing was in vertical thin-film algae-solar bioreactors. Getting the whole thing to run smoothly, though, was tougher than expected. The company also found its system would cost more than twice its target [Kanellos 2009b].

The week GreenFuel folded, the DOE awarded an Arizona utility $70.6 million to scale-up the firm’s technology [Waltz 2009]. Additionally, Mark Edwards cited by Rapier [2009c] also argued that GreenFuel made “some serious mistakes in executing strategy.” “We are a victim of the economy,” said (a representative of) a VC company which invested in Greenfuel.

However, the company had also been chronically saddled with delays and technical problems. In 2007, a project to grow algae in an Arizona greenhouse went awry when the algae grew faster than they could be harvested and died off [Rapier 2009b]. In retrospect GreenFuel's claims were viewed so overblown that they "became a joke" [Waltz 2009a].

And generally, there was *much suspicion about the claims of algae startups*, with regard to their technological development state, prediction of time when fully commercializing their technology and particularly with regard to numbers of quantities of biofuel (gal/ac/yr) to be obtained from land. And it was also questioned in how far data obtained on the lab scale will also be valid for large scale production.

Finally, several analyses pointed out algae firms' claims of productivity to violate various physical laws. Near-term technologies may allow algae to produce up to 6,000 gallons of oil per acre per year. "If you really push the limits, then maybe 10,000 gallons per acre," commented a researcher at a National Laboratory. "This figure could improve with advances in cultivation, species selection, breeding and genetic modification, but only to a certain extent. The laws of thermodynamics and the limits of photosynthetic efficiencies just won't allow it." "When you see 20,000 or beyond – that's total bologna." Yet there are companies claiming they can make up to 100,000 gal/ac/yr, and raking in tens of millions in investment based on those promises.

There was a broad opinion that "only a handful of companies are really serious." [Rapier 2009; Waltz 2009b] Wesoff [2009] presented the citations: 1) "As soon as I see an article touting algae's production of oil per unit area over terrestrial plants – I know the author(s) are clueless about the financial economics of algae fuel processing."; 2) "Bottom line – in our opinion the reality of economically viable algae fuel production is still quite a few years in the future – unless someone finds a truly novel short cut through the Laws of Thermodynamics and basic economics."

Correspondingly, there is a serious *credibility issue* for most of the numerous algae startups entering the scene and adding to the "algae bubble." "Most algae-to-fuel companies refuse to reveal much information about their technologies, which has led to more skepticism." [Waltz 2009b]

> Hence, one of *the basic prerequisite to start an algae firm is to get credibility*, for instance, by corporate venturing of big firms in the startup or research or development alliance agreements with big firms, public research institutes or universities, and creating an advisory board with scientists with high reputation.

After a proof-of-concept in the (research) laboratory in many cases the development status of algal startups is demonstration on the level of a Feasibility Assessment Unit (FAU).

In the US Solazyme which established an alliance with Chevron (Table I.83) was the first NTBF entered the algae biofuel field in 2003, after which the algae field has attracted many entrants. As Virent Energy Systems (Table I.85) Solazyme has its technological roots in hydrogen (H_2) generation. This occurred while the "Zeitgeist" of "The Hydrogen Economy" [Runge 2006:325] was in full swing.

With its growing investor population and grant acquisitions, strategic partnerships, and a varied product line (not wholly focused on biofuels) based on its platform technology, Solazyme was assumed to be able to weather future storms. Solazyme not only created biofuels for the transportation industry, but was experimenting with ways to tailor its processes and products for the cosmetic and food and feed industries (Figure I.176).

By the end of 2009, Solazyme has produced only limited quantities of biofuels, including several hundred thousand liters to the US military, which is seeking to promote alternatives to conventional fuels and it focused on the high margin areas of the algae business (Table I.90).

Table I.90: Solazyme's approach to biofuels and additionally high value products using algae. *)

Company (Foundation) Remarks	**Major Funding**	**CEO, Other Executives, Foundation, Key Researchers; Technology Protection and Position**
Solazyme, Inc. South San Francisco (CA) (2003) A renewable oil and bioproducts company utilizing innovative algal biotechnology Employees: 2006: >20, [Wilson 2007], 2007: 33 [ZoomInfo 2008], 2008: 45 (late '08 60) [Melendez 2009], 2009: 65 [Melendez 2009].	[CrunchBase 2009b] Latest round $7M Series C, brings the total funds to $76M; will be used for commercialization of its technology; Solazyme added $12M in an interim round standing at $57M [Lemos-Stein 2009] $45.4M, 8/27/08 (?) Total Investment:	Jonathan Wolfson CEO and co-founder; overseeing the management team and strategic direction of the company; held a variety of positions in finance, business, and law; was a co-founder and President and Chief Operating Officer of InvestorTree, a financial software and ASP services firm; also worked as an investment banker for Morgan Stanley, in the M&A department of Fried, Frank, Harris, Shriver & Jacobson, and also as a business/legal analyst; he holds J.D. (Juris Doctor) and MBA degrees. Harrison Dillon is the President, CTO and co-founder; overseeing technology strategy, intellectual property and legal affairs; he is trained in the field of microbial genetics, formerly managed the biotechnology patent portfolio of the University of Utah in the University's Technology Transfer Office. Dr. Dillon received a J.D. Arthur Grossman is the Chief of Genetics at Solazyme. Dr. Grossman is a world renowned scientist and has spent over twenty-five years in microalgal research.

Revenues: 2007: $2.6M [ZoomInfo 2008]. When doubled the size of the firm (from 25 to 52 employees) in 7 months developed a human capital management plan and changed organization was necessary ("10 – 25 - 150" rule, Table I.72) [ZoomInfo 2008; Yatedo].	$11.6M Series D (06/2009), $45.4M Series C (8/2008), $10M Series B (03/2007) (cf. also [Crunch Base 2009b] $5M Debt funding (09/2007) 2004: Harris & Harris Group, Inc. invested $310,000 as part of a larger funding round [Harris & Harris 2005]. 2009: received a $21.8M federal grant from US DOE to build its first integrated biorefinery in rural Riverside (PA); located on the site of Cherokee Pharmaceuticals' existing commercial biomanufacturing facility (make diesel from sawdust and cooking oil from food-factory waste; on an industrial scale), Solazyme will add $3.9M; goal: to prove this (refining) can be an in-	Currently, he shares his time between Solazyme and the Carnegie Institution/Stanford University where he is a Senior Staff Scientist at Carnegie and a Professor at Stanford; overseeing of current R&D projects and the development of strategies for initiating and implementing new projects. Prior to becoming a member of the management team, Dr. Grossman was the Chairman of Solazyme's Scientific Advisory Board and has been a key part of the R&D team since 2004. Jurgen Dominik is the SVP of Process Development; most recently, Mr. Dominik was senior vice president of global operations for CP Kelco focusing on manufacturing, logistics, capital spending, and process research. Mr. Dominik brings over 30 years of experience in technology, manufacturing, research and development, and international management. His duties included the management of design, construction, startup, and operation of large-scale fermentation facilities and natural product extraction manufacturing plants. Peter Licari is the Senior Vice President of Research and Development at Solazyme. Dr. Licari has over 20 years experience in biochemical engineering and bioprocessing, most recently as a Senior Vice President at Kosan Biosciences, Inc. where his responsibilities included development and manufacturing operations; he served also as Senior Scientist at BASF Bioresearch Corporation, responsible for fermentation process development. In 2005 he obtained an MBA degree. David Brinkmann VP of Manufacturing, has over 30 years of technical, operations, and leadership experience in the bioprocess industry. Mr. Brinkmann came to Solazyme from CP Kelco, where he spent ten years managing all operational aspects of a large biotechnology pilot plant and semiworks that provided process R&D and manufacturing support programs, such as productivity improvement, cost reducetion, and new product development. David Isaacs SVP of Government Relations of Solazyme, is responsible for formulating and executing the company's government strategy at the federal and state level. In this capacity, he is working to advance the company's

	dustrial method, not just an experiment [DiStefano 2009]; two contracts with the US Navy, one worth $200,000 to supply 1,500 gallons of jet fuel in 2010; another separate contract worth $8.5 mil. to research, develop and deliver 20,000 gallons algae derived fuel for use in Navy ships [DiStefano 2009; Nagappan 2009]. Both grants used for learning to scale-up 2007: received a $2M grant from the National Institute of Standards and Technology to develop a substitute for crude oil based on algae [Bullis 2008a].	priorities on funding opportunities, legislation, regulatory matters, and policy, particularly with regard to the Congress, the Departments of Defense and Energy, the Environmental Protection Agency, and key states (cf. also BluefFire, Table I.86). Solazyme believes in intellectual property and in-licensed technology; has issued patents and more than 20 (published) patent applications. The founders Dillon and Wolfson met on their first day of college back in the 1980s; wanted to start a company together but had only a vague notion of what to do. Dillon went into biotechnology and ultimately also became a patent attorney. Wolfson got a law degree and an MBA and went into finance [Kanellos 2008]. Foundation of the company in Dillon's garage in 2003 [DiStefano 2009]. Originally focused on hydrogen (H_2) production by GM algae [Kanellos 2008] (Dillon granted patent US 7135290 "Methods and compositions for evolving hydrogenase genes"). When the two first sought funds, most venture capital firms were intrigued by their idea, but did not know how to position the company in their portfolio. Ultimately, investors shuttled the two to the partners who handled pharma deals [Kanellos 2008]. "We're developing a production platform (and) are looking for commercialization partners." It doubled its lab and office space to 7,000 square feet and increased head count from 20. Wolfson said Solazyme had narrowed its initial algal library from "the low thousands" to five or six strains [Wilson 2007]. Patented process: maximize triglyceride production through fermentation (US Patent 2008/0124756 A1) [Waltz 2009b].
Technology, Goals, Strategy	Solazyme uses synthetic biology [Waltz 2009b] for the renewable production of biofuels, industrial oleochemicals, and health and wellness ingredients. Self-Description: It modifies microalgae to produce tailored triglyceride oils that can be re-	

fined into biodiesel in the same facilities that refine petroleum. They produce crude oil, which can be turned into anything that is made from oil. They genetically engineer the cells' ability to handle different feedstock, as well as the structure of the oil produced.

It is not photosynthetic. *Some algae naturally produce oil more effectively when fed biomass in the dark* – an adaptive mechanism that allows them to survive in the event that sunlight is blocked for extended periods. Solazyme enhances this ability. It feeds its algae various cellulosic and other waste materials rather than CO2 and sunlight. Some algae produce polysaccharides from biomass, instead of oils. Solazyme uses synthetic biology also to modify these, as well, and some may be commercialized.

The company uses different strains of algae to produce different types of oil. The process also has significant advantages. First, keeping the algae in the dark causes them to produce more oil than they do in the light. That is because while their photosynthetic processes are inactive, other metabolic processes that convert sugar into oil become active.

Just as important, feeding algae sugar makes it possible to grow them in concentrations that are orders of magnitude higher than when they are grown in ponds.

Solazyme uses traditional industrial fermentation equipment [Voith 2009b].

Solazyme is the only microbial biofuel company to produce an oil-based fuel, Soladiesel®. Solazyme said it produced thousands of gallons of fuel from algae that was tested to meet strict ASTM international standards for jet fuel. Solazyme has already road-tested its diesel fuel for thousands of miles in unmodified cars.

Co-founder Dillon said the company is about 24 to 36 months away from hitting its target manufacturing cost of $2 to $3 a gallon, or $40 to $80 a barrel [AP 2009b].

Feed wood chips, switchgrass, waste glycerin (cf. BioMCN, Table I.87) to algae in a process where the algae will convert that biomass into crude oil, which "can be used to make" diesel fuel, jet fuel, high-nutrition edible oil like olive oil, or plastics.

As Solazyme can convert sugars directly into oils without photosynthesis this allows the organisms to be grown in fermentation tanks, which reduces the costs of a still-expensive process.

Solazyme is not only focused on scale-up, production and road testing of a variety of advanced biofuels, but simultaneously diversifies its platform into other products and markets.
It develops products across distinct market segments, leveraging algae's unique oil and material production capabilities:

- Fuels
- Chemicals,

	- Nutritionals (Human + Animal Nutrition), e.g. selling the non-oil biomass for animal feed, - Health Sciences (Cosmetics + Nutraceuticals). Solazyme is interested in developing collaborative R&D and commercialization relationships, working with partners to develop and commercialize new or improved processes and products in its target markets (e.g. Chevron, BlueFire, Imperium Renewables, Inc.) The US Navy agreed to pay for 22,000 gallons of Solazyme jet fuel and ship fuel for delivery in 2010 [DiStefano 2009]. B&D Nutritional Ingredients (B&D) has formed a strategic partnership with Solazyme Health Sciences whereby B&D will promote and distribute Solazyme Golden Chlorella {algae} products for the functional foods and dietary supplement markets [Neutraceuticals World 2009]. In 2010, the Company launched its products, the Golden Chlorella line of dietary supplements. In March 2011, the Company launched its Algenist brand for the luxury skin care market through marketing and distribution arrangements with Sephora S.A. (Sephora International), Sephora USA, Inc. and QVC, Inc. In 2010, Solazyme and Roquette, the global starch and starch-derivatives company headquartered in France, formed Solazyme Roquette Nutritionals, a joint venture bringing to market an entirely new line of microalgae-based food ingredients. [103]

*) From the firm's Web site if not stated otherwise by a reference; firm's status: early 2010.

Indeed, Solazyme has positioned itself first and foremost as a "renewable oils" company, as a producer of sustainable *triglyceride oils* that can be used to replace or enhance oils derived from petroleum, animal fats, and plants. According to Figure I.176 fuels actually stand at the bottom of the company's target markets when considering the concept of profit margins.

Correspondingly, in April 2012 Solazyme announced an agreement with Bunge Global Innovation to build a factory in Brazil that would make triglyceride oils for both chemical and fuel products. Under the joint venture, whose financial terms were not disclosed, the factory would rise next to Bunge's Moema *sugarcane* mill and have an annual capacity of 100,000 metric tons of oil. It would start production in the second half of 2013, making oils for fuel as well as additives for soaps, detergents and plastics [Cardwell 2012].

In February 2011, Solazyme entered into a joint development agreement with The Dow Chemical Company to jointly develop and commercialize non-vegetable, microbe-based oils and related products like those for dielectric insulating fluids and other industrial applications. In March 2011, the company entered into an agreement to purchase a development and commercial production facility with multiple 128,000-

liter fermenters, and an annual oil production capacity of over 2,000,000 liters (1,820 metric tons) located in Peoria, Illinois for $11.5 million [Riddell 2012].

In March 2011 Solazyme filed for a $100 million IPO. Solazyme had found little support over the last year when it comes to Wall Street. The company, which priced its initially well-received IPO at $18/share, managed to raise $227 million that year. In doing so, it raised a sum of capital that has thus far been projected to be adequate to sustain the company until it becomes cash flow positive. But, by May 23, 2012 the closing price was $9.72, a 46 percent discount to its IPO price (ca. $11 end of 2013). The market and its analysts continued to express doubts over the advanced biofuels industry [Bomgardner 2011d; Quon 2012].

The company had raised $128 million in venture capital since its founding in 2002. In its Annual Report 2011 (US SEC Form 10K) Solazyme reported revenues of $38 million for 2010 and a net loss of $16.3 million and $39 million for 2011 and a net loss of $53.9 million. However, a breakdown of total revenues (2011) reveals that there are only $12 million in reveues from selling products or licenses:

Research and development programs	$26.793 mio.
Product revenue	$7.173 mio.
License fees	$5.000 mio.

This is – after almost nine years of existence – an amount obtained also by the algae firms Cyanotech Corp in the US and German BlueBiotech GmbH mentioned above. Particularly with regard to nutritional and cosmetics aspects one can expect Solazyme to encounter difficulties in selling its products in certain areas of the world, particularly Europe, due to the use of genetically modified objects for production.

The promise of using algae to make biofuels – a dream scientists have chased for decades – might have seemed particularly welcome in a time of stubbornly high oil and gasoline prices. But the path to commercial-scale production has been circuitous.

Algenol Biofuels (Table I.91) with its proprietary Direct to Ethanol™ process is the only bioethanol producing algae company. Furthermore, rather than harvesting the algae as such for post-processing of algae's "biomass deliverables" the "algae" are utilized "like getting the milk rather than killing the cow" [Woods 2009a; Woods 2009b].

It actually uses *cyanobacteria* (formerly known as blue-green algae). Cyanobacteria have been isolated from various habitats both from freshwater and marine systems. Since cyanobacteria show an impressive variation in physiological properties a collection of cyanobacteria from various habitats also provides an excellent platform for experimentally selecting suitable strains.

The organisms produce some ethanol naturally, but Algenol has patents to selectively breed and genetically manipulate them to pump out more. In essence, each cell acts as a tiny ethanol factory (Figure I.178).The Algenol process consumes CO2, which means biologic sequestration and generates photolytically sugar which is fermented intracellularly into ethanol. The outstanding feature of this technology is that it fundamentally uses carbon dioxide as its source to make ethanol. However, some types of cyanobacteria are responsible for so-called "algae blooms" through explosive growths and some cyanobacterial blooms are toxic. Some common bloom-forming species produce potent toxins that can even be lethal.

Algenol is *privately funded* and was not seeking outside investment during the stages of development and primary commercialization. Algenol's ongoing financing needs continued to be financed privately through the initial commercialization phase but Algenol continued to investigate the optimal *funding opportunities* including licensing fees and royalty payments, partnering arrangements, government financial support and government land access for facilities. In the US, in particular, Algenol planned to seek federal, state and local assistance to bring US facilities online [Gelsi 2008].

Algenol works directly and indirectly with a number of collaborators and (small to large) companies in the US and Germany to further develop and commercialize its existing technology. It reported to have 100 employees and consultants (40 Ph.D.'s) in early 2010 and biological laboratories in Baltimore, Maryland and Germany [Woods 2009b]. This makes Algenol's *entrepreneurial constellation rather complex* concerning other involved companies, intellectual property rights (IPRs), scientific advisors and R&D arrangements, credibility build-up as well as strategic partnerships with large firms and financing through federal and county agencies.

Apart from its own research efforts in Baltimore and cooperation in the US Algenol organized massive R&D support in Germany (Figure I.179; Box I.25). Algenol was getting help from experts at the Johns Hopkins University and the University of Maryland Biotechnology Institute. Frank Robb, a professor at UMBI's Center for Marine Biotechnology, had been contracted by the company to help with its research. Joseph Katz, a professor of mechanical engineering at Hopkins, signed on as a consultant, in part to help design the "bioreactors" in which the blue-green algae are to grow [Wheeler 2009].

As outlined for BioMCN (Table I.87) and ZeaChem (Table I.88) Figure I.179 exhibits *Relationship Mapping*. This is a method of visualizing, describing, and analyzing all the individual and organizational relationships of an existing firm, may be also prospective business partners, by establishing a *dynamic* "map." This map provides background on the target company by showing direct, indirect, and business and social relations among individuals within the organization and of the company as a whole.

Networking of NTBFs discussed so far, hence, reflects a special relational mapping restricted to organizational relationships for a particular time span.

Figure I.179 is an illustration of what is described in detail in Table I.91 and Box I.25.

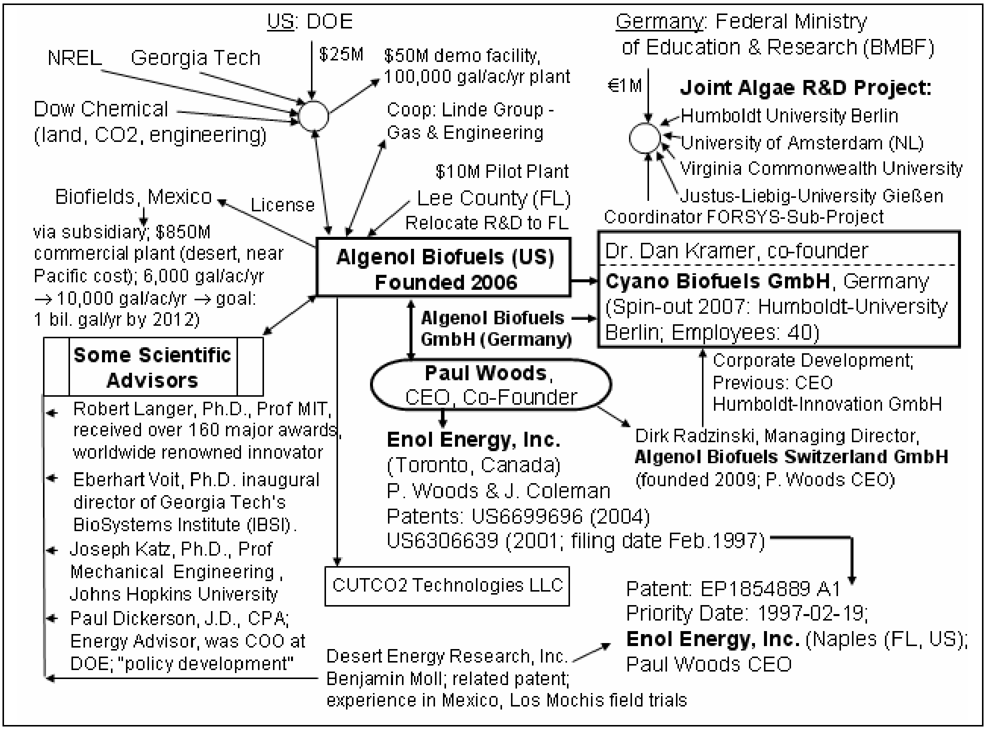


Figure I.179: Algenol's encapsulated web of firms, R&D and financial resources, partnerships as well as persons (by 2009/2010).

Table I.91: Algenol Biofuels and its path to bioethanol directly from algae. *)

Company (Foundation) Remarks	**CEO, Other Executives, Foundation, Key Researchers; Technology Protection and Position**
Algenol Biofuels, Inc. Bonita Springs (FL) (2006) Administrative offices in Bonita Springs, but a laboratory in Baltimore (MD) with ca. 15 company scientists and technicians	Paul Woods CEO, co-founder and co-inventor of Algenol's basic technology; when working as a student in Canada in genetics at Western Ontario University in 1984, Paul Woods discovered a method for producing ethanol from cyanobacteria (blue-green algae); related patents with Prof. John Coleman (now Algenol's CSO) as a co-inventor are assigned to the firm Enol Energy, Inc. (Figure I.179); The split of IPR between a firm owned by a person to just exploit these in another startup is also observed for BlueFire (Table I.86). Wood's invention did not appear to have much commercial promise until the early 2000s. Meanwhile, he started a couple natural gas businesses in Canada and US. He started his business career in 1989 at Alliance Gas Management, which completed an IPO in 1997. He built the firm, raised

[Wheeler 2009]. **Major Funding:** Some $70M in private backing [Gelsi 2008; Wesoff 2009], invested by P. Wood personally and a few partners [Wheeler 2009] 2010: Lee County (FL) approved a contract with Algenol, a $10M grant to build a facility during the next two years [CNN 2010] Algenol got a Department of Energy (DOE) grant for up to $25M, or no more than half the cost of a $50 million facility at a Dow Chemical plant.	$80 million in capital, and sold the business in 1999. In 1997 he founded United Gas Management Inc. in the US. But the natural gas marketing company he launched wound up in bankruptcy and was sold in 2000. He said he retired after that, until launching Algenol [Wheeler 2009]. In March 2006 Woods formed Algenol along with Craig Smith and Ed Legere armed with patents, several test facilities around the world and, according to the literature, some $70 million in private backing [Gelsi 2008]. He and his partners started Algenol Biofuels Inc. to commercialize the process "algae-to-ethanol" on an industrial scale. More on the background of Algenol's foundation and the associated foundation of Cyano Biofuels GmbH (Figure I.179) in Germany is described in Box I.25. Craig Smith, MD Executive VP COO and co-founder; from 1993 to 2004 Dr. Smith served as Chairman, President and CEO of Guilford Pharmaceuticals, Inc., a publicly held biopharmaceutical company that he co-founded in 1993; from 1988 to 1992 Dr. Smith was a VP and Senior VP of another publicly held biotechnology company; from 1975 to 1988 he served on the faculty of the Department of Medicine at The Johns Hopkins University School of Medicine; has served on several corporate and charitable boards and is still a member of the Johns Hopkins Alliance for Science. Edward Legere, MBA Executive VP and CFO and co-founder; he has over 18 years experience in the biotechnology industry as a consultant and active business manager and has over ten years of public company experience in the role of member of the Board of Directors; he has also served as the President and CEO of the publicly traded biotechnology company Peregrine Pharmaceuticals, Inc. John Coleman, Ph.D. CSO and co-inventor, was the Vice-Principal (Research and Graduate Studies) at the University of Toronto Scarborough, and a Professor in the Department of Cell and Systems on the St. George campus of the University of Toronto prior to joining Algenol. He was Chair of the Department of Botany from 1998 to 2004 and played a primary role in the formation of the new Department of Cell and Systems Biology in 2006. Dr. Coleman's research interests and experience lie in the fields of molecular biology and biochemistry of photosynthetic carbon metabolism in higher plants and cyanobacteria. Initial proof of science for Algenol's technology was generated by Dr. Coleman at the University of Toronto between 1989 and 1999. Since then, the process has been refined to allow algae to tolerate high heat, high salinity, and the alcohol levels present in ethanol production. The key basic patents for Algenol's technology are those assigned to Woods and Coleman (and a third inventor) given in Figure I.179.

Technology, Goals, Strategy Business Model: Owner-operator and partner for bioalcohol production from algae; Expand into "green carbon" building block monomers (bio-refinery model), such as ethylene or propylene (from ethanol); Look also into biobutanol production [Woods 2009c] Licensing business **Revenue** (2010): $3.1 mio. (according to Wikipedia) **Employees**: 120	Using a patented metabolically enhanced cyanobacteria, or blue-green algae, to directly synthesize ethanol – one of the few, if only, companies working with direct production of this algae; blue-green algae, since they also use photosynthesis – sunlight – to convert nutrients and carbon dioxide into fuel. Algenol estimated that its technology can produce 10,000–12,000 gal/ac/yr of ethanol in the near term. This has been questioned based on a simple calculation which would make it hard to believe those yields will make Algenol's biorreactors economical [Waltz 2009b]. So far, Algenol claims its test facilities have yielded 6,000 gallons of ethanol per acre per year, with yields expected to grow to 10,000 gallons of ethanol per year. The metabolically enhanced algae are resistant to high temperature, high salinity, and high ethanol levels; they do not produce human toxins. Algenol's "Direct-to-Ethanol" process gathers ethanol produced by algae without destroying the algae and without the necessity of refining oil into biodiesel. This method, if viable and scalable, seems to have huge potential cost and embedded-energy advantages. "Ethanol is almost infinitely mobile in a cell, and essentially leaks out into the bioreactor after synthesis," Coleman said. "Through some various condensation steps we collect it." [Hamilton 2009] The algae strains are genetically modified – and that might be a hard sell in the US [Wesoff 2009] and elswhere. The production plants will need vast tracts of land for row upon row of algae-filled bioreactors (filled with sea water), but the company is targeting desert or arid lands; so no usable farmland will be taken out of cultivation. The ethanol-making process will yield fresh water as a by-product (Figure I.178) which could be used to irrigate nearby lands. [Wheeler 2009] Algenol had licensed its technology to Biofields of Lomas de Chapultepec, Mexico (for more than $100 million [Donner 2011]). Biofields said it has committed $850 million to building the industrial-scale ethanol facility on 102,000 acres in the Sonora Desert. As the algae grow, Algenol will tap into carbon dioxide from a nearby power plant and funnel it into the tanks. By 2012 Biofields' subsidiary Sonora Fields S.A.P.I. de C.V. intended to produce a whopping one billion gallons of ethanol per year. Much of the ethanol shall be transported by ship to Mexican oil refineries nearby to be blended into gasoline [Waltz 2009b; Gelsi 2008]. The Mexican company secured an exclusive license for the Algenol technology until 2013 when the company expected to reach its 250 MGY target. It will be run by a former Mobil Oil senior construction executive. According to CNN for expansion, by the end of 2009, Biofields had invested $30 million in the project, which is reporting yields of 6,900 gallons per acre at the Sonora site [Lane 2010b]. As displayed in Figure I.179, by December 2009 Algenol got a Department

	of Energy (DOE) \$25M grant (approximate half of the estimated cost of a \$50 million facility) to install a photobioreactor-based algae-to-ethanol demonstration plant at a Dow Chemical site in Freeport, Texas [Voith 2009; Wesoff 2009; Hamilton 2009]. The rest of the capital would be provided by Algenol, which would also own and operate the plant. Dow would contribute 25 acres of land, the CO2 supply and technical expertise. Dow's chemists and engineers would help design a process that can scale-up for commercialization [Voith 2009a]. In Algenol's case, the photobioreactors are simply plastic covered troughs housing a mixture of saltwater, algae, nutrients, and CO2; plastic material will be supplied by Dow [Wesoff 2009]. The initial target production was up to 140 gallons of algae fuel per day, or 51,000 gallons per year at a yield of 2,120 gallons per acre [Lane 2010n]. Dow would also help develop advanced plastic films for covering the bioreactors. But fuel-quality ethanol must be distilled from the bioreactor condensate, which is a major focus for the pilot plant. For this process Algenol will use advanced membrane technology and separations, a Dow competency, that are more energy efficient [Voith 2009a]. Dow would also assist with process engineering [Hamilton 2009]. The \$25 million Energy Department grant to help fund the Algenol Dow plant designed to produce 100,000 gallons of ethanol a year at a target cost of \$1-\$1.25 per gallon will be associated by continued research by the National Renewable Energy Laboratory (NREL) and Georgia Tech [Clanton 2009]. The Algenol-Dow experiment could have several important implications. It points the way to a more sustainable path for making ethanol as a biofuel, but also producing common building block chemicals now derived from fossil fuels (such as ethylene). With regard to process engineering Algenol followed also a further route (outside Dow). By the end of 2009 Algenol and the German Linde Group, an internationally leading gases and engineering company, have agreed to collaborate in a joint development project in order to identify the optimum management of carbon dioxide (CO2) and oxygen (O2) for Algenol's algae and photobioreactor technology. The cooperation will aim the companies to join forces to develop cost-efficient technologies that capture, store, transport and supply CO2 for Algenol's proprietary process for the production of biofuels. In 2008 Algenol Biofuels and Codon Devices announced that the companies have entered into a multi-year partnership utilizing Codon's proprietary BioLOGIC^{TM} protein engineering platform. A key strength of Algenol is: "Exceptional group of partners from industry and academia, some are announced publicly, some surprises are in store…" [Lane 2009c]. Some of this is discussed Box I.25.

	As Algenol sought to seek federal, state and local assistance to bring US facilities on line [Gelsi 2008], Algenol accompanied technical advances with Current Policy Initiatives [Woods 2009b].

*) From the firm's Web site if not stated otherwise by a reference; firm's status: end of 2009.

It is interesting to note that the other US chemical giant, DuPont, concentrates on macro-algae to produce biobutanol (Table I.83).

Box I.25: Algenol Biofuels as a catalyst for helping to found and use Cyano Biofuels GmbH in Germany as an "external" R&D resource.

When Algenol founder Paul Wood re-assed the commercial promise of his early algae-to-ethanol invention during the emergence of the "algae boom" of the early 2000s he turned to Germany, in particular to Cyano Biotech GmbH co-founded by Dr. Dan Kramer (with two additional co-founders) in 2004 in Berlin, Germany. As he has been occupied by research of natural products delivered by bacteria the foundation idea of Dan Kramer was to investigate the little studied potential of cyanobacteria to produce natural products, particularly those that have application in or for pharmaceuticals, utilizing genetic optimization.

Cyano Biotech GmbH was created as a spin-out from the Institute of Biology of Humboldt-University, Berlin, with the aim to commercially exploit the results of 20 years of R&D in the field of cyanobacteria generated by the group of Prof. Dr. Thomas Börner (Dept. of Genetics), in particular, by metabolic engineering. On the basis of "incubation options" ("Gründerlabor") and special "seed fundings" and grants by German ministries and Berlin authorities during the first three years Cyano Biotech utilized the university laboratories and facilities [BMWi]. By the end of 2007 Cyano Biotech GmbH moved to own facilities in the Technology Park Adlershof/Berlin.

During the pre-startup phase, prior to foundation, Dan Kramer performed a feasibility study [122], including a proof-of-concept, in cooperation with an industrial partner in Potsdam adjacent to Berlin with respect to the commercial opportunity of cyanobacteria as a source for biologically active compounds [BMWi]. There is high evidence that this firm in Potsdam is AnalytiCon Discovery GmbH (an R&D spin-out of AnalytiCon AG) and is currently a cooperation partner of Cyano Biotech. With currently 60 employees it is one of the leading companies in research and development of products made from natural materials for the pharmaceutical, food, and cosmetics industries. AnalytiCon Discovery claims to be leading worldwide with libraries (MEGAbolite®, NatDiverse™) of natural product small molecules as screening compounds to accelerate natural product based drug research.

After two years the feasibility study was completed and also a business plan finalized. Dan Kramer acting as managing director looked for two technology-oriented co-founders, one being a specialist in natural products research, the other in cyanobacteria and bio-active compounds. After the "seed phase" financing of Cyano Biotech was by a special governmental support program comprising a public subsidy and equity stake by a governmental equity investment organization for NTBFs (tbg – Technologie Beteiligungsgesellschaft). Based on his experience as project leader Dan Kramer grasped the essentials of “professional management” by a “learning-by-doing” approach; accounting and controlling activities for the firm were outsourced [Bowie].

Cyano Biotech, (with 8+ employees in 2008 [Bowie]), is one of the few firms, if not the only one, in the world that identifies and characterizes natural products by screening cyanobacteria (“drug discovery”). It optimizes derived related bioactive compounds regarding pharmacological needs employing combinatorial biosynthesis to generate novel lead compounds (or “active pharmaceutical ingredients”) for the pharmaceutical industry. A part of the natural products was sold as extracts from bacteria. But another firm was planned to commercialize the isolated natural products itself [Technology Park Adlershof 2008]. In 2010 Cyano Biotech had revenue of €276,000 (according to the German Creditreform – Firmenwissen Database).

Cyano Biotech’s business is aligned with the diverse microalgae-based products and applications in the pharma, agrochemical, food and cosmetics industry as well as in regard to the sustainable production of raw materials, CO2 sequestration and waste water sanitation.

Equally important for the assessment of the entrepreneurship is the fact that, within ca. 80 miles, Humboldt-University in Berlin is at a center of various cyanobacteria R&D (Figure I.179) and commercialization activities for more than 20 years which covers other research universities, public research institutes and private firms involved in cyanobacteria commercialization. This constellation appears formally as a part of the general biotechnology “Competence Cluster Berlin-Brandenburg” which has additional links to other related areas in Germany and Austria. For instance, a scientific advisor from the Austrian Academy of Science runs simultaneously a cyanobacteria project with Cyano Biotech.

By subject and by (spatial) proximity Cyano Biotech’s leaders can be assumed to have had links to people in a related “*joint project*” (in German Verbundprojekt) of the cluster. A “Verbundprojekt” is a special German approach to technical innovation (ch. 1.2.6). It is a systemic interconnection tied together by a common explicit goal (and achievable result) through coordination and control and assigning different contributing sub-projects to different elements (organizations) of a related value system.

This project was the “Hydrogen from Microalgae: With Cell and Reactor Design to Economic Production” project (HydroMicPro; Table I.92) funded by a €2.1M grant of the Federal Ministry of Education and Research (BMBF) and conducted jointly by universities, research institutions and enterprises. The notion microalgae comprises essentially also cyanobacteria.

HydroMicPro targeted developing an inexpensive, highly efficient production process with optimized biology and process technology, which is suited for the mass production of hydrogen. It focused on the photobioreactor, gas separation by membrane processes, biological sensor technology for cellular oxygen, biotechnological optimization of algae, and systems integration and was led and coordinated by the Karlsruhe Institute of Technology (KIT). It included also practical field tests [Knuber-Knost 2009].

A tempting offer from America (Paul Woods to Dan Kramer of Cyano Biotech) marked the birth and catalysis for further development of Cyano Biofuels GmbH. Decades of research and commercialization activities and competence in and around Berlin concentrating on cyanobacteria obviously attracted Paul Woods [Technology Park Adlershof 2009].

Paul Wood's idea to further develop and commercialize his discovered method for producing ethanol from cyanobacteria led him look for partners to assess his approach for feasibility (cf. below Perkin case; A.1.2). And linked to the available competence the order for the feasibility study was addressed to Berlin.

According to Dan Kramer the promising results initiated foundation of a second firm in April 2007 ("Unsere Untersuchungen haben so gute Ergebnisse geliefert, dass wir im April 2007 eine zweite Firma gegründet haben," said Kramer) [Viering 2009] Together with a colleague (Dr. Heike Enke) Dan Kramer founded Cyano Biofuels GmbH, again as a spin-out of Humboldt University. Cyano Biofuels with about 40 employees in 2009 [Seidler 2009, Martin 2009] and more than 30 scientists [Humboldt Innovation 2009] succeeded in making the cyanobacteria produce preferentially ethanol rather than sugar by a proprietary process.

The formal setup of Cyano Biofuels as an LLC (GmbH) involved legally several partners (Figure I.179) – from Cyano Biotech and from Algenol Biofuels GmbH. According to an official legal documentation ("Elektronischer Bundesanzeiger") Algenol Biofuels GmbH was a one-man-firm of Paul Woods without any employees. Algenol Biofuels Inc, Bonita Springs, FL, USA is the full owner of Algenol Biofuels GmbH. Additionally Algenol Biofuels Switzerland played a role (Figure I.179).

Concerning genetic engineering of cyanobacteria, the rod-shaped bacterium *Zymomonas mobilis* for making Mexican agave tequila turned out to be three to four times as efficient as local beer yeasts when applied to the plants. Correspondingly Cyano Biofuels took the gene for the enzyme pyruvate decarboxylase (Figure I.178) out of the tequila tribe and implanted it into the genome of cyanobacteria [Donner 2011].

In the US using corn for biofuels reached 3,700 liters per hectare per year. Under *ideal laboratory conditions* researchers of Cyano Biofuels in Berlin claimed to have achieved 112,000 liters. And in November 2011, a pilot plant with 3,000 tubes as bioreactors was announced to be built in Texas [Donner 2011].

In essence Cyano Biofuels is a research and development firm for biofuels and building block chemicals utilizing optimized cyanobacteria to be channeled into industrial scale production via a direct process [Humboldt Innovation 2009]. The vision and the mission of Cyano Biofuels embraces knowledge and know-how transfer from a university into business, development and optimization of cyanobacteria for the production of biofuels (currently bioethanol).

Some key challenges on the route to commercialization of algae-to-ethanol not tackled by Cyano Biofuels include design of massive pipeline systems to bring seawater to the algae, cleanliness for the large scale growing and processing units to avoid other bacteria to overcome the cyanobacteria in the bioreactors and separation of ethanol [Seidler 2009].

In 2010 Cyano Biofuels was acquired by Algenol Biofuels and is now a member of the Algenol Group. Algenol LLC, Bonita Springs, Florida, held previously a minority position in Cyano Biofuels. According to an official legal document ("Elektronischer Bundesanzeiger") the minority stake was 40 percent which was transferred to Algenol Biofuels Switzerland GmbH.

Growth of Cyano Biofuels in terms of number of employees was:

2011 ca. 50 employees [Donner 2011], 2010 ca. 40 employees, 2009 33 employees, 2008 24 employees (the last figures from "Elektronischer Bundesanzeiger").

The Institute of Biology of Humboldt-University, Berlin (Dept. of Genetics), is not only the connection between the startups Cyano Biotech and Cyano Biofuels (via the co-founder Dan Kramer). It has two working groups dealing with the production of biofuels or hydrogen by cyanobacteria providing simultaneously the connection to the joint project HydroMicPro (Table I.92).

Furthermore, it participates in the FORSYS (*Research Units for Systems Biology in Germany*) research project funded Germany-wide by the Federal Ministry of Education and Research (BMBF) with € 45 millions until the end of 2011. The co-founder of Cyano Biofuels acts here as the project coordinator (Figure I.179) for the FORSYS sub-project "Systems Biology of Cyanobacterial Biofuel Production." This sub-project is supported by a €1M grant from the BMBF [Kramer 2007; Glocalist 2008].

When Cyano Biofuels was taken over by Algenol Biofuels Paul Wood characterized the situation as follows (Humboldt Innovation, Mar. 23, 2011):

"The Greater Berlin is known for its diverse and high-profile research on microalgae and a perfect place to attract research talent for Algenol. We want to support Cyano Biofuels' networking with German universities and further believe that generate new ideas and technologies emerge."

An overall position of a joint project or "joint R&D project", respectively in the German industry development approach, such as HydroMicPro, is shown in Figure I.40 in relation to a structural value system. Furthermore, there is a planned connection to the Enertrag AG hybrid power plant project combining wind, hydrogen and biogas (Figure I.104) located also in the German competence region for algae.

Table I.92: Example of a “Verbundprojekt” in Germany (“Hydrogen from Microalgae” – HydroMicPro) to illustrate its systemic character.

Organization, Partners	Sub-Project Goal
Professor Clemens Posten KIT Institute of Life Science Engineering (Karlsruhe)	*Coordination*: Expected result: prototype reactor that allows an economically efficient hydrogen production by microalgae. Next steps for large plants: Automation of the plant, optimization of service life, and mass production of materials (microstructurization of membranes and coating of transparent materials).
KIT Microalgae Working Group; KIT’s Engler-Bunte Institute (from Chemical and Process Engineering Department)	Develop an optically structured photobioreactor (first enlarge the inner surfaces of the reactor); Photobioreactor: First step, a high amount of biomass shall be produced. Such high amounts will also be needed for producing other valuable materials from algae in the future. Second step, the system will be optimized for hydrogen production.
University of Bielefeld	Identification and biotechnological optimization of the algae for biomass and H2 production in the photobioreactors.
Organization, Partners	**Sub-Project Goal**
Max Planck Institute for Molecular Plant Physiology (MPI), Potsdam (adjacent to Berlin)	Focus on the regulation and control of cell-internal oxygen concentration and develop a sensor based on transgenic and physiological/biochemical processes
University of Potsdam (adjacent to Berlin)	Develop a method to measure cell-internal oxygen concentration.
Ehrfeld Mikrotechnik BTS GmbH (EMB), Wendelsheim	Provide experience gained from using a micro photobioreactor and elaborate the concept of the production plant.
IGV (Institut für Getreideverarbeitung) GmbH, Nuthetal (near Berlin)	Contribute experience from the use of a thin-film reactor; assess the new process under close-to-practice field conditions. (IGV will be described later)
OHB-System AG, Bremen (ch. 2.1.2.4; [Bläske and Kiani-Kreß 2010])	Connect the bioreactor system for hydrogen production to energy-transforming systems; in addition, evaluate adaptation of the system to space applications.

Table I.92, continued.

The KIT Institute for Technology Assessment and Systems Analysis (ITAS)	Evaluate the potential contributions of HydroMicPro technology to sustainable hydrogen supply; identify the ecological and socioeconomic "hot spots" of the technology; feedback: based on the results, processes for hydrogen production from microalgae will be improved and appropriate applications in the energy system identified.

Another algae startup in the US, Sapphire Energy, Inc. (Table I.93), is not only notable with regard to the huge amount of invested capital, but how it positioned itself: "We're an energy company," "and, really, who we are competing with is big oil and gas." [Schwartz 2010]. The founders express competitive antagonism (Table I.32).

During the process of setting up Sapphire founder and serial entrepreneur Jason Pyle was also in contact with Big Oil: "We've had conversations with all six of the largest oil companies in the world." [Bigelow 2008] Morrison [2008] characterized this situation from a different perspective: One of the distinguishing factors of algae startups is that they tend to dream, and talk, rather large, and Sapphire is no exception. Like other companies, however, its algae have yet to be proven at commercial scales.

The origins of Sapphire began in 2006 as a handful of venture capital leaders began looking for the right technology. Typically, the innovator who develops a new technology looks for the right venture capital firms to provide funding for the idea. Pyle said his discussions began with Kristina Burow, a chemist-turned-partner at Arch Venture Partners, biotech CEO Nathaniel David and scientist Mike Mendez. "We started *analyzing different kinds of biofuel deals and technologies* and asking ourselves what's great about this and what's not," Pyle said (emphases added).

After determining that their best prospect was to become a producer of gasoline and diesel fuels Pyle said they set out to identify the best green technologies for making it. They found what they were looking for in the research of Stephen Mayfield, an algae biologist at The Scripps Research Institute in La Jolla, and Steven Briggs, a professor of cell and developmental biology at UC San Diego. The founders and their scientific collaborators officially launched Sapphire in May 2007 [Bigelow 2008].

Table I.93: Sapphire's approach of serial entrepreneurs to algae-based biofuels following opportunity identification and assessing technical and financing options. *)

Company (Foundation) Remarks	**CEO, Other Executives, Foundation, Key Researchers; Technology Protection and Position**
Sapphire Energy, Inc. San Diego (CA) (2007) Headquarter and primary research labs in San Diego, CA, engineering and project management, Orange County (CA), a research and development complex in Las Cruces, New Mexico; to build a 300-acre full size open-pond algae farm demonstration project in Luna County, New Mexico by the end of 2010 (Intgrated Algal Bio-Refinery). Employees: 2008: ca. 80 [Bigelow 2008], 2009 ca. 120 [Bigelow 2009b]. **Major Funding:** $100M million in a second venture round [Bigelow 2008]	Jason Pyle, MD, PhD CEO and co-founder, also on the Board of Directors; was formerly CTO and co-founder of Epoc, Inc., a privately held medical engineering company. Dr. Pyle holds an appointment as adjunct professor of bioengineering at Vanderbilt University where he has worked to develop cross-disciplinary programs of biological and engineering research. As the co-founder and CTO of Pria Diagnostics, Dr. Pyle was named Innovator of the Year (2006) by Frost and Sullivan. Dr. Pyle holds numerous pending and issued patents in the engineering and biological sciences. In addition to his broad technical abilities, Dr. Pyle has established numerous corporate partnerships between small technical companies and some of the world's largest corporations. Cynthia J. Warner President; brings more than 27 years of experience in the energy, refining and transportation industries. A chemical engineer by training and one of the very few senior women in the oil and gas industry, Ms. Warner served as an executive with energy industry giants British Petroleum, Amoco Oil Company and UOP. Warner left her post as Group Vice President of Global Refining for BP. At Sapphire Energy, Ms. Warner is tasked with driving the company's initiative to transition technology trials and research into commercial-scale crude oil operations. She is a featured leader in the 2008 book "Becoming a Resonant Leader: Develop Your Emotional Intelligence" (Harvard Business School Press). Mike Mendez VP Technology; has held a number of top industry positions at the forefront of the molecular biology revolution. In addition to serving as Director of Bioengineering at GenWay, Mr. Mendez was also associate director of Exploratory Research at Syrrx, Inc. (presently Takeda Pharmaceuticals). There he established a new department that focused on novel platforms for over-expression, purification, and crystallization of membrane proteins. Mr. Mendez co-founded and led the technical program at MemRx, a structural biology company. He has served as a genetic consultant and scientific adviser for numerous biotech and academic institutions; he is also the founder and principal scientist of Gryffin Consulting, Inc., a genetic engineering consulting firm specializing in the areas of gene therapy and antibody and membrane protein production. Tim Zenk VP Corporate Affairs; has spent much of his career shaping public policy – in helping leaders become better leaders and the public become more educated about key issues impacting the nation and the globe. He is known nationally for his political acumen, particularly regarding his

$50M first large venture funding. (5/28/2008) [CrunchBase 2009c]; for construction of the Algal Bio-Refinery in New Mexico. Sapphire received a $50M demonstration-scale grant from the DOE and a $54.5M DOE Loan Guarantee [Lane 2009k]	work on key campaigns ranging from gubernatorial (governor-related) to congressional to presidential. His global work for the Clinton/Gore administration has left him with professional and life experiences that will last forever. His passion for legacy energy solutions is top on his agenda. Tim Zenk had worked on projects with some of the Sapphire investors previously [Schwartz 2010]. Stephen Mayfield, PhD co-founder, Chairman Scientific Advisory Board; is Director of the San Diego Center for Algae Biotechnology (SDCAB), and the John Dove Isaacs Professor of Natural Philosophy at the University of California San Diego. Formerly a Professor of Cell Biology, and Associate Dean of the graduate school at The Scripps Research Institute (TSRI), Dr. Mayfield has worked on the molecular genetics of green algae for over 25 years. His research focuses on understanding gene expression in the green algae; he is a leading expert on the genetics of algae. He set also the stage for the use of algae as a platform for therapeutic protein production, including the expression of human monoclonal antibodies. These studies resulted in the founding of Rincon Pharmaceutical. Nathaniel David, PhD co-founder, ARCH Ventures; teaming with ARCH in 2009, Dr. David was building new companies that create disruptive technologies to address global-scale problems. Co-founder of Sapphire Energy and formerly CSO and co-founder of Kythera, he is also co-founder of Syrrx (acquired by Takeda for $270 million in 2005) and Achaogen. Dr. David has demonstrated experience creating and growing innovative biotechnology companies. He was named one of the Top 100 innovators in the world under 35 (2002) by the MIT Technology Review. He holds numerous pending and issued patents in fields such as nanovolume crystallography, antibiotic resistance, and aesthetic medicine. Kristina Burow co-founder, a Principal, ARCH Venture Partners, joining the firm in 2004; is primarily focused on companies in the life sciences and materials sciences. Ms. Burow joined ARCH from the Novartis BioVenture Fund in San Diego where she was involved in numerous investments in the life science sector. She was a co-inventor of key technology platforms that formed the core of Kalypsys, a GNF spin-off company. Ms. Burow holds an MBA. from the University of Chicago, an MA in Chemistry from Columbia University, and a BS in Chemistry from the University of California, Berkeley. Sapphire Energy originated from a debate between three friends, Jason Pyle; Kristina Burow and Nathaniel David: “Why is the biofuel industry spending so much time and energy to manufacture ethanol – a fundamentally inferior fuel?” In the end a biofuel company was envisioned with the goal to be the world’s leading producer of renewable “petrochemical” products. “To produce a droplet of gasoline” from algae to show their possibilities to investors launched a cascade of funds which has allowed the founders, at

	latest count, upwards of $200 million of running room to get their algae biofuel approach up to scale. Backers include Bill Gates' venture capital wing, Cascade Investments, and the US Department of Energy. Sapphire has invested more than any other private or public entity ever in the business of turning algae into an industrial crop and something that can be considered a true drop-in replacement fuel [Schwartz 2010]. As part of the American Recovery and Reinvestment Act and through the biorefinery assistance program in the 2008 Farm Bill, Sapphire has partnered with both the US DOE and the USDA to build a next-generation algal biorefinery. Sapphire is also collaborating with scientists from the Department of Energy's Joint Genome Institute; University of California, San Diego; The Scripps Research Institute; University of Tulsa; and San Diego Center for Algal Biotechnology. The ambition of the founders of Sapphire is: not just to replace a small fraction of the oil use in the US, but the algae that Sapphire is working on could replace all of it. And founder Pyle believed that there will be many winners in the algal biofuel space. "In a trillion dollar market, it's hard to believe in a winner take all strategy." [Morrison 2008] Sapphire has over 230 patents or applications spanning the entire algae-to-fuel process [Lane 2009k] – from genetically engineering algae to maximize the production of biological oils to extracting the oils, which constitute the "*green crude*" that can be refined into gasoline, diesel, and jet fuel. Part of the IP stems from Rincon Pharmaceuticals founded by Mayfield to begin commercializing his research on algae as vehicles in which to produce biotech drugs. Rincon was acquired by Sapphire in 2008 [Gellene 2009] Sapphire Energy is supported by a syndicate of investors led by co-founder ARCH Venture Partners; along with The Wellcome Trust; Microsoft founder Bill Gates' Cascade Investment, LLC; and Venrock, the fund of the Rockefeller family.
Technology, Goals, Strategy Business Model: Develop technology and operate along the entire pond-to-pump value system – except refining. Focus on manu-	Sapphire produces so-called "*green crude*" (that exhibits many of the same molecules that are in petro-crudes from the ground) which can be refined into "normal" fuels – gasoline, diesel and jet fuel. These meet ASTM standards and are compatible with the existing petroleum infrastructure. Sapphire said its technology is "carbon neutral" because its algae absorbs as much carbon dioxide as a car releases when its fueled by renewable gasoline. When on its Web site referring to "Green Crude Production," Sapphire tells us that "the world needs a radical new solution." Sapphire works with multiple strains, based on geography, climate, what is available naturally,

facturing infrastructure compliant *green crude* that fits with the fuel transport and distribution systems we use today. In line with a biorefinery approach focus on concentrating on the best co-products to produce for sales. Claim: not to use genetically modified organisms.	and what can be manipulated. Acccording to Sapphire it does not develop genetically modified organisms, but selective breeding. Using high throughput screening (HTS) Sapphire said it looks at 8,000 strains every single day and is just entering the pre-commercial demonstration phase [Schwartz 2010]. Sapphire plans to use non-potable water like agricultural runoff and salt water and locate its biorefinery in the desert. As algea grow in brackish water scientists are evaluating how different species of algae react to variations in salinity, pH, temperature, humidity, and other factors. HTS helps accelerated identification of the strains that are best-suited to produce lipids under any given condition. Stephen Mayfield (a Sapphire co-founder and scientific advisor) would require pumping CO2 into the desert. Just how this would work without carbon dioxide escaping into the atmosphere is not clear, but Sapphire officials say it is *one of many issues the company must address* as it develops its 100-acre pilot facility near Las Cruces, NM [Bigelow 2009b]. But, in 2008 the founder Pyle said “we use genetic engineering, directed evolution, synthetic biology and (agricultural) breeding” and specifically that does not include fermentation. And with regard to the process in which algae “directly converts sunlight and carbon dioxide into hydrocarbon products,” Pyle said “all of our systems are photosynthetic.” [Bigelow 2008] According to Waltz [2009b] experts said some of their organisms are genetically engineered, but the company has not yet publicly confirmed this. Sapphire is also collaborating with scientists from the Department of Energy’s Joint Genome Institute; University of California, San Diego; The Scripps Research Institute; University of Tulsa; and San Diego Center for Algal Biotechnology. Sapphire claims: “We don’t have any questions about whether the technology works. The only question is about the cost of production.” [Bigelow 2008] Sapphire’s concept calls for creating enormous “algae farms” throughout the desert lands of the southwestern United States [Bigelow 2008]. Sapphire is focused on the entire “pond to pump” value system. It will do everything but refining which will be done by a partner, Dynamic Fuels, in Louisiana. The algae and processes developed are field tested at a New Mexico research and development center where all the processes – from biology to cultivation to harvest and extraction – can be performed at a pilot scale. [Lane 2009k; Schwartz 2010]. Sapphire’s position: “We’re an energy company,” “and, “really, who we are competing with is big oil and gas.” There might be a distribution deal with Big Oil (e.g. Shell), but not being acquired by Big Oil. There are large amounts of biomass left over from the process. In line with

	its "*Algal Bio-Refinery*" approach Sapphire studied to figure out what are the best co-products to produce, and it will probably deliver these to others that take the material and do something with it [Schwartz 2010]. During 2008/2009 Sapphire's products were used for first commercial air-line test flights using algae-based, drop-in replacement fuel and a first vehicle to cross the US fueled by a blend of algae-based gasoline in an unmodified engine. Within 3 years Sapphire Energy expected to be nearing completion of a demonstration and test facility and well on its way to producing 1 million gallons of diesel and jet fuel per year over the next 5 years. By 2018, Sapphire expected to grow this to 100 million and by 2025 1 bil-lion gallons of diesel and jet fuel per year and to be able to produce green crude at \$60 – \$80 per barrel [Lane 2009k]. Sapphire is pro-actively lobbying; it wants to cooperate on policy, wants to cooperate making sure there is a playing field that allows everybody to compete. As a prerequisite for the development of the (transportation) biofuel industry, Sapphire assumes that there has to be a price on carbon and to have cap and trade. In this line Sapphire is also heading up the task force appointed by New Mexico Governor Bill Richardson, a former Energy Secretary in the Clinton Cabinet, who has visions of New Mexico's leadership in renewable energy [Schwartz 2010].

*) From the firm's Web site if not stated otherwise by a reference; firm's status: end of 2009.

Sapphire had been moving quickly to build a 300-acre algae farm as a large-scale demonstration of its process for making algae oils which was planned to be completed by the end of 2010 (Table I.93). In 2012 the US government supplied over $100 million of the investments, including a $50 million Recovery Act grant designed in part to spur job creation. Sapphire is a major beneficiary of the US government – in line with its strategy concerning public policy and execution by implementation of a VP Corporate Affairs (Table I.93).

Sapphire's rapid expansion raised the question of whether it is scaling-up its techno-logy too soon. Some of its ideas for reducing the cost of algae fuels appeared at too early a stage to be implemented at the new farm. The new funding will allow Sapphire to finish building its algae farm near the small town of Columbus, New Mexico; a 100-acre segment of the farm has already been finished. When the whole project is complete, planned by 2014, Sapphire would have the capacity to produce about 1.5 million gallons of algae crude oil, which can be shipped to refineries to make chemi-cals and fuels such as diesel and gasoline [Bullis 2012a].

According to its Web site in April 2012 Sapphire Energy said co-founder Jason Pyle has stepped down as chief executive officer of the startup company that has raised then close to $350 million to develop algae as a viable biofuel alternative to crude oil to become a member of the Board. Founding CEOs do not often walk away from startups that have amassed a $1 billion valuation and that have drawn nationwide attention for developing potentially transformational technology. As usual there is an official reason for such a step and a hidden one.

Bullis [2012a] assessed the current situation of Sapphire rather detailed. Knowing when to move technologies out of the lab and into large-scale demonstrations is a perennial challenge for energy startups. According to some experts, Range Fuels (ch. A.1.1.3; Table I.99), founded to produce ethanol from wood chips, foundered because it built a large-scale plant too soon, before the bugs had been worked out of its technology at a smaller scale. As a result, the plant did not work well enough to be economical (cf. also CHOREN Technologies, A.1.1.3).

“Sapphire hopes to lower the cost of producing algae fuels by changing every part of the production process. That includes increasing the quality and the amount of oil produced, reducing the cost of building ponds, and developing low-cost ways to harvest the oil.” Sapphire is working with Munich-based Linde Group to develop a low-cost way to supply the algae with carbon dioxide, which is a key to high productivity. Linde has developed systems for supplying greenhouses with carbon dioxide from a refinery. “The company aims to have a product that is competitive with oil priced at $85 per barrel, and it expects to meet this goal once it reaches full-scale production in about six years.”

When complete, the new 300-acre algae farm project is expected to produce about 100 barrels of algae crude per day, or 35,000 a year. Sapphire Energy’s vice president of corporate affairs Tim Zenk said the process will not be commercially viable without the economies of scale that will come with much, much bigger farms – 1,000 to 5,000 acres.

> Achieving these cost targets will require significant innovation. In 2011 studies from the National Renewable Energy Laboratory (NREL) concluded that *algae-based diesel made by scaling up existing algae technologies would cost several times as much as conventional diesel*. According to one of the studies, it would cost about $9.84 per gallon to make algae diesel, as opposed to $2.60 per gallon for petro-diesel, at January 2011 costs.

Phil Pienkos, a research scientist at NREL, said that Sapphire is doing a number of good things to reduce costs. Yet he said making algae fuels competitive will be a challenge. “It takes a certain amount of faith that there is going to be a business there,” he said.

Furthermore, experts agree that non-fuel markets can be profitable for Solazyme and other algae firms, but they warn that *investors will be impatient* to access the multi-billion-dollar fuel market. *That may set the industry up for failure*, because it will be many years – if ever – before algae can be cost-competitive with petroleum [Bomgardner 2011d].

One aspect with all the above discussed algae startups, Cellana/HR Biopetroleum, Solazyme, Algenol Biofuels and Sapphire Energy, is the strong focus on policy initiatives and lobbying for governmental financial and legislative support, specifically through politically experienced firm representatives. In case of algae it is not surprising that, apart from the US Department of Energy (DOE) and Department of Agriculture (USDA), in the US also the Department of Defense is a target for seeking support for activities in algae, particularly, with regard to the algae-to-military jet-fuel production process [Gaithwaite 2009].

> For entrepreneurs in biofuels, the potential payoff is obviously big enough that it is worth hiring appropriate persons and spending time and money away from firms' sites to take the risk that the administration and authorities will not pick their technologies. Success in the capital simultaneously increases the firms' credibilities and facilitates to win funds from venture capital.

Whereas innovative and entrepreneurial activities have the same key targets in the US and Germany regarding plant-based biomass or waste, biofuels, reducing carbon dioxide emissions and lifting/reducing petro-oil dependencies, things are different for aquatic biomass (algae).

Basically, the US "owns sunshine" for certain areas or states, respectively, as a natural resource, as are coal, petroleum or forests/wood [Runge 2006:287]. This means, national advantages in natural resources and traditional industries can be fused with related competencies in broad technological fields thus providing the basis for technological directions and advantages in new product fields and often new and strong and innovative companies.

> In Germany activities with algae are generally held back to a certain degree by the all over on average low duration (and strength) of sunshine, at least with regard to open pond or outdoor settings. Hence, related innovation and entrepreneurial activities which are also supported by governmental programs emphasize closed photoreactors, greenhouses and algae feeding, light, temperature control and mass transfer (algae; CO2 in, oxygen (O2) out) and an *engineering approach* to optimize relevant process parameters.
> Furthermore, due to stronger societal attitudes against GMOs, in Germany, more than in the US, bioengineering routes are only rarely followed by startups, but the focus is on breeding and cultivating naturally occurring algae.

There are some visions in Germany to install huge bioreactors with sea water and algae at the Mediterranium, in which CO2 from power plants are converted to biomass [Anonymus 2007b] similar to the constellation now being established by Sapphire in New Mexico or Algenol and Biofields in Mexico (Table I.91).

Disregarding the above described exceptional startup Cyano Biofuels, rather than following strongly the fuels/energy route, in Germany algae activities including those of NTBFs, focus largely on *higher value products from algae* (Figure I.176) and *carbon* *dioxide sequestration.* Due to “cap and trade” legislation in Germany (as also requested for the US, for instance, by Sapphire (Table I.93)) carbon sequestration works as an incentive for firms because trading and selling from created CO2 emission permits will lead to financial revenues.

The current general view is that algae are only an option as an energy source in combination with high value algae products. In Germany’s largest algae farm (near Klötze) with an annual production of 60 tons biomass per hectare (2.47 acres) utilizing the ingredients is the priority. And everything that cannot be extracted and sold at a high price will be converted to animal or fish feed and sold at competitive prices. Also experts from large German power companies, such as RWE, share the general view: “currently we exclude large energetic exploitation {of algae}” [Müller-Jung 2010].

Correspondingly, compared to the US level, there are relatively little entrepreneurial activities with algae in Germany. On the other hand, its giant power suppliers E.ON, RWE and EnBW or their respective subsidiaries run or have run several pilot projects targeting carbon dioxide sequestration requirements by transferring flue gas containing CO2 of their power plants into algae and to algae fuel producers – for instance, in cooperation with the NTBFs BlueBioTech GmbH (mentioned above), Novagreen Projektmanagement GmbH or Subitec GmbH and federal or state financial support (Table I.94).

There is also considerable research in Germany with regard to producing biogas, consisting essentially of methane (ca. 65 percent) and carbon dioxide (ca. 30 percent) from algae as a biofuel for cars, trucks and busses. A conversion of algae into biogas that then will be burned in a *closed loop process* (Figure I.177) would capture CO2 permanently from the air!

Table I.94: Algal pilot projects of German power suppliers concerning carbon dioxide sequestration and producing high value algae products involving NTBFs.

Power Supplier and Project Partners	Details
RWE Power [RWE 2009a; RWE 2009b] With: (Federal) Research Center Jülich, Jacobs University Bremen , *NTBF* Phytolutions GmbH (a spin-out of the Jacobs University Bremen). at: RWE Power’s Coal Innovation Center, at its Niederaussem power plant site. Partial financing is envisioned via selling CO2 emission permits. Operational since 2008,	Goal: optimize the whole process from algae cultivation to end product; produce 60 – 100 tons of biomass per hectare and year Tests: different types of algae and reactors for energy efficiency, photobioreators (outdoor) without greenhouse, other applications, such as biofuel and building material; inquire into *hydrothermal carbonization* (HTC), also for opening a new field of

project end 2011. The pilot plant covers 600 m2 (148 acres) (can be extended to 1,000 m2) Process details: A suspension of microalgae from sea water is mixed with flue gas and transferred into a photobioreactor in a greenhouse. Currently patented vertical column photobioreactors (transparent plastic hoses fixed in V-form) from Novagreen are used; shall be replaced by “endless hoses.”	chemistry and development of new materials. Results so far: The plant produces up to 6,000 kg (dry) algae mass and binds 12,000 kg CO2; a high value product has been obtained.
RWE Power [RWE 2010] With: German biotech firm Brain AG at: RWE Power’s Coal Innovation Center, at its Niederaussem power plant site Biotech firm Brain provides innovative enzymes and synthesis routes and pathways. Its comprehensive “natural toolbox” shall allow synthetic biology to produce innovative microorganisms that are able to capture more CO2 from a lignite-fired power station	Goal: convert carbon dioxide into microbial biomass or biomolecules – joint research alliance between RWE Power and BRAIN AG using “designer microorganisms” in search of biotechnological solutions to CO2 conversion and developing further intelligent uses. Applications to be explored include building and isolation materials and the production of fine and specialty chemicals.
EnBW Energie Baden-Württemberg AG [EnBW 2008]. With: *NTBF* Subitec GmbH (founded in 2000; a spin-out of the Fraunhofer Institute for Interfacial Engineering and Biotechnology (IGB) in Stuttgart at: Eutingen, a biogas plant; running and cultivation a system for microalgae with CO2 feeding from a (block) combined heat and power (CHP) plant EnBW acts as a project client, Subitec as the owner and operator of the pilot plant	Goal: carbon dioxide sequestration by algae; focus on efficiency of CO2 binding. Subitec’s business model: provide its patented thin channel airlift and forced flow photobioreactors and develop and operate pilot plants of various dimensions and develop concepts for utilizing and post-processing algae related biomass [Ripplinger 2009]; the pilot plants will sometimes be constructed at the company’s own expense, and sometimes on behalf of customers or cooperation partners.

Table I.94, continued.

E.ON Hanse [E.ON 2008; Anonymus (2007b] At: a natural gas storage facility at Hamburg-Reitbrook; provides flue gas from a CHP Sponsors together with the city of Hamburg run the project TERM (Technology for the Exploitation of the Resource Macroalgae) of several universities from northern Germany and NTBF Subitec. E.ON adds a researcher and several technicians; who research together with Subitec as a partner; E.ON provides technology, logistics, infrastructure and research services and an area of 1 hectare to TERM and Subitec. SSC Strategic Science Consult GmbH coordinates and leads the project.	Goal: planning, construction and technical assistance for the operation of a cultivation system for microalgae; E.ON and Subitec add reactors for cultivating algae and develop these further; Operation is in an open air outdoor (no greenhouse); Project cost: €2.2M; Hamburg's contribution €0.5M [Anonymus 2007b] R&D focus: ▪ Optimizing bioreactor technology for optimal growth and high efficiency for converting primary energy (day light) into biomass, ▪ Optimize microalgae on the species level, biomass composition and physiology, ▪ Automate the plant, to facilitate industrial production.
E.ON Ruhrgas [Böttcher, C. 2006] With: IUB (International University of Bremen) and BlueBioTech GmbH is working on research and development A project "Biofixing of Greenhouse Gases with Microalgae Biotechnology" (2005-2007) was funded by E.ON	Goal: produce biodiesel and animal feed from flue gas and marine microalgae using a small greenhouse with a 150 l photobioreactor.
Using carbon dioxide emissions from an E.ON Ruhrgas 350 MW coal-fired power plant in Bremen supported by the state (city) of Bremen was a basis of the Greenhouse Gas Mitigation Project (GGMP) [Golon 2006] 4 micro-photobioreactors were connected to the flue gas from the power plant. Project partner: Jacobs University Bremen BlueBioTech GmbH Novagreen.	Goals: Experimental micro-facility to test the tolerance of microalgae to the flue gas ▪ Test facility, establishing proof of principle ▪ Planning and construction of pilot plant with a capacity of 500 tons CO2/year ▪ Planning and construction of plant to treat 15,000 tons CO2/year Status/results: microalgae removed CO2 (and NOx) from flue gases and recycled it in form of

With sales of the CO2 emission permits cost of the plant and fuel production are envisioned to be covered	biomass and derived products; no negative effect of flue gas on the production of microalgae; concentrations of pollutants were significantly below the values accepted for animal feed

The innovative/entrepreneurial approaches in Table I.92 as well as Table I.94 reveal that *governmental/public funding and grants in Germany are provided preferentially to defined technical projects with partners from industry (large firms and NTBFs) and public research organizations* (universities and/or federal/state research centers) with a systemic orientation whereas in the US the focus is often on individual firms (large or small).

Another topic of interest in the context of algae as biomass (RWE Power) is "*hydrothermal carbonization*" (HTC) which was developed by the Max Planck Institute of Colloids and Interfaces in Potsdam/Germany. It is a new variation of biomass conversion.

In contrast to other biomass carbonization techniques that require dry biomass, the HTC process is a highly efficient "wet'" process that avoids complicated drying schemes and costly isolation procedures (biomass + water +catalyst+ pressure in the absence of air) to produce carbonaceous materials ("biocoal"). This would also apply to wet biomass from algae. The method – "pressure cooking biomass till it boils dry" – is relatively inexpensive, widely applicable and quickly scalable and can produce clean energy in the form of gas or oil along with a "*biocoal*" powder. And it opens a new field of chemistry and development of new materials, such as nanotubes. [104]

A German NTBF founded in 2007 to exploit HTC technology is Suncoal Industries GmbH (B.2).

Apart from BlueBioTech GmbH in Germany there are two algae-oriented NTBFs particularly notable, NOVA green Projektmanagement GmbH (also written as Novagreen; Table I.94) and IGV GmbH (Institut für Getreideverarbeitung; The Institute for Cereal Processing Ltd.; Table I.92). Novagreen has its root in horticultural engineering (project management!); IGV originated with food and nutrition engineering, but then also added algae-related biotechnology as a key area of activities.

Novagreen was founded in 2004 by an engineer (Rudolf Cordes) and Dr. Theodor Fahrendorf, with more than twenty years of (industrial) experiences in plant physiology, biochemistry and biotechnology. Novagreen originated with the firm Agrinova Projektmanagement GmbH, which was established by Cordes in 1997. Agrinova is active in cultivating and breeding fruit and vegetables. Agrinova focuses on "secondary plant ingredients" which are marketed as food additive with protection capacity against cancer. Hence, Novagreen can be seen as a spin-off complementing horticulture by algae-oriented aquaculture.

Agrinova does not only breed backcrossings to still more primitives to get more substantial varieties which are closer to the wild-type related varieties. It develops also advanced harvesting technology and processing know-how. The company isolates and extracts raw and finished materials and supplies raw materials and pharmaceutical intermediates for the manufacturing industry. Its mechanical engineering branch develops prototypes and machines to harvest, for instance, cabbage more softly directly in the field. Agrinova sells its product directly via its Web online ("Agrinova-Shop") and supports its marketing by public presentations about the health supporting roles of their products.

T. Fahrendorf joined Agrinova in 2005 to lead the science direction of the firm (CSO). Cordes and Fahrendorf became partners and managing directors of Novagreen GmbH (LLC) which focuses on algae and could rely on development systems set up already in 1998 by Cordes which were subjected to continuous improvements. [Agrinova].

According to its Web site Novagreen is a developer and provider of novel bioreactors for the production of microalgae in a closed environment. Simultaneously Novagreen is a producer of selected bulk microalgae and ingredients using these bioreactors for the food, cosmetics, and pharmaceutical industry.

The bioreactors are adapted to producing different types of algae – and for freshwater or sea water. Novagreen's patented production platform using a unique three-layer film "tubing system" ("hoses") can be implemented in almost any standard greenhouse facility worldwide to fit existing infrastructure. It offers also a power (heat) concept for connecting to an existing biogas plant utilizing the waste heat of a combined heat and power (CHP) plant, to reduce carbon dioxide (Figure I.177).

Hence, Novagreen may provide new streams of revenue for the agro industry, particularly horticulture. Production takes place in a closed and controlled environment that guarantees the high quality distributors and consumers are looking for (high quality certified microalgal products). Novagreen *uses pre-existing, well established horticultural production systems, distribution and marketing channels*. Novagreen is introducing production of microalgae as an integral part of modern horticulture.

Novagreen pursues R&D activities, usually in cooperation with other firms (Table I.94) via projects subsidized by policy. For instance, for optimization, in its laboratory all the species of algae are matched to the carbon dioxide sources as well as their intended use.

Microalgae can also be used for production of recombinant proteins. Novagreen is planning the production of antibodies and vaccines for the veterinary market. For 2012 it planned to establish a production system for heterologous antibodies and vaccines in transgenic microalgae. Since 2008, preliminary tests were run in cooperation with European and American institutions [Daniel Meier Medienteam 2010].

According to the Creditreform/Firmenwissen database Novagreen had revenues of €310,000 in 2010. It is not clear whether this corresponds to sales of offerings. One can assume that there is additionally a large hidden contribution of project capital attributed to Novagreen. Furthermore, apart from the two founders, the GmbH (LLC) has a third partner who may contribute equity. Moreover, it is not obvious in how far Novagreen and Agrinova are run as financially independent firms.

In the sense of an engineering-type firm technical offerings by Novagreen include [Fahrendorf 2008]:

- Developing algae-bioreactors and production plants for algae up to 100 hectares
- Power concepts for biogas plants
- V- and H-reactors
- Foil tunnels
- Harvesting and processing technology (pumps, driers)
- Production of algae for various purposes
- Precursors for pharmaceuticals
- Reference proteins
- Transgenic algae
- Commercialization (marketing) of the customers' algae.

Services covers:

- Consulting, concepts for utilizing heat, assessments
- Tailored solution that guarantee an optimal utilization of heat
- Construction of plants
- Management, central laboratory and analytics
- Approval and commercialization of the algae.

In 2010 Novagreen's demonstration greenhouse with production of algae was coupled for the first time to a biogas plant. With its self-developed, proprietary cascade system it was tested under which conditions algae show best growth and bind the most carbon dioxide of the biogas. The greenhouse is covered with photovoltaic glass panels and will produce die 630 Kilowatt-Peak (KWp) electricity per hour. The light transmitted to the algae in the photobioreactors suffices to generate 80 metric tons of biomass per hectare. Additionally the demonstration setup was used for trial with algae that produce essential omega-3-fatty acids which is interesting for the animal feed industry as a fishmeal replacement [Daniel Meier Medienteam 2010].

DTB – Deutsche Biogas AG, a German NTBF in renewable energy – produces and sells electricity and heat from biogas plants, which it designs, builds, and operates in partnership with farmers. In 2011 it started am algae program together with Novagreen. The aim of the common project was to test Novagreen technology, and further develop and optimize the technology. Here, the waste heat from the biogas plant is used for the operation of the greenhouse and thus integrated into the value chain. With the help of the algal and special cultures carbon dioxide from the exhaust gases of the related CHP will be “stripped,” so that the production of biomethane is not only CO2-neutral, but has reduced CO2 [DTB 2011].

Previous discussions related the German IGV GmbH (Institut für Getreideverarbeitung; The Institute for Cereal Processing Ltd.) to the US startup Greenfuel Technologies founded in 2001 as a cooperation partner regarding biofuel from algae (ch. 2.1.2.8; A.1.1.3). However, IGV represents also one prototypical case of *necessity entrepreneurship* enforced by the re-organization of the industry and the science and technology system of the former socialistic German Democratic Republic (GDR – in German DDR – occupied by the USSR) after the German Re-Unification around 1990.

Due to the devastation of Germany after World War II and particularly the lack of resources in its Eastern part and lack of money for imports the GDR followed often the technological paths of Nazi Germany to become self-sufficient (autarky) concentrating on optimizing what is available and the focusing on the notion “Ersatz” which is “substitute,” such as “Ersatz-Holz-Zucker” (synthetic sugar from wood) [Runge 2006:270-272, 566] (cf. above CHOREN Industries and Bioliq – Figure I.173).

IGV addresses necessity entrepreneurship of employees of a state-owned research institute in the former GDR, located in the German state Brandenburg rather close to Berlin. The privatization of IGV corresponded formally and regarding the result to a management buyout (MBO; ch. 2.1.2.4), but there was a legally complicated process behind it as for a public research institute or firm the “normal” approaches to an MBO did not apply in the capitalistic Federal Republic of Germany.

IGV was founded in GDR in 1960 in Brandenburg which is a state with a dominant food industry. Ca. 50 percent of Brandenburg’s area was and is used for agriculture. And also after the German Re-Unification, the food industry with a turnover of €2,402.5 million (in 2004) remained the industry showing the highest overall revenues. It was set up as a *practice-oriented research institute for the milling, bakery and food industry*.

Furthermore, its location in Nuthetal near Brandenburg’s capital (and Berlin) provided an environment with universities and non-university research institutes for food science and nutrition. And for decades the IGV was a leader of the food industry and in processing of vegetable raw materials in the GDR.

When the IGV added biotechnology to its main fields of research Prof. Dr. Otto Pulz became the leader of biotechnology in 1975. Since 1981 he was engaged in biotechnology of algae, particularly focusing on design and construction of photobioreactors, on active ingredients and raw materials for cosmetics [succidia]. That means he started during the first “algae wave,” in the late 1970s and early 1980s.

Another important person of IGV was Peter Kretschmer who is a passionate scientist (“Ich bin eben ein leidenschaftlicher Wissenschaftler”) [Steyer 2007]. In 2010 the engineer P. Kretschmer was promoted with a doctoral degree by the Technical University of Berlin at the age of 72 [Meuser 2011]. He was seen as “the Gyro Gearloose of the GDR-food industry” (“Peter Kretschmer war der Daniel Düsentrieb der DDR-Lebensmittelindustrie.”)

Dipl.-Ing. Peter Kretschmer (in 2012 74 years old and still the managing director of the new IGV) had a research focus on bread and bakery and he became a world re-nowned expert in this field. Also apprenticeship for people in the bakery industry was established and provided by the IGV under his supervision.

Basically, Kretschmer had to respond to the command of the GDR government: “Re-duce the time of our women to stay in the kitchen” (“Verkürzen Sie unseren Frauen die Zeit in der Küche.”). Even if this aimed officially at improving the life balance of women between family, children and profession and career, actually the GDR was is heavy need of more people to have its industry grow [Steyer 2007].

As described by Meuser [2011], after the German Re-Unification, “The German Treu-hand Agency” was leading the re-organization of the socialistic economy, industry and research organizations of the former GDR. In 1990 IGV got the legal status of a lim-ited liability company (LLC – GmbH) and the Treuhand became its single owner. The Treuhand wanted to eliminate the existing IGV and laying off ca. 180 employees.

As a consequence, there was a massive layoff of employees and in 1990 Peter Kretschmer became managing director supposed to be able to lead IGV into the market environment. All IGV employees were aware that the IGV could only survive focusing on its core competencies. This orientation was appreciated by the German Science Board which acts as a consultant for the Federal Government.

In 1991, after a careful assessment, the German Science Board suggested to keep the IGV with all its research priorities. Many options were explored to transfer IGV ownership of the Treuhand into a State custody. However, after all the options had turned out to be negative, only privatization remained as a solution.

Since an additional objective of IGV’s future was the preservation of the autonomy and independence, in 1994 an MBO occurred with retaining the LLC-structure in which Dipl.-Ing. Peter Kretschmer, Dr. Helmut Barnitzke and Prof. Dr. Otto Pulz were partners [Meuser 2011]. Later H. Barnitzke changed into the Supervisory Board of the firm, and P. Kretschmer became managing director and Prof. Pulz a representative.

IGV now is a private and independent applied research institute with key competen-cies in food processing, biotechnology and processing of biomass materials with cur-rently about 100 employees. The proportion of people with a scientific or engineering education and technical employees (masters, chemically-technical assistants and laboratory technicians) is about 4 to 1.

The focus of the competence and research spectrum is on production and process in-novations, their efficient development, commercialization and technology transfer to small and medium-sized enterprises in food processing and related areas. The scientific and technical services include the operation of an accredited testing laboratory.

Sales and distribution of IGV's offerings take place worldwide [BMWi 2011]:

- Ca. 30 percent of the orders are captured in the state of Brandenburg or Berlin.
- Ca. 60 percent of the orders are requested by medium-sized or large firms in Germany or the EU.

Since 2002 there is a close cooperation of IGV with the University of Applied Sciences of Lausitz (in German Fachhochschule) concerning phototrophic biotechnology whose major theme is algae. In 2006 this cooperation was formalized and contractually extended. In particular, it included establishing phototrophic biotechnology as a field of education and research and having Prof. Pulz of IGV as a visiting professor to hold lectures [Witzmann 2006].

Common research fields focused on

- Building a unique collection of microalgae species (after four years the collection had more than 250 originals – an invaluable genetic potential);
- Search for species-specific active substances (an example is to develop a special line of cosmetics);
- CO2 sequestration and climate protection (Table I.92).

A similar approach of necessity entrepreneurship out of a large research institute of the Academy of Science in Berlin-Adlershof (in the GDR-part of Berlin) induced by the German Re-Unification is observed for ASCA GmbH (Angewandte Synthesechemie Adlershof GmbH), active in the area of fine chemicals and active pharmaceutical ingredients. It acts as a private research institute focusing essentially on contract research. As the IGV also ASCA financed its early life and survival by special grants which were established by German state and federal governments and the EU to support the transition of the socialistic system of the former GDR into the Nippon-Rhineland capitalism (ch. 1.2.4) of the Federal Republic of Germany.

> And looking also at the below discussed case of "Bioprodukte Prof. Steinberg Produktions- und Vertriebs GmbH & Co KG" one realizes that independence and determining one's own destiny (Table I.39) are very strong drivers for entrepreneurship demonstrated by people who were living in a society where both aspects were suppressed and became founders when the restrictions were lifted.

IGV now exhibits healthy growth. Total revenues of IGV amounted to €6.52 million in 2010, €4.70 million were achieved by selling to the market and €1.83 million were obtained by grants related to projects financed by the public (German state and federal governments as well as the European Union). Currently growth in revenues is almost determined by sales to industry. While the proportion at 2002 was 50:50 (each ca.

€2.15 million), the contribution from grants stayed almost constant at ca. €1.8 million. For instance, the proportion for 2007 was €4 million to €1.4 million [IGV 2011].

Looking at algae IGV developed plants for breeding and harvesting algae in *closed systems focusing on photobioreactors*. Since the middle of the last century microalgae have been produced in open ponds, mainly in South East Asia and the US. These ponds are about 15 cm deep and are stirred at one or more points. In 1995 a technique was developed in Germany for cultivating microalgae which centered on a *closed system of glass tubes*, rather than a “continuous aquarium,” to expose the algae to maximum light.

Cultivation of algae in glass tubes has considerable advantages over cultivation in ponds, particularly for high value products (Figure I.176):

1. Light can reach the algae from all sides through the glass tube; they are exposed to maximum light and can grow well. There are no areas which are deficient in light such as those occurring in the deeper layers of ponds.
2. All the environmental factors which are important for healthy growth of algae, such as pH, temperature and carbon dioxide supply, can be controlled and adjusted to the optimal setting.
3. External uncontrollable influences, such as rainwater, dust, insects, waterfowl and their droppings, blue-green algae etc., can be eliminated. And this difference in quality can be measured, for example, in terms of heavy metal and toxin contamination.
4. There is no evaporation of water over a large area.
5. Only a fraction of the space taken up by a pond system is required.

Over the years IGV built up much experience in using algae for food and nutrition, pharmaceuticals, cosmetics and animal feed. But, for a long time, Pulz had also the idea that one could use the microalgae for the production of biofuels using particularly the type *Chlorella vulgaris* and to use carbon dioxide generated by power plants or exhaust gases generated by particular manufacturing plants. Already in 1996 Otto Pilz cultivated *Chlorella* in plate reactors for biodiesel.

The related techniques were implemented at a lime burning plant in cooperation with the German conglomerate Preussag AG which at that time (until 2000) was focusing on exploitation of mineral resources and their processing, for instance, mining of coal, metal ores, potash and rock salt and limestone. Back in 1996/1997 Prof. Karl-Hermann Steinberg of Preussag AG (1995 – 1999 Director of Innovation, Preussag AG Hannover responsible for microalgal research, etc.) was also considering the question of how carbon dioxide emissions from power stations, for example, could be put to good use.

Together with the holder of a patent for algae-breeding IGV developed the Preussag algae manufacturing plant. That is, the production plant and the method of cultivation were protected by patents. Construction of a microalgae production plant began in

Klötze in 1999 (in the German state Sachsen-Anhalt; see below). One year later the first algae of the *Chlorella vulgaris* species were already being cultivated in this unique facility, the first of its kind in the world. However, the low petro-oil price forced Preussag as the owner/operator of the algae production plant to give up after four years.

Prof. Pulz continued to complete Europe's largest microalgae production plant. It produced 130 metric tons of algae per year. The system of production halls contained 500 km of arm-width glass tubes filled with green water and meandering through the halls. The water is mixed with a starter culture; then the tiny organisms multiply with the help of light and carbon dioxide. At the end of the plant a large centrifuge concentrates the liquid to a thick green grits, which is dried. The result is purest microalgae – packed into bags as a fine greenish powder. The powder is used as an additive to food or cosmetics [Schürmann 2007; Schibilsky 2008].

In the meantime, IGV's researchers developed a so-called 3D-matrix system in which to grow two to three times as many microalgae as in the conventional, essentially linear photobioreactors made of glass tubes. Here, microalgae grow in geometric structures. The novelty was that the distribution of algae is in three dimensions, as the light is distributed, and thus light and algae are constantly in contact. Thus, one achieves a better photosynthetic performance and highest yield. If sunlight is not sufficient energy-saving light bulbs will support providing necessary light intensity [Schibilsky 2008].

US startup Greenfuel Technologies took notice of this new type of reactor which led to development cooperation with IGV. For instance, a stepwise process of feeding the algae was found to be important. At first, the algae are still supplied with everything needed for rapid growth. Then the food intake is reduced. And the algae react to the sudden shortage by converting up to 70 percent of their weight into oil, which can be processed into biodiesel [Schürmann 2007; Schibilsky 2008]. However, not related to technical shortcomings, a number of other factors ultimately led to the bankruptcy of Greenfuel as described in previous chapters (ch. 2.1.2.8; A.1.1.3).

One lesson learned concerning algae is that so far technology has not reached its goal and "under the present price situation a large-area production of microalgae for energy under Central European climatic conditions is not realistic." [Schibilsky 2008]

The IGV/Preussag cooperation in Klötze gave rise to a further technology entrepreneurship case of a former citizen of the GDR involving the Preussag partner of IGV, in particular, Prof. Karl-Hermann Steinberg, and the marketing of algae under the Algomed® brand. When Preussag stepped out of the algae project in 1999 Prof. Steinberg founded the firm "Bioprodukte Prof. Steinberg GmbH" (BPS) to organize distribution and selling of algae products [Zentner 2004].

Also in 1999 the "algae-patent" was licensed to a startup "Ökologische Produkte Altmark GmbH" (ÖPA) and the algal production plant was finalized in Klötze. It was claimed that nowhere else in the world algae are produced with such high standards of purity and quality. But in 2001 ÖPA went bankrupt. [105] Steinberg attributed commercial difficulties to the termination of production after less than one and a half years in charge. Due to excess capacity and a more expensive building the company became uneconomical [Voigt 2008]

Prof. Dr. Karl-Hermann Steinberg (born in 1941), growing up in the former GDR, graduated in chemistry (Dr.) at the Merseburg Technical University and became full professor of chemical engineering, Leipzig University in 1991. Further steps in his life included [106]

1989 – 1990: Deputy Minister of heavy industry of the GDR, environmental protection department;
1990: Minister for environmental protection, nature conservation, energy and reactor safety in the "de Maizière government" of the former GDR;
1991: Joined Noell GmbH, Würzburg (Germany), in essence a subsidiary of Preussag AG and active in various fields, such as systems and mechanical engineering, steel construction and machinery, energy and environmental technology, process engineering and services;
1995 – 1999 Director of Innovation, Preussag AG Hannover.

In 2004 insolvency assets of ÖPA were taken over by Prof. Steinberg's firm assisted by a group of private investors to form "Bioprodukte Prof. Steinberg Produktions- und Vertriebs GmbH & Co KG." The facility was partially rebuilt, renovated and modernized and production of microalgae was launched within a new constellation. The next year the laboratory was extended, an extensive collection of algal strains was built up and a scale-up line established to produce and sell ALGOMED® products, for instance, also via its online shop or pharmacies [Zentner 2004; Voigt 2008] [105].

"We had to invest nearly €4.5 million to build technology anew and eliminate the damage caused by the long shutdown," said Steinberg [Voigt 2008] For his investments Prof. Steinberg could get a loan guarantee of the State of Sachsen-Anhalt for €1.2 million [Lieske 2004] – and it can be assumed that his political experiences and networking had paid off.

With 17 employees in 2008 sales of the business went up. In 2006, revenues from sold algae in many different forms were almost €1 million; one year later sales climbed to €1.2 million euros and for 2008 Steinberg expected to reach €1.5 million. 60 percent of the products were exported. Customers from Switzerland, France and even Malaysia were on the list [Voigt 2008].

But, since January 2008, the company belongs to the French group Roquette Frères, which is Europe's biggest starch producer [Voigt 2008] – and since October 2008 Steinberg worked as an external consultant. [106] The new firm's name is Roquette Klötze GmbH & Co. KG.

In line with the German firms Novagreen, “Bioprodukte Prof. Steinberg Produktions- und Vertriebs GmbH & Co KG” and the private research institute IGV the US firm Solix Biofuels^{TM} (now Solix BioSystems) with its AGS^{TM} Technology (Algae Growth System) cultivates oil-rich microalgae in a *controlled* environment. It is involved in the production of a “biocrude” (algae oil), “green” diesel (jet fuel and biodiesel), methane, chemical intermediates, feed and other important products. Actually Solix, headquartered in Ft. Collins, Colorado and founded in 2006, aims to build a commercially viable alternative to petroleum-based fuels and chemicals. It is a university spin-out transformed into a *VC-based startup* with currently a *“veterans” management team*.

According to research done by the Laboratory for Algae Research & Biotechnology, closed system photobioreactors, like Solix’s AGS^{TM} Technology, have seven times the biomass productivity of open pond systems.

Solix Biofuels was founded by private entrepreneurs Jim Sears and Doug Henston (then CEO), Colorado State professor Bryan Wilson (then CTO), and Colorado State University (CSU) itself. Working to refine and scale Sears’ original bioreactor design, the group has called on the resources of CSU’s Engine and Energy Conversion Laboratory in constructing a working prototype of a closed-tank bioreactor [Madrigal 2007].

By August 2006 a first generation prototype had been built, tested, and analyzed, and a second generation prototype was launched. Furthermore, Solix housed at Colorado State University, has spent a year sorting through 40 strains of algae collected from around the world. The startup sought for the best strains and best environment for the organisms [Procter 2008; Narvaes Wilmsen 2006].

Now Solix Biofuels’ AGS algal production system is designed to enable the industrialization of algae at scales suitable for large volumetric production of biocrude in volumes. At the center of the AGS^{TM} Technology is Solix Biofuels’ proprietary photobioreactors. The photobioreactor contains closed chambers rather than tube systems as used by its German counterparts. The technology circulates algae within the chamber using controlled turbulence in order to maximize exposure of algae to light and thus algae growth by photosynthesis. More details of the technology are given in The Energy Blog [2006].

Solix provides essential technology for industrial algae production. Apart from acting as a producer it offers also its system as an integrated, flexible algae growth system addressing various capacities utilizing Solix’s proprietary, floating photobioreactor panels (Lumian^{TM} panels) to provide a high productivity growth environment for the outdoor cultivation and evaluation of algae species.

Funding steps according to CrunchBase were:

- $16M in Series B funding (3/28/2011)
- $2M in Venture Round funding (1/4/2010)

- $2.5M in Venture Round funding (11/23/2009)
- $500k in Venture Round funding (11/6/2009)
- $6.3M in Series A funding (7/2/2009)
- $10.5M in Series A funding (11/12/2008).

Solix converts the algae biomass it produces at its Demonstration Plant with peak production capacity of 3,000 gallons per acre per year of algal oil into biocrude oil using its proprietary extraction process that removes the triglycerides from the biomass (algae oil, Figure I.177) [Ritch 2010]. Solix is also offering the residual biomass that remains after the triglycerides have been extracted. This biomass is rich in protein and carbohydrates and has potential as a source for various food ingredients or as an animal feed or for aquaculture. It is also rich in other products including amino acids, carotenes and antioxidants.

Solix Biofuels' demonstration facility is located at Coyote Gulch in southwestern Colorado. This large-scale facility complements the pilot facility in Fort Collins, Colorado. The demonstration facility is located on land provided by its partner, the Southern Ute Alternative Energy Fund. It is using waste water generated during coal-bed methane production thus reducing the need for fresh water.

In 2010 Solix was in talks with potential partners interested in building, owning and operating plants using Solix's technology to produce algal oil and downstream products [Ritch 2010]. In the same year Solix signed an agreement to investigate the use of algae for the German firm BASF, the world's largest chemical company. For BASF the emphasis is on commitment to generate growth from industrial biotechnology and on algae representing an addition to BASF's technology portfolio as they offer the potential to produce a number of specialty chemicals and products.

A.1.1.5 Structuring Entrepreneurship in Biofuels

Previous sub-chapters have largely focused on the *large firms' intrapreneurial approach to biofuels involving NTBFs* in the field or a technical*/engineering approach* following an engineering, procurement and construction (EPC) project for scaling-up to commercialization (Figure I.180). Without much own research the last approach concentrates on process and plant engineering. Additionally, it focuses on

- Improving and *modifying existing, proven technologies* and exploiting whatever is available or purchasable, such as using Lego-type commercial-off-the-shelf (COTS) components, retrofitting existing plants etc.;
- Managing and execution by "*technology veterans*" with large experience in the (technical) field and a related *management team with long and broad managerial and project leading experiences* in the oil industry or related industries and connected by previous common affiliations and presently common interests; moreover, the veterans approach has emerged often from "old boys networks";

- Having managers or persons, respectively, with experience in government relationships (grants, funding, permits etc.) to play an important role in the management team.

In an RD&D scale-up process as depicted in Figure I.180 this approach steps in essentially at the "Initial System Prototype" phase.

On the other hand, there are startups (often RBSUs) which have to do much research and start from scratch in the process ("Research") which later have to add engineering competencies for scale-up ("Demonstration & Development"). This characterizes the proceedings as a *scientific/engineering approach*.

In particular, with regard to the "veterans" aspect it is to be noted that new firms' foundation was done often by *serial entrepreneurs*. On the other hand, the examples of Sapphire (Table I.93) (and later Coskata, Table I.99) exhibit a pro-active role of venture capital for foundation.

Given the myriad of technological options, innovation approaches and financing options by private and public organizations the "acid test," the rigorous or crucial appraisal to start a biofuel firm, is the comparison of the startup's production cost versus the petro-fuel production cost or oil price, respectively. Startups usually flag their (competitive) position by the price (in $ or € per gallon/liter) they would have to charge for their biofuel.

For RBSUs considering a scale-up approach from research and lab to a large-scale commercial plant one issue is whether a corresponding calculation done for a lab or pilot plant setting is also valid for the large-scale manufacturing setting. Still, most biofuel NTBFs will have to prove they can deliver on those low prices at full-scale commercial production.

However, the basis of the individual calculations is mostly not compatible due to intransparency of the underlying components and assumptions. For instance, the price per gallon may be calculated as *cost of production* minus revenue from co-products, and assuming particular feedstock cost (type of feedstock, dry or wet?) and their process energy cost which may refer totally to natural gas cost or even may contain energy delivery through a side-chain of their biofuel process.

Comparing the RD&D process for biofuels (Figure I.180) for a policy-driven market with the common value chain (Figure I.7) of technology-based firms one observes that marketing plays a minor or even negligible role.

Right now there are many products and technologies out there and no dominant design, and startups are trying to choose from these and make decisions about. But one cannot be sure that the best technology will win. It may be that the best management team or the best marketing team will make it or the realities of the market will decide otherwise.

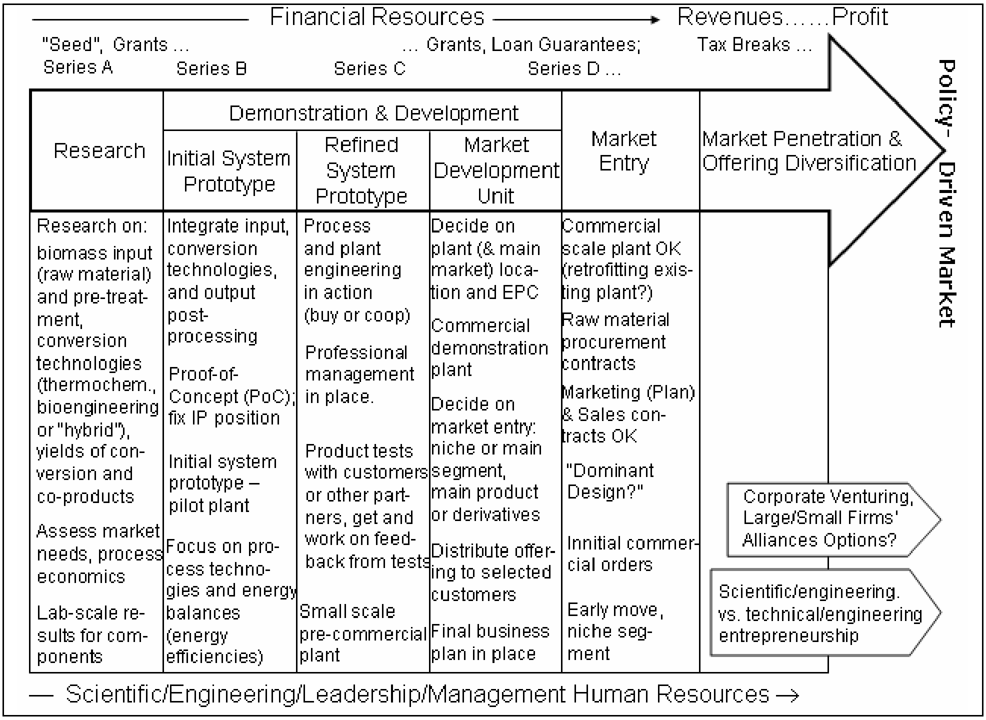


Figure I.180: The RD&D staged path of innovation for biofuels.

Pamela Contag [2008a] of Cobalt Biofuels (Table I.96) and focusing on biobutanol describes entrepreneurship in biofuels in the US as follows (author's emphases and additions in braces): "If public financial support does not dry {in the US and also Germany}, there is a good startup funding base (via grants) for new biofuel firms. However, the plant-and waste-based base biofuel business is essentially *squeezed between* two commodities: the biomass feedstock of the *agriculture community* (or municipal communities) and the *oil industry*." "Although this represents an opportunity for a lot of people, it is a very unpredictable place to be, and it is very high risk."

"The price of oil determines how investors think about the adoption rate of biofuels. Technology development around biofuels resides in the hands of people with a relatively short-term view. Biofuel projects take huge amounts of capital to get to commercialization. There is a hurdle, because my first commercial-scale plant will be first in kind. It's very difficult to put a finance package around a first-in-kind technology."

And Rick Wilson of Cobalt Biofuels added [NewNet]: "If you develop a technology, you have to build your first plant to prove to the world you can do it and for that you require an investor with deep pockets, which are definitely lacking in this space. The venture investors like to develop the technology, while "project finance" investors enjoy funding after the technology is proven commercially, but there remains a grey zone in the middle where someone is needed to step up and provide the capital for the first plant, and it's a big number."

Concerning the industry, for the *biofuel race* in the world ca. 350 companies, from startups to oil and chemical giants, are developing second- and third generation biofuels using a *bewildering array of technologies* [ISEE] on the laboratory scale and very many pilot and demonstration plants are operating or are under construction.

Every year Biofuels Digest publishes (on the Web) a list with the "50 Hottest Companies in Bioenergy." However, replacing mineral oil with biofuels is a tough business. *The competition is intense.* It is a multimillion-dollar question of how to translate a beaker of success to global scale. It is estimated that, even as the industry develops, many of the companies – probably most – will not survive.

Basically, converting biomass to biofuels requires breakthrough developments in the production orientation in any type of process (Figure I.171):

- Thermochemical,
- Bioengineering/biotechnological or
- "Hybrid" ("biothermal") approaches relying and combining thermochemical and bioengineering sub-processes.

A research roadmap for biofuels of the US Department of Energy [DOE 2006] may be a guideline for entrepreneurs (and venture capitalists) to put their corresponding ideas and opportunity identifications into perspective, whether they are from the US or Europe. Though this roadmap acknowledges the validity and public support options for other technologies and type of biofuel, there is a strong focus on the bioengineering approach and particularly (bio)ethanol. This means, there is an implicit effect that may direct entrepreneurial ideas toward the explicitly expressed goals and related routes.

Indeed, in the US the majority of biofuel startups follow the bioengineering and biotechnology route (Figure I.171) using microbes/bacteria, yeast or enzymes to convert (various forms of) sugar into alcohols (bioethanol or biobutanol). But when biomass is broken down into sugars, it still contains substances such as lignin that can poison other microorganisms. In most processes, lignin has to be separated from the sugars to keep the microorganisms healthy. On the other hand, the tolerance of the algae to lignin, however, makes it possible to skip this step, which can reduce costs [Bullis 2008a].

For a bioengineering or biothermal process *naturally occurring* species can be used or *genetically modified objects* (GMOs) – "*designer microbes*" – focusing on several approaches, methods and processes (Figure I.181).

Being proteins *enzymes* participate in cellular metabolic processes with the ability to enhance the rate of reaction between biomolecules. They thus represent biocatalysts (for "industrial biotechnology") which may perform the same functions as "chemocatalysts [Runge 2006:165-169, 571-583]. Both are related as *generic technologies* (Table I.12).

Yeast is a microorganism of the type of single-celled fungus and used as an agent in baking and in brewing beer and is responsible for the conversion of sugars in must to alcohol (“alcoholic fermentation”). Usually chemical process and plant engineers of the world love chemocatalytic processes and, as you can control the yield and scale, make a plant or refinery easier from different (and the least expensive) feedstock.

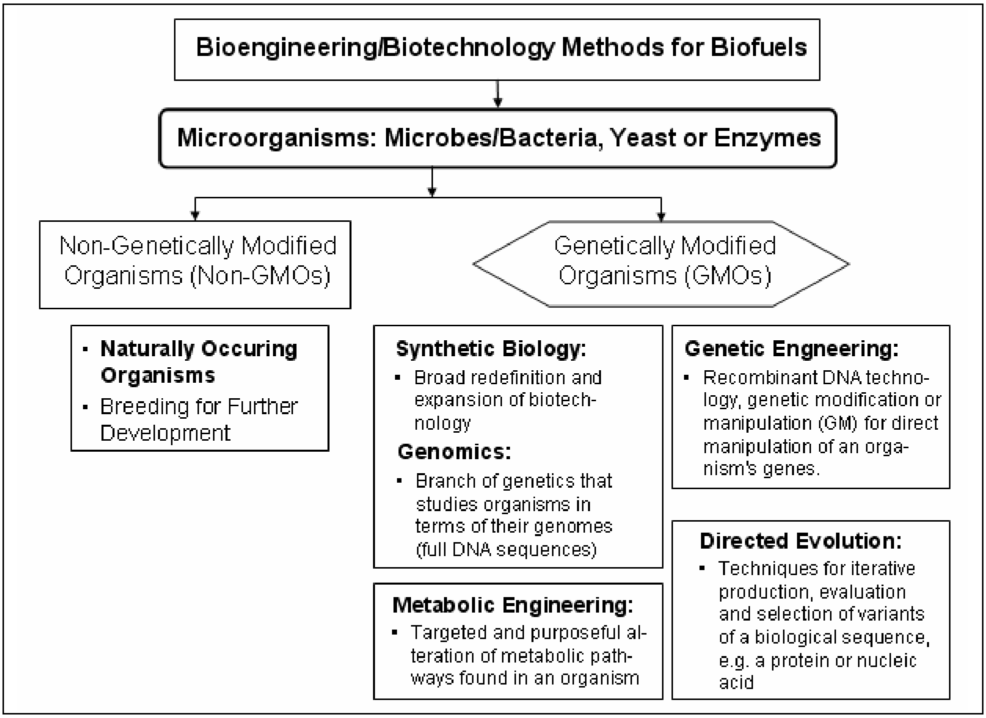


Figure I.181: Bioengineering approaches to convert biomass including algae to biofuels.

Irrespective of the particular bioengineering approach each company has a fundamental decision to make: whether to engineer a biofuel-producing capability into a well-known, robust industrial organism or to engineer industrial fitness and other necessary attributes into an organism that is a natural producer of the molecule of interest.

Generally, with regard to cost minimization an issue of production economy is in how far production can use proven, purchasable and integratable sub-processes or components. Correspondingly, a question for a bioengineering approach is whether to develop microbes/enzymes in house or purchasing them (for instance, the US firm KL Energy purchases enzymes from the big Danish enzyme company Novozymes).

A further idea is to replace the need for enzymes, which are often expensive, with a *mixed culture of bacteria*. The availability of cost-effective enzymes for breaking down cellulose will be critical for the success of the second generation biofuels field. But hydrolysis of cellulose and hemicellulose requires about 20 distinct enzymes that are normally provided by commercial suppliers, such as Novozymes (Denmark) or the Genencor subsidiary of Danish Danisco (no owned by DuPont). But the hydrolysis process can also result in the production of by-products, including acids, ketones and aldehydes, which can inhibit the growth of cells as well as the secreted enzymes.

Working and experimenting with microbes or enzymes always opens a way for *serendipity*. For instance, Mark Emalfarb, founder of Dyadic International Inc, just wanted a better enzyme to soften blue jeans. The search led him to a new fungus from Russia, and then to a *serendipitous mutation* that turned the organism into a biofactory capable of churning out vast amounts of enzymes that can give denim (the fabric for jeans) a prized lived-in look. “By accident, we came by the world’s most prolific fungus,” he said [Anonymus 2006a]. Actually, after the fall of the Berlin Wall, he hired Russian scientists and took the fungus to the US. [108]

With technical hurdles abound there may be also societal, attitudinal (acceptance) hurdles with bioengineered biofuels. Genetically modified crops have met generally with stiffer resistance from a public in Europe that has labeled such crops as “Franken foods” [Mandaro 2007] and a similar attitude may extend into the biofuels area. In particular, in the US, “the food versus fuel” debate was bad press for biofuels and the “Frankenalgae” debate would be even worse.” [Wesoff 2009]

More on Bioalcohols: Rerun of Biobutanol

Using naturally occurring microbes is not only practiced since ages to ferment sugar to ethanol. Since 1916, it is known that microbes, such as *Clostridium acetobutylicum*, can ferment sugar to produce a *mixture* of acetone, butanol, and ethanol in large volumes – by the ‘“ABE process” exploited mainly for its acetone during the First World War. The butanol was a by-product of this fermentation (twice as much butanol was produced). Yet microbial breweries were discarded by the 1980s in favor of a cheaper petrochemical route, via the reaction of carbon monoxide and hydrogen (from syngas) with propylene. Currently, there have emerged several startups following the ABE route [Kiplinger Washington Editors 2007].

For instance, over years, David Ramey in the US, founder of the engineering and consulting firm Environmental Energy, Inc., then ButylFuels, LLC, has *further developed and patented the original ABE process* that makes the fermentation process *more economically viable* and competitive (by a continuous two stage anaerobic fermentation process without significant amounts of acetone or ethanol). In particular, he demonstrated to the public that there is an alcohol made from corn (butanol) that can replace petro-gasoline totally (Table I.82). In 2005 he ran a conventional unmodified

"2 Buick Park Avenue" car with no modifications across the US with 24 miles per gallon on butanol.

ButylFuel was supported by several federal and state grants ($0.6 mio. by US Department of Energy Small Business Technology Transfer Program [Wilder 2004]) [109] Then, for collaboration with Dr. S.T. Yang at the Ohio State University, he obtained a $1 million dollar grant through the SBA's Small Business Innovation Research (SBIR) program to research, develop and commercialize butanol fermentation.

In particular, the project was to *develop novel engineered Clostridia strains* for fermentation to economically produce butanol as a biofuel from sugars derived from starchy and lignocellulosic biomass [Ramey 2007]. ButylFuel was planning to market its *biobutanol as a solvent* first, and then market it as a fuel in the future. Generally, it is assumed that *existing bioethanol plants can cost-effectively be retrofitted to biobutanol production*.

David Ramey (of ButylFuel) is a *veteran in biobutanol*. He started around 1990 when he asked himself "Why Not Butanol in the 1970s." He noted that (in the US) "people are surprised to learn that it hasn't been firmly on the radar screen as an alternative fuel. On the other hand, butanol was on the alternative fuels map three decades ago. We had a choice to subsidize either ethanol or butanol and we went with ethanol."

Then, Ramey's butanol was produced by his own patented process, and for his pioneering efforts to bring this organically derived fuel to market, he was recognized as the "1996 Technologist of the Year" by the Ohio Academy of Science [Ramey 2007].

> Though by all criteria biobutanol is a much better biofuel than bioethanol (Table I.82) policy driven by the agricultural corn-lobby attributed the lion's share of support to bioethanol.

But by 2012 ethanol producers began switching to biobutanol and chemicals [Admin 2012; Bevill 2012]. Longer term, butanol is a superior "drop in" biofuel and can directly replace gasoline as a fuel. It is a superior blend stock as well, and can be blended with diesel as well as other biofuels, such as biodiesel, ethanol and isobutanol. The blend stock opportunity for butanol exceeds $80 billion per year. Butanol also has the potential to be upgraded to aviation jet fuel, a $50 billion market driven by increasing global interest in reduction of carbon emissions.

For ethanol producers, it is the path of least resistance in getting around the ethanol blend wall. For the high priests developing the new technologies and magic bugs, it is an opportunity to partner with companies that have feedstock, infrastructure, 90 percent of the required steel in the ground, and existing markets for co-products. [Admin 2012]. In monetary terms it was estimated that butanol has a high value of £900 (ca.$1,500 in 2012) per ton compared with the £300 per ton price of ethanol.

The production principles of butanol according to an ABE-process from agricultural residues is the same as that of cellulosic ethanol. It involves four steps: 1) pretreatment, which opens the cell wall structure and removes lignin; 2) hydrolysis of hemicellulose and cellulose into simple hexose (C6) and pentose (C5) sugars using enzymes; 3) fermentation of simple sugars into butanol using a microbe; and 4) recovery of the butanol.

However, there is an inherent paradox in the microbial fermentation of butanol: Butanol-producing bacteria produce the enzymes that convert simple sugars into the alcohol, but butanol itself is toxic to those same bugs. This butanol inhibition (once its concentration rises above about 2 percent) results in a lower alcohol concentration in the fermentation broth, which leads to lower yields of butanol and higher recovery costs. These are challenges that surface when even highly pure feedstock is used [Ebert 2008; Van Noorden 2008].

To grasp the related opportunity, butanol production is generally in search for input substrates, which are not only economical on the lab level, but also on the production level. The major barrier to butanol production has been the high cost of the conventional starch fermentation process. US ButylFuel was already on the route to improve butanol yield through ABE fermentation by genetically manipulating related microbes.

But, in 2012, ButylFuel with 4,000 ft² lab and office space in Ohio and 40 employees, many of whom have advanced degrees in microbiology, biochemistry or biochemical engineering, merged with the UK startup Green Biologics Ltd. (GBL; Table I.95).

GBL's strengths in biobutanol technology were seen to complement ButylFuel's strengths in the design, build and operation of large scale bioprocessing facilities, particularly in the US market. Post-merger, the combined entity is claimed to be a global leader in biobutanol and other C4 chemicals, with skills and assets spanning microbiology and metabolic engineering through advanced fermentation and commercial production scale [GBL 2012].

The key butanol players divide neatly a pair of producers pursuing essentially isobutanol – Gevo (Table I.99 and Butamax (Table I.83, a BP-DuPont JV) – and two pursuing n-butanol, Green Biologics and Cobalt Biofuels (Table I.96).

In the UK since 2003 the startup Green Biologics Ltd. (GBL) pursued optimization and "*re-commercialization*" of the n-butanol fermentation process aiming for a two- to three-fold reduction in cost (Table I.95). GBL focuses on *thermophilic microbes and thermostable enzymes*. These are robust, faster, more effective and cheaper than conventional microbes operating at ambient temperatures. GBL also *looked into input options (feedstock)* and directed their *market orientation towards India and particularly China* taking the same view as BioMCN for biomethanol (cf. Table I.87) – and recently also towards the US.

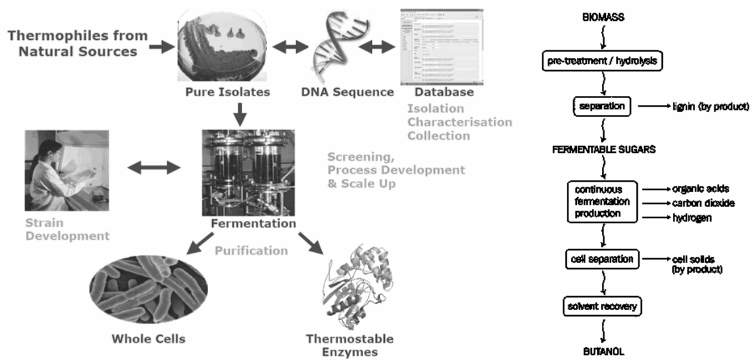
Green Biologics is pursuing a model in which it and an ethanol producer will co-invest in a project, and both earn off the increased revenue flow from the sale of biobutanol into higher-value markets. Green Biologics offers the sales and marketing for n-butanol. Payback was expected to be within three years for an ethanol plant partner [Admin 2012].

Table I.95: Pursuing biobutanol as a biofuel and C4 chemicals and derivatives by Green Biologics. *)

Company (Foundation) Remarks	**Major Funding**	**CEO, Other Executives, Foundation, Key Researchers; Technology Protection**
Green Biologics, Ltd. – GBL Abingdon, UK (2003) Vision: Become the world's leading supplier of advanced fermentation techniques for conversion of lignocellulosic plant material to renewable biofuels and chemicals. Employees: 2003: 4, 2004: 6, plus access to Georgia University scientists 2007: 13 [VentureBeat], 2008: 20 [Guardian 2008], 2009: 25. Revenues: 2003: £160,000 [Koenig 2005] 2008: £700,000 – forecasted	By 2012 GBL has raised over $15 million in equity financing from angel investors and venture capital firms. Launched a £6.5M (ca. $10M) round (Series B) to close in April 2010 [Lux Research 2009] 2009: completed round with Hong Kong investment group Morningside (its Dr Gerald Chan joining GBL's board). 2008: £3.5M (ca. $6.33M) fundraising round 2007: £1.58M (ca. $3.2M) completed Awarded £560,000 (ca.	Sean Sutcliffe CEO since 2008, came from Biofuels Corporation Trading Ltd, which operates one of Europe's largest biodiesel plants, where he has been CEO since 2005; worked for BG Group plc for 14 years in a variety of roles spanning operations, business development and strategy, most recently as Executive Vice President with responsibility for Corporate Development and New Businesses; he is a Chartered Mechanical Engineer with an Engineering degree from Cambridge University. Dr. Edward Green founder and CSO, gained PhD in Biochemical Engineering in 1993 from the University of Manchester Institute of Science and Technology (UMIST); after 5 years in academia in 1998 joined Agrol Ltd., a UK startup where he established a multi-disciplinary team that developed a high temperature ethanol process; has delivered technical improvements in microbial fermentation processes for biofuel production over the past 17 years contributing to numerous scientific publications and patents. Fergal O'Brien VP Commercial Operations; a Biochemist with 25 years experience in the Biotechnology/Fine Chemical Industry; held positions in R&D, operations, business development and senior management for a number of UK-based companies including Celltech, Enzymatix, Chiroscience, Chirotech and Dow Pharmaceuticals; was CEO of Warwick Effect Polymers Ltd from 2004-6 and joined GBL from his own Business Development Consultancy where he has focused on assisting SME's. GBL utilizes closely connected "Advisors": Robert Rickman, Feedstock Advisor Steve Vaux, Feedstock Advisor Dr. Martin, Comberbach Bioprocess Consultant

[pipeline 2008]. Estimated $150,000 annual burn per employee [Lux Research 2009]. Funding mode: equity, grant aid from central and local government, contract services.	$1.1M), with £250,000 (ca. $500,000) from the Department of Trade and Industry-led Technology Program and £310,000 ($610,000) from shareholder investors and business angels £250,000 grant awarded to GBL and EKB 2005: First funding round, £63,000 (primarily business angel investors in the community)	Professor, David Jones Scientific Advisor. GBL Technology Strengths and/or Differentiator: A unique collection of thermophilic microorganisms; a comprehensive and searchable database for the culture collection (library of organisms includes over 120 *Clostridia* strains and over 800 thermophilic organisms used for high temperature processes); unique access to large-scale fermentation at the University of Georgia; advanced separation process. In-house IP covers microbe and fermentation processes as well as solvent recovery, but some overlap exists with other fermentation technologies; their patented biobutanol: Butafuel™. GBL has wide ranging portfolio of proprietary technology relating to ABE fermentation using *Clostridia* organisms as biocatalysts.
Technology, Goals, Strategy Goal: to produce a wide range of C4 chemicals and derivatives, including C4 biofuels The technology and IP estate includes lignocellulosic processing which allows utilizing both C5 and C6 sugars to extract much higher energy content than processing sugar and starch alone.	The company has a biorefinery approach, but focuses on the production of only n-butanol (not isobutanol) on the basis of ABE fermentation; follows genetic manipulation of microbes to *improve butanol yield*; they optimize and "re-commercialize" the butanol fermentation; although *cheaper feedstock* decreases major costs, energy expenditure required for solvent recovery is a major challenge that has to be resolved; GBL aims to retrofit (grain) ethanol plants; considers also co-products (acetone and ethanol of ABE process); process (Figure) aiming for a two- to three-fold reduction in cost. To circumvent "butanol toxicity" claims to have developed "solvent tolerant" strains; has a microbial platform technology based on a unique and proprietary collection of heat resistant microorganisms (thermophiles) and thermostable enzymes that operate at higher temperatures than other industrial microorganisms; metabolic engineering is used to generate a second generation of Industrial thermophiles (Figure). GBL's microbial platform technology provides flexibility across a "range of different feedstock" due to its options to use different microbial species and strains for specific feedstock; microbial strains and cocktails are tailored for wide variety of feedstock	

Business model: License technology (focus on "upgrading" biobutanol plants); provide consultancy, contract services and contract research; solution provider (integrated technology provision participation in production assets); focus on China and India as key markets (US added recently) Services: High throughput screens for thermophiles and thermostable enzymes; microbial expression systems in robust hosts; metabolic pathway engineering to improve product yield and other strain characteristics; fermentation process development to improve both yield and productivity.	fermentation; yet process remains unproven at large scale. Using its library of thermophiles and thermostable enzymes GBL has isolated a cocktail of thermophilic microorganisms for the rapid enzymatic hydrolysis and release of fermentable sugars from biomass. The company planned to integrate this patented hydrolysis technology with a proprietary butanol fermentation process. Partners with EKB Technology (specialist in process technology) to develop the advanced fermentation process for butanol with improved yields. EKB aims to create new and highly configurable platform technologies that combine advances in bioreactor technologies and previously separate downstream process technologies into a single step; also suited to chemical syntheses that utilize fermentation technologies and biocatalysts. Ultimate GBL process: continuous fermentation, advanced separation process. Develops also advanced and renewable fermentation technologies for conversion of biomass to higher value chemicals and biofuels; solving problems in both existing and emerging markets for fuel and bulk chemical manufacture as well as environmental waste treatment. Equipped at GBL's Milton Park headquarters with a 300 liter pilot plant and a 140 liter pilot plant allowed producing small amounts for thermophile fermentation testing and new patent developments, provides also confidence to GBL's feedstock partners. The most significant emerging opportunities for GBL are in China. "China is a key market for Green Biologics." The focus is introducing its improved technology to their plants to radically reduce the cost of local biobutanol production. Green Biologics works directly with commercial butanol producers at scale (300 m3 to 400 m3 fermentation volume) by licensing its microbial technology and process solutions; working with several butanol producers in China, due to the accessibility to existing plants and large market for butanol. It expects to reach commercial production there, with an estimated capacity of 30,000 tons/year; this serves simultaneously to rapidly demonstrate the GBL technology to potential clients around the world. it is also working with sugar and ethanol producers in India, due to accessibility there of cheaper feedstock, and converting sugar ethanol plants into butanol plants. Ties to China are broadly developed, from the Hong Kong investor Morningside to appointing Intelligent Sensor Systems (ISS) as its commercial representative in China to support GBL in exploiting the rapidly expanding commercial opportunities for its technology and services to Chinese biochemical and biofuel producers and appointing Professor Zhihao Sun as a Scientific Advisor.

	In 2008 GBL and the Energy Research Institute, Shandong Academy of Sciences and Green Biologics (SDERI) of Jinan, China. established a technical collaboration agreement on the production of biobutanol; involved transfer of GBL's technology into a purpose built pilot facility at SDERI's research center; serves GBL as a local commercial demonstrator and supporter of marketing of GBL technology to Chinese biobutanol producers; also in 2008 an agreement between GBL and Laxmi Organic Industries to develop and construct a commercial scale demonstrator for biobutanol in India; the demonstrator plant was expected to produce 1,000 tons of butanol a year starting in 2010, the biobutanol plant will run on molasses produced by the Indian sugarcane industry. The £3.5 million ($6.33 million) fund raising was intended to roll out GBL's renewable chemicals technology. In 2005 GBL developed, for instance, a novel solvent system to remove chewing gum waste from pavements. The company estimated a total fuel butanol market size of £3 billion growing at 4% per year. **Figure:** GBL's bioengineering approaches to biobutanol. 

*) From the firm's Web site if not stated otherwise by a reference;
firm's status: early 2010 and selected relevant additions till 2012.

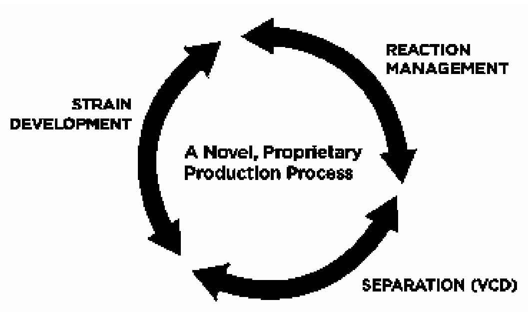
In the US one of GBL's close competitors is Cobalt Biofuels (Table I.96) which addresses *cost reduction* through three processes or areas, respectively: 1) strain development, 2) reaction management and 3) vapor compression distillation (VCD) as a separations technology that removes alcohol from the fermentation steep. Cobalt brought down the overall cost of production through a systemic approach involving the three key sub-processes or areas rather than focusing on just one or another sub-process. In contrast to GBL, which already created revenues in 2008 by contract services and consulting, Cobalt Biofuels did not seem to generate revenues (that far).

Table I.96: Pursuing biobutanol as a biofuel and for C4 chemicals and derivatives by Cobalt Biofuels ***)**

Company (Foundation) Remarks	**CEO, Other Executives, Foundation, Key Researchers; Technology Protection**
Cobalt Biofuels, Inc. Mountain View, (CA) (2006) Employees: 2008: 25 (Oct. 20, 2008) [Contag 2008b]; 2010: 40 [Stroud 2010]. Biobutanol Scale-Up Plan: 35,000 gallons per year pilot in 2009, 2.5 mil. GPY pre-commercial in 2010 25 mil. GPY plant in 2012 2015: jumpstart revenue in the chemicals market [Contag 2008b]. **Major Funding** In 2011 raised a new $20 million Series D venture round $25M (10/2008) Series C, to	Dr. Pamela Contag CTO and founder (President and CEO Cobalt 2005-2008); serial entrepreneur, prior to founding Cobalt Biofuels, founded Xenogen Corp. in 1995 and served as President and concurrently as CEO of Xenogen Biosciences. Xenogen Corp. went public in 2004; sold it as it merged with CaliperLS in 2006. Pamela Contag is a representative of a “*stage-oriented entrepreneur*” founding and leading a new firm to a particular state of development and then handing over to professional management (ch. 2.1.2.6). With more than 25 years of microbiology research experience, Contag has widely published in the field of non-invasive molecular and cellular imaging. She received her PhD in Microbiology at the University of Minnesota Medical School in 1989; since December 2008 she has been a director of Delcath Systems. “I generally invent and develop technology and then take on investors who ultimately direct the company. I put all my energy into the demonstration of the technology and business model,” Pamela Contag said [Ainsworth 2008]. Hence, after having raised $25M she withdrew to CTO to hand over commercialization to investors and a professional management. Dr. Rick Wilson CEO; over twenty years of global energy commercial and technology experience, recently including VP of British Petroleum’s Global Derivatives Chemicals business unit, background in process engineering and broad executive experience in the fuels and chemical industries; received an MBA from the University of Chicago Graduate School of Business and a PhD in Chemical Engineering from Lehigh University, where he focused on energy efficiency. During his seventeen years at BP/Amoco, Dr. Wilson held a variety of technical, trading and executive positions and was also responsible for BP’s $3.5 billion petrochemical business, ultimately spun out as Ineos. Mark Dinello SVP Engineering; extensive experience in the chemicals and refining industry; during his 30-year career with BP/Amoco Dinello held a variety of senior positions in engineering, procurement, construction, and management, for chemical and refining operations worldwide. He earned a BS Degree in Chemical Engineering from the Pennsylvania State University and an MBA from The University of Chicago. Prior to joining Cobalt, Mark founded and served as President and Senior Consultant of Plan B Consulting Inc. At Cobalt, he will be responsible for capital projects, operations, engineering, and company health, safety and environmental policy and practice.

expand from lab scale production to pilot facility – capacity of 35,000 gallons of fuel per year, 2007: $12M Series B; 2006: $1M Series A. Opened up its first pilot plant in 2010 [Fehrenbacher 2010].	David Walther, PhD: Director Engineering; has over ten years of experience directing research teams focused on developing and implementing microsystems in the areas of biosensing, power and energy; he was granted Exceptional PI status for several US Government, State of California and Industry Sponsored Research Grants. Hendrik Meerman, PhD: Director Bioprocessing; is an acknowledged expert in fermentation technology and bioprocess development, possessing a keen understanding of microbial physiology. Prior to joining Cobalt, Dr. Meerman served for over ten years in process development at Genencor International, where he was responsible for developing and transferring several scalable processes that quickly moved product concepts from the bench to commercial manufacture. Cobalt and, in particular Pamela Contag and her husband Christopher as inventors, and their university and Xenogen, have proprietary technologies in microbial physiology, strain development and fermentation. It is interesting to note that Cobalt sought professional services to establish its communication and media strategy. Cobalt Biofuels asked Ecofusion, a strategic communications and media company, to build an *identity, a story, and a public relations platform* to spread the word about biobutanol and the range of solutions the company will develop in the future. After constructing and delivering a new biofuel brand and message systems Ecofusion implemented a third phase of the communications strategy; planning and managing a press and media rollout for major milestones in the company's early development [Ecofusion]
Technology, Goals, Strategy Business model: Very low cost producer/owner incl. low cost feedstock and process efficiency; Be determined by a project-by-project basis; Sell co-products into the chemical solvent market, then butanol (primarily as a substitute for	Cobalt follows the ABE-process to produce normal butanol (not isobutanol) with modified *Clostridium* microorganisms thus increasing the amount of butanol produced to decrease cost. Generally some other factors are also seen as important (Figure): mainly the consumption of energy and the consumption of water. To reduce energy the company has licensed a new technology, called vapor compression distillation (VCD), for separating the butanol and water; traditional butanol separation (distillation) accounts for 40-70% of total production energy [Contag 2008b]. VCD removes alcohol from the fermentation steep using one-half the energy required for typical separation techniques [Fehrenbacher 2010]. To reduce water use, the company has turned to proprietary water purification and recycling systems; the company has further increased butanol production by engineering a bioreactor [Bullis 2008b]. Additionally, it is said [Lane 2010m] that residual "lignin is passed to the onsite boiler and generates sufficient power to serve the needs of the biorefinery, with significant excess power exported to the grid." One of Cobalt Biofuels' key advances is a technique for genetically engineer-

gasoline); See to become a licensor; Assess how to grasp opportunities overseas.	ing strains of *Clostridium* so that they produce a luminescent protein whenever they produce butanol; “When the *Clostridium* are happy and producing butanol, they’re also producing light,” Contag said. When they are paired with light detectors, the company can quickly sort through new strains of the bacteria, as well as tailor their environment, to increase production [Bullis 2008b]. Their patented reaction management technology – production monitoring technology – maintains their continuous fermentation process at peak production rates and an optimal concentration of butanol in the steep, for extended periods of time. It is this bioreactor technology that forms the basis of the production process. Cobalt does not do genetic engineering but accelerates the evolution of the bugs to produce more product at higher concentrations by conditioning them to adapt; is focused on putting waste biomass to good use [NewNet] and can tailor its microbes for different regionally available feedstock, optimizing its process for deployment anywhere [Fehrenbacher 2010]. But it can also use more traditional feedstock including corn and sorghum; this means Cobalt can site their facilities in a wide range of geographies and use the feedstock available locally. The focus is on DOE-favored, low-cost feedstock with high hemicelluloses content, - Wood pulp, - Sugar beets and beet processing by-products, - Energy crops, forage or sweet sorghum [Contac 2008b], in particular, forest waste and mill residues. In 2010 Cobalt announced a breakthrough in producing biobutanol from beetle-killed lodgepole pine feedstock. They claimed to be able to scale-up to a commercial facility within the next two years, (first commercial sales of biobutanol in 2011) and “multiple facilities” by 2014 [Fehrenbacher 2010]. Has a strategic partnership with EPC firm Fluor Corp., with a strategy of designing low-cost plants [Lane 2010m]; engineering and construction giant Fluor Corporation should bring its technology to commercial scale. Fluor would provide engineering consulting, advise Cobalt on how to scale up, put together a design package for Cobalt’s future plant, and execute the construction part of the project [Stroud 2010]. Cobalt intends to position butanol as a high value chemical or fuel additive; the plan is to sell into the chemical solvent market at pre-commercial stage [Contag 2008b]; can offer also a small amount of acetone;

	and as Cobalt scales up production, it plans to sell the butanol as a substitute for gasoline [Bullis 2008b]. The interrelation how Cobalt brought down the cost through three processes or areas, respectively, is illustrated in the Figure. **Figure:** Cobalt's systemic approach to three key processes for biobutanol.  *Strain Development*: developed proprietary, high-throughput processes for identifying and engineering the optimal microbial strains for converting a given plant material (a range of feedstocks). *Reaction Management*: the patented reaction management technology poises the continuous fermentation process at peak production rates for extended periods of time. This increases productivity and ensures optimum feedstock utilization (creating sensor production strains using bioluminescence; real-time monitoring allows avoiding poising of fermentation). *Vapor Compression Distillation (VCD)*: patented fluid separations technology removes alcohol from the fermentation steep using approximately one-half the energy required compared to typical separation techniques; has the additional advantage of drastically reducing water usage (recycling the VCD-purified water back into the production process). Cobalt was looking early for opportunities overseas, though the company had not been ready to discuss them [Wang 2008].

*) From the firm's Web site if not stated otherwise by a reference; firm's state: early 2010.

By the end of 2011 Cobalt Technologies appointed as chairman and CEO Bob Mayer replacing Rick Wilson. Most recently Bob Mayer was CEO of Genencor [Admin 2011b]. And currently there are additionally some new faces in Cobalt's executive team. That means, after five years of existence Cobalt's founder/leadership team has been almost completely changed.

Over the 2011/2012 period a lot of demonstrations occurred by Cobalt regarding its various sub-processes. In 2012 Cobalt has successfully demonstrated one of its advanced biocatalysts in partnership with the National Renewable Energy Laboratory (NREL). It completed multiple fermentation campaigns in a 9,000 liter fermenter, exceeding the target yield and other performance metrics for a commercial scale facility.

The demonstration showed the biocatalyst's ability to convert non-food based substrates into renewable n-butanol and resulted in high sugar conversion and high yields of butanol. "Ultimately, we're showing performance is achievable at commercial scale across our technology platform," said Bob Mayer, CEO of Cobalt Technologies.

The advanced (non-GMO) biocatalyst fermentation demonstration confirmed that the Cobalt process to produce renewable butanol could be 40-60 percent less expensive than production of petroleum-based butanol using the traditional oxo-alcohol process.

While Cobalt's technology is claimed to have the ability to perform on a continuous basis, this testing was conducted using batch processes to fully demonstrate the flexibility of the technology to meet the needs of potential customers and partners. The butanol produced during this demonstration will be sent to several customers for product certification (cf. this approach with that of Perkin, Table I.100; A.1.2).

Concerning sub-processes on the road to commercialization, as reported on its Web site as news, in March 2012 Cobalt's dilute acid hydrolysis *pretreatment* process (Figure I.171, Figure I.185), which extracts sugars from lignocellulosic biomass, was validated on woody biomass, bagasse and agricultural residues.

Cobalt conducted the testing in the Andritz pulp and paper mill demonstration facility. Andritz is a supplier of technologies, equipment and plants for the pulp and paper industry. The test runs processed up to 20 *bone-dry* tons of biomass per day. This milestone also marked the first phase of Cobalt's partnership with specialty chemical company Rhodia in Brazil to develop bio n-butanol refineries throughout Latin America utilizing bagasse as a feedstock.

Cobalt and Rhodia intend in the medium term the construction of multiple biorefineries co-located with sugar mills, firstly in Brazil to demonstrate Cobalt's technology on local and competitive feedstock. Subsequently, the proven technology shall be extended to other Latin American countries.

Furthermore, the US Naval Air Warfare Center Weapons Division (NAWCWD) awarded a manufacturing contract to global specialty chemical firm and catalyst supplier Albemarle Corp. (in February 2012) to complete its first biojet fuel production run based on biobased n-butanol provided by Cobalt Technologies. For this production run, Albemarle will utilize NAWCWD alcohol-to-jet (ATJ) fuel technology to convert Cobalt's biobased n-butanol into biojet fuel at its Baton Rouge, La. processing facility.

The resulting jet fuel should be tested by the NAWCWD as a continuing process for military certification through the Department of Defense. According to Cobalt this underpins two main objectives set out by the firm. "First, it basically helps us scale up and derisk the catalyst." "The second thing this relationship really does for us is that it allows us an avenue and platform to actually generate quantities of fuel required for certification, both military and commercial."

And there was another important aspect of the collaboration with Albemarle that extends beyond exclusively jet fuel production; it provides exploiting other chemical derivatives of n-butanol. NAWCWD's ATJ technology is capable of converting n-butanol into other high-value platform chemicals like 1-butene. For example, the process allows Cobalt to produce butadiene using the 1-butene pathway from n-butanol as the starting point. Butadiene is a valuable industrial chemical used typically for the production of synthetic rubber (A.1.1.6; Box I.26). With regard to 1-butene, Cobalt addresses directly what Gevo (Table I.99) is doing on the basis of bio-isobutanol.

Cobalt Technologies as well as Gevo reveal a shift of biobutanol producers putting the emphasis on a biorefinery aspect with the main stream of revenues being generated by biobased chemicals (cf. A.1.1.6):

> Biofuels (butanol) + chemical co-products (butanol compounds) →
> Chemical products (butanol derivatives + chemical intermediates for platform chemicals, plastics, and rubber) + biofuel (butanol for blending or butanol as a replacement for petro-gasoline)

The challenge and constraint for entering the biofuels race is delivering technology, which enables *cost-efficient production*. Cost efficiency means biofuel that can compete with oil at around $80/barrel.

Many industry participants appear to be focused on large volume production facilities ("owner/producer model") that are highly dependent on significant quantities of biomass feedstock gathered (and transported costly) from long distances. *People have to be broad-minded about what is out and what is in* (technology intelligence!). Structuring technical hurdles according to the biofuels value system (Figure I.171) simultaneous provides startup opportunities in terms of solving associated problems.

The very fundamental problem is growing enough green plant material or harvesting or having enough cellulosic residuals or usable waste. The first hurdle for everyone in the game may be characterized by the questions: *how are we going to grow and/or collect, transport, store, and pretreat, if applicable, the biomass for processing; which kind of biomass; is it wet or dry?*

Furthermore, an inherent issue of processing biomass is *consistency*. The fluctuation in feed material composition and quality that ensures success in the real world is usually far from laboratory-controlled conditions. Processes that work well in the lab often run into problems when scaled up to commercial size. For instance, Iogen (Table I.83) found that enzymes that effectively convert pure wheat straw to sugars fail when faced with 1,000-pound bales laced with dirt, soil, dead mice, and stones [Carey 2009].

In general, it has often turned out that when a cheaper biomass substrate is used for a bioengineering process, additional microbial inhibitors are generated during the pretreatment process. Raw material for second-generation bioalcohols and biogasoline are listed in Table I.97.

Table I.97: Selected raw material for biofuels

- Agricultural residues: like corn stover or cobs or cornstalks (stalks that remain after the corn has been harvested), straw (from cereals), bagasse (the fibrous residue remaining after sugarcane or sorghum stalks are crushed to extract their juice);
- Municipal waste: paper trash and pulp, other municipal garbage, municipal solid waste (MSW);
- Residues from forestry, wood processing or "recycled" wood (for instance, from houses), construction and demolition wood waste, timber harvesting residues, wood chips (for instance, KL Energy Corp. using Ponderosa pines), sawdust, Cobalt Technologies also tried beetle-killed lodgepole pine feedstock);
- Highly productive ("energy-rich") existing or cultivated grasses and trees: switchgrass, eucalyptus and hybrid poplar;
- Carbon-based waste, like old tires.

This raw material for second-generation bioalcohols and biogasoline is associated with a number of issues concerning the most efficient raw material or by-products generated by a particular process. For instance, for its two-step thermochemical process the NTBF Range Fuels (Table I.99) reported that "over 10,000 hours of testing has been completed on over 30 different non-food feedstocks with varying moisture contents and sizes, including wood waste, olive pits, and more." [107]

Sugars found in wood in the form of lignocelluloses are not naturally well digested by microorganisms which convert biomass into usable raw materials. First these complex sugars have to be released and broken down into digestible units. This process often gives rise to harmful by-products, including furans, which can have a strong inhibiting effect on the fermentation process.

However, reminding ourselves of the heavy localization of corn ethanol plants in the US "Corn Belt" and the role of lobbyists from the related states in pushing special focus on corn ethanol in legislation, it may be that the technology development for second-generation bioalcohols and biogasoline will exhibit considerable "*path dependency*" in terms of corn alcohol versus lignocellulosic alcohol or raw materials' availability for input rather than performance (and perhaps even price).

And thinking of bioengineering methods there are still some doubts: "It is not yet clear whether a fully synthetic genome will ever be deployed in a live production environment. A fully synthetic microorganism may not have the robustness which is needed for large-scale industrial bioprocesses." [Sheridan 2009]

Tackling the issue of procurement of biomass for processing and production (input for conversion) is approached by startups and NTBFs in various fashions depending on whether the emphasis is on biofuels for transportation or biorefinery: When we are talking about full-scale production and biofuels we speak of thousands of tons of biomass per day, per biorefinery. On the other hand there would be a sub-1,000 ton per day input for biobased chemicals or the smaller scales for fine chemicals or nutraceuticals.

There are a number of factors which may drive input selection. Criteria may refer to

- *Offering destination*: where to sell the products, and probably co-products, most profitable (product localization. market localization; California represents ca. 20 percent of the US ethanol consumption)
- *Input localization*: where input is plentiful and cheap and in sufficient proximity to the production plant(s) to minimize transportation and storage cost, addressed for Brazil by BP/Verenium JV Vercipia (Table I.83, Table I.84), Cobalt/Rhodia (Table I.96), and Amyris (Table I.99)
- *Input-output efficiency*: localization selection for the production plant, which means focusing on biomass input where it is cheap and where there is a huge existing market for the biofuel, such as ethanol in Brazil, many autos in California; FFVs in Brazil.
- *Legislation localization*: China, for GBL E85 of biobutanol (Table I.95), biomethanol for BioMCN (Table I.87).

Issues of localization of input have been tackled by the German Bioliq approach (Figure I.173). In this sense, for instance, Range Fuels' model (Table I.99) required to "bring systems to sources where biomass is most plentiful, instead of having to transport biomass to a central processing site. This reduces transportation costs and related transportation fuel consumption." [107]

Coskata's model (Table I.99) based on sugarcane bagasse biomass was explicit in this regard. "To generate 100 million gallons in this model, Coskata will need 1 million tons, or 900,000 tons of biomass. That will require 15,000 hectares, or 37,000 acres. That's 51 square miles, or the area within 4 miles of a 100 million gallon refinery. A mighty plantation, but not long hauling distances." [Lane 2009o].

Venture Capital for Biofuels

Rather than looking at corporate venturing and/or aliiances with large firms the alternative option for entrepreneurship in biofuels in the US was venture capital firms which played a very aggressive role for CleanTech and especially biofuels (VC- based startups). Fundamental assumptions and rationales of VCs in that area are:

> There were lots of efforts underway in the race to find a better biofuel, and that it is possible that one particular technology will take a dominating position ("dominant design"). Hence, put money into a host of promising new technologies (startups) and push them out into the market. Vinod Khosla (Khosla Ventures), more than anyone, was investing in many different efforts, on the idea that one of them will pan out, and he said. "If you back a lot of horses, it's more likely you're going to win." [Marshall 2006]

Getting involved in some project and provide some project equity actually means to really prove the technology at the commercial scale.

However, in CleanTech and especially biofuels venture capital had filled also roles that were previously occupied by project finance (venture) capital. In biofuels, venture capitalists were foregoing their customary role as just technology investors. They contributed to the cost of demonstration plants and were putting their money into infrastructure as well. This emphasis might stem from the perceived big biofuel opportunities that let venture capitalists fund biofuel infrastructure to push themselves toward a potentially bigger payoff [Barron 2007].

But there was another change of approach of VC-backing of biofuel startups, essentially driven by billionaire Vinod Khosla who founded Khosla Ventures in 2004. Khosla, an electrical/biomedical engineer and MBA by education, himself operated as a very successful entrepreneur and was founding Chief Executive Officer of Sun Microsystems before he turned in 1986 to the venture capital firm Kleiner Perkins Caufield & Byers (KPCB) as an Experienced Team Member focusing rather early on biofuels [Khosla 2006]. By 2009/2010, funding CleanTech startups was about two thirds of Khosla's existing portfolio [Schonfeld 2009b, Khosla 2009].

Khosla's approach of a "*science project to a company*" in biofuels was driven by his "own passion – green investing" and the related opportunities he envisioned for himself. His answer to the challenges was an unprecedented coordination of capital, intellect, and pragmatism associated with the confidence to succeed. And he referred to an *innovation architecture* which he calls an "innovation ecosystem at work," *solving large problems* by harnessing the power of ideas fueled by entrepreneurial energy of scientists, technologists, and entrepreneurs – very bright people working on solving a problem.

This is actually a "*VC-based and managed" multiple-stage entrepreneurial process* being close to an innovation or new business development process of corporate entrepreneurship (intrapreneurship). The innovation project related approach relies on three "legs" [Khosla 2008b]:

- Bright academics from various scientific/engineering disciplines whose competencies complement each others (founders and advisory board members);
- Talented entrepreneurship-minded people who want to make money – and make a difference – based on profound professional management experience (15-35 years) in related industries (oil industry or biotechnology or bioengineering area) – essentially industry veterans with track records ("entrepreneurs and executives");
- Intelligent capital and financial resources through committed people stepping up to the challenge and experience towards building businesses for the long run.

Khosla Ventures did seed, A and B and C investments and "don't mind larger technology risks especially in the smaller seed fund" [Schonfeld 2009a]. However, Khosla's basic attitude underlying his approach is not different from that of other venture capitalists: "If we did not have corn ethanol priming the pump, it would be too risky for me to invest in cellulosic ethanol," he said [Anonymus 2006a].

Khosla's focus on people with significant experience in the related or closely related field is in line with the above described innovation/entrepreneurship architectures for NTBFs with "subject veteran" founders, such as Bodo Wolf of German CHOREN Industries, David Ramey of ButylFuel, Arnold R. Klann of BlueFire Ethanol, Charles Wyman and Lee Lynd of Mascoma Corp. or Paul Woods of Algenol Biofuels.

Khosla's innovation architecture is often characterized as a *VC-backed spin-out* (RBSUs) *with professional and experienced managers* from almost the point of firm foundation. Khosla himself was also often heavily involved in firm foundation. For instance, one company was originally formed casually in response to a bet.

In a conversation with Professor Frances Arnold of the California Institute of Technology, Khosla suggested that "You can't do that with synthetic biology economically yet." She disagreed, and argued that a couple of graduate students working in the area could design bugs to make fuel – economically. Along with Matthew Peters and Peter Meinhold, also of Caltech, Gevo (Table I.99) was formed [Khosla 2008b].

Another example was the transformation of Kergy, Inc., a Silicon Valley engineering-type startup in alternative energy. It is a Menlo Park startup, which raised $3.3 million in a first round of funding from Khosla Ventures to become later Range Fuels and Khosla appeared as one of the founders (cf. also KiOR; all in Table I.99).

Khosla's process is structurally related to particular innovation approaches in large and giant firms:

- The leadership sponsor process of innovation (Table I.98) as described by Runge [2006:748,749] and
- Utilizing features of a standard "Stage-Gate®" innovation or New Product Development (NPD) processes of large firms [Runge 2006: 653-654].

Khosla was investing heavily in biofuels as he could see a financially viable path to the future. "The *risk profile* has to work for investors," Khosla said: "They see that this works in the marketplace over two years, not 20, and then they take the next step. It's stair-step, incremental investment." [Oneal 2006].

As in staged innovation processes (Stage-Gate, PhaseGate) Khosla also applies the "*failing fast*" principle [Runge 2006:787] as he said: "The ones we have cut off, we cut off relatively early." [Rapier 2009a] But additionally, one key risk, Khosla said, is the power of the oil lobby [Oneal 2006], which in the US already played a "negative role" in the 1920s when there was a strong movement towards a "biobased chemistry" [Runge 2006:565-566].

Table I.98: Comparing leadership activities of the innovation sponsor process and Khosla's innovation "ecosystem process.

Sponsor Process (Sponsor's Job)	**Khosla's "Innovation Ecosystem"**
Set the context – communicate a clear vision	Have a clearly communicated vision and mission (defining a related portfolio): "My mission now is to put the fossil in fossil fuels."
Choose projects to sponsor	Initiate a startup or find portfolio-driven startups/NTBFs to be invested in
Find and select innovators – bet on people, not just plans	Focus on bright scientific/technical and managerial innovators ("top-down team building")
Form cross-functional project teams – strive for functionally complete teams	Build multidisciplinary teams with complementary competencies
Support the team – provide resources and a "one stop shop" for decisions that will stick	Organize and lead equity financing for the "startup-project"
Guide the team – set milestones, ask the right questions, know when to redirect the team's efforts	Organize (and lead) staged financing referring to milestones ("gates"; series A, series B,…) and influence decision-making
Reward the team – keep them on track	dto.

In Figure I.182 Khosla's CleanTech Portfolio [Khosla 2009a] is presented. Related biofuels startups or NTBFs are further described and characterized in Table I.99. This set shall simultaneously be used to discuss entrepreneurship options in biofuels, related technologies and their hurdles, and selected business models of the new founded firms referring to the value system in Figure I.171.

> As is found often in previously discussed cases the majority of NTBF leaders of the set of companies Khosla has invested in have a very strong technical background and management experience by doing and executive management training doing a job rather than by higher education.
> Concerning the appropriateness of his portfolio "Khosla says his previous investments in CleanTech companies have generated nearly $1 billion in profits." [Reisch 2011b]

Notably, Khosla Ventures has not invested in algae firms so far. Generally, he has five criteria for investing in cutting edge energy technologies. Algae meet four of those criteria but fail on the last: He seems to believe that the engineering problems of growing and harvesting algae are manageable. And he obviously believes algae will have manageable startup costs and a quick innovation cycle.

But, Khosla does not believe algae (exploiting algae biomass, not necessarily ethanol from algae) will be able to compete unsubsidized with petroleum and other alternatives unsubsidized in the next five to seven years – after looking at “maybe two dozen.” “The economics of algae don’t seem to work,” he said [Kho 2009]

And skepticism has not only increased with the VC community. The sentiment is: “We just don’t believe in the economic” and one is not sure that “algae is going to come down the cost curve.” This view is also shared by BP. BP, which has invested in algae startups Martek Biosciences (Table I.83), questioned the viability of different types of algae technology, and more specifically the kind that ExxonMobil recently invested $600 million in Synthetic Genomics [Phuong Le 2008; Oilgae Blog 2008; Kho 2009].

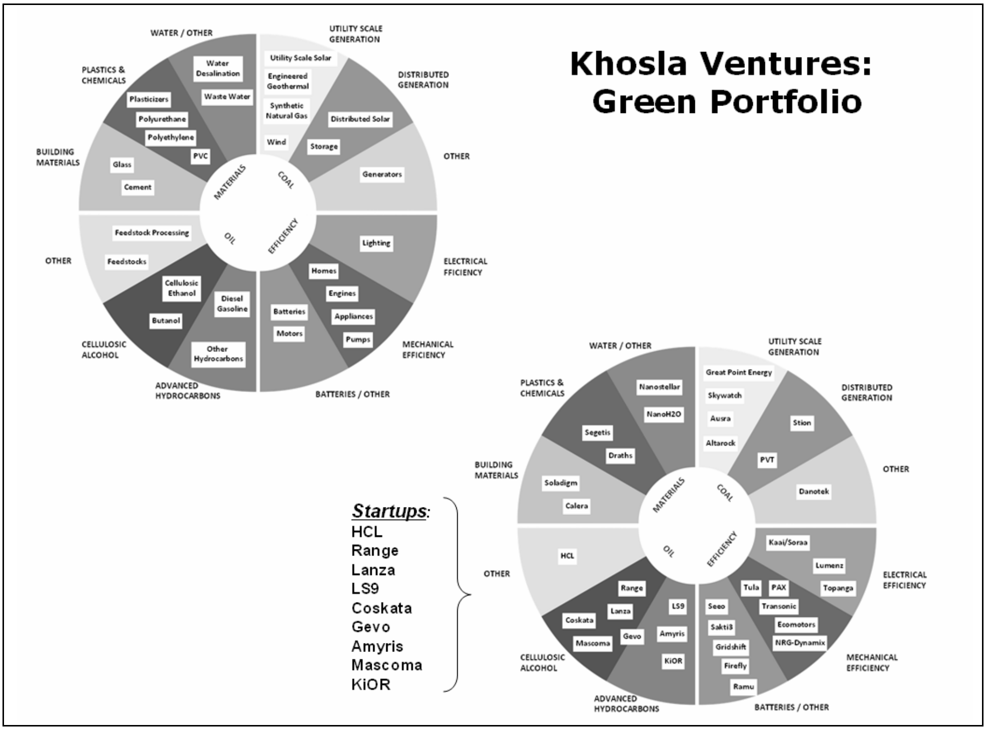


Figure I.182: Khosla Ventures Green Portfolio by industry, industry segments and applications/materials as well as technologies and equity-backed biofuels startups [Khosla 2009b].

When in 2008 the UK’s Carbon Trust Investments, which invested in biobutanol firm GBL (Table I.95), set out to fund algal biofuels research, it was confronted with a mélange of overzealous claims coming from the industry. Companies were projecting biofuel yields ten times what is theoretically possible and proposing techniques that are not now and may never be economical.

A year later, after wading through the claims and gathering opinions from a network of more than 300 experts, the agency announced the creation of the Algae Biofuel Challenge, a £16 (ca. $24) million fund that would support the development and large-scale production of algal oil. The Carbon Trust's experience navigating algae excitement is one that generally funding groups and investors in the biofuels industry increasingly face [Waltz 2009b].

The firms in Table I.99 provide developments of startups/NTBFs, usually until the end of 2009, focusing on various types of biofuels backed by Khosla.

Table I.99: Selected startups backed by Khosla Ventures reflecting a venture capitalists' portfolio approach to CleanTech and specifically biofuels. *)

Company (Foundation) Additions and Remarks	**Funding: Khosla Ventures and Several Other VC Firms**	**Technology**	**CEO, Other Executives and Key People**
Altra Biofuels, Inc. Los Angeles, Calif. (2004)	Over $415M; in 2006 the company secured $63.5M	Leverages various kinds of biofuel manufacturing processes. 2009: A half-built $220M, 110M-gallon (416M-liter) per year corn ethanol plant developed by Khosla-backed Altra in Nebraska has been sold piece-by-piece. Altra began building the dry mill ethanol facility in Carleton in late 2006 but halted development in November 2007 after completing approximately 50% of the project because the company was unable to secure additional financing	CEO Larry Gross
Cilion Goshen, CA (2006) As California represents 20% of the US ethanol consumption, Cilion has distinguished itself by its *destination-based business model* and *energy efficient* ethanol	$200M, Cilion raised $105M in debt financing (2007), for the construction of two ethanol plants in California; $170M (09/2005)	Converts corn into ethanol to power cars and trucks; rather than building a central plant to supply the whole country, Cilion was putting up multiple plants near population centers and livestock markets, including three plants in California and two in New York. Apr. 2009: A leak in the tank at the Cilion Ethanol plant in Stanislaus County caused it to collapse into itself last month. The facility re-	Mark L. Noetzel, President and CEO, entered 2007 from BP; previously Group Vice President of BP PLC

facilities. The destination model creates *added value by distillers grain* which is a co-product of ethanol production. Distillers grain is an economic, high protein dairy and cattle feed – localization in producer area or country, not near (steel) industry	Series B	mained closed, ceased operations in March. Other factors behind the demise of the facilities, industry experts say, include *too-rapid growth*. Originally, said Harrigfeld, "they were to be down three to four weeks. Now, because of the market, they are not sure when, or if, they are going to reopen. (Sonya Harrigfeld, director of the Stanislaus Department of Environmental Resources) [Anderson and Moran 2009]. "When Cilion was formed in 2006, they announced they would have 8 plants in operation by 2008 and achieve an energy return of better than twice that of gasoline. Here in 2009 they have zero plants in operation." [Rapier 2009]	
Hawai'i BioEnergy Honolulu (2006) Partnering also with Hawaiian Electric Co. on testing and implementing such clean technologies as solar power; Hawaiian Electric is partnering in an algae production project with Maui landowner Alexander & Baldwin Inc. and startup HR BioPetroleum Inc. (Table I.89). The plan was to create a commercial-scale algae facility adjacent to the Ma'alaea Power Plant [Moresco 2008]	Hawaii BioEnergy <$1M [Rapier 2009]	Researching the development of ethanol plants on Hawaiian islands; Hawai'i BioEnergy (HBE) is a corporation established by three of Hawai'i's largest landowners. Mission is to reduce Hawai'i's energy costs, green house gas emissions, and dependence on imported fossil fuels through the research and development of local renewable bio-energy projects; a variety of energy crops, including but not limited to sugarcane, woody biomass, and algae. Hawaiian Electric is also a partner in the proposed BlueEarth Biofuels LLC 40 MMGYbiodiesel processing plant on Maui, which was expected to be operational in early 2010. The goal was to use locally grown oil feedstocks such as algae, jatropha or palm.	Paul S. Zorner President and CEO; joined Hawai'i BioEnergy in 2008; was the CSO and Executive Director of Principle Energy Limited, a venture oriented to establish sugarcane conversion to ethanol and power in Mozambique; also served as the Chairman of the Board of Directors for Kuehnle AgroSystems, a Hawaiian company specializing in the research and development of algae as a source of renewable fuels

Mascoma Corporation Cambridge, Mass. (2006) Founders of Mascoma Corp.: Charles Wyman and Lee Lynd; Charles Wyman's interest in alternative fuels propelled his career during the late '70s and early '80s when he served as the Director of the Biotechnology Center for Fuels and Chemicals at the National Renewable Energy Laboratory (NREL). Wyman (doctoral degree in Chemical Engineering from Princeton University in 1971) became an authority in the field of cellulosic ethanol in 1996 when he published the "Handbook on Bioethanol." Alliance partner of General Motors (GM), Chevron, Marathon Oil	$61M (5/2008), Series C, {$30M (11/2006), Unattributed} Raised about $100M in equity investments and ca. $100M in state and federal grants by 2009. That included the $61M in a third round of funding, with GM and Marathon Oil. Secured $26M from the Department of Energy and $23.5M from the State of Michigan to build commercial plant in Michigan [St. John 2009]	Producer of biofuels from lignocellulosic biomass using microorganisms and enzymes; unique technology developed by Mascoma *uses yeast and bacteria that are engineered* to produce large quantities of the enzymes necessary to break down the cellulose and ferment the resulting sugars into ethanol. Claim: combining the two steps (enzymatic digestion and fermentation) significantly reduces costs by eliminating the need for enzyme produced in a separate refinery; process, called Consolidated Bioprocessing or "CBP"; started producing cellulosic ethanol from wood chips at a demonstration-scale plant (1,000-5,000 gallons scale) in Rome, NY. Said its microbes can convert plant material like wood chips, tall grasses, corn stalks and sugar cane bagasse into sugar; still feedstock testing: coop with Chevron and GM; Stepped down CEO Jamerson would become chairman of Mascoma and CEO of the company's Frontier Renewable Resources subsidiary in partnership with timber and mining company JM Longyear, that meant developing a 20-40 MGY cellulosic ethanol plant in Kinross, Michigan for 2012 (sought funding for $250 million to $300 million).	Jim Flatt, PhD, Acting President - Executive Vice President, Research & Development / Operations; served as Sr. VP of Research for Martek Biosciences Corporation (Columbia, MD), while the company searched for a new CEO; in 2009 CEO Bruce Jamerson stepped down. Co-founder Lee Lynd, was working on a farm where he noticed heat energy emanating from a compost pile. The observation of microbes producing energy from biomass sparked Lynd to speculate on the possibility of using biomass as a fuel source. He followed this idea with tremendous passion for decades; Masters and PhD degrees in engineering from Dartmouth College where in 1987 he joined the Dartmouth faculty.
Range Fuels Broomfield, CO (2006) Started as Kergy, Inc. and Bioconversion Technology (BCT), LLC, founded in 2003 in Colorado Replacement of Range Fuels founder and CEO	Undisclosed round from Khosla, plus a $75M grant from DOE; dreamt of IPO already for 2008; $100M Series B, $28.2M Series C (4/2008)	Using modular facilities to bring the conversion process to the biomass source, thereby reducing the energy expended with supplying the facility with feedstock; will grow as more biomass becomes available; Claims it can account for fluctuations in feed material in terms of type, consistency, moisture content, quality; Over 10,000 hours of testing has been completed on over 30 different	David Aldous CEO and Director; experience in the energy, oil and petrochemical industries, was Executive VP Strategy and Portfolio for Royal Dutch Shell; Replaced former CEO Mitch Mandich Key persons from Kergy, Inc. connected to Range Fuels:

Mitch Mandich, who led the company through a $100M capital raise and secured $80 million funding for cellulosic ethanol demonstration from the DOE [Lane 2009e]; Business Model: Designing, building, and operating its plants; Be first to market with commercially produced cellulosic biofuels; Thermochemical syngas approach allows production of various biofuels (e.g. bioethanol, biomethanol) and chemicals); Rapidly gain market share by capturing the best plant locations (is independent from type of biomass). Will need to capture a healthy percentage of the fuel ethanol market and be cost competitive to earn a reasonable return on the already substantial investment.	Range Fuels' Soperton Plant was supported by over $250M in support from public and private sources; huge loan guarantees. Its first commercial cellulosic biofuels plant under construction and was scheduled to begin production in the second quarter of 2010. Pilot plant (25 tons per day scale) was at its Development Center in Denver, CO (here 25 employees) [Schuetzle et al. 2007] Has raised the necessary capital to begin construction of a commercial-scale cellulosic biofuels plant.	non-food feedstocks. Originated with Bioconversion Technology's process of Bud Klepper (as described in the text). Two-step thermochemical process; converted into syngas, cleaned syngas is passed over a proprietary catalyst and transformed into cellulosic biofuels; to low carbon biofuels, such as cellulosic ethanol and methanol etc. (Figure I.174); Working on a 100 million-gallon-per-year facility by 2011 [Fehrenbacher 2008]. Had some delays; said it had raised $100 million to build a commercial scale plant in Soperton, GA to make ethanol from wood waste, and said the plant's first phase of 20 million gallons per year would be complete in 2009 [St. John 2009]; Despite some delays, it said it is about half done with construction of the full-scale plant in Soperton, GA [Wald 2009b]; the plant shall produce about 40 million gallons of ethanol per year and 9 million gallons per year of methanol; about 1,200 tons per day of wood chips and forest waste feedstock are expected to be processed at full operating capacity [Schuetzle et al. 2007]. (Cf. text in A.1.1.3 on "Range Fuels: Years of Broken Promises.") In December 2011 Range Fuels, one of the first companies in a wave of startups that promised cheap biofuels made from sources such as wood chips rather than corn, shut its doors for good and was forced to auction off its assets!	Arie Geertsema (here Senior VP), Mitch Mandich CEO, Robert ("Bud") Klepper (inventor of the Range Fuels technology). Robert "Bud" Klepper acted as advisor and Chief Technical Specialist and Inventor; brought many years of process equipment design and fabrication experience to the team. Arie Geertsema on the Scientific Advisory Board; was Managing Director of Corporate Research and Development and managed a team of over 400 R&D staff at Sasol, the largest and most successful gasification company specializing in coal gasification and gas-to-liquids production; was also a Director of the University of Kentucky's Center for Applied Energy Research and a tenured associate professor in chemical engineering (with doctorate in chemical engineering and an MBA).

Coskata Warrenville, IL (2006) Incorporated by GreatPoint Ventures; was the culmination of research of Aaron Mandell and Andrew Perlman, two GreatPoint Ventures partners, had been doing since 2001 into alternative concepts for low cost cellulosic ethanol production. Mandell began following ethanol research taking place at Oklahoma State University and the University of Oklahoma with the help of founding scientist Rathin Datta. When the University's scientific teams identified a potent set of anaerobic microorganisms for the conversion of synthesis gas to ethanol, Mandell secured rights to license the technology and began to formulate the development strategy. The team initiated experimental work at Argonne National Laboratories, and started to advance the organism and build a top-tier biofermentation technology team.	\$40M (11/2008), Series D; Raised \$19.5M in a second round of funding that should be used towards construction costs of its first 100 MGY cellulosic ethanol plant \$10M (06/2006), Series A	Vision: be the global leader in the syngas to biofuels platform, beginning with ethanol. Hybrid technology: Gasification of raw material is released into a bioreactor where microbes convert the gas into ethanol. The integrated biorefinery – utilizes Westinghouse Plasma Gasification on the front end and Coskata's syngas-to-biofuels conversion process on the back end – delivered to General Motors for early testing of bioethanol. The company can co-locate with steel mills to convert CO into gasoline. Ethanol commercial-scale plant should produce from either biomass (like wood biomass, agricultural waste, energy crops, switch grass) or municipal solid waste or other recycled materials (like old tires – one reason GM is interested); the emphasis was on sugarcane bagasse. Claims a yield of 100 gallons per ton of feedstock at a cost of less than \$1 per gallon. Differentiator: secret sauce of microorganisms + microreactor for syngas conversion in a "hybrid" process [Fehrenbacher 2008] Pilot-scale facility opened in Warrenville, IL. first for hybrid process; about to build a 40,000 gallon demonstration plant for cellulosic ethanol in Madison, PA., Uses filter – membrane for separations. Business model: Biorefinery orientation (bioethanol, co-products); Technology licensor (to feedstock suppliers, chemical manufacturers, petroleum companies, ethanol distributors/blenders,	William Roe President and CEO; prior to Coskata, a 29 year career with Nalco, the world's largest provider of industrial water-treatment chemicals and process additives, served as COO; Dr. Rathin Datta CSO; more than 32 years experience in developing and commercializing process and product technologies for both established and emerging companies. Rathin founded Vertec Biosolvents, a technology, manufacturing and marketing company dedicated to providing biologically-derived renewable resource alternatives to petroleum-based solvents (ch. A.1.1.6). Prior to Vertec Biosolvents, Rathin was the VP of Research for the Michigan Biotechnology Institute, where he led the commercial development of lactic acid/polymer technology and the commercial development and successful implementation of a fluidized bed reactor for specific waste treatment technology; Richard E. Tobey VP R&D, spent 28 years developing and commercializing new products and processes for The Dow Chemical Company within their Ion Exchange, Anti-Microbial,

In the spring of 2007, Coskata moved out of Argonne. (Cf. text in A.1.1.3 "The Risks, Translated from SEC-speak.")		project developers); hopes that licensees enable rapid scale-up; owner and operator (of currently) a demonstration-scale facility; orientation: flex ethanol [Roe 2009]	Pharmaceutical and Agricultural business units.
Gevo, Inc. Pasadena, CA (2005) Gevo Development, LLC is the development arm; seeking opportunities to access ethanol production assets to make biobutanol by retrofitting ethanol plants at a low capital cost. Spin-out: three co-founders, renowned researchers Frances Arnold (Prof.), Matthew Peters and Peter Meinhold of the California Institute of Technology, plus co-founders James C. Liao (Prof.) and Christopher Ryan. In 2007 acquired an *exclusive license* to use UCLA's method for modifying *E.coli* bacteria for use in biofuel development; has exclusive rights to integrate Cargill's world class microorganisms (yeast strains) into Gevo's Integrated Fermen-	Reported $17M Series C; (05/2009) $10M as Series B; backed also by French oil giant Total SA. Awarded $1.8M from the US Departments of Energy and Agriculture's Biomass Research & Development Initiative to help fund ongoing development of its yeast strain to produce biobutanol [Pruitt 2009a]	Technology: an enzyme process, developed at CalTech, that converts biomass (corn stover, switchgrass, forest residues, and other sustainable feedstock) to next-generation biofuels like butanol, which can be used in the existing petroleum supply chain; looks specifically into isobutanol; fermentation of all sugars including mixed (C6, C5) sugars. Business model includes selling products and licenses; raise capital to acquire assets either through direct acquisition, joint venture or tolling arrangements; retrofitting of existing ethanol plants; focus on biorefinery approach – products include biobutanol, isobutanol, biodiesel, jet fuel and biobased plastics [Lane 2009d]. Differentiates through three pieces from other firms: Gevo's "veteran team of research scientists" has developed a proprietary process" based on "Protein Engineering of Biocatalysts" (to convert agricultural waste products into different types of renewable, alcohol-based, liquid fuels), "veteran leadership team" almost entirely from polylactic acid plastics firm NatureWorks, LLC; Metabolic Engineering of Suitable Host Organisms (engineering suitable host organisms that utilize carbon and energy efficiently for fuel production; strains to exhibit increased yield and productivity to be	Highly experienced management team with roots in biobased chemicals and polymers. Patrick Gruber, CEO; several general management positions in technology and business development for Cargill Inc., one of the founders of NatureWorks, LLC (formerly Cargill Dow, LLC) focused on polylactic acid (PLA) where he was the VP of technology and operations and the CTO from 1997 until 2005 [Runge 2006:130, 245]; Christopher Ryan, EVP; served as COO and CTO for NatureWorks, LLC; David Glassner, Executive VP Technology; led the development of novel yeast biocatalysts for the production of lactic acid and ethanol at NatureWorks, LLC; also during this time he led the development of cellulosic processing technology and economic models for PLA manufacture; Jack Huttner Executive VP Commercial & Public Affairs, came from DuPont

tation Technology (GIFT®) process for the production of butanols from cellulosic sugars that are derived from biomass; Gevo and engineering firm ICM have entered into a strategic alliance for the commercial development of Gevo's technology GIFT® process for production of biobutanol and hydrocarbons from retrofitted ethanol plants.		sufficient to produce commodity chemicals – "green chemicals" – and fuels on a large scale); Process Engineering (developed a proprietary process technology to enhance productivity and lower product separation costs). Has announced (9/30/09) the start up of its 1 million gallon per year demonstration plant (through deploying its technology by retrofitting existing ethanol plants to produce biobutanol). Claims successful retrofit completed in less than 3 months [Pruitt 2009a]; for expansion, Gevo planned to acquire three to five ethanol plants over the next 12 to 18 months [Gevo 2009].	Danisco Cellulosic Ethanol (DDCE); prior to joining DDCE, he was VP of biorefinery business development at Genencor; Brett Lund VP & General Counsil, served as chairman of the legal, IP, and licensing group for Syngenta's biofuels business; Glenn Johnston, VP Regulatory Affairs, prior to joining Gevo he was director of regulatory affairs with NatureWorks, LLC.
LS9, Inc. **San Carlos, CA** (2005) How the idea of the technology and firm foundation came across is described by Svoboda [2008]. In 2008 made about 5,000 liters of biofuel in a pilot fermenter at its headquarter [St. John 2008]. Already in 2008 wanted to raise $75M to $100M to build a demonstration plant (2.5 mil. gallons per year) By the end of 2010 began engineering work on a full-scale commercial plant (up to 100 mil. gals.); could be up and running by 2012	$30M (12/20/2010) Series D; $25M (10/2009), Series C; $15M (10/9/07) Series B; $5M (3/1/2007) Series A; $20M from Lightspeed Venture Partners, Flagship Ventures and Khosla Ventures (latest Khosla investment, $5M). In 2009 applied for a multi-million dollar Government Integrated Biorefinery grant which would cover 80% of the re-	Uses *synthetic biology* to develop biofuels (gasoline, diesel, and jet fuel) from *traditional* feedstock that contain more energy than current biofuels; require less energy to produce and can be distributed through the existing petroleum infrastructure; commercializing and scaling-up DesignerBiofuels™ products; Basically, a technology platform with designer microbes converting renewable materials directly (one step to ultra-clean diesel) into transportation fuels and chemicals (strategic partnerships) [Del Cardayre 2009]. Metabolic engineering replaces whole swaths of genes inside microbes to turn them into tiny chemical factories; have engineered a strain of *e. coli* with a genome that can convert sugars into a fatty acid methyl ester (FAME) which is chemically equivalent to California Clean diesel; LS9's *1-step technology*, compared to competitors' multi-step processing technology, seemed to be highly cost competitive; Does not have to kill its microbes to	The company was bringing together leaders in synthetic biology and industrial biotechnology. George Church is Professor of Genetics at Harvard Medical School and a co-founder of LS9; directed one of the first funded genome technology centers since 1987 – now a DOE GTL systems biology center focused on photosynthesis and biofuels. Chris Somerville is Director of the Energy Biosciences Institute (BP funded) and a professor of plant and microbial biology at the University of California Berkeley, and a co-founder of LS9. Bill Haywood CEO; was Senior VP Manufacturing for Tesoro Petroleum, where he was responsible for the company's seven refineries.

[St. John 2008]. In 2009 revealed that it has a promising opportunity to purchase an already existing plant at a reduced cost but would not say where as of yet; Expected to have commercial plant by 2013 in Brazil as the cost of sugarcane is the lowest in Brazil [Stromeyer 2009]. Business model: Single platform: multiple products (biofuels, specialty chemicals); Low-cost producer; Proprietary single-step technology; Feedstock agnostic technology; Capital efficient scale-up (retrofit); Localization-oriented [Del Cardayre 2009]	trofit and operating cost associated with a demonstration plant. Biorefinery emphasis; two partners, with P&G for sustainable chemicals and with Chevron; equity investment from Chevron; P&G has invested tens of millions of dollars in LS9 to produce "green surfactants" [Stromeyer 2009].	get the oil; they secrete it naturally and then can live to feed, digest and excrete more dollops of oil; has a similar microbe that can make fatty alcohols [Kanellos 2009; Del Cardayre 2009]. Said that LS9, along with its competitors, will have to prove it can deliver on those low prices at full-scale production; LS9's goal was to be able to show that it could produce synthetic diesel for $45 to $50 a barrel by mid-2011 [Kanellos 2009]. Would not reach commercial production levels until 2013 [Lane 2009f, Del Cardayre 2009]. Indications for the issues of early promises: LS9 went through two leaders in the three years since its founding; Haywood took the helm of LS9 from Robert Walsh, former president and a 26-year veteran of Royal Dutch Shell. Walsh replaced LS9's first acting CEO, Doug Cameron, who was also chief scientific advisor for Khosla Ventures, in July 2007.	Stephen del Cardayre VP R&D, biochemist by education, spent 9 years at Codexis and Maxygen, was directly involved in the development, application, and commercialization of technologies for the engineering of biocatalytic processes for the pharmaceutical and chemical industry. Wei Huang VP Process Development and Engineering, over 17 years of industrial bioprocess experience, including process scale-up, facility and equipment design, process simulation, construction support, facility start-up, operation support, as well as process development and research. NOTE: By Jan. 2014 LS9 was acquired by Renewable Energy Group, Inc. (REG) with most of the LS9 team incuding .the whole R&D leadership group.
Amyris Biotechnologies Emeryville, CA (2003) Did not start as a fuel company in 2003; it started with $40M in funds from the Gates Foundation to develop Artemisinin, used for the treatment of malaria; transforming itself additionally into a next generation biofuels company. Amyris engineered yeast to produce a	Raised over $130M from the sale of equity from 2/2008 to present to support scale-up operations and initial commercial plant work [Lane 2009j]. $41.8M (10/2009), Series C, $70M (09/2007), Series B, $20M (10/2006),	Uses synthetic biology to create biofuels that can replace gas, diesel and jet fuel and chemicals; is engineering microbes specifically for that purpose. Make fuel from any kind of fermentable sugar, start with sugarcane via relationships with producers in Brazil. Amyris' portfolio of patents includes renewable diesel, renewable jet fuel, renewable gasoline, and renewable lubricants. Building relationships with feedstock producers around the world; can retrofit existing ethanol plants. JV with Brazil's second-largest sugarcane grower, a demonstration	John Melo CEO, before joining Amyris, Melo was President of US fuels operations for BP. Paul Adams Senior VP Fuels, spent 25 years with BP in its supply and trading business, where he was instrumental in building internal processes and policies to successfully maximize BP's profitability in the supply chain. Jack D. Newman co-founder and Senior VP of Research; over a decade of experience

malaria drug now being developed by Sanofi-Aventis; its genetic processes to deliver the low cost anti-malarial drug could be exploited for producing biofuels (since around 2006). Products: Renewable Fuels, Chemicals, Malaria treatment (Artemisinin-based). As a producer of biofuels covering the whole value system. Amyris Fuels, LLC. (wholly owned subsidiary), formed to develop a robust network for supplying and distributing renewable fuels. The company is growing its footprint by sourcing current generation of biofuels – such as ethanol – from US and international producers and bringing them to market at the lowest possible cost. Formed wholly-owned subsidiary Amyris Brasil tapping into one of the most economical and sustainable energy sources – sugarcane. Fuels Industry Experience: Amyris Fuels has understanding and	Series A. In 2009 received $25M through the US government's advanced biorefinery project stimulus award. Wanted to generate diesel fuel from sugarcane; Amyris wanted to use its $25M award for a pilot plant that will produce a diesel substitute by fermenting sweet sorghum and other petrochemical substitutes [Riddell 2009]	facility was located amid Brazil's sugarcane fields; Brazil is the No. 1 exporter of ethanol and is moving into biodiesel production. Planned to pump out a billion gallons within the next five years; planned to develop renewably sourced gasoline and jet fuel – but diesel was an ideal place to start. "Diesel fuel is what drives industry." Amyris Brasil announced that it has entered into letter of intent agreements with three sugar and ethanol producers in Brazil, Bunge Ltd., Cosan and Açúcar Guarani, with the purpose of partnering for the production of high value renewable specialty chemicals and fuels. These products should be distributed by Amyris. In December 2009, Amyris announced it had entered into an agreement with the São Martinho Group to acquire a 40% stake in the Boa Vista mill; the parties would convert this mill to achieve the first production of Amyris products; wanted to invest up to $200 million in the project [Lane 2009j]. Agreements are key steps toward building-out a fully integrated renewable products company – a company that encompasses the technology, industrial-scale manufacturing and product distribution capabilities. Also investigate the feasibility of developing an optimal economical model using Amyris technology to produce cane-derived diesel fuel from molasses rather than from traditional sugarcane juice. New "capital light" model: Amyris will partner with a mill and provide its technology through an off take agreement – not a licensing agreement. Amyris Brasil will provide mill owners	researching bacterial physiology and genetics, co-authored the groundbreaking work underlying the technology of microbial terpene production. Neil Renninger co-founder and CTO; has a cross-disciplinary understanding of both the micro-world of strain engineering and the macro-world of chemical engineering; received a doctorate in chemical engineering from the University of California, Berkeley, studying the metabolic engineering of bacterial cells for chemical transformations. Jeff Lievense Senior Vice President of Process Development and Manufacturing; 25 years of industrial experience in bioprocess engineering and a proven track record developing, scaling, and commercializing advanced fermentation processes. Dr. Lievense served also as VP of technology and process development for the R&D organization of Tate & Lyle, where he led the fermentation R&D program, commercializing three large-scale industrial fermentation products and pioneering a production process for Bio-PDO™ (1,3-propanediol).

seeks to deepen experience in the fuels industry; Has developed advanced capabilities in fuels marketing, supply, distribution, blending, systems development, accounting, and risk management [Lane 2009j]. GreenLane®: a typical "crossover strategy involving renewables" – prepare to commercialize renewables by learning from operation with non-renewables [Runge 2006:584, 855] In the US Amyris currently transports, stores, and markets ethanol from US domestic and overseas sources through Amyris Fuels, LLC. – will allow quick and reliable distribution of biofuels in the US; building strong customer relationships throughout the world and credibility as a reliable current generation fuel supplier.		with yeast strains, production processes and engineering design to produce Amyris products. The mill owner will provide capital to convert mill to produce Amyris products. Amyris Brasil will then purchase Amyris products from mill owners at contracted price and distribute product directly to customers. To achieve planned 2011 commercialization, has engaged a leading engineering, procurement and construction management (EPC) firm for final design and construction of commercial production facilities. Stages to commercialization: Emeryville Pilot Plant – Designed to mimic the full-scale fuel manufacturing process; Campinas Pilot Plant – second pilot plant, in Campinas, Brazil, is strategically located at the doorstep of Brazil's sugarcane industry, similar to the Emeryville plant will validate technology for use in Brazilian production conditions Q2 2009 Amyris Renewable Products Demonstration Plant – also in Campanis (14,000-square-foot facility) to conduct in-country scale-up, demonstration and optimization of all Amyris fuels and chemicals manufacturing processes; the production of more than 10,000 gallons of Amyris products under conditions representing full-scale manufacturing.	

Celunol Corporation (now Verenium Corp.) Cambridge, MA (1994) Founded 1994 as BC International; traded on the NASDAQ, bought by Diversa for $150M+, became **Verenium** (Table I.84) in 2007 [Childs 2007]. Business Units: Biofuels, Specialty Enzymes	Reportedly raised more than $60M from Khosla Ventures, Braemar Energy Ventures, Charles River, Rho Ventures	Produces enzyme-based (bioengineering) cellulosic ethanol; has proprietary biotechnology processes and project development know-how. Biomass used: sugarcane bagasse, corn stover, rice and wheat straws, wood waste, energy crops. Celunol's microorganisms consume C6 and C5 sugars (not commercially fermentable by yeast as C6); emphasis on cellulosic ethanol from agricultural waste left over from processing sugarcane. Exclusive licensee of key cellulosic ethanol (CEtOH) technology developed at the University of Florida; R&D facilities in Gainesville, FL; Operating plant in Jennings, LA; Pilot facility (1st CEtOH in US) operational Nov.2006, demonstration-scale CEtOH facility entering construction in 2007 when merger was already announced [Howe 2006] CEtOH facility in Osaka, Japan (wood waste) developed by Celunol licensee Marubeni Corp; Licenses technology domestically and internationally.	Diversa Enzymes prospects in hot springs, ocean beds, soda lakes, and on the Arctic tundra for genes potentially useful in industry. Verenium achieved growing portfolio of specialty enzyme products and "unique technical and operational capabilities." Verenium claimed to be the only company to offer fully integrated, end-to-end capabilities in pre-treatment, novel enzyme development, fermentation, engineering and project development [Childs 2007].
HCL CleanTech Ltd. Israel/US (2007) In 2012 re- named to **Virdia** Virdia is headquartered in Redwood City, but has a technology center in Danville, Virginia, and a research center in Tel Aviv, Israel. Improved a freely available technology, uses a ca. 80	$5.5M (06/2009), Series A In 2012 Virdia closed its latest round of financing, raised over $20 mil. from insiders, Khosla Ventures, Burrill & Company and Tamar Ventures; in addition, the company received $10 mil. in a venture debt	Virdia has developed the CASE™ (old acid solvent extraction) process, which converts cellulosic biomass to high quality fermentable sugars and lignin, and is based on a series of patented and patent-pending technologies. Use of fuming hydrochloric acid to catalyze the hydrolysis of cellulose to glucose and, generally, all polycarbohydrates to their constituent monomers. Hydrolysis yields of the sugar fraction are over 95-97% (a significant improvement compared to traditional enzymatic processes) and lignin solids are recovered practically intact.	Eran Baniel – Founder and CEO, serial entrepreneur. Robert Janse, Head of engineering, 33 years of experience in corn, wheat, sugar processing and fermentation at Tate & Lyle. Paul McWilliams (USA) – US Engineering, 31 years at Cargill working on wet milling plants. In 2012 Virdia got a new CEO Philippe Lavielle, a veteran of the industrial biotech sector. Lavielle

years old, industrially-proven German cellulosic to fermentable sugars and ethanol process, the Bergius process (named after its Nobel Prize winning developer) – technically superb, but associated with operating high cost. Virdia focuses on fermentable C6 and C5 sugars and lignin from biomass for industrial uses. Strategy: Virdia's cellulosic sugars and lignin are intermediate products in supply chains that can lead into biochemicals, biofuels, plastics and carbon fibers, as well as nutritional supplements for food and feed. Verdia is looking for partners to offtake those quantities of sugars and firms interested in the conversion of the sugars.	deal with Triple Point Capital.	Virdia's use of fuming hydrochloric acid (HCl) allows a large variety of feedstocks to be used with minimal change of configuration. Using the proprietary technologies developed in house, it has improved the recovery of the acid, as well as the recovery of valuable by-products, such as high quality lignin and high quality tall oils. Its technology for the recovery of HCl from aqueous solutions and industrial processes can also provide complete acid recovery solutions to HCl dependent industries (such as the PVC industry). In 2012 Virdia together with Virent (Table I.85) debut drop-in aviation biofuels made from *drop-in cellulosic pine tree sugars.* In 2012 Verdia announced a deal with the Mississippi Development Authority to build a plant to derive sugar from wood chips, a plentiful by-product of the state's forestry industry. That deal included $75 million in low-interest loans and up to $155 million in tax incentives over a 10-yr period. The first plant, due to start up in late 2014 or early 2015, will have capacity for 150,000 tons (300 million lb) of sugars per year. Virdia eventually aims to build plants for 500,000 tons (1 billion lb) per yr.	replaced co-founder Eran Baniel as CEO, who now serves as Vice President of Business Development. Before joining Virdia, Lavielle was a member of the executive management at Genencor. The company is now led by a new management team with decades of industrial-scale manufacturing experience ("veterans") in industrial biotech, chemicals and sugar production.
KiOR Inc. US / KiOR BV ,The Netherlands (2007) In 2007, KiOR was founded by Khosla Ventures and a group of catalyst scientists who shared a vision of making renewable fuels from cellulosic biomass through a	$12.9M (06/2008), Series B, $1.4M (11/2007) Series A	KiOR targets the fuel markets only. The technology originally pioneered by Bioecon in 2006. Converts biomass, particularly the recalcitrant polymeric biomass residue, to valuable molecules which can be utilized by the chemical and fuels industry. Biomass catalytic cracking process – a thermochemical process that produces biocrude from grass, wood and plant waste that can then be refined – has significantly lower	The Company was incorporated and commenced operations in July 2007 as a joint venture between Khosla Ventures and BIOeCON BV. KiOR BV, a Netherlands company, was formed on March 4, 2008 and commenced a process of liquidation in March 2010. As of December

one-step catalytic process. Biofuel JV of Khosla Ventures and Dutch biofuel startup BIOeCON Number of employees (around 2008): 15 Khosla Ventures' involvement with what would become KiOR started with a call from an engineer from Holland to Vinod Khosla. In contrast to the inventor's interest in a licensing business model, Khosla envisioned that the KiOR process could lead to an oil exploration and production company. Has adopted a build, own and operate strategy; Hopes also to license the technology to customers like oil refineries and feedstock owners.		capital costs compared with other biomass conversion technologies (claim); Develops and commercializes Biomass Catalytic Cracking (BCC) technology. BCC technology converts lignocellulosic biomass into a "biocrude" which is suitable for upgrading to transportation fuels; "Biocrude": a mixture of small hydrocarbon molecules that can be processed into fuels, such as gasoline or diesel in existing oil refineries. Renewable biocrude oil can be refined in a conventional hydrotreater into light refined products (gasoline and diesel blendstocks). Technology produces hydrocarbon blendstocks that will "*drop in*" to the existing transportation fuels infrastructure for use in vehicles on the road today. Technology platform combines proprietary catalyst systems with well-established fluid catalytic cracking, or FCC, processes that have been used in crude oil refineries to produce gasoline for over 60 years. Constructed a pilot unit outside of Houston, Texas to continue developing and validating the technology; this pilot unit has amassed over 9,000 hours of operation and evaluated more than 250 catalyst systems [Admin 2011d] In 2010 was producing 15 barrels per day of biocrude (229,000 gallons per year) using its fast pyrolysis technology and a proprietary catalyst	31, 2010, all of the operations of KiOR BV were combined into the operations of KiOR, Inc. Khosla targeted the hiring of mission critical technologists to the company, ultimately leading to the hiring of Fred Cannon as KiOR's President (in 2008), and later CEO (2010). Prior to KiOR, Cannon was president of AkzoNobel Catalysts LLC from 1997 until the divestment of the business in August 2004. KiOR Columbus, LLC, a wholly owned subsidiary of the Company ("KiOR Inc."), was formed on October 6, 2010.
LanzaTech Ltd. Auckland, New Zealand Founded in 2005 in New Zealand and now headquartered in Roselle, Illinois In 2010 LanzaTech	Between foundation in 2005 and 2010 LanzaTech has raised $30 mio. in venture capital and $10 mil. from the New Zealand gov-	The LanzaTech Process captures gas (CO) as a resource; innovation lies in using a bacterium to produce ethanol not from a carbohydrate, but from a gas (cf. Coskata) A "hybrid" ethanol production process that can be retrofitted to industrial facilities, generates ethanol from	Notably, David C. Aldous, was a member of the LanzaTech Board since October 2008; a former Executive VP of Strategy and Portfolio for Shell – was also Range Fuels' CEO and

announced that it had engineered a microorganism that can produce 2,3-butanediol, a chemical precursor that can be used to make the solvent methyl ethyl ketone (MEK), which is used in dry erase markers and in the manufacture of plastics and textiles. The same chemical can produce butanes and butadiene, which can then be used to make a variety of plastics and hydrocarbon fuels. While the chemical market is smaller than the fuel market, it can be more profitable, since chemicals such as MEK sell for more than twice the price of ethanol.	ernment. Throughout 2005 and 2006, the company raised funding through New Zealand-based angel investors and secured grants. $3.5M (4/2007), Series A (for pilot plant) Series A investment was from a consortium led by Khosla Ventures; the Series B financing was led by Qiming Ventures. In 2012 it closed Series C investment led by the Malaysian Life Sciences Capital Fund ($56 mio.). New investors included Petronas Technology Ventures Sdn Bhd, the venture arm of Petronas, the national oil company of Malaysia.	the carbon monoxide (CO) of waste flue gases (little or no hydrogen as is in syngas; e.g. steel and other industries); can also use thermochemical syngas based on any biomass resource (municipal waste, organic industrial waste (tires), waste wood); CO used as a food source for proprietary LanzaTech microbes during the biofermentation process (hybrid process), non-genetically modified, non-pathogenic bacteria, isolated from natural environments [Lanza Web]. The carbon monoxide containing gases are scrubbed, cooled and sent to a bioreactor. The carbon component is used as a food source for the proprietary LanzaTech microbes during the biofermentation process. The microbes use this energy to produce ethanol. With its hybrid process LanzaTech claims to become the lowest cost, highest volume producers of fuel ethanol. Claimed major advantage over existing gas to liquid conversion technologies: Able to virtually eliminate capital cost associated with gas conditioning. Rapidly growing patent portfolio, adopted a stage-gated critical path through process piloting to commercialization [LanzaTech Media Release Aug. 18 2009]. Claims to have one of the world's largest collections of industrial fuel and chemical production microbes. The fermentation suite comprises more than 20 bench-top gas fermentation reactors and a test-bay allowing the development and demonstration of several prototype reactor designs in parallel and at scale.	Director; Currently, LanzaTech is led by a multinational Board of Directors and Management Team with offices in New Zealand, China and the US. Dr. Jennifer Holmgren is the Chief Executive Officer. Jennifer has over 20 years of experience in the energy sector including a proven track record in the development and commercialization of fuels and chemicals technologies. Prior to joining LanzaTech, she was Vice President and General Manager of the Renewable Energy and Chemicals business unit at UOP LLC, a Honeywell Company. Dr. Sean Simpson is the Chief Scientific Officer and co-founder of LanzaTech. He spent the first 12 years of his life living in various countries around the world, including Mauritius, Zambia and Gibraltar, before his family returned to England. He now lives with his family in Auckland.

*) From the firm's Web site if not stated otherwise by a reference;
Firms' states: usually end of 2009, if not stated otherwise.

The biofuels investments of Vinod Khosla in startups (Table I.99) show various fates so far, from bankruptcies to good financial returns by IPOs, from promising developments to recent change of development directions away from biofuels and covering a very broad spectrum of technical approaches – and cooperation (LS9 and HCL Cleantech/Verdia) or interconnections ("networking effects") via technology or people (for instance, Range Fuels and LanzaTech).

For instance, in January 2012 LanzaTech purchased a facility in Soperton, Ga. previously owned by bankrupt Range Fuels at auction for $5.1 million. Range Fuels' lender took control of the facility for non-payment and held the auction to recoup some of a $38 million loan, which had been guaranteed by the Department of Agriculture. Range was also awarded a $43 million grant from the Department of Energy to help construct this facility. LanzaTech acquired the facility for its location and access to cheap feedstocks from local timber operations.

LanzaTech's plan was to leverage some of the existing technology at the facility alongside own proprietary technology to produce renewable and domestic fuels and chemicals from the bountiful waste biomass in the region [Bomgardner 2012b]. The Soperton site, already renamed Freedom Pines Biorefinery, will be LanzaTech's first production facility. The firm is currently working to launch a demonstration facility in Shanghai that will use waste gases from a steel mill operated by China's Shougang Group.

The fact that Range Fuels and LanzaTech share a lead investor – Khosla Ventures – has raised eyebrows because LanzaTech bought the Soperton site for a fraction of the amount spent developing the facility.

As a summary, VC-backed startups, at least in biofuels, can be differentiated by

- Financial backing of early stages ("technology investors");
- Backing specifically industrial scale-up of proven R&D ("project investors," late-stage funding, also corporate venturing);
- VCs being pro-activley involved in firm foundation;
- Initiating firm foundation and proceeding along a defined development path.

Furthermore, entrepreneurship in biofuels (and also other CleanTech areas) exhibits a number of founders who were riding the first wave of renewables in the late 1970s and 1980s.

As observed with corporate venture oriented startups with oil companies in the venture capital community impatience was also rising with the pace of commercialization. Generally, it is a rather normal process when the R&D/pilot phase changes into the engineering/scale-up phase to change the management team, in particular, the CEO who will have to emphasize commercialization rather than technology. But an indicator of problems with biofuels was successively fast change in NTBFs' leadership teams.

For many new biofuels firms the proof-of-concept in the lab is not being translated quickly enough into production results at the plant and they still have to prove they can deliver on those low prices at full-scale production. Pressure related to the promises and postponed milestones into commercialization have built up. Examples of CEO or founders, respectively, stepping down or being replaced include LS9, Range Fuels and Mascoma [Lane 2009e].

The Great Recession 2009/2010 had also a great influence on financing (biofuels) startups' further developments by VC firms. For instance, biotech and CleanTech fundraising from venture capital declined in the third quarter of 2010 [Voith 2010a; Voith 2010b]

On the other hand, policy continued to step in. There have been established a number of programs by the US Federal Government to support technology entrepreneurship. The US Department of Agriculture (USDA) and Department of Energy (DOE) were investing $47 million over three years in eight pilot-scale R&D projects to make biofuels and other products from various biomass sources [Mukhopadhyay 2011c].

For a bargain price of $1,000, start-up companies can get up to three of the thousands of unlicensed patents in the Department of Energy's portfolio. The aim is to double the number of startup companies emerging from DOE's 17 national laboratories, which hold more than 15,000 patents. Only 10 percent of federal patents are currently licensed to be commercialized, according to the agency. By simply submitting a business plan and signing a generic agreement, available as a template on the DOE Web site, interested startups can apply to license up to three patents from a single laboratory at the reduced $1,000 fee [Mukhopadhyay 2011b].

Also the US military will play an important role here. The US military consumes more energy than is used by two-thirds of all nations worldwide! DOD needs cheaper and more abundant energy sources to power its global operations.

Collaboration between the Departments of Defense and Energy was established to reduce the US's dependence on oil. DOE is the nation's largest funder of the physical sciences and DOD will act as a test bed for innovative technology. There are three areas that will benefit from the partnership: batteries; fuel cells; and alternative fuels derived from sources such as biomass, natural gas, and algae [Mukhopadhyay 2011d].

In 2011 many of the firms listed in Table I.99 targeted an IPO for financing further developments. Coskata's approach when it looked in December 2011 for an $100 million IPO has already been discussed (A.1.1.3).

Basically, revenue streams of these NTBFs include

- Grant revenue,
- Licensing revenue
- Biofuel sales and sales of related products.

Aspects of partnering in biofuels include

- Feedstock sourcing and testing;
- Product development and testing;
- Final end use product formulations;
- Commercialization of developed technologies;
- Equity investments and development support.

Mascoma (Table I.99) also filed an S-1 registration for a proposed IPO. For Masoma's IPO several red flags were raised [Fehrenbacher 2011; Admin 2011c], for instance, expressed by "The Risks, translated from SEC-speak" [Admin 2011c].

Wanting to raise $100 million, Mascoma generated $34.5 million in revenue along the way, primarily government funding for R&D. They have not yet commercialized their corn ethanol technology or the hardwood process. The accumulated deficit as of June 30, 2011 was $118.722 million. The net losses were $30.4 million, $38.3 million and $25.7 million for the years ended December 31, 2008, 2009 and 2010, respectively, and $14.8 million for the six months ended June 30, 2011 [Admin 2011c]. Mascoma said for its revenues in 2010, government grants constituted "86 percent of our revenue" while "product sales and other service agreements constituted 14 percent of our revenue." [Fehrenbacher 2011]

"It's not a pretty prospectus: Mascoma's auditors have questioned its ability to remain a going concern, and its debt carries interest rates as high as 11%. This is all to make cellulosic ethanol a fuel whose commercial viability many experts question. The trouble is, Mascoma's plant was supposed to be virtually built by now. The company's plan in early to mid-2008 was to leverage a grant from the state of Michigan to get debt financing, but that never did happen because the markets for energy-project finance closed after Lehman Bros. collapsed. More disturbing, perhaps, is the silence about Mascoma that has emanated from venture-capital firm Khosla Ventures, the company's second-biggest shareholder." [Mullaney 2011]

IPOs of other firms in which Vinod Khosla invested include Amyris, Gevo, and KiOR (all in Table I.99). But here, for instance, Amyris raised around $363 million through its IPO and the IPO translated Khosla Ventures' $15.59 million investment into a worth of $65.36 million meaning a 4X return at that time [Wesoff 2010].

According to McDonald [2011] "Much advanced biofuel development is a combination of hype and science fiction, but these companies have practical business plans, near-term commercial objectives and the financial resources to get across or near the goal line." Cellulosic ethanol is the biggest disappointment, and so *now attention is likely to switch to drop-in (road-ready) biofuels* like renewable gasoline and diesel or jet fuel.

For instance, for policy in Germany, in 2012, one year after its introduction and aiming to become the major type of fuel for Otto-engines, E10-gasoline flopped. E10 achieved just 13 percent of all transportation fuels. Users did not accept E10 – not because of concerns it might damage the current engines, but the population has serious doubts whether such biofuels show benefits for the environment and the climate [Eicher 2012].

Regarding companies, for instance, early in 2012 *Shell* announced that it has built the next generation biofuels pilot plant at Shell's Westhollow Technology Center in Houston, TX, to *produce drop-in biofuels rather than ethanol*. It uses a thermocatalytic process technology licensed from its commercial partner Virent (Table I.85), which is similar to the process being used at the Virent pilot plant in Madison, Wisconsin [McDermott 2012].

The benefits of drop-in biofuels from the perspective of being able to use existing fuel infrastructure without modification should not be overlooked. Drop-in biofuels have the same properties as conventional fuels. This eliminates the need for additional blending and storage infrastructure as well as engine modifications (Table I.82) that may be required for the use of more ethanol in blends with conventional fuels. That means there are a lot of sunk costs there financially.

In early 2011 Khosla-backed *KiOR* focusing on *drop-in "biocrude*" (Table I.99) filed for an IPO. At that time KiOR signed an offtake agreement with Hunt Refining of Tennessee for biofuels produced at the facility KiOR is developing in Columbus. The company was planning to invest $500 million in three wood chip-to-biofuel plants in Mississippi and the Columbus plant was expected to be online in 2012. The state's development authority was granting KiOR $75 million based on the deal with Hunt [Admin 2012d]

"We are a development stage company with a limited operating history, and we have not yet commercialized our cellulosic gasoline and diesel nor have we generated any revenue. Until recently, we have focused our efforts on research and development, and we have yet to generate revenue." "As a result, we had generated $108.7 million of operating losses and an accumulated deficit of $130.4 million from our inception through December 31, 2011. We expect to continue to incur operating losses through at least 2013 as we continue into the commercialization stage of our business." [KiOR 2012]

In raising $150 million by its IPO, the Khosla Ventures-backed KiOR raised 50 percent more than expected at the time of its initial filing, but well short of the $241 million potential the company had tipped in filings over the past month. Through the IPO Khosla Ventures retained up to 70 percent voting control through the structure outlined by the company. That means, Khosla Ventures controls a majority of the outstanding common stock and will continue to control a majority of KiOR's common stock after the IPO. As a result, KiOR is a "controlled company" [Admin 2011d; Admin 2011e].

"In November 2007, Khosla Ventures bought in to the old BioeCON technology (valued at the time at $2.6 million) for $4.4 million at $0.36 per share. By June 2008, the company sold another $10 million in shares to Khosla at $0.97 per share – and another $15 million came in via a promissory note. The company came back in spring 2010 with a $95M capital raise at $9.80 per share – that's a lot of added value based on the $30 million invested." [Admin 2011e]

KiOR said it has completed construction of its first commercial-scale facility on budget and ahead of schedule. The company was commissioning the plant in Columbus, Miss., and expected to begin production in summer 2012. Once it is fully operational, the facility will have an annual capacity of 11 million gal. The feedstock will be local southern yellow pine [Bomgardner 2012a].

> Furthermore, many promising biofuels startups changed their focus softly, declared as "initial orientation," from biofuels to biobased specialty chemicals.

Amyris Biotechnologies (Table I.99) now intends to become a leading provider of renewable specialty chemicals and fuels worldwide. In 2010 it went public [SEC 2010], as mentioned above. Its initial focus was on farnesene, a sesquiterpene that exists as a variety of isomers and stereoisomers. It intended to convert farnesene into diesel and jet fuel and materials for detergents, cosmetics, perfumes, and lubricants. Capital injection was $244 million in funding since its inception [Tullo 2010]. The Amyris strategy: commercialize farnesene on a contract manufacturing basis, then turn to farnesane, produced by adding hydrogen to farnesene. Farnesane is the company's showcase diesel molecule.

Amyris had, as its primary post-IPO challenge, to tackle the proof that it can replicate its lab and pilot results at scale. Apart from *scale-up* Amyris' further Achilles heel is the *dependence for the near term on Brazilian sugarcane resources for its sugar feedstocks*. Sugar is half the price of farnesene in the Amyris equation – near as any analyst has been able to decipher, and with the price of Brazilian sugar doubling in the 2008-10 time frame before retreating in 2011 – the dependency will not only be on Brazilian harvests, but India's (which are more subject to variance) [Administrator 2010].

According to Amyris' annual report 2011 [Amyris 2012] total revenues and net loss, respectively, developed as follows:

Revenues ($ mio.)	**2011**	**2010**	**2009**	**2008**	**2007**
Product sales	129.8	68.7	61.7	10.7	-
Grants and collaboration revenues	17.2	11.7	2.9	3.2	6.2
Total revenues	147.0	80.3	64.6	13.9	6.2
Net loss ($ mio.)	(179.5)	(82.8)	(64.8)	(42.3)	(11.8)

In 2011 and 2012, Amyris leveraged contract *manufacturing capabilities* to begin producing Biofene®, Amyris's brand of farnesene, at three sites in three countries around the world: Biomin (Piracicaba, Brazil), Tate & Lyle (Decatur, Illinois), and Antibioticós (Leon, Spain).

With regard to *execution* its strategy Amyris established a number of partnerships, co-operation, JVs with established large companies addressing their anticipated applications of farnesene. In 2010 Amyris announced a series of agreements with The Procter & Gamble Company (P&G). The agreements focused on the use of farnesene in certain specialty chemical applications within P&G's products.

Also in 2011 Amyris Inc. and French energy giant Total have expanded a partnership to produce renewable diesel products through a joint venture, to which Total will contribute an additional $105 million on top of the $180 million the companies already have committed, according to financial filings (approximately 17 percent equity interest in Amyris). The 50-50 joint venture has the exclusive rights to produce and market renewable diesel and jet fuel worldwide. It also has a non-exclusive agreement to develop and market other non-fuel products [Riddell 2011].

In a partnership, French tire maker Michelin has joined with Amyris to develop renewable isoprene. Amyris said it will use technology similar to its process for making farnesene [Bomgardner 2011e]. Under the agreement, Amyris and Michelin will partner to contribute funding and technical resources to develop Amyris's technology to produce isoprene from renewable feedstocks. Amyris expected to begin commercializing this isoprene in 2015 for use in tire and other specialty chemical applications. Michelin is committed to off-take volumes on a ten-year basis. In addition, Amyris retains the right to market its renewable isoprene to other customers.

Furthermore, in 2011 Amyris signed a collaboration agreement with the Japanse firm Kuraray Co., Ltd. to develop innovative polymers from Biofene. Under the agreement, Kuraray will use Biofene to replace petroleum-derived feedstock such as butadiene and isoprene in the production of specified classes of high-performing polymers.

And, as part of an effort to solve production problems, in 2012 Amyris made a $59 million private placement of common stock and issued $25 million in convertible bonds. Most of the new capital came from existing investors. The firm, will use the new funds to pay for the scale-up of its commercial operations [Bomgardner 2012c].

However, *in February 2012 Amyris said it is giving up making fuels*. Instead, it will focus on higher value products, such as moisturizers for cosmetics. The company learned firsthand just how difficult it is to achieve the kind of yields seen in lab tests in large-scale production. Range Fuels, one of the first of the current crop of companies, recently went out of business. Others were giving up on making biofuels too, also hoping to break into markets for higher value chemicals.

Amyris's technology may still be used to make renewable fuels, but this will happen not at Amyris, but under joint ventures established with Total and Cosan. These ventures will need to build up their own production capacity. Amyris had said that in 2012 it would produce 40 to 50 million liters of farnesene, basically a fragrant oil.

Amyris also said it is indefinitely delaying plans for one of two large production facilities it was to have built this year [Bullis 2012b].

In 2012 Neil Renninger, a co-founder of Amyris Technologies (Table I.99), stepped down as CTO. Concerning science versus business the visions of the CEO and CTO for the company proved incompatible. CEO John Melo came from a big-company culture at odds with Amyris's freewheeling researchers. The scientists balked when he tried to apply big-company rigor and measure employees' contributions and their performance [Grushkin 2012].

A related execution of its strategy is observed for Gevo which also went public. And Gevo seemed to hope to become profitable by turning corn into chemicals. According to its prospectus Gevo showed a net loss of $78.579 million from June 9, 2005 (date of inception) through September 30, 2010 [NASDAQ 2011]. According to Gevo's annual report 2011 total revenues and net loss, respectively, developed as follows:

Revenues ($ mio.)	**2011**	**2010**	**2009**	**2008**	**2007**
Bioalcohol sales and related products	63.74	14.77			
Licensing revenue		0.14			
Grant, research and development program revenue	0.81	1.49	0.66	0.21	0.28
Total revenues	64.55	16.40	0.66	0.21	0.28
Net loss ($ mio.)	(48.21)	(40.11)	(19.89)	(14.54)	(7.23)

According to Gevo's IPO prospectus, venture capitalists own 60 percent of the company (Khosla Ventures, 26.8%; Virgin Green Fund, 10.5%; Total Energy Ventures International, 9.2%; Burrill & Company Life Sciences, 7.1%; Malaysia Life Sciences, 6.3%) and LANXESS Corporation owned 4.7 percent. The German firm LANXESS is the world's largest synthetic rubber producer. But, after the IPO, LANXESS increased its position to 9.1 percent. Total Energy Ventures is the VC arm of French oil multinational Total SA. Gevo management and directors own 22.7 percent.

In and after 2011 Gevo received important foundational patents for its operations, but it was also involved in a heavy litigation with Butamax Advanced Biofuels LLC (Table I.83).

In 2012 Gevo was awarded US Patent No. 8,071,358, covering additional "Methods of Increasing Dihydroxy Acid Dehydratase (DHAD) Activity to Improve Production of Fuels, Chemicals, and Amino Acids." This invention further details and protects the innovations contained in the *Gevo yeast organism* to turn an industrial yeast strain into a highly efficient cell factory to produce isobutanol. Also in 2012 the USPTO granted

US Patent No. 8,153,415 entitled "Reduced By-Product Accumulation for Improved Production of Isobutanol." The '415 Patent" covers technology which *eliminates two pathways* that compete for isobutanol pathway intermediates in yeast.

Gevo was awarded US Patent No. 8,101,808, "Recovery of Higher Alcohols From Dilute Aqueous Solutions." This patent addresses the *separation technology* used to produce propanols, butanols, pentanols, and hexanols. The claims also address *how ethanol plants can be retrofitted* to produce higher alcohols. It solves the long-standing problem for the practical production of higher alcohols, specifically how to separate these alcohol products from fermentation broth and achieve economic concentrations.

This is the technology, along with Gevo's proprietary yeast, being implemented at the Luverne, Minnesota plant, which Gevo acquired in September 2010. The Gevo Integrated Fermentation Technology (GIFT® system) permits the *continuous removal of isobutanol as it is formed*.

In 2011 Gevo was awarded US Patent No. 8,097,440 "Engineered Microorganisms Capable of Producing Target Compounds Under Anaerobic Conditions." It refers to Gevo's yeast technology to enable the low-cost, high-yield production of biobased isobutanol. Gevo has been awarded a *patent for an anaerobic yeast utilizing a novel enzymatic structure*. Gevo believes the most efficient and economical way to make isobutanol through fermentation is to use yeast that is anaerobic, or does not need oxygen.

In 2011 Gevo filed a lawsuit against Butamax™ Advanced Biofuels, LLC and its affiliate DuPont. Butamax has publicly disclosed its use of Gevo's claimed technology in several later-filed patent applications. Butamax has attempted to reach commercial-scale production of isobutanol for several years (Table I.83). To produce commercially relevant levels of isobutanol, however, one must use the technology covered by Gevo's 8,153,415 Patent. This patent illustrates the importance of eliminating these pathways before Geve's competitors do.

In March 2012 the USPTO rejected all patent claims of Butamax covering isobutanol-producing yeast in US Patent No. 7,851,188 which is currently being asserted against Gevo. Gevo also successfully petitioned the USPTO to reexamine Butamax's claims in US Patent No. 7,993,889 covering a method of producing isobutanol using a recombinant yeast microorganism. The USPTO actions in the '188 and '889 patents also reinforced Gevo's position that the technologies and process steps claimed by Butamax were known in the field, published in numerous scientific journals or invented by others, including Gevo, before Butamax applied for its patents.

The recent emphasis of Gevo turned to biobased chemicals and intermediates, in particular, biobased solvents (isobutanol and n-butanol) and synthetic rubber and plastics, based on isobutene derived from isobutanol. Concerning biofuels the focus turned to biojet fuel. Further promising developments with Gevo depend essentially on achieving commercial scale production of isobutanol. To drive developments Gevo is working directly with its important potential customers.

Gevo, Inc. through its wholly owned subsidiary, Gevo Development, LLC, has entered into a joint venture transaction (“JV”) with Redfield Energy, LLC of Redfield, SD, to retrofit Redfield’s existing ethanol plant into an isobutanol plant with an expected production capacity of approximately 38 million gallons per year (MGPY). The retrofit commenced by year end 2011, and Gevo expected to begin commercial production of isobutanol at the facility in the fourth quarter of 2012.

In July 2012 Gevo succeeded to ferment isobutanol in large (250,000 gallon) commercial fermenters, isolate the product and get it into tanks and railcars. The learnings gained in achieving this milestone are viewed as enormous and further derisk Gevo technology.

In 2012 Gevo established itself as a company producing bio-based solvents, meeting industry standard specifications for all current isobutanol and n-butanol applications, particularly derived solvents for the coatings market.

Also in 2012 Gevo received a USDA $5 million grant for development of jet fuel from woody biomass and forest residues. The award is a portion of a $40 million grant presented to the Northwest Advanced Renewables Alliance (NARA), a consortium led by Washington State University (WSU). Other NARA members include the firms Weyerhaeuser, Catchlight Energy and Oregon State University, Pennsylvania State University, and the University of Minnesota.

The airline industry and the US Department of Defense are eagerly looking for near-term alternatives to petroleum-based jet fuel. Gevo previously announced its progress to airline engine testing using starch derived isobutanol to jet fuel. Gevo expects to receive full fuel certification by 2013 from the American Society for Testing and Materials (ASTM) for its biojet fuel.

In 2011 Gevo successfully completed the construction and commissioning of the world’s largest ATJ biofuel demonstration plant at South Hampton Resources’ facility near Houston, TX. The facility has begun operations and is delivering test volumes of ATJ biofuel to Gevo’s initial customers. Gevo was awarded a contract by the Defense Logistics Agency to supply up to 11,000 gallons of ATJ based biojet fuel to the US Air Force. Also the German airline Lufthansa evaluates Gevo's renewable jet fuel.

The German chemical firm LANXESS plays a key role for Gevo. It is not only the world’s largest synthetic rubber producer. Butyl rubber represents 25 percent of LANXESS’ sales. It is the world’s largest purchaser of isobutene and, for instance, in the long term, biobased isobutene will account for half of LANXESS synthetic rubber production at its plant in Sarnia, Canada. LANXESS strengthened its commitment to produce premium synthetic rubber from biobased raw materials and, as part of this commitment, it increased its minority shareholding in Gevo, Inc. in early 2011 amounting to 9.1 percent after having invested $17 million in Gevo's IPO. LANXESS initially invested $10 million in Gevo as part of a private placement in May 2010.

The LANXESS-Gevo partnership is working on a unique method that may hold the key to the sustainable production of isobutene and created a breakthrough dehydration process that converts isobutanol into isobutene. The dehydration process has not only proven to be successful in the laboratory by the end of 2011, but has also undergone several months of practical testing in a small-scale reactor at LANXESS' site in Leverkusen, Germany

In 2011 Gevo announced a groundbreaking agreement with The Coca-Cola Company (Coca-Cola) to create renewable para-xylene from plant-based isobutanol. Gevo will work to develop an integrated commercial-scale system to produce renewable para-xylene, a key building block towards reaching Coca-Cola's goal of leading the beverage industry away from fossil-fuel based packaging by offering an alternative made completely from renewable resources (PET plastic packaging). The global market for PET is 54 million metric tons and has a value of $100 billion, with approximately 30 percent used for plastic bottles.

Isobutanol that can be converted into para-xylene using known chemical processes is a key raw material in PET production. Gevo has previously set up a cooperation and is supplying the Japanese chemical giant Toray with lab-scale quantities of renewable para-xylene. Toray has successfully converted Gevo's para-xylene into PET films and fibers. Toray employed its existing technology and new technology jointly developed with Gevo and used Gevo's para-xylene and commercially available renewable mono ethylene glycol (MEG) to produce fully renewable PET (all of the carbon in this PET is renewable).

Box I.26: Drivers for Synthetic Rubber from Biobased Intermediates [Bomgardner 2011e].

The common automobile tire contains rubber that is extracted from latex-bearing trees and rubber that is synthesized from petroleum feedstock. Industrial biotechnology companies such as Amyris, Gevo, and Genencor (belonging to Danisco which is now owned by DuPont) want to give tire manufacturers a third option: biobased rubber intermediates. Microbial fermentation targets three renewable rubber intermediates: isoprene, isobutene, and butadiene. Five-carbon isoprene is used to make synthetic latex similar to that of the rubber tree. Isobutene and butadiene are four-carbon intermediates used to make butyl rubber and styrene-butadiene rubber.

Two leading tire makers – Goodyear and Michelin – along with synthetic rubber manufacturer LANXESS have entered into partnerships with industrial biotech firms to advance the commercial production of biobased rubber intermediates. But, it is still assumed that new renewable sources will not be commercially available for another three to five years.

For instance, Goodyear partnering with Danisco's Genencor confirmed that biobased isoprene meets specifications for the catalysts it uses in rubber manufacturing and has even made concept tires with it. But, the project originally targeted 2013 for commercialization has been pushed back a few years. DuPont acquired Genencor's parent company, Danisco, and now the new owner is weighing in.

But it is not just that tire makers want to ride a "green wave." They are also motivated by tightening supplies of both natural and synthetic rubber, driven in recent years by strong global demand, especially from emerging economies, by soaring postrecession demand and constraints on the expansion of rubber plantation acreage. The cost of a common grade of natural rubber shot up.

Furthermore, today, the chemical intermediates come from the cracking of liquid feedstocks in ethylene plants. But as petrochemical makers switch to lighter natural gas feedstocks, production of C4 and C5 chemicals is drying up. Hence, tire makers want something to help them *control volatile raw material costs*.

It is expected that overall global demand for both synthetic and natural rubber will grow to 35.9 million metric tons by 2020, from 25.7 million metric tons in 2011. Demand will be met roughly equally by synthetic and natural rubber.

Basically, it is assumed that for renewable isoprene, isobutene, and butadiene the volumes produced in the next five to ten years will remain quite small. And regarding their suppliers "it very much remains to be proven if they can produce on a cost-competitive basis {compared} with more traditional petrochemical pathways." Despite these facts industry representatives maintain that renewable feedstocks will be valuable to cushion swings in raw material costs.

Though also emphasizing jet fuel another biofuel NTBF that changed its business direction and strategy is Virdia (Table I.99). It focuses on high-quality C6 and C5 cellulosic sugars which can replace corn, beet, and cane sugars (!) and dry solid lignin.

These sugars that do not compete with sugars for food consumption and lignin are ready for fermentations or chemical conversions as products and intermediates for industrial uses. That means Virdia offers products that are directly usable by industries with well established conversion processes for sugars (Figure I.184). Virdia can act as a raw material (input) supplier (Figure I.183). In this way, Virdia can address the following markets:

- Diesel, jet fuel, gasoline, butanol (sugars);
- Surfactants, lubricants, plastics, synthetic rubber (sugars);
- Lignin as an energy source (for Virdia plants (cf. Table I.88) and other manufacturing plants);
- Lignin-based complex carbon fibers to incorporate into composite materials for a large number of industries.

Early in 2012 Virdia announced major company milestones, including a new brand and CEO, and a $75 million deal with the Mississippi Development Authority to build manufacturing plants in the state. The agreement includes an incentive package with $75 million in low-interest loans, as well as up to $155 million in various tax incentives over a 10-year period.

Furthermore, to fund its piloting activities and engineering plans, Virdia recently closed its latest round of financing, raising over $20 million from insiders, Khosla Ventures, Burrill & Company and Tamar Ventures. In addition, the company closed a $10 million venture debt deal with Triple Point Capital.

The company will build, own and operate its first plant, and after that the company will pursue other business models including licensing its technology There are a number of competitors in the rush for sugar as a raw material, including Renmatix, Inc. (A.1.1.6) and BlueFire's SucreSource (Table I.86) [Lane 2012r].

Emphasizing diesel and surfactants and lubricants Virdia has interfaces to LS9 (Table I.99). As other "biofuels startups" LS9 has shifted its emphasis more towards the chemicals side of its portfolio [De Guzman 2012a]. LS9 now positions itself as a supplier and licensor of technologies to the fuels industry, but will entertain direct project participation on a case-by-case basis. In its chemicals orientation it envisions more of a partner-venture model or potentially select LS9-only investments.

LS9's target is to provide drop-in chemicals and fuels. Its chemical products are the building blocks for many functional materials, such as surfactants, lubricants, emollients, and functional fluids. Drop-in biofuels are fuels containing hydrocarbons identical to those in petroleum-based gasoline.

By the end of 2011 LS9 scaled its technology to the 20,000 liter scale, demonstrating continued progress in the scale-up and commercialization of its biobased chemicals and fuels technology platform. From initial production of 1,000 liters at the Company's pilot plant in South San Francisco, California, LS9 has utilized a 20-fold step-up process to produce approximately one ton of a specific chemical for its strategic partner, Proctor & Gamble (P&G).

LS9's initial products in the chemicals arena were sugar-based fatty alcohols (C10-C18) and specialty esters, such as biodiesel fatty acid methyl esters (FAMEs) and fatty acid ethyl esters (FAEEs) under the banner of UltraClean Diesel, which can be directly blended into current petroleum-based diesel. And the company said it has already shipped a ton of fatty alcohol from its pilot facility (and headquarters) in San Francisco to P&G for sampling into surfactant products [De Guzman 2012a]. These products are directed against natural oils as a raw material (Figure I.184).

Biobased feedstock means essentially traditional feedstock. These include traditional feedstocks, such as sugarcane and corn syrups, waste products such as molasses and glycerin, and emerging feedstocks such as sweet sorghum syrup and the hydrolysates of plant biomass (for instance, from Virdia). Addressing all of these, LS9 avoids the many issues with the procurement and pretreatment processes in biomass/waste to biofuels conversions (Figure I.184).

By mid of 2011 LS9 in conjunction with partner Virdia (HCL CleanTech) was awarded a $9 million grant from the Department of Energy (DOE) to improve and demonstrate an integrated process to convert biomass feedstocks into fermentable sugars (Virdia part) and then into diesel and other fuel and chemical products (LS9 part). Virdia addresses surfactants and lubricants explicitly as its markets. LS9 is also looking to build a brownfield 10,000-25,000 tons/year facility initially in Brazil to produce sugarcane-based chemicals [De Guzman 2012a].

For June 2012 LS9 planned the opening of its scaled-up demonstration facility. LS9 uses genetically engineered microbes to convert biobased feedstock to diesel and chemical intermediates in Florida. The Okeechobee plant, which will start making biodiesel, contains a 135,000-l fermentation vessel, a jump from earlier production of 50,000-l quantities. The output shall provide commercial samples for testing by prospective customers [Bomgardner 2012a].

LS9 is hoping to hit their commercialization target by the end of 2012 (obviously they were about 85 percent). Its 135,000 liter fermentation vessel is a key: “At that scale, we are close to world-scale fermentation, which is about 3-4x away. We are well along the pathway towards de-risking our technology processing. The Florida facility has four (each at 700,000 liter) world-scale fermentation capability.” “The company is looking for a strategic round of funding this year to go to commercial-scale up by the end of 2014.” [De Guzman 2012a]

Since around 2010/2011 bio-lubricants are in the spotlight of NTBFs like Virdia or LS9 which originally targeted biofuels. And also Amyris formed a joint venture with distributor US Venture to produce, market and distribute finished lubricants for the North American market using Amyris’ farnesene-derived base oils. Amyris is said to be working on the production of a complete line of renewable lubricants, including hydraulic, compressor, turbine and gear oil and grease, as well as 2-cycle and 4-cycle engine oil [De Guzman 2011a].

Typically lubricants contain 90 percent “base oil” and less than 10 percent additives. Base oils are mostly derived from a mixture of fractions of the crude petroleum oil refining process. Natural (vegetable) oils (Figure I.184) are also used as base oils and there are already a lot of biobased lubricants in the market especially derived from vegetable oil.

For instance, bio-based hydraulic fluids are estimated to grow 5-10 percent per year worldwide and now represent 2-4 percent (US) and 3-7 percent (EU) of the hydraulics markets mostly because of advancement in performance, cost and its “green” factors. Amyris’s modified yeast converts the cane syrup to farnesene (Biofene™) which then has to be finished chemically to create base oils [De Guzman 2011a].

Structuring Complexity of Biofuels for Entrepreneurship and Intrapreneurship

With all the outlined empirical observations concerning involved firms (players), their technologies, types of offerings, financing and leadership/management approaches, development and innovation processes (Figure I.180) and hindsight, one can take a more fundamentally structured view of biofuels and their promise to be available, affordable, and clean.

Taken all the input and process variables together biofuels production and commercialization represents a combinatorical complex problem. Systemic complexity of entrepreneurship in biofuels referring to the input-conversion-output block (Figure I.5) may be approached by Equation I.21 where co-product variety may induce the consideration whether the co-products shall become significant contributions to the firm's revenue stream or fed back into the production process, for instance, for energy (steam) generation.

Equation I.21 and the implicitly associated hurdles (Figure I.171) represent simultaneously the space of business opportunities, the *opportunity landscape*, in biofuels. But, there are almost too many options to choose from, particularly if the chosen option shall give a sufficiently reliable assessment regarding 1) the overall energy efficiency (energy input; Equation I.20:), 2) overall Greenhouse gas emissions (by products and processes) and 3) whether the cost to produce in relation to the mineral oil price calculated for laboratory or pilot plant arrangements will also materialize in large-scale commercial plants.

Equation I.21:

Biofuels Input-Output Complexity →

Input type variety (types of biomass/algae) ⊗ Input location/transportation variety ⊗

Conversion sub-process variety (thermochemical, bioengineering, "hybrid") ⊗

Microbe/bacteria/yeast/enzyme/microorganism variety ⊗ Scale-up approaches ⊗

Output/product variety (type of biofuel) ⊗ co-product variety ⊗ by-product variety …

As the space provided by the biofuels value system is so large and complex, one sees a myriad of diversity in the range of business models – and entrepreneurial risks. Major risks and development hurdles are listed below. A very detailed description of risks and hurdles can be found, for instance, in the offering prospectus of Amyris Biotechnologies [SEC 2010].

- Contextual legislative/regulatory risks (changes of biofuels related laws and programs, for instance, blending mandates, requirements of certificates; "policy and politics");
- Special Regulatory Risks (plant permissions);

- Funding Risks (by VCs, large firms, government, funding priorities among different types of biofuels or input); research approach highly dependent on grants: change of government – change of programs and financial support;
- Technological Risks (scale-up, cost)
- Environmental Risks (societal attitudes; products are not so “green”; GMOs);
- Supply Risks (type of biomass input; cost of biomass procurement and logistics, biomass price developments);
- Financial Risks (CAPEX, OPEX; profit, exit in VC-backed NTBFs);
- Operational & Execution Risks (management, partnerships with other firms);
- Market Risks (adoption; oil price, natural gas price for thermochemical processes, acceptance of GMOs for bioengineering/hybrid processes; special situation of policy-driven markets);
- Infrastructural Risks (Big Oil’s role for the transportation fuels industry).

When producing next generation biofuels from renewable, non-food feedstocks like wood-chips, roughly 25 percent of the output is lignin. Firms can burn the lignin and thus transform a “by-product” into an energy contribution to drive their processes.

However, lignin and the chemical properties and functional attributes of a wide range of lignin derivatives, for instance, lignins in carbon fiber, open also new opportunities for entrepreneurship: High purity lignin extractives (and their subsequent derivatives) which can be engineered to meet the chemical properties and functional requirements of a range of industrial applications that until now has not been possible with traditional lignin by-products generated from other processes.

On the input and output level one can differentiate “plant-based biomass” and appropriate waste versus aquatic biomass like algae and output in terms of bioalcohols (biomethanol, bioethanol, or biobutanol), biogasoline and biodiesel and jet fuel.

For most business plans of biofuels startups addressing a policy-driven market was central. And often the business models for many biofuel companies were predicated on a much higher price of crude oil, making biofuels more attractive.

Concerning output the fundamental “pure biofuel versus biorefinery model” was actually often reduced to a “biorefinery light” model providing just small volumes of selected biobased chemicals for various industries originally encountered as co-products.

The actual complexity expressed in Equation I.21 can be visualized by a number of graphics. In Figure I.183 key components for business models and the financing models are summarized. There is a broad diversity in the range of business models. Input, conversion technologies and output options are largely specified in Figure I.184.

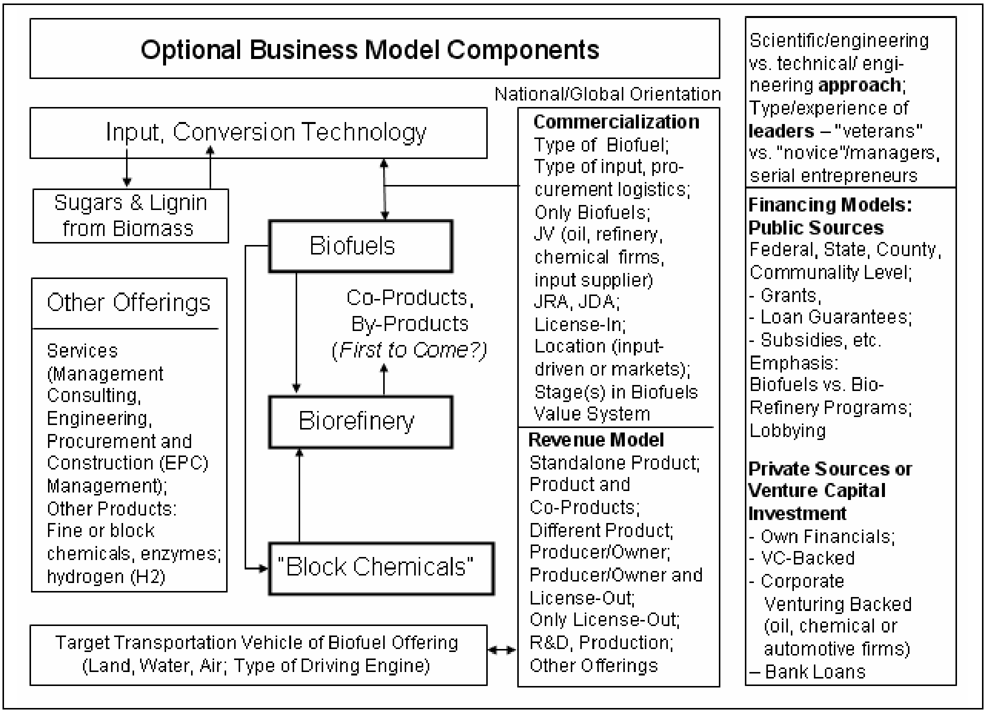


Figure I.183: Optional components and financing options for business models of biofuels NTBFs.

One important model for these CleanTech companies is to make strategic alliances with big or giant companies. For example, they can trade sales and marketing rights for a capital investment. Or they can sell the licensing rights for a product in exchange for an investment. Or they establishe JRAs or JDAs.

There was a clear focus of the cooperative model on "*Big Oil*" and "*Big Chemistry*" and sometimes also the automotive and tire industry. As many NTBFs emphasized a producer/owner and licensor approach, as they stumble, big companies will be able to snap up technologies on the cheap, when and where they need them [Carey 2009].

Finally, an important business model addresses input localization, establishing production (subsidiaries or JVs) where input is plentiful and cheap and in sufficient proximity to the plant(s) to minimize transportation and storage cost. In this regard, for instance, BP/Verenium JV Vercipia (Table I.83, Table I.84), Cobalt/Rhodia (Table I.96), Amyris and LS9 (Table I.99) addressed Brazil. On the micro-level one also finds localization near steel or power plants for flue gas (LanzaTech and some algae firms) or land fills (waste).

For to-be entrepreneurs in biofuels this does not only mean to know critically these competitive technologies, but also to know the patent landscape around the anticipated technology to be used and the related existing intellectual property rights.

Figure I.184 summarizes essentially the technologies discussed so far for generating second and third order biofuels.

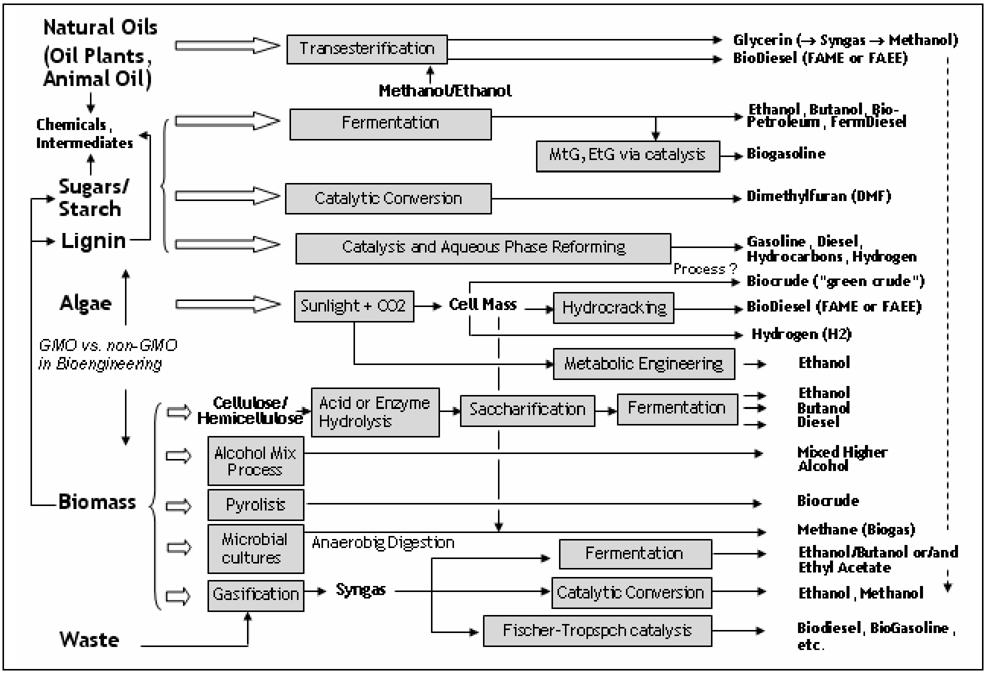


Figure I.184: Biomass conversions: many feedstocks, many conversion options, many products; different economics and energy balances (adapted from Khosla 2009a]).

Figure I.184 does not address explicitly the pretreatment and hydrolysis sub-processes leading to fermentable sugars and correspondingly whether the subsequent fermentation proceeds with C6 or C5 sugars or C6 and C5 sugars. The pretreatment process of biomass has several options, for instance,

- Water-based (hot water or steam explosion, combination of both)
- Chemistry-oriented (acids, alkaline bases, ammonia or oxidative processes);

- Solvent-based (alcohols, esters or both); especially “supercritical water” (A supercritical fluid is any substance at a temperature and pressure above its critical point, where distinct liquid and gas phases do not exist (A.1.1.6). Supercritical water is suitable as a substitute for organic solvents. Supercritical water oxidation is a process that can be used to advantage in the destruction of hazardous wastes.)
- Biological (enzymes or microbes; enzyme activity and cost?).

Which process will be adopted by around 2020 as the leading technology is still hard to predict because process economics are key and industrial scale production are just emerging.

Figure I.185 illustrates rather than completely reflects the issues and complexity of cost and energy efficiency consideration for manufacturing second-order bioalcohols.

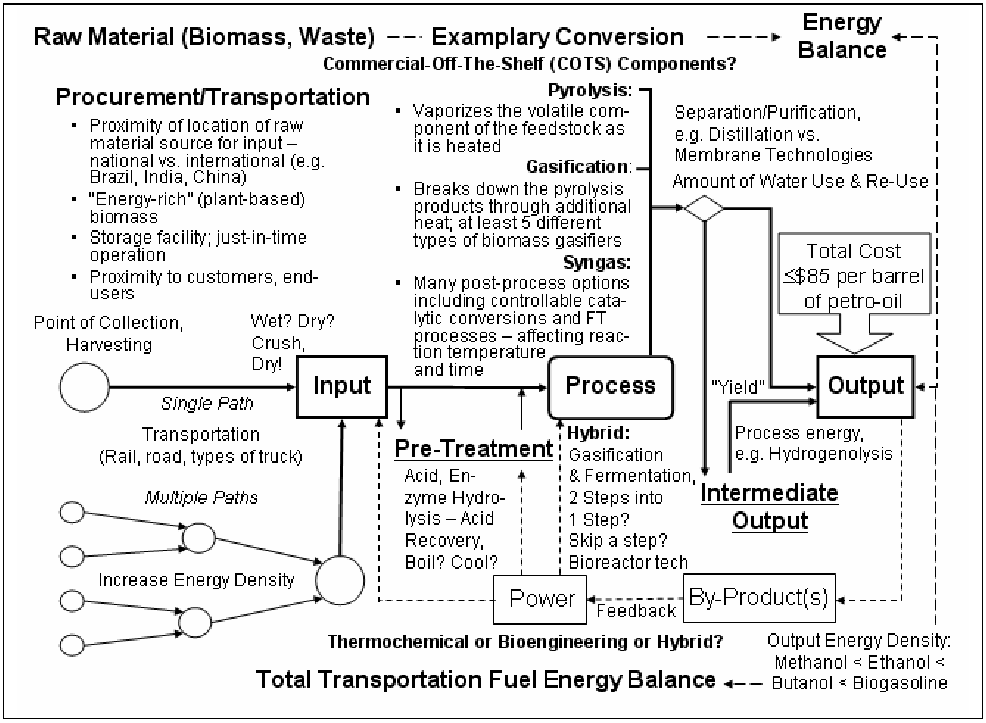


Figure I.185: Some biofuels energy and cost efficiency options for input and conversion emphasizing second-generation biofuels.

One key issue of biofuels economics is find feedstock (Table I.97) at a good relatively stable price over a mid-term period. Basically, it seems that sugarcane and its bagasse and the plant that the sugarcane comes from is going to be the cheapest, most scalable feedstock on a global basis for quite a while. Obviously, sugarcane is going to be best within some distance from the equator. And biofuels startups seek localization of subsidiaries or JVs to be established in Brazil.

Correspondingly, firms, such as BASF and Monsanto as described above (A.1.1.1), are genetically engineering sugarcane to produce more sugar per acre and take less fertilizer and less water.

In different climates other (non-waste) feedstock exhibit also good potential. For instance, sugar beets, sorghum, cassava, and things like this have very high sugar content.

That means economically, any biofuels startup whose process requires to first converting biomass into sugar(s) is squeezed between two benchmarks:

- Output cost has a ceiling related to the price of petro-oil (currently ca. $100 per barrel rather than $85 as given in Figure I.185 for 2008/2009).
- If fermentable sugar is the key input cost will have to meet the price of Brazilian sugar derived from sugarcane.

By mid of 2011 one would have spotted the probable winners to be those with deep pockets and patience, such as Royal Dutch Shell, BP, chemical giant DuPont, agriculture giants Archer Daniels Midland (ADM) or Cargill or the rare startups with significant revenues from businesses other than biofuels, such as making biobased chemicals (specialty or fine chemicals or building block monomers or drugs) or serving the health and nutrition segments as in case of algae.

But, what are then options of biofuels startups lacking the above features as a preferred exit strategy, acquisition or IPO? Obviously, going public is pretty much difficult. If there is a very sound prove that the startup has economical and scalable biofuels, and it is IP protected, then there is a chance to become a public company. But the reality is that most firms that are venture-backed actually will sell. Many people think if they can get a good valuation on a merger and acquisition transaction, they should go ahead and do that instead of get in a critical public market.

All these difficulties do not mean advanced biofuels are not coming, or that they will not play a role in fighting climate change. But everything will happen more slowly than many venture capitalists and government expect.

Indicative of this situation, in 2012 BASF and Archer Daniel Midlands (ADM) made opposite announcements within few weeks around the same overall subject. BASF invested in a company which proposes a singular technology to address a “sugar platform” to transform biomass into fermentable sugars (A.1.1.6) while ADM at the very end of the same biochemical value chain decided to exit from its five-year-old venture bioplastic’s JV Telles with Metabolix [Molitor 2012, Runge 2006:871].

Telles produces Mirel, Metabolix’ biobased biodegradable plastic at a fermentation facility in Clinton, Iowa, that has capacity to produce 50,000 tons per year of Mirel, a polyhydroxyalkanoate, or PHA, plastic. The facility is adjacent to an ADM corn-processing plant and was built and owned by ADM. With ADM exiting the venture Metabolix will lose access to the facility and its corn sugar feedstocks. The intellectual property related to Mirel will revert back to Metabolix. "ADM says financial returns from the five-year-old venture, called Telles, were too uncertain." [Bomgardner 2012d] Already in January 2010 it has been reported that the "PHA project between Metabolix and ADM has suffered delays and cost overruns." [Taylor 2010].

The ADM decision puts a spotlight to the entire family of polyesters and their monomers (for instance, including the 3-hydroxypropionic acid – 3-HP [Runge 2006: 867-868]).

Beyond the production of bioplastics several companies intend to convert the 3-hydroxypropionic acid into acrylic acid (for instance, OPX Technologies; A.1.1.6). "No doubt that the ADM decision will have an impact on future IPO's or investment rounds of start-ups whose businesses have to pass the so-called 'valley of death' when development cost unexpectedly increase and the perceived risks and uncertainty." [Molitor 2012]

"Both decisions point the current perceived risks and uncertainty in the white biotechnology field: on one hand biorefinery concept as an alternative to a petrochemical feedstock and on the other hand the scale-up of fermentation processes to economic viable and attractive margins." [Molitor 2012]

The mid-2012 economic developments indicated the possibility of another downturn – with consequences for the biofuels field and one is reminded of what has happened before. In the early 1980s, higher-mileage cars and an economic downturn sent petroleum prices swooning, killing off many renewable energy efforts, including those supported by Big Oil.

Remarks Concerning the Role and Effects of Policy on Technology Entrepreneurship and Innovation

With all the issues and problems of biofuels and Cleantech in general "thank goodness cleantech has the government as a customer." [Bormgardner 2011c]

Policy as an "investor" in capital-intensive innovation and entrepreneurship is not new, particularly not in Germany (ch. 1.2.6; Box I.2, Box I.3; A.1.1.2). But also in the US much more than one hundred and fifty years ago this was not unusual, for instance, with regard to Samuel Morse (1791 – 1872), the co-inventor of the telegraph code and American contributor to the invention of a single-wire telegraph system based on European telegraphs. Morse combined *marketing and political skills to secure state funding for development work,* and to spread the concept of communication over vast distances on the continent of America in 1844. [110]

However, over the last decade also the US encountered very strong intervening into the entrepreneurship arena generating policy-driven markets. But, the mental framework of policy concerning entrepreneurship and innovation is very simplistic (in the US and Germany). Take biofuels or biorefineries:

A government agency puts into place an alternative feedstock program, identifies molecules, and provides funding; national labs or research centers develop the organism; and then a private company works with development partners to move the R&D project through to commercialization.

For instance, US President Bush outlined his plan to offer tax credits, subsidies, and federal research support to fuel a drive for (bio) ethanol that would move the nation "beyond a petroleum-based economy and make our dependence on Middle Eastern oil a thing of the past."

Bush's support for ethanol and his mix of energy, economic, and electoral policies have been continued by President Obama, particularly the push for fuels made from cellulosic feedstocks. They have provided billions of dollars to support cellulosic ethanol R&D and biorefinery construction. But despite the money and talk, no commercial cellulosic ethanol biorefinery is operating in the US [Johnson 2010].

President Obama has explicitly called for government funding to be used as a tool to promote the next great companies. And the National Economic Council announced a "National Innovation Strategy" in which "the government should make sure individuals and businesses have the tools and support to take risks and innovate." [Bandyk 2009]

> Generally, for the (renewable) energy and CleanTech field there was a growing interaction and collaboration between federal and state governments and authorities and the country's entrepreneurs.
>
> The potential payoff for entrepreneurs in these fields was big enough that it is worth spending time and money. And it cannot be excluded that one or the other entrepreneur can be a beneficiary of favoritism.
>
> For policy-driven markets it is important for NTBFs looking for or being dependent on grants to have persons in their leadership team early on with experience and preferentially established contacts to the political world on the federal, state and county/communality level.
>
> The job this personnel has and the related importance emerges as "VP of Regulatory Affairs" (Gevo, Table I.99), "SVP of Government Relations" (Solazyme, Table I.90) or as a role and responsibility assigned to a particular SVP (Bluefire, Necy Sumait) or even hiring a former US state governor like Renmatix (B.2).

There is some evidence that the increasing role of the federal government has forced many entrepreneurs in the US to emphasize lobbying, politicking, and jumping through administrative hurdles (cf. SiGNa, ch. 1.2.2; B.2). Similar effects – more under the surface – can also be envisioned in Germany.

During a conference in Washington D.C. in 2009 one panelist, Jonathan Wolfson, CEO of biofuel firm Solazyme (Table I.90), was somewhat surprised he found himself in D.C. "In the 50, 60s, and 70s, entrepreneurs did not come to Washington," he said. The difference in culture is stark between the world of politics and the world of entrepreneurship. "Silicon Valley is a meritocracy. Best business strategy wins," said Wolfson, whose company Solazyme recently just won a contract with the Department of Defense to develop clean biofuel produced from algae for the US Navy, as well as a Department of Energy grant to build a biorefinery [Bandyk 2009].

And Wes Bolsen of the cellulosic ethanol company Coskata (Table I.99), a speaker at the conference, added. "Washington, D.C. has become the new Wall Street when banks aren't lending." But many attendees expressed skepticism that any one entrepreneur with a great idea could attract the federal government's attention – and wallet – without significant political connections.

But despite all this investment in high-tech companies, venture capitalists who work in the field were skeptical that the money will find the new drivers. "Is {the stimulus money} a good use of tax dollars? Maybe," said John Backus, managing partner at a VC firm. "But will it spur innovation? No." One concern is that the brand-new innovative companies will get left out." "The government doesn't know how to work with 20-person companies," said Backus. "Most cleantech money in stimulus won't go to the startups. It goes to the defense contract giants." [Bandyk 2009]

And Bandyk [2009] continued: Those who have won contracts with the government are much more comfortable with the growing collaboration between Washington and the nation's entrepreneurs. "Government has always had a major role in the energy industry," Wolfson said. In the case of his firm, government might be necessary. Getting production of his company's algae-based biofuels off the ground will require significant investment – over $100 million for one plant – that the capital markets simply cannot supply right now, he said. But he did not want to be a beneficiary of favoritism – Wolfson said that after government investment gets the ball rolling, the market should take care of the rest. "Policy should be driven by ends and be technology-agnostic," he said.

For entrepreneurs like Wolfson, the potential payoff is big enough that it is worth spending time and money away from Silicon Valley to take the risk that the Obama administration will not pick their technologies.

For instance, expenses for lobbying for Sriya Innovations Inc. (connected to RenMatix in A.1.1.6, B.2) amounted to $30,000.00 in 2010 for Provisions in pending energy and climate legislation (S.1462, S.2877, Draft APA by Kerry / Lieberman) related to Biofuels.

In the face petro-oil drying out and soaring energy demands over the past decade, more than 50 countries, including the US and Germany, have been scurrying to implement policies to integrate biofuels into the transportation infrastructure in the face of a number of pressing needs – national energy security, a sustainable agricultural sector, job creation in the rural economy, and reduction of carbon dioxide emissions to curtail climate change.

“The biofuels business globally would not exist if it weren’t for the mandates.” Thanks to the policies, global biofuel production has gone from about 4 billion gal in 2000 to more than 26 billion gal in 2010 [Mukhopadhyay 2011e].

A recent detailed analysis [Mukhopadhyay 2011e] culminated in the conclusion that *government mandates have shaped the market but not always for the best due to unsustainable production* (Box I.1).

It has becoming clear that biofuels will not solve all the problems proponents had hoped they would solve, but many countries are still rushing headlong as though they will, with policies that, experts say, are doing both harm and good. Governments need to pause, step back, and take a more nuanced and sophisticated view of biofuels, taking into consideration their sustainability and social costs – and, furthermore, should be aware of *systemic effects* they may induce (Box I.1) – as painfully encountered by the recent Great Recession and the financial crisis.

A particular questionable role of government for CleanTech is observed in the US looking at massive bankruptcies of solar, photovoltaic firm Solyndra, Inc. (ch. 4.3.5.2), battery NTBF A123 (ch. 3.2.1) or most recently electric car manufacturing NTBF Fisker Automotive (founded in January 2005). Fisker is the US Government’s “biggest public loss since the infamous Solyndra Solar debacle.” [Koetsier 2013] Fisker was one of the largest US venture capital backed companies ever.

Based on exclusive documents PrivCo [2013] outlined how a “billion dollar startup became a billion dollar disaster” and “2 of America’s smartest VCs – Kleiner Perkins & New Enterprise Associates & others to lose over $1 billion dollars in ‘The Largest Venture Capital Investment Debacle in U.S. History.’“

The PrivCo Fisker Papers released “never before seen original government documents regarding the Department of Energy’s $529 Million loan to Fisker Automotive, definitively proving loan underwriting that no rational lender would have ever undertaken, waiver after waiver from the D.O.E. after Fisker missed covenants of the Loan, and the subsequent concerted effort by the Loan Programs Office to cover up and obfuscate the unraveling of Fisker and the inevitable erasure of U.S. taxpayer collateral that funded the Loan.”

Explicit descriptions of the DOE $529 million loan issue on the "Fisker case" are also given, for instance, by Koetsier [2013], Chernova and Ramsey [2013] and Vlasic [2013]. "The untested Fisker loans totaled $529 million, more than the company had initially requested, and an amount that encouraged private backers to chip in more funds." [Chernova and Ramsey 2013] (See also Figure I.34 for encouraging private backers in policy-driven markets.)

"Fisker has become – to lawmakers and others – the Solyndra of the electric car industry." "Fisker, with its technical problems, management turmoil and mounting losses, offers a cautionary tale in the fiercely competitive arena of alternative-fuel vehicles and of government subsidies for start-up businesses." [Vlasic 2013]

A.1.1.6 The Shift from Biofuels and Co-Products to Biobased Chemicals as the Primary Target of Entrepreneurship

Back to the Agricultural Future for Chemical Innovations:
What's a rerun?
[Runge 2006:563

A Different Context

An overview of the biofuels industry situation by 2010 is given by Wikipedia. [111] As outlined in the previous sub-chapter there emerged a clear shift of many "promising" biofuel NTBFs' business models from biofuels to biobased chemicals. Here, the type of advanced biofuels (fuel not made from food-like feedstocks such as corn sugar) was cellulosic ethanol [Bomgardner 2011b].

With so much land devoted to raising livestock feed the focus of biofuels startups could also be on feed. For instance, animal feed is a lucrative business for the US, with China importing it at rates of up to 50 cents a lb. If methods can be developed to break down plant cell walls to get the sugars for biofuels while saving the proteins for animal feed, biofuel sources, such as corn or algae (Table I.90), can provide fuel and feed [Mukhopadhyay 2011e].

Also the role of the US chemical giants DuPont (Table I.83) and Dow Chemical (Figure I.179) in biofuels has been tackled above.

In the area of polymers and plastics DuPont followed a *stepwise crossover strategy* for biobased products. This means for chemical products produced by a proven process by several components the overall transition to a fully biobased product proceeds through substituting the components separately by already available biobased components.

For instance, DuPont used petroleum-derived propanediol (PDO) to produce some 10,000 metric tons of Sorona per year. DuPont's Sorona® 3GT is a copolymer designed to be made from corn-derived 1,3-propanediol and petroleum-derived terephthalic acid (Sorona: polytrimethylene terephthalate (PTT) polyester). DuPont then started construction of a large-scale propanediol fermentation facility in collaboration with carbohydrate processor Tate & Lyle. Intermediates for DuPont Sorona® polymer would then use Bio-PDO™ to get a partially biobased copolymer [Runge 2006:583] – but have to wait for availability of biobased terephthalic acid.

The enormous and looming challenge facing biofuels companies, of which none have actually gotten far enough with the research process to confront, is scaling-up to the enormous requirements of the transportation fuel market and getting the costs down to achieve pump parity. Without those two achievements and the necessary capital, all of these firms remain science and technology experiments. Additionally, for the bioengineering route to biofuels a genetic breakthrough has nothing to do with a (production) breakthrough when scaling-up to large-scale production.

Things are different if biomass from food-like feedstocks, such as corn or sugarcane, is taken into consideration. For instance, *NTBFs with a biorefinery approach* with food-related ethanol as a basic chemical for biobased polyethylene or polypropylene may find strategic partners in the Brazilian plastics industry (cf. Figure I.174).

Braskem SA, the largest (petro-)chemical company in the Americas by production capacity and among the top ten largest in the world, initiated a five-year project with Danish enzymes manufacturer Novozymes to work on a new sugarcane-based route to polypropylene. Braskem has already synthesized polypropylene from sugar-based ethanol.

In 2009 Braskem was constructing a 200,000-metric-ton-per-year plant to make polyethylene from ethanol, planned to be completed in 2010. And it signed contracts to sell the "green" polyethylene to the global packaging giant Tetra Pak [Tullo 2009]. And in 2011 Braskem started up the 200,000-metric-ton ethanol-based polyethylene plant in Brazil [Tullo 2011].

For instance, German LANXESS does not only target biobased butylrubber through its cooperation with Gevo (see above), but also ethylene propylene diene monomer (EPDM) synthetic rubber. It plans to use ethylene derived from the purely renewable resource sugarcane. Braskem shall supply the bio-based ethylene via pipeline to LANXESS' existing EPDM plant in Brazil. It will be the first form of bio-based EPDM rubber in the world [Specialchem4polymers 2011] and will be sold under the brand name Keltan Eco.

Activities of the chemical industry until 2005/2006 are described by Runge (The Chemical Industry in a Biobased Economy [Runge 2006:567-571], White (Industrial) Biotechnology in a Biobased Chemical Industry [Runge 2006:571-578] and Research, Development and Innovation with Renewable Resources in the Chemical Industry – Green Chemistry [Runge 2006:578-590]).

The concept of a “biobased chemistry” including biobased plastics is not new. In the 1920s in the US there was a strong movement in that direction under the name “*chemurgy*,” but was ultimately stopped by political interference of the petrochemical industry [Runge 2006:565-566].

Some early entrepreneurial activities in biobased chemical solvents were reported in the 1990s [Runge 2006:860-861]. The bio-oriented small- and medium-sized enterprises (SMEs) often targeted areas that were niches. The “green solvents” niche at that time was a generic thrust in line with general trends to replace organic solvents due to regulatory pressures. The emphasis was on oxygenated solvents, such as lactic acid esters (like ethyl lactate) and soy-based solvents (methyl soyate).

For instance, Vertec Biosolvents Inc. (assumed to be founded in 1997 and currently having five issued US patents) produced environmentally friendly solvents made from ethyl lactate derived from farmer grown corn and soybeans. Vertec BioSolvents offered also environmentally-friendly ink cleaners. Vertec Biosolvents, in particular, was planning to replace NMP (N-methyl pyrrolidone, Figure I.187), a powerful organic solvent with broad solubility for resins and high chemical and thermal stability.

Currently Vertec Biosolvents manufactures and sells biosolvents and formulations (blends) based primarily on four major ingredients – ethyl lactate, fatty acid methyl esters (soy methyl esters), d-limonene and ethanol for a variety of specialty applications in industrial and agricultural markets targeting replacement of petrochemical solvents in use, even NMP and hydrocarbon solvents.

Another firm which, by the mid of the 1990s, focused early on green oxygenated solvents was Diversified Natural Products, Inc. (DNP), an industrial biotechnology company organized into two divisions, Biobased Fuels and Chemicals, and Gourmet and Functional Foods. Its main product was succinic acid.

DNP addressed another niche which comprises “short chain diacids” called “building block chemicals” (see below) that can serve as key feedstock for future biorefineries (for instance, adipic acid = hexanedioic acid HOOC-(CH2)4-COOH or succinic acid = butanedioic acid HOOC-CH2-CH2-COOH) or even long-chain diacids. DNP received investment from several Japanese venture firms including Toyota Tsusho Corp., a sister company of Japanese automaker Toyota Motor Corp. [Runge 2006:860-861].

The origins of the DNP’s succinic acid business go back to 1995, when it was established by a company called Applied CarboChemicals. The company operated under this name until 2003, when it was restructured, refinanced and renamed Diversified Natural Products. The company subsequently expanded its activities into other fields; succinic acid became just one of its businesses [ORNL 2010].

In 2006, Diversified Natural Products established a collaborative R&D effort with Agro Industrie Recherches et Développements (ARD), the R&D subsidiary of a French agricultural consortium led by Champagne Cereales. The focus was on disuccinate esters as “green solvents.” Over the next two years the partners scaled-up succinic acid production to 80,000 liters and developed an economical, aqueous based isolation and purification process [ORNL 2010].

DNP Green Technology was established in 2008, when all succinic acid assets, including all intellectual property, contracts, joint venture interest and employees, were spun off from DNP. Following the spin off, the company’s shares were distributed to Diversified Natural Product’s shareholders, making DNP Green Technology a standalone legal entity with no ties to Diversified Natural Products.

A joint venture called Bioamber SAS between ARD and its US partner DNP Green Technology was established in 2008, resulting from the R&D partnership between its two shareholders. BioAmber targeted succinic acid production. The existing organism for production, originally funded by the DOE in the late 1990s, was further developed and scaled-up, and optimized at the large-scale manufacturing facility in France [De Guzman 2011b]

ARD industrialized its laboratory procedure and invested €21 million in an industrial demonstration facility with a capacity of 2,000 tons per year. BioDémo enjoyed also financial support from the General Council of the Marne Département (€1.25 million), the Champagne-Ardenne Region (€1.25 million) and the ERDF (€2.5 million). Diversified Natural Products contributed its intellectual property portfolio.

DNP Green Technology fully executed an exclusive license agreement for three patents invented solely by Argonne National Laboratory and jointly by Oak Ridge National Laboratory (ORNL) or Argonne National Laboratory (ANL), one patent specifically was on “*Mutant E.coli Strain* with increased succinic acid production” [ORNL 2010]. Their process uses a strain developed particularly to produce succinic acid, with wheat-derived glucose currently being used as the substrate.

In 2009, DNP Green Technology completed a $12 million financing with a group of institutional investors led by Sofinnova Partners, a European venture capital firm, and including, for instance, also the Japanese Mitsui & Co. Venture Partners. In 2010 DNP Green Technology acquired 100 percent of the shares of its BioAmber joint venture from ARD. Concurrent with the acquisition of the joint venture, DNP Green Technology changed its name to BioAmber Inc. Siclae, a leading European agricultural group and the principal shareholder of ARD, became a shareholder in BioAmber through the transition [ORNL 2010].

BioAmber owns or have exclusive rights to specific microorganisms, chemical catalysis technology and a unique, scalable and flexible purification process. BioAmber manufactures its bio-succinic acid in a facility using a commercial scale 350,000 liter fermenter in Pomacle, France, which was used to refine its process and issue a claim to make cost-competitive bio-succinic acid. The purpose of the Pomacle plant is to showcase the production technology, which is available for license by other parties.

As expected, BioAmber has set up a “veterans approach.” Its management team consists of experienced professionals, possessing on average over 25 years of relevant experience in scaling-up, manufacturing and commercializing chemicals, gained at large companies or entrepreneurial startups.

Since its creation in 2008, BioAmber executed its strategy by several business partnerships and had successfully commissioned an industrial scale production facility. It has moved down the value chain through its acquisition of Sinoven Biopolymers, which produces modified PBS (Figure I.187), an innovative biodegradable polymer. BioAmber has licensed DuPont’s hydrogenation catalyst technology to make bio-based 1,4 butanediol (BDO). The major uses of BDO (Figure I.187) are in the production of tetrahydrofuran (THF) and polybutylene terephthalate (PBT).

Recently, BioAmber has signed an agreement with Mitsui to jointly build a facility in Sarnia, Ontario, that is expected to produce bio-succinic acid and bio-BDO with a total capacity of 34,000 metric tons of bio-succinic acid and 23,000 metric tons of bio-BDO at full capacity.[Bomgardner 2011g].

The Sarnia plant will be operated by BioAmber’s new subsidiary Bluewater Biochemicals, and will have initial capacity of 17,000 tons per year by 2013. This capacity will increase to 35,000 tons/year by 2014 and will then use next-generation yeast developed by Cargill and successfully used and commercialized by Cargill in lactic acid production.

The Bluewater Biochemicals subsidiary was specifically created as a Canadian legal entity that will own and operate the Sarnia plant. The Sarnia plant investment was supported by government grant/loans [De Guzman 2011b]. The Sarnia plant will initially use corn kernels as a sugar source for *E. coli* fermentation. But the switch to the engineered yeast licensed exclusively from Cargill will mean producing succinic acid from hydrolyzed agricultural wastes, such as corn stover [Ritter 2011].

In 2011 BioAmber formed a number of partnership, for instance, with Mitsubishi Chemical Corp. (MCC) of Japan to produce bio-succinic acid for MCC’s joint venture company PTT MCC Biochem. The joint venture will manufacture and market bio-poly-butylene succinate (PBS). BioAmber plans to have its succinic acid facility located next to PTT MCC Biochem’s 20,000 tons/year PBS plant in Thailand.

Since its inception, BioAmber raised an aggregate $76.1M from private placements of equity securities and convertible notes. It expected to spend around $200 million per plant on construction and start-up operating costs for facilities in Canada and Thailand [De Guzman 2011b]

In 2011 *BioAmber filed for an IPO* hoping to raise up to $150 million with the US Securities & Exchange Commission. BioAmber said it has made 221 metric tons of biobased succinic acid at its facility in Pomacle, France, *but has yet to book any sales*. Instead, the firm touts its strategic partnerships with potential succinic acid buyers.

BioAmber's filing acknowledges that it faces *tough competition in the nascent bio-based succinic acid market* both from startups and from established companies. [Bomgardner 2011g; De Guzman 2011b].

In 2013 BioAmber announced the pricing of its initial public offering of 8 million units consisting of one share of common stock and one warrant to purchase half of one share of common stock at $10 per unit, before underwriting discounts and commissions which means it would raise $80M at $10. But its per-share stock price fell from $10 to $8 in its first five days of trading. In the first quarter of 2013 BioAmber posted small sales of about $330,000 and posted a loss of $9.6 million for the quarter [PlasticsNews 2013].

In 2012 BioAmber set a strategic collaboration with the German firm LANXESS in the field of plasticizers to show that bio-succinate esters are viable alternatives to phthalates, which have come under scrutiny for their potential toxicity. It has also completed its Series C round of financing with net proceeds of $30 million involving existing investors and LANXESS.

Many advanced biofuel startups have been diversifying into the biobased chemicals sector given the higher potential profits for chemicals versus biofuels. For most of all, it appears to be quicker (but not easier) to get into the chemicals sector especially if you are looking into drop-ins as long as you have partners who know *the chemical industry's well-oiled system*. For instance, above the cooperation of US Gevo and German chemical firm LANXESS was described concerning their isobutanol/isobutene efforts to produce renewable butylrubber.

But many startups perceive opportunities to focus essentially on chemicals or more generally biorefineries and to execute their strategies, *seeking alliances with chemical firms* which are making considerable investments into what they call "sustainable chemistry," "green chemistry" or "CleanTech Chemistry."

For instance, OPX Biotechnologies (see below), founded in 2007 and emphasizing "good chemistry," and chemical giant Dow Chemical announced a collaboration to develop an industrial scale process for the production of biobased acrylic acid from renewable feedstocks. The global petroleum-based acrylic acid market is estimated to be $8 billion and growing 3 to 4 percent per year. Acrylic acid is a key chemical building block used in a wide range of consumer goods including paints and coatings, adhesives, diapers and detergents [Bomgardner 2011h].

Simultaneously with the increasing interest of the chemical industry and the disappointment of VCs with biofuels venture capital is re-directed towards startups targeting biobased chemicals, intermediates, resins and plastics for the petrochemical branch.

There was a golden age, from the late 1930s through the mid 1960s, when the chemical industry invented and commercialized most of the polymers we use today

[Runge 2006:411-424]. Those early plastics were so successful that it has become difficult to launch newer polymers in the marketplace.

Furthermore, an established infrastructure of resin producers, plastics converters, and processing machinery makers is dedicated to multi-million-ton-per-year applications. Many companies have since unveiled ambitious plans to establish new resins, but the history of the plastics industry is littered with their failures. “But some companies are still inventing polymers much like their counterparts did in the old days: by coming up with novel chemistry and then sorting out where it will be useful.” [Tullo 2011]

The most promising way for plastic success lies in a global view, from design up to finished devices. Design integrating multiple functions is by far the most important aspect followed by compounding integration [112] preferentially supported by modeling and simulation.

> Any to-be entrepreneur addressing biobased chemicals or plastics is advised to read the story of Patrick Gruber, innovator of polylactic acid (PLA) plastics at US giant Cargill and now CEO of Gevo (Table I.99) [Benda 2003]. A further very lucid article by C. Benda (http://www.cargill.com/news/00_08_cd.htm: *Mission Possible*! Cargill News International) is unfortunately no longer accessible on the Web.

New polymers have rather long scale-up and gestation periods. And this applies also to biobased plastics, for instance, those derived from Ingeo polylactic acid [Tullo 2011; Runge 2006:129-130,581,756].

NatureWorks, a subsidiary of US giant Cargill, opened its Ingeo polylactic acid (PLA) plant in 2002 with 70,000 metric tons of capacity. At that time the company had high hopes merely because bioplastics were still new. Converters started experimenting with it for nearly every conceivable application. But, it had to cultivate markets. Simultaneously PLA took advantage from improvements in blending and multilayer technology and, finally, over the past two years, NatureWorks’ sales have grown by more than 25 percent annually.

Entrepreneurship and Intrapreneurship in Drop-In Building-Block Chemicals

Riding a wave

> Over the last two to five years two strong trends have emerged – not just for existing biofuel NTBFs to jump on, but also for the foundations of new firms. They relate to shifts of advanced bioalcohol NTBFs, whether bioethanol or biobutanol, to producing *non-food related C6 and C5 sugars* and/or *drop-in biobased chemicals* (“*CleanTech Chemistry*”). In particular, there is a rush for low-cost *non-food industrial sugars* as reflected, for instance, by Bluefire’s wholly owned subsidiary SucreSource (Table I.86) and Virdia (Table I.99)!

Since 2006 a new wave of findings of biotechnology companies, primarily in the US, has changed the landscape that people had about the field. Driven by big players and, to a large portion, venture capital new biotech companies propose to replace petrochemicals originated *raw materials* by chemically identical products originated from biomass feedstocks. Based on generic technologies this family of biobased products is currently called "*drop-in" technologies* because of addressing markets of existing and identical or very similar products.

Biobased chemicals appeared in the focus, not just as an expression of a "green" attitude and sustainability, but the chemical industry is also looking for ways to attenuate generally the impact of cost fluctuations in fossil-fuel feedstocks (Box I.26).

According to Lux Research biobased chemicals and materials was expected to grow to $19.billion in 2016 as its global capacity jumps 140 percent. Lux Research said that it has listed down 151 global facilities and their intended operational dates, products and capacities. These capacities are expected to climb to 9.2 million tons in the next five years [De Guzman 2011c],

In particular, the reports says [De Guzman 2011c]

> *Bioplastics* will slow down in terms of expansion though capacity is still expected to grow 57 percent from 2011 to 2016. From 2006 to 2011, bioplastics have experienced explosive growth of 1,500 percent to a current aggregate capacity of 470,000 tons, and a 10.9 percent share of all bio-based materials.
>
> Cellulose polymers and starch-based plastics remain dominant but their share of total capacity will slide from 45 percent in 2011 to 21 percent in 2016. Cellulose polymers and starch-derived materials still rule because they are durable, strong and easily biodegradable: They have been widely used in high-performance plastic coatings, buttons and yarns, and even early LEGO bricks.
>
> By 2016, there will be *consolidation* – both within sectors of biobased materials manufacturing, and regionally, as *leaders buy up technologies and access to feedstock*. Momentum derived from existing capacity – ethanol from sugarcane being converted to ethylene and propylene, for instance – will influence regional specialization.

Related *VC-based startups* bring a unique set of technical core strengths, processes and long-term business approaches again by a *"veterans" management team* to deliver a consistent, readily convertible sugar feedstock that can compete on price and quality with crude oil feedstock for petroleum fuels and chemicals and food-based industrial sugars from corn and sugarcane.

Within a *biorefinery concept* which is heavily supported in the US and Germany by policy [Runge 2006:849-873] and which embraces fuels (energy), chemicals and materials referring to non-food biomass as feedstock there are *a sugar platform and a syngas platform* [Runge 2006:865] and the two main process options to use are the (sugar-oriented) *biochemical platform* and the *thermochemical platform*. The technology platforms will be featured by industrial biotechnology, materials technology, and reaction and process design.

Notably, there is a pioneer plant demonstration to produce cellulosic ethanol by syngas fermentation, Coskata (Table I.99), which was basically co-founded by Argonne National Laboratory scientists. This means, there may be combining both platforms.

In the US a list of chemicals was created by industry and academia that considered the compounds' compatibility with existing petrochemical processing, technical complexity of the syntheses from biomass, known market potential, and other factors. A shortlist of 30 compounds was selected and from among those compounds a final 12 *top-tier compounds* that can be produced from plant sugars were chosen [Runge 2006:871].

Of the hexosen (C6 sugars) glucose derivatives offer most potential for *top-tier building-block chemicals* as key feedstocks [Runge 2006:867-868]:

- Lactic acid (cf. the graph "chemicals from lactic acid" [Runge 2006:868]);
- 3-hydroxypropionic acid (3-HP; cf. [Runge 2006:249-251,584,871-872], in particular, the graph "3-Hydroxypropionic acid (3-HP) – A New Chemical Intermediate Platform" on page 249)
- Succinic acid.

Further notable building-block chemicals for the chemical industry include acrylic acid and 1,4-butanol (1,4-BDO). Acrylic acid ($H_2C=CH-COOH$) may be derived from 3-HP. 1,4-butandiol is one of the many compounds that can be obtained from succinic acid by established chemical transformation (Figure I.186).

> Different from a start in biofuels to enter the chemical industry a deep knowledge of the broad application spectra of the targeted offerings is necessary, and also the current and anticipated regulatory environment.

Novel chemicals' market barriers are well known: product registration, performance and costs versus established products, switching costs, long market introduction cycles to name a few.

But, *drop-in chemicals will experience quite different challenges compared with novel chemicals, converging to a large part around the cost of goods* – that is levels of innovativeness, conservatism, and risk aversion of potential customers (ch. 4.2.1.1). Hence, for biochemicals-oriented startups a "*veterans approach*" has turned out to be mandatory with managers having not only broad experiences in the chemical industry, but also being appropriately connected in related networks.

Execution of a startup's strategy (commercialization) requires intense *partnerships* with firms from the sugar and/or biotechnology-oriented nutrition industry and, very importantly, the *rather conservative chemical industry* in terms of large and giant chemical companies, particularly from the US, Germany, The Netherlands and Japan.

For instance, 1,4-butanol from succinic acid provides a typical example for the highly competitive situation for entrepreneurship/intrapreneurship in biobased chemicals, particularly with regard to economies of petroleum-based chemicals (Figure I.187).

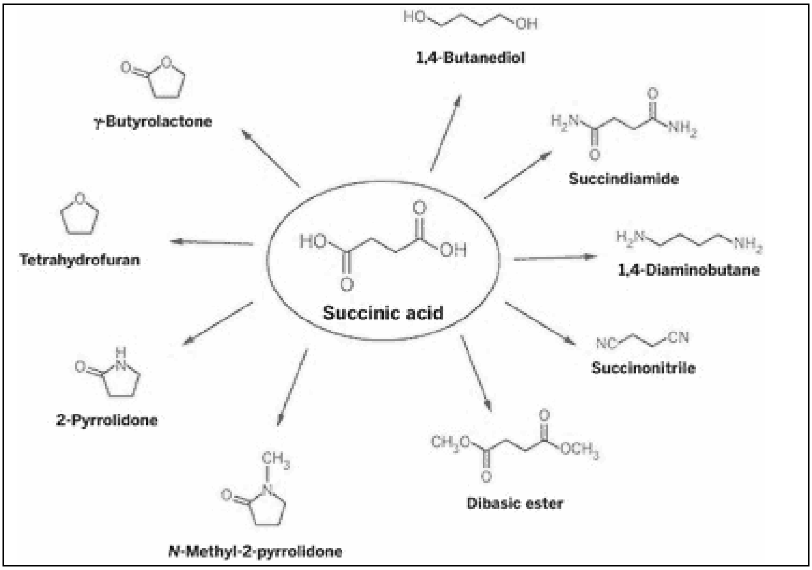


Figure I.186: Chemicals and intermediates derived from succinic acid.

US firm Genomatica, Inc., which in 2011 filed for an initial public offering (IPO) of stock worth up to $100 million [Bomgardner 2011f; Admin 2011f], is known for making as a first product 1,4-butanediol (1,4-BDO) by feeding sugar to an engineered strain of *Escherichia coli*. But, in 2012 Genomatica withdrew its $100m IPO – “in light of current market conditions.” [De Guzman 2012d].

On the basis of demonstration-scale tests with sugar processor Tate & Lyle, Genomatica said it can produce the intermediate at lower cost than petroleum-based processes. Its second product made from renewable feedstock shall be butadiene [Bomgardner 2011a]. In line with numerous examples from the biofuels scene, in 2012 Genomatica pushed back the timeline for commencing commercial-scale production of renewable butanediol from 2012 to 2013 [Lane 2012q].

Concerning renewable butadiene Genomatica clashes with Amyris (Table I.99 and below text), but more importantly its focus must be on butanediol made from biobased succinic acid which is offered by many other firms. Among the largest emerging applications of bio-succinic acid is the production of “green” 1,4-butanediol (BDO). Furthermore, consideration of just butanediol and producing it at lower cost than petroleum-based processes will not suffice: The overall cost of the customer in a system of other products related to succinic acid and BDO is relevant (Figure I.25, Figure I.187).

Moreover, by mid of 2012 LanzaTech (Table I.99) signed a joint development agreement with one of the world-leading nylon producers INVISTA focused on bio-based butadiene. According to the agreement, INVISTA and LanzaTech will collaborate on projects to develop one-step and two-step technologies to convert industrial waste gas carbon monoxide (CO) into butadiene. Initial commercialization is expected in 2016. The collaboration will initially focus on the production of butadiene in a 2-step process from LanzaTech's CO-derived 2,3-butanediol (2,3-BDO). A direct single step process will also be developed to produce butadiene directly through a process of gas fermentation.

Butadiene is a key intermediate chemical used by INVISTA in its proprietary butadiene-based adiponitrile (ADN) production technologies. ADN is a critical intermediate chemical used in the manufacture of Nylon-6,6.

Currently LanzaTech runs a 15,000 gal/year pilot facility at a steel mill in New Zealand that produces ethanol and 2,3-BDO from waste carbon monoxide gas. In Shanghai, China, LanzaTech's 100,000-gallon-per-year demonstration plant uses waste gases from a Baosteel steel mill to produce ethanol.

The issues of introducing and ultimately replacing biobased succinic acd and/or 1,4-butanediol to a large chemical firm can be lucidly illustrated looking at the specific situation of BASF.

The world's largest chemical company BASF with its "Verbund"-approach [Runge 2006:369-370] can interconnect biobased succinic acid and 1,4-BDO with its production streams for petroleum-based derivatives and products with production sites all over the world as given in Figure I.187. This provides a huge potential for *crossover strategy* for products containing various amounts of biobased components and thus a great potential for cost management and price settings. While mostly succinic acid is currently made mainly from fossil-derived maleic anhydride that provides the basic four-carbon backbone BASF can utilize its proprietary acetylene platform.

Furthermore, contrary to its peers and other large chemical firms, such as US firms DuPont or Dow Chemical, BASF has an oil business including exploration through its 100 percent subsidiary Wintershall Holding GmbH [Runge 2006:63-64,586]. It is the largest crude oil and natural gas producer in Germany (turnover of €12.1 billion, $15.8 billion) in 2011, net profit €1.1 billion). Wintershall is a big revenue contributor to BASF. Hence, BASF does not depend fundamentally so much on oil price swings as other chemical companies do.

Combining bio-BDO and bio-succinic acid opens up the possibility of greener biopolymers, such as polybutylsuccinate (PBS), which is used in biodegradable packaging films and disposable cutlery. Another potential market is in polyester polyols and polyurethanes, currently dominated by the use of adipic acid as a precursor. Companies are looking at replacing the six-carbon adipic acid with four-carbon biosuccinic acid, providing the costs become comparable, because adipic acid production is a messy process that produces a lot of carbon dioxide [Taylor 2010].

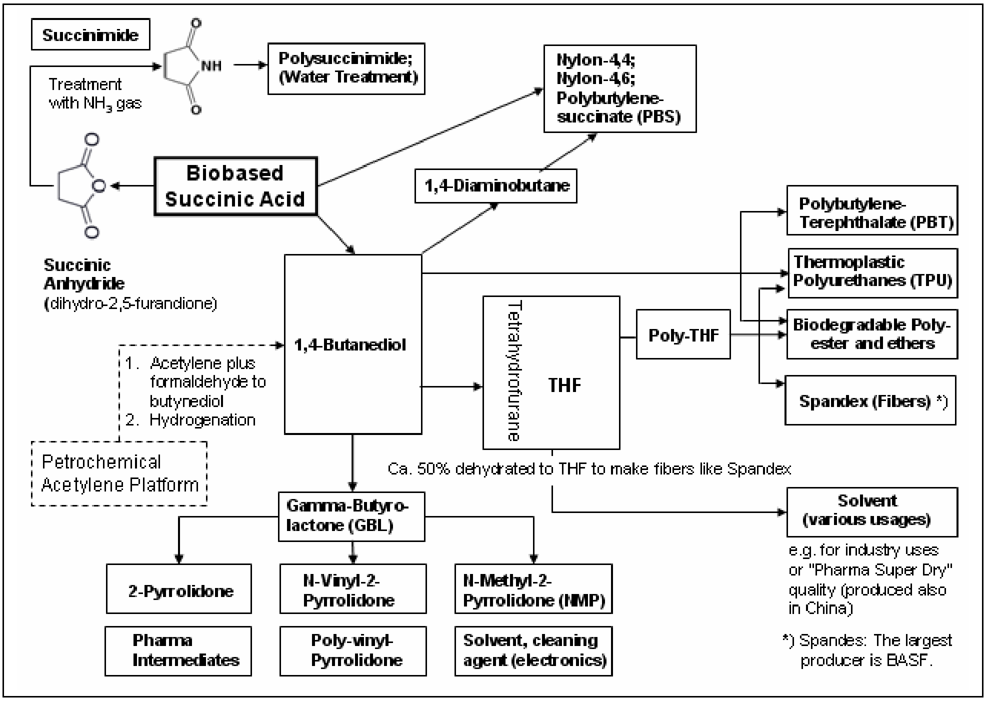


Figure I.187: The role of succinic acid for BASF in its production Verbund environment.

Currently the majority of polyamides (PAs) of the Nylon-type is on C4 and C6 components (succinic or adipic acid). But interest in polyamides based on α,ω-diacids (long-chain diacids) and diamines (C10– C18) emerged. There was already interest in "green" long-chain α,ω-diacids (with 9 or more carbon chain atoms) rather than the C4 or C6 diacids before 2007. The German firm Cognis, acquired in 2010 by BASF (now BASF Personal Care and Nutrition GmbH), was particularly active in this field targeting polyamides, polyesters, and polyurethanes. A series of Nylons were synthesized and tested using octadecanedioic acid (C18 diacid) made from Cognis's biofermentation process.

Cognis had developed a proprietary strain of the yeast "*Candida Tropicalis*" which efficiently *oxidizes natural based fatty acids produced from vegetable, animal or tall oil sources to produce the novel diacid momomers*. *Candidas Tropicalis* was developed to oxidize terminal ("end") methyl groups on the molecules efficiently into terminal carboxylic acid groups. Thus an alkane or renewable monobasic fatty acid feedstock can be oxidized to a dicarboxylic acid [Runge 2006:861].

Interestingly, Wallace Carothers, who was the first to develop polyamides (Nylon-6,6) at DuPont in the 1930s [Runge 2006:414-418], insisted that Nylon-5,10 is better than Nylon-6,6 or Nylon-6 of BASF (then I.G. Farben), the latter two of which are the most common for textiles and plastics. Carothers had wanted to bring Nylon-5,10 to commercial status, but was unable to, because he could not identify an economically efficient production process [Ravenstijn 2011].

BASF has developed a 100 percent bio-based PA-5,10 with performance suitable for automotive applications. However, Bio-PA-5,10 is rather expensive and thus limits its applications. Dutch firm DSM works on PA-4,6 grade expected to replace metal parts under the hood, such as turbo diesel systems components.[113] DSM's high-heat polyamide Stanyl 4,6 was one of the few successful polymer introductions since the 1980s.

Succinic acid is currently only a niche product, with the 30,000 tons produced a year creating a market worth $225 million. Market research firm Frost & Sullivan believes the market will expand six-fold to 180,000 tons by 2015, thanks largely to the introduction of bio-succinic acid. There is a rather strong competition in the bio-succinic acid arena.

The emerging bio-succinic acid market in particular shows a very competitive environment with small and large players – from Europe, the US, Japan, China and Thailand.

Apart from BioAmber discussed above at least four other groups are gearing up to develop commercial capacity for bio-succinic acid. The companies investing in bio-succinic acid clearly believed these projections are reasonable, given that collectively three of them intended to bring over 140,000 tons of capacity online by 2012 [Taylor 2010]. According to the BASF/Purac JV (see below) the main drivers are expected to be bioplastics, chemical intermediates, solvents, polyurethanes and plasticizers.

US-based Myriant Technologies is among the companies which see the main potential for bio-succinic acid as lying in the BDO market. As BioAmber also Myriant (motto: "Chemistry Refined …Naturally") filed for an IPO in 2011 worth up to $125 million. Myriant's filing disclosed that it was planning a 220 million-lb-per-year bio-succinic acid facility in China in partnership with China National Bluestar, in addition to a smaller plant to be built in Louisiana. This plant in Louisiana should have a capacity of 15,000-ton succinic acid and should be built by 2012 with the help of $50 million in Department of Energy funding.

Founded in 2004 as BioEnergy International, Myriant focused on the production of renewable biobased chemicals using a proprietary biocatalyst platform. Myriant is the exclusive licensee of technology from the University of Florida and has since expanded its intellectual property portfolio with internally generated patents, patent applications and a scientific knowledge base. In 2009 bioethanol specialist BioEnergy International span out Myriant as an independent company and incorporated all of its biobased chemicals business and intellectual property.

The other players include very large chemical firms. Dutch DSM and the French firm Roquette Frères, through their Reverdia joint venture, expected their 10,000-metric-tons plant in Spinola, Italy, to be online in the second half of 2012. Finally, Mitsubishi Chemical Corp. (MCC) has been making PBS from fossil-based succinic acid [Taylor 2010]. It has developed its own process for making bio-succinic acid from biomass, although no details of its process are known.

The company was formerly collaborating with Ajinomoto on the project. Mitsubishi wanted to follow the typical "crossover strategy" and wanted to target the market being developed by the (then) Dow-Cargill JV NatureWorks for PLA. [Runge 2006:861]. Mitsubishi currently has also a joint venture with the Thai company PTT (PTT MCC Biochem) to develop bio-succinic acid-based PBS and also BioAmber envisions a partnership with that firm.

Owing to BASF's traditional raw material base interconnected with research, applications, and product driven business approaches it is not surprising that a leading white biotechnology project is the production of succinic acid (Figure I.187; cf. also Quantifying the BASF "Knowledge Verbund" – Figure I.188). In 2009, BASF and Purac announced they will form a joint venture to produce up to 25,000 metric tons of the intermediate in Barcelona (Spain) by 2013 planning already a world-scale plant with a capacity of 50,000 tons [Taylor 2010; Purac 2011].

Purac is a subsidiary of the Dutch firm CSM, a global player in bakery supplies and food ingredients and preservations. Purac (revenue ca. €400 million, 1,100 employees) is active in a variety of markets, with a focus on natural food ingredients, lactic acid, biogases, chemicals and biobased monomers for PLA [Taylor 2010; Purac 2011].

The JV will make bio-succinic acid using a BASF-developed bacterial strain (*Basfi succiniproducens*) which can process a wide variety of C3 (glycerin), C5 and C6 (glucose) renewable feedstocks, including biomass sources. Using a fully equipped fermentation and down stream purification plant the partners will demonstrate the economical production of succinic acid on industrial scale; carbon dioxide (CO2) will be used as a raw material and fixed during the highly efficient fermentation process (cf. BioAmber's process).

The BASF/Purac JV followed closely a stringent typical scale-up process (Figure I.8). Critical steps of the jointly developed production process have been validated in several successful production campaigns. The resulting volumes were used to evaluate the market. In particular, the giant BASF can simultaneously provide a very large in-house test field.

"After successfully testing the BASF in-house applications we are now able to make large volumes available for external customers." In view of the risky situations of existing or to emerge bio-succinic acid startups as competitors BASF emphasized that "The goal is to globally provide a high product quality and offer security of supply to the customers." [Purac 2011] This means BASF is very serious about its inroads into the bio-succinic acid intermediate – and that does not bode well for startups.

Differently to the startups BioAmber and Myriant which rely on cost models for just the production of bio-succinic acid the BASF/Purac JV works together to achieve manufacturing cost levels by empirical in-house and outside tests for making biobased succinic acid competitive for a systemic context of a wide variety of novel applications.

Correspondingly, BASF and Purac are establishing a joint venture for the production and sale of biobased succinic acid named Succinity GmbH with headquarters in Düsseldorf, Germany which should be operational in 2013. "We know from many discussions with customers and samples we sent them that the demand for biobased succinic acid for example for biodegradable plastics is set to grow faster and more strongly than expected earlier," said the President of Purac [BASF 2012c].

Generally, the demand for succinic acid is anticipated by Succinity to grow strongly in the years ahead, driven mainly by bioplastics, chemical intermediates, solvents, polyurethanes and plasticizers and Succinity to take advantage from all of these fields. This plant, having commenced operations in March 2014 with an annual capacity of 10,000 metric tons of succinic acid, will put the new joint venture company in a leading position in the global marketplace. This is complemented by plans for a second large-scale facility with an annual capacity of 50,000 metric tons of succinic acid to enable the company to respond to the expected increase in demand. The final investment decision for this facility will be made following a successful market introduction.

Additionally in 2013 BASF planed to begin also production of 1,4-butanediol based on renewable feedstock (renewable 1,4-BDO) using the patented process of Genomatica utilizing a license agreement allowing BASF to build a world-scale production facility. The one-step fermentation process is based on sugars as a renewable feedstock. And concerning non-food sugars as a renewable feedstock BASF has linked itself to Renmatix (see below). Furthermore, "initial lifecycle analyses show that Genomatica's Bio-BDO will require about 60 percent less energy than acetylene-based BDO" (cf. Figure I.187 and [Bomgardner 2011i]).

Genomatica will continue to advance its patented renewable BDO production process while BASF will produce renewable BDO, which shall be available in the second half of 2013 for sampling and trials. "We are pleased to cooperate with BASF, the leading global BDO manufacturer with a worldwide manufacturing and sales network and many years of market experience," said Christophe Schilling, Chief Executive Officer of Genomatica, and continued: "This agreement highlights Genomatica's commitment to delivering innovative process technologies to the global chemical industry." [BASF 2013]

The starting materials for the production of conventional petrochemical BDO are natural gas, butane, butadiene and propylene. BASF currently produces BDO and BDO-equivalents (Figure I.187) at its sites in Ludwigshafen, Germany; Geismar, Louisiana; Chiba, Japan; Kuantan, Malaysia; and Caojing, China, and has an annual capacity of 535,000 metric tons. BASF has recently announced the intention of building a BDO complex in China with a capacity of 100,000 annual metric tons [BASF 2013].

Biobased chemicals and plastics as a new wave is about to emerge. But, according to BioAmber's CEO Huc for entrepreneurship the wave will have a serious threshold for startups: "A lot of large chemical companies are still looking at bio and saying 'prove it.'" "In the sphere of succinic acid, if any of the early players fail it will undermine the credibility of the whole industry." [Taylor 2010]

> Obviously there is a "Catch 22" situation: Green startups need large capital and big companies waiting for proven startups.

While succinic acid addresses the "4-component" in Nylon derivatives adipic acid addresses the "6-component" which also brings up the "BASF-factor" for startups. BASF, the innovator of Nylon-6 in the 1930s from ε-caprolactam [Runge 2006:416-417] and the world's largest manufacturer of caprolactam, is generally a leading manufacturer of carboxylic acids. Its product portfolio reaches from monocarboxylic acids to dicarboxylic acids like adipic acid and fumaric acid to name the most important ones. Correspondingly BASF is one of the leading manufacturers of polyamide intermediates and polyamides with production sites all over the world. The BASF process for making adipic acd is by direct oxidation of cyclohexane using air only [ChemSystems 2010].

US startup Verdezyne, Inc. ("Green Chemistry by Design") is developing a yeast platform to optimize metabolic pathways, microorganisms and fermentation processes for the conversion of sugars to biofuels (bioethanol from C6 and C5 sugars) and biobased chemicals and plastics by proprietary metabolic pathway engineering tools. In particular, by the end of 2011 it opened its first pilot plant to produce adipic acid, the key component of Nylon-6,6. The company said "the plant will be used to demonstrate scalability of their process, validate their cost projections and generate sufficient quantities for commercial market development."

Verdezyne was founded in 2005 as CODA Genomics, a University of California at Irvine spin-out that used computational technology to design genes for the research world. In 2008 it transitioned from being a lead synthetic gene provider to pharmaceutical and industrial enzyme businesses to focus on fermentation pathway engineering for renewable fuels and chemicals. As expected it currently follows a "veterans approach" for its executive management with personnel having 25+ years of experience. Among investors in Verdezyne BP Alternative Energy Ventures and DSM Venturing BV are notable in this context.

CODA Genomics (Computationally Optimized DNA Assembly) was founded by members of UC Irvine's Intitute of Genomics and Bioinformatics as an LLC. In 2007/2008 CODA overhauled its core business strategy, recruited a new CEO, William Radany, along with a new management team, changed its name, and moved its headquarters from Orange County to Carlsbad, CA, near San Diego [Bigelow 2009c].

The business model emphasized 1) the company to look for having core expertise around developing a process and 2) validating out that process in a 10 liter laboratory scale fermentor. “After validation, it requires scale-up and that’s where partnership with chemical companies has to come in.” [De Guzman 2009]. Verdezyne seems to have kept its strong research orientation. Asked about its driver we read: “An exceptional R&D team.” [Admin 2011g].

Foundation was actually by “stage-oriented entrepreneurs” as is Pamela Contag of Cobalt Biofuels (Table I.96). Both co-founders Rick Lathrop (Professor of computer sciences, then 51 years old) and Wes Hatfield (Professor of microbiology and molecular genetics, UCI School of Medicine. Professor of chemical engineering, UCI Samueli School of Engineering. Director, UCI Computational Biology Research Laboratory, then 65) had already founded other biotechnology firms. Hatfield’s favorite quote that characterizes their stage-oriented entrepreneurship is: “Do good science and leave management to professionals.” [Stewart 2006]

Originally, Verdezyne focused on fatty acid distillates or soapstocks from the oil seed processing industry (a by-product of soybean processing) [De Guzman 2009; Admin 2011g]. Verdezyne needed help with breaking down cellulosic (and hemi-cellulosic) materials into the sugars to tackle converting grass, straw, sugarcane stalks and other such tough plant material into chemicals. Interestingly in this context, one of BP’s other big moves into biofuels came with its purchase of the lignocellulosic biofuels business of Verenium (Table I.84) [St. John 2011]. As investors in Verdezyne BP represents the bioethanol side, DSM is interested in the chemical side.

From the beginning of chemistry and chemical endeavors plant oils played a key role as a raw materials for the chemical and then also the cosmetics and nutrition industries. The surfactants (soaps!), detergents and oleochemicals industries existing since ages provide a strong bridge into biofuels (biodiesel) and a biobased chemical industry [Runge 2006:252-256, 563].

Relevant plant-based oils contain large varieties of fatty acids and their esters. Olefin metathesis technology has emerged as key for converting biobased oils to industrial chemicals, feedstock and consumer products [Runge:865-867]. Correspondingly, we encounter considerable entrepreneurial activities in this segment.

Through the acquisition of German firm Cognis the chemical giant BASF [Runge 2006:188] is now back-integrated to a large extent also in renewable oleochemicals. Similarly, US “food and feed giant” Cargill plays a key role here [Runge 2006:244].

Industrial Non-Food Sugars versus Petroleum as a Feedstock and Raw Material

Fundamental components of a business model of biobased chemicals oriented start-ups are producing and selling cellulosic industrial sugars and a synergistic back-end to proprietary chemical companies to produce high value products.

From an economic point of view cellulosic industrial sugars to be used for key intermediates to create the biochemical products and biofuels are a raw material *commodity* and, consequently, the business really is a cost game. And the competitive situation is envisioned as follows:
"In the end, the lowest cost providers will be the winners, and maybe a couple or three will be there. There won't be twenty." (Renmatix, B.2).

BASF is back-integrated in oil and gas as key raw materials for its intermediates. And BASF's $30 million investment in 2012 in US cellulosic sugar developer Renmatix (B.2) signals the German chemical firm intends to expand its feedstock sources and raw materials especially for its renewable chemicals and materials portfolio [De Guzman 2012b; BASF 2012a; Fehrenbacher 2012].

Renmatix (derived from **Ren**ewable **Mat**erials) claims itself to be the current lowest-cost producer of industrial sugars, the building blocks of renewable ("green") chemistry, utilizing non-edible biomass as feedstock. Mike Hamilton, the chief executive of Renmatix, said in an interview that the startup plans to build a facility by 2014 that will ship *sugar that can compete in cost with Brazil's sugarcane crop, the global benchmark for the commodity* [WOC 2012].

The end products in the two-step Plantrose™ process of Renmatix are C5 (xylose) and C6 (glucose) sugars, and optionally lignin. Basically, the process follows a patent protected "*supercritical fluid hydrolysis*" technology as well as patent-protected (supported liquid membranes, SLM) separation technology.

Supercritical fluids for use in processing biomass are used as mixtures. These include water, carbon dioxide and ethanol at selected temperature and pressure intervals, for instance, above the critical points for ethanol and carbon dioxide but at a temperature and/or pressure below that of the critical point for water, etc. Furthermore, the Nano Carbonic Solvothermal Technology (NCST) provides methods for generating micro- or nano-structured raw materials and performing biomass and particularly cellulose hydrolysis (Renmatix, B.2).

Apart from Renmatix there have emerged a number of pure-play sugar technology developers and manufacturers, such as Bluefire's wholly owned subsidiary SucreSource (Table I.86) and Virdia (formerly HCL CleanTech) (Table I.99) which changed its emphasis away from biofuels. Also Sweetwater Energy launched in 2006 in the US under the name SweetWater Ethanol, LLC, belongs to that category. It intends to advance a decentralized business model it developed to allow farmers to produce ethanol from crops right on their farms.

On the other hand, London, Ontario-based Comet Biorefining Inc., founded in 2009, produces its cellulosic sugar as syrup which has high glucose concentration. The Comet cellulosic sugar process uses a two stage process to activate cellulosic biomass, followed by conversion to glucose at very low enzyme loading. Co-products are used for energy production [Sims 2012]. It has demonstrated its cellulosic sugar technology at pilot scale and is currently scaling up to commercial applications. However, it was not saying much about the company's technology. What it said is that the firm's process uses fewer enzymes to break down biomass than in competing processes (Renmatix, B.2).

Having sugars next to come is the conversion of these into various products. In this line BASF announced by mid of 2012 a collaboration with BioTork, LLC of Gainesville, FL. According to its Web site after six months of a pilot study, both firms are going into a combination of their complementary approaches to strain development to improve the efficiency and resulting economics of biochemical production processes.

Created in 2008, BioTork LLC is a biotechnology company developing certain microbial strains for the industrial production of biobased polymers and green chemicals. BASF has been conducting intensive research on the use of microorganisms for the production of proteins, enzymes, vitamins and other high value and low cost chemicals.

> In their natural environment, microorganisms generally synthesize these chemicals only to meet their own requirements for survival. The challenge faced by chemical companies is to push these microorganisms to produce these chemicals faster, in much larger quantities, and under industrial conditions that are different from the microorganisms' natural environment. This is the only way to use microorganisms for commercially viable production of chemical products.

In addition in 2010 BASF and Solix Biofuels (now Solix BioSystems) (A.1.1.4) started a collaboration demonstrating the BASF commitment to generate growth from industrial biotechnology and algae representing an addition to BASF's technology portfolio as they offer the potential to produce a number of *specialty chemicals* and products.

Apart from "sugar entrepreneurs" and existing firms focusing on bioplastics and chemical products firms are also using 3-hydroxypropionic acid (3-HP) as a chemical intermediate platform to produce acrylic acid (and esters), acrylamide and acetonitrile, 1,3-propanediol, and malonic acid esters [Runge 2006:248-249]. Acrylic acid is a key chemical building block used in a wide range of consumer goods including paints, coatings, adhesives, diapers and detergents.

At first, in the US Codexis and food and feed giant Cargill cooperated and announced a breakthrough in developing a novel microbial process that will convert corn sugar to 3-HP [Runge 2006:248-249]. Currently Cargill and its Danish partner Novozymes are assumed to be planning to release their technology available for licensing within the next couple of years [De Guzman 2012c].

By August 2012 BASF joined the Cargill and Novozymes cooperation to develop the process for conversion of 3-HP into acrylic acid. All three firms have signed an agreement to develop technologies to produce acrylic acid from renewable raw materials. Presently, acrylic acid is produced by the oxidation of propylene derived from the refining of crude oil. BASF is the world’s largest producer of acrylic acid and has substantial capabilities in its production and downstream processing. BASF plans initially to use the bio-based acrylic acid to manufacture superabsorbent polymers [BASF 2012b].

The three companies bring complementary knowledge to the project. Novozymes is the world-leader in industrial enzymes. BASF and Cargill are global leaders in their industries. Together this trio is uniquely positioned.

The large French specialty chemicals firm Arkema will look at the direct conversion of glycerin to acrylic acid, as well as the conversion of glycerin to acrolein (propanal) and use of conventional technology to oxidize acrolein to bioacrylic acid. The process is not new; the Japanese firm Nippon Shokubai has developed catalysts for conversion of glycerin to acrylic acid.

Arkema is the third-largest player in the huge global acrylic acid market after number one BASF and Dow Chemical as number two. As early as 2004, Arkema had been working on a method to make acrylic acid from renewable resources. Hence, startups in the field have to encounter heavy competition in the bioacrylics area with petroleum-based acrylics [Reisch 2010].

Dow has a rather small biotechnology portfolio compared with BASF and DuPont, but they were among the first to invest in bioplastics via the firm NatureWorks, the JV with Cargill. But Dow sold its stake at a time that the 100,000 tons plant was almost idle in 2005 [Runge 2006:129-130,245].

In 2011 Dow and startup OPX Biotechnologies, Inc. (OPXBIO) signed a joint development agreement to prove the technical and economic viability of an industrial-scale process to produce acrylic acid using a fermentable sugar feedstock with equal performance qualities as petroleum-based acrylic acid, creating a direct replacement option for the market. If collaborative research is successful, the companies will discuss commercialization opportunities that could bring biobased acrylic acid to market in three to five years [OPXBio 2011]. In 2011 OPXBIO raised $36.5 million in an equity financing round C. This added to a total of more than $53 million OPXBIO raised so far with venture investtors.

Dow is focusing on the use of sugar feedstock and the conversion process of sugar to bioacrylic acid while OPXBIO is focusing on its microbe using its “Efficiency Directed Genome Engineering” (EDGE™) platform, as well as developing the 3-HP bioprocess. OPXBio uses microorganism to biosynthesize 3-HP by fermentation of sugar and subsequent dehydration of the 3-HP to acrylic acid. Both Dow and OPXBIO will jointly fund the development, demonstration and commercialization of bioacrylic acid. OPXBIO’s rebuttal against the Cargill technology is that OPXBIO claims to have a lower-cost biobased route (and also the competitive to petroleum-based route) [De Guzman 2012c].

OPXBIO was founded in 2006/2007 and follows currently a “veterans” approach for its management team. For instance, Charles R. (Chas) Eggert, the current President and CEO, has more than 30 years of experience in the global specialty chemical industry. He began his career with Monsanto Company, progressing through roles in technology, manufacturing, business development, marketing and general management.

Michael D. (Mike) Lynch, MD, PhD – the Chief Scientific Officer and Co-Founder – is still on board. He received an AB in anthropology as well as a BS and MA in biomedical engineering from Washington University in St. Louis, followed by a PhD in chemical and biological engineering from the University of Colorado in 2005 and an MD from the University of Colorado Health Sciences Center in 2007. He has nearly a decade of research experience in the life sciences, including the fields of molecular biology, protein thermodynamics, microbiology, and metabolic engineering, and is the primary inventor behind OPXBIO’s platform technologies.

In 2006, Lynch started OPX Biotechnologies, and successfully raised three rounds of financing after demonstrating the concept’s viability. In 2009 the company had more than 30 employees. After launching with $1 million in seed capital in 2006, OPX Biotechnologies closed funding rounds in October 2007 and April 2008 of $1.3 million and $2.6 million, respectively, before closing on an impressive $17.5 million round in 2009 [INITIAL LIGHT BULB 2009].

OPXBIO’s goal is to compete with petroleum-based chemicals and fuels on both quality and price. OPXBIO has developed and piloted the microbe and bioprocess that will produce its first renewable chemical product, BioAcrylic. In 2011, based on pilot-scale development, it announced that it has achieved the commercial bioprocess performance and cost goals for BioAcrylic. The company plans to diversify its product portfolio into the fatty acid and acrylamide sectors. But both products are still in the early phase of development [De Guzman 2012c].

OPXBIO has scaled up its bioacrylic acid production to 3,000 liter fermentation (equivalent to 60,000 lbs/year) at the demonstration plant in Lansing, Michigan, owned by MBI, a non-profit organization owned by Michigan State University (MSU) Foundation. OPXBIO said the company plans to have a second demonstration plant with a capacity of 600,000 lbs/year in 2013. A commercial plant with a capacity of 100 million lbs/year is expected by 2015 [De Guzman 2012c].

Like in previous market hypes (US) *investors seemed to be ready to invest in almost any biotech company provide they follow the mainstream which this time is the "drop-in" technology*.

But a recent Wall Street Journal article (of September 2013) referring to OPX entitled "Biotech Firm Tests Investors' Patience" emphasized it may be a test case of private investors' appetite for risk with investing in related startups. Specifically, OPX "Chief Executive Charles R. Eggert has said the company doesn't expect to generate any commercial revenue until at least 2017. That is hard math for some investors."

A.1.2 William Henry Perkin and Industry Genesis in the Last Third of the Nineteenth Century

In Runge [2006:397-402] the Berlin (Prussian) Blue innovation from 1704 and the related birth of inorganic chemistry has been mapped against current notions, concepts and thinking of innovation and entrepreneurship. Furthermore, in the same way key aspects of William Henry Perkin's synthetic dye innovation in 1856 in the UK by serendipity has been roughly mapped to current concepts of radical innovation [Runge 2006:295]. Therefore, it is of interest to inquire in more details into the entrepreneurial aspects of Perkin's dye innovation (Figure I.87).

There is a myriad of literature on the synthesis of the iconic dye mauveine by (Sir) William Henry Perkin as a major landmark in the history of science and technology, as it led to the establishment of the synthetic dye industry and further development of organic chemistry. But, apart from the emphasis on history of industry, Perkin and the dye industry provide a wealth of generic features of entrepreneurship in the environment of entrepreneurial capitalism. Furthermore, it can be viewed as an example for one of the first research-based startups (RBSUs) in a broad sense. Actually Perkin was a "university drop-out."

In Table I.100 the combined entrepreneurship and innovation concepts are displayed focusing on industry genesis [Runge 2006:266- 269, 274-276; 293-296; Ball 2006] [114].

Table I.100: Current entrepreneurship and innovation concepts and processes reflected already during the middle of the nineteenth century by William Henry Perkin.

Scientific and Socio-Economic Context	There was a scientific vision of the famous German Justus von Liebig in line with societal attitudes and convictions. We "believe that tomorrow or the day after tomorrow someone will discover a process ... to make the wonderful dye of *madder* or helpful *quinine* or morphine from coal tar." [Runge 2006:293]

Table I.100, continued.

Idea and Serendipity	Following Liebig's vision August Wilhelm Hofmann at the Royal College of Chemistry based in London targeted the demand of the market to have an antimalarial drug (quinine). Ball [2006] describes the chemical rationales at that time for selecting a specific route to synthesizing quinine. William Henry Perkin, a student of A. W. Hofmann of 18 years, had been directed to make the anti-malarial drug quinine based on material from coal tar by an oxidation route. Initial trials with an envisioned starting material failed, but when using the coal tar product aniline things changed dramatically. "The resulting black sludge dissolved in methylated spirits, and the resulting solution was a beautiful purple."
Revealing the Opportunity	Perkin "stumbled" over an unexpected result, serendipity. Silk dipped in this solution took on the same royal hue. Perkin grasped that his purple solution could be used to color fabric. And Perkin took the recklessly bold move of quitting his studies to exploit the opportunity.
Opportunity Evaluation Early Assessment by a Potential Customer	Perkin realized that this coloring matter had the properties of a dye and resisted the action of light very well thus making it the world's first synthetic dye. He quickly grasped that his purple solution could be used broadly to color fabric. Perkin *changed the project direction* – he wanted to exploit the *first* synthetic organic dyestuff based on *abundantly available feedstock*. He sent some specimens of dyed silk to a dyeing firm in Perth, Scotland, which expressed great interest provided that the cost of the cloth would not be raised unduly. "It was to his credit, and luck, that he sought out the advice of Robert Pullar, the owner of a well-regarded dye works in Scotland. Pullar encouraged the eighteen year old Perkin to manufacture more dye, and told him that if the dyed fabric would remain color-fast and not fade in the sun, Perkin would be a very wealthy man." [Nelson 2002]
Securing Intellectual Property Rights	Referring to this situation, Perkin filed for a patent in August 1856, while he was still only 18.
Venture Financing and Formation	*Against* Hofmann's recommendation Perkin believed in his business idea and convinced his father to invest in his idea and borrowed his father's life savings. With the help of his father and brother (*3F financing*), Perkin set up

	a dye factory in 1857 (Perkin & Sons) at Greenford Green, near Harrow, for mass production of the first synthetic organic dye – mauveine – on a six-acre site near the Grand Union Canal, not far from London. The *location* was selected for cheap transportation of coal-tar from London, the by-product for the emerging gas lighting infrastructure.
Commercialization Issues	Inventing the dye was one thing, raising enough capital for manufacturing the dye in quantity cheaply, adapting it to cotton, getting acceptance from commercial dyers, and creating demand for it in the public was something else. Perkin was active in all of these areas. In a whirlwind of activity, he got his father to put up the capital, his brothers to partner in the creation of a factory, (as a response to Robert Pullar's remark) he *invented a mordant* (a pre-dyeing treatment) for cotton, became a one man technical service operation, and publicized it in the marketplace.
Production; New-to-the-World Products	Utilizing the cheap and plentiful coal tar that was an almost unlimited by-product of London's gas street lighting the dye works began producing the world's first synthetically dyed material in 1857. Initially there were *difficulties*. Since aniline was not readily available, it had to be produced at the factory from benzene. Manufacturing of synthetic dyestuff also revealed large *needs for inorganic basic chemicals*, such as sulfuric acid and alkalis, caustic soda, lime and soda ash.
Unexpected Market Success Stepwise Market Entry via Customer Segments	Already historic in its very founding, the company received an unexpected commercial boost from the Empress Eugenie of France when she decided the new color flattered her. In short order, mauve was the necessary shade for all the fashionable ladies of France. The product *met immediately a market with high purchasing power* based on fashion and "life style," and only *later expanded into the large end-user markets* via the textile industry.

Table I.100, continued.

Competition Hyped Industry Genesis	Ten years after Perkin's discovery of (synthetic) mauve organic chemistry was perceived as being exciting, profitable, and of great practical use. Many other dyes and new firms followed, and Perkin & Sons was soon facing stiff competition from manufacturers in England and France. By the mid-1860s, the German (later giant) companies Bayer, Hoechst and BASF were already in business making dyes, as were Ciba and Geigy in Switzerland [Runge 2006:266-269] (and Figure II.20 in Runge [2006:275]). *Britain and France dominated the dyestuff industry till ca. 1870* to then encounter a dramatic decline through the new players from Germany. The important lesson learned is that the companies and industry of the country the innovation originated in do not necessarily win. A similar situation occurred currently: First the US leadership in the photovoltaic (solar cells) industry was overtaken by Germany, and currently both the US and Germany are behind China – and China having overcome both previous leaders. Perkin discovered and marketed also other synthetic dyes.
Profits and Harvesting	Over the next few years, Perkin found his research and development efforts increasingly eclipsed by the German chemical industry, and in 1874, he sold his factory and retired from business, already a very wealthy man at the age of 35. He devoted the rest of his life to research in pure science. For instance, he became particularly interested in Faraday rotation [115] and produced over 40 papers on this topic. After Perkin's retirement from the industry he remained active in his field in other ways, such as being secretary of the Royal Chemical Society in 1869 and he became president in 1883. He also sat on the boards of several scientific journals.
Multidimensional Innovation Success:	*Industrial*: created and/or stimulated new industries (the organic color industry of coal tar dyes and pharmaceuticals); *Scientific*: stimulated organic chemistry and the search for a better understanding of the structure of molecules

It should be noted that malaria is still a very serious problem. The search for an anti-malaria drug is currently repeated by Amyris Biotechnologies (Table I.99).

By 1914 Germany dominated the world of synthetic dyes by ca. 85 percent. As described by Runge [2006:266-269] Murmann [2003] has attributed the exorbitant rise and superiority of German dye companies largely to a *co-evolutionary*, self-reinforcing development of *higher education, university research – the S&T system – and the industry system* – by strong *political involvement* outlined in detail by Streb [1999].

However, Streb [1999] made some important additions to the co-evolutionary explanation pointing out some important other external drivers and an innovative marketing and sales strategy of the German firms. On the one hand, it was both decreasing imports of natural dyes during the German-French War of 1870/71 and government's demand for dyed tunics which accelerated the innovation of coal tar dyes in Germany (cf. also the. Prussian/Berlin Blue innovation and its role for the Prussian army).

On the other hand, it is little noticed that the German producers of coal tar dyes also owed their success to the two new *marketing* strategies "*customer consulting service*" and "*customer training*." Furthermore, the German chemical firms of the late 19th century had both technological and economic innovation capital. And innovation of coal tar dyes occurred in cooperation with the textile industry in the second half of the 19th century [Streb 1999].

According to Streb [1999] German chemical firms, such as BASF, established so-called "Coloristische Abteilungen" ("Dyes Departments") to *generate new markets for product innovations* in the field of coal tar dyes. These were responsible for implementing new marketing strategies in the textile industry. Therefore, the Coloristische Abteilungen were affiliated with the industrial research laboratories and *filled with both commercial and technical staff*.

Chemists provided c*ustomer consulting service* who did not only know the special characteristics and performance of new coal tar dyes but were also trained to demonstrate how to dye and print textiles. These chemists did understand the problems and the "language" of textile producers. *Before sales* they explained textile producers how to apply the new coal tar dyes in production plants and also provided technical help in cases of actual processing problems ("*after sales service*").

Around 1900 the Coloristische Abteilungen developed *customer training*. The Coloristische Abteilungen used customer consulting service and customer training to gain textile firms as long-term buyers by technological knowledge transfer. They taught employees of textile firms how to handle the latest techniques of dying and printing. Of course, they informed the trainees only about their own products inducing preferences.

Obviously their one-year training was advantageous for textile firms. The chemical firms on their part won the *loyalty of future customers*. In our times firms these marketing strategies are recalled when playing the game of technological cooperation for various areas by "Technical Service Centers."

"The enormous expansion of universities, technical universities (in German Technische Hochschulen) as well as the many research institutes formed after the 1880s was orchestrated from the desk of Friedrich Althoff, who all handled professorial appointments at Prussian universities and Technische Hochschulen, between 1882 and 1907, serving under five successive ministers.
Because he shared the vision that broad scientific and technological research and education would be of immense benefit to society, he was a key ally in the efforts of the dye industry to expand educational facilities. Furthermore, given his unique control over the direction of the Prussian university system and Prussia's trend-setting role for other German states, the dye industry would have to form an alliance with him if they wanted to be successful at all during his long tenure. The German dye industry employed three strategies to upgrade its supply of scientific and engineering talent that could staff its firms: 1) use collective organizations to mobilize support, 2) lobby parliament directly, 3) create private-public academic partnerships." [Streb 1999]

There are also mentioned some more factors contributing to the exorbitant rise of the German synthetic dye industry. The development of a very broad variety of dyes could be based on many *platform technologies* (chemically different types of dyes) [Runge 2006:268].

According to the patent law of 1877 the chemical industry could only protect processes in Germany, contrary to the situation in France or the UK where also products (substances) could be protected by a patent. Therefore during the acquis the new law had less protection impact than expected by the firms. And it is argued that, as no one could afford to rest on its monopoly, the German patent law "outright drove the companies into innovation competition." [Hoffritz 2013]

A.1.3 Structures and Issues of Current University-Industry Relationships

Emphasizing technology transfer (ch. 1.2.6.3) there is a broad diversity of approaches and models for university- and public research institute-industry relationships. Diversity does not only result from the involved units of two partners, but also from the number of different partners and the more or less active role policy may play. There is a pentuple of partners: industry firms (from medium-sized to giant), universities of different types, national laboratories or research centers, other public research organizations and policy. Usually, the relationships can be characterized as *project-like* goal- and time-related endeavors, which are rather firm-specific concerning preferences.

> Persons working in particular university-industry or public research institute-industry organizations may take the experience they gained here (Figure I.64) as a springboard for technology entrepreneurship.

Examples in the US for biofuels of such relationships with "Big Oil" companies are described above (A.1.1; Table I.83). For instance, chemical giant DuPont got $9.0

million for a partnership with the biofuel startup Bio Architecture Lab from the US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E). Chevron had a biofuels development agreement with the National Renewable Energy Laboratory (NREL) and also an agreement with Texas A&M University (four-year period). It formed research arrangements with Georgia Tech, the University of California, Davis and the Colorado Center for Biorefining & Biofuels, which is a consortium of the Energy Department's NREL, three major Colorado universities and other private companies (Table I.83).

Royal Dutch Shell established a joint venture Cellana LLC in 2007 with HR BioPetroleum to build a pilot facility for growing marine algae and producing algal oils that can, in turn, be used to make biofuels. HR BioPetroleum Inc., headquartered in the State of Hawaii, is a developer of large-scale microalgae production technology. It is a University of Hawaii, School of Ocean and Earth Science and Technology based company. Additionally, an academic research program would support the project. The program would include scientists from the Universities of Hawaii, Southern Mississippi and Dalhousie, in Nova Scotia, Canada; with professional management (Table I.89).

Industry calls for proposals for collaborative research networks (like US firm HP); the German government may call for development projects across the value system (in Germany "Verbundprojekte" – "joint projects").

For technology entrepreneurship university-industry relationships based on exchange of R&D personnel or sharing R&D personnel in a dedicated organizational unit, such as a laboratory or a firm (Figure I.41), can play an important basis *for potential entrepreneurs to gain experience and first insights into the business world* (ch. 2.1.2.4), but also *may reveal opportunities* for to-be entrepreneurs. Generally, the personality- or personnel-oriented R&D-industry relationship types are as follows.

1. Sponsorship of a professorship or a network of professors for given research or technology directions by industry
2. Exchanging research personnel in both directions
3. Sharing personnel in joint firms (or joint projects)
4. Sharing research personnel at a firm's site (laboratories) or on the campus.

More in the US than in Germany sponsorship of individual university professorships mostly refer to sponsorship by (wealthy) individuals or foundations. But sponsoring professorship or research units involving several professors mostly from different disciplines has become also of interest to industry as a mode for creating knowledge and technology transfer.

For instance, BP provided $500 million over ten years to establish a dedicated biosciences energy research laboratory attached to a major academic center. BP funding for the Energy Biosciences Institute (EBI) is led by Berkeley and includes additionally Lawrence Berkeley National Laboratory and the University of Illinois at Urbana-Champaign (Table I.83).

German firms have historically had very close ties to academia (Box I.3; A.1.2). For the German industry it is quite common that people from industry hold teaching positions or professorships at universities. Current university-industry-relationships do not only follow common tracks, but, often with support from policy, try new approaches. For instance, the German Karlsruhe Institute of Technology (KIT, Table I.20) established the concept of "*Shared Professorship*." The concept is based either on a 1:1 research institute-industry relationship or a 1:many relationship.

In one case capable young scientists are given the opportunity to gain experience in research and industry (basically for a period of four years) in order to facilitate their later decision in favor of a university or an industry career. The model for a shared professor means working half of the time period at industry and the other half of the time at the KIT. This close-to-industry professorship is to enhance permeability between the KIT and industry by a *talent transfer in both directions* – with benefits for both partners, the KIT and industry [KIT 2008].

In another case [KIT 2009] the shared professorship involves several enterprises as industry partners. For instance, a cooperation designed for a period of five years will comprise KIT, Bayer Technology Services, BASF SE, and Roche Diagnostics, each industrial partner contributing a quarter of the funds – apart from a professorship – the setup of an institute-overlapping thin-film-technology platform [KIT 2009].

Thin Film Technology (TFT) deals with the setup and properties of thin layers and the devices and process technology required for their production. The thickness of the layers varies between a few micrometers and a few nanometers. A particularly promising new market is Organic Electronics with organic photovoltaics. In this field, TFT mainly focuses on polymer solar cells and hybrid solar cells, which means, on polymer solar cells with inorganic nanoparticles. Other projects cover medical diagnosis test strips, coatings and varnishes as well as functional thin layers and structures for thin-film batteries and optical foils.

A related approach to intensify industry and science and universities relationships was followed by German Henkel AG & Co. KGaA. In 1998 Henkel and "to-be-professors" and researchers from a university worked in dedicated projects for a restricted period in the industrial research environment [Runge 2006:689-690]. A specific description involving the chemical industry in Germany is described by Runge [2006:687-692].

A very special situation of technology transfer in the context of entrepreneurship is the private-public-partnership (PPP) firm founded by a university and a large company. These firms do not only do research, but develop marketable products. Here, a legal entity is set up between the two partners.

Henkel AG & Co. KGaA set up a biotechnology and cell physiology PPP-firm Phenion GmbH & Co. KG with the Johann Wolfgang Goethe-Universität in Frankfurt am Main and merged it with Henkel AG & Co. KGaA effective January, 1 2009. Furthermore, it set up a new materials firm Sustech GmbH & Co. KG on the campus of the Technical University of Darmstadt [Schweinberg 2007].

The research company SusTech Darmstadt with an appropriate legal form was established by Henkel, the Technical University of Darmstadt, and five professors from different disciplines and different universities – with Henkel having a majority stake in it and concentrating on management and commercialization (Table I.101). The start phase of the PPP-firm was supported by the German Federal Ministry of Education and Research (BMBF).

Table I.101: Organizational setup of the PPP-firm Sustech GmbH & Co. KG.

Henkel Henkel AG & Co. KGaA	**Technical University of Darmstadt**	**Five Professors from Various Organizations**
60%	10%	30%
Finances Utilization, Exploitation Management Legal and Patents Chairman of Advisory Board: CTO of Henkel	Offices, Laboratories, Infrastructure Foundation: 2000 Acquired by Henkel: Sep. 2008 Employees: 16 (Sep. 2008) 20 (2006)	Colloids, Emulsions (U Saarbrücken). Polymers, Surfaces (U Aachen, RWTH), Biomineralization (MPI Desden), Particular Systems (HGF FZK Karlsruhe, now KIT), Modeling (TU Darmstadt)

When it started Sustech had an international team of 30 scientists that should develop new materials, systems and products. It was set up to enable the fast conversion of innovative ideas into economically usable products and processes. The emphasis was on utilizing the practical potential of nanoparticles to tackle the widespread problem of sensitive teeth. Founded in 2000 Systech was acquired by Henkel in Spetember 2008.

A similar PPP-approach is also found in the UK, for instance, for ionic liquids technology Scionix Ltd. Scionix is set up as a joint venture between the University of Leicester and Genacys Ltd., a wholly owned subsidiary of the Whyte Group Ltd., Britain's largest privately owned chemical company (A.1.5 and Scionix in Bioniqs Ltd. – B.2).

Chemical giant BASF follows basically two approaches for sharing research personnel, at a firm's site (laboratories) or on the campus.

Combining the creative freedom and rapid exchange of ideas unique to the academic environment with the resources of a giant company, BASF wanted to create a new paradigm for productive academic-industrial research, with all the benefits of both worlds. The concept relies on bringing academic and industrial researchers physically as close as possible together in one laboratory.

In 2003 it opened a laboratory at the Institut de Science et d' Ingenierie Supramoleculaires (ISIS), Louis Pasteur University, Strasbourg (France). The ISIS group was headed by a researcher from BASF. Along with BASF's own expertise with nanostructured polymeric materials, a multidisciplinary international team of postdoctoral researchers provided a wide range of scientific backgrounds, from supramolecular complexes to polymer/layered silicate nanocomposites, to sol-gel condensation of highly porous silica networks, to the design and use of automated reactor systems for high-output polymer chemistry [Runge 2006:691-692].

The BASF lab at Louis Pasteur University in Strasbourg (ISIS) is specialized in supramolecular chemistry, developing synthesis pathways for synthetic foams with nanometer-scale pore sizes. These nanopores prevent cell gas molecule collisions, and in this way reduce heat conduction in the foam to less than half of that observed with conventional materials. The nanofoam is designed as an insulating material for refrigerators, buildings, cars and even planes. It will reduce energy consumption and save materials, thus benefiting the environment.

Furthermore, since 2006 BASF and Heidelberg University run a Catalysis Research Lab (CaRLa) [116] led by BASF in the Technologiepark Heidelberg (Technology Park Heidelberg) devoted to homogeneous catalysis. The laboratory was funded by both partners and by the State Government of Baden-Württemberg. Furthermore, the Chemistry Department of the University of Heidelberg has a catalysis research area specially funded by the German Research Foundation DFG ("Sonderforschungsbereich," SFB 623 (*Collaborative Research Centre)*: Molecular Catalysts: Structure and Functional Design).

CaRLa is led by a Steering Committee with representatives of the University of Heidelberg and BASF. It has six postdocs from the University and funded by the University. Also six postdocs and a senior researcher from BASF as managing head of the laboratory are financed by BASF. The laboratory's proximity to Heidelberg University as well as to BASF's global Research Verbund with its Ludwigshafen based Research Headquarters offers ideal conditions for outstanding catalysis research and for a swift transfer of technology. The joint laboratory has become a prime research location attracting catalysis researchers from around the world.

Another approach of BASF concerning innovation and technology transfer is the company InnovationLab GmbH (iL) [117] inaugurated in September 2006, a "Joint Innovation Lab" (JIL). Here, BASF experts are collaborating with partners from industry and academia on materials and device structures from the field of organic electronics. The researchers at the JIL are currently focusing on the areas "Organic Light Emitting Diodes" (OLEDs) and "Organic Photovoltaics" (OPV) and also fuel cells.

Referring to the photovoltaics value system (Figure I.11, Figure I.12) iL reflects an innovation strategy of BASF turning to a higher level in the value system. It is funded equally by science and industry. It is conceptually embedded in the so-called "Top

Cluster Organic Electronics" including printed electronics supported and awarded as an excellent cooperation network by the Federal Ministry of Education and Research (BMBF) comprising twenty-five firms, universities and research institutes working in the field on organic electronics.

The Universities of Heidelberg and Mannheim (near Heidelberg) have 40 percent and 10 percent stakes, respectively, and industry hold the other with 8,33 percent each for the chemical firms BASF SE, Merck KGaA and Freudenberg & Co., Heidelberger Druckmaschinen AG (the printing machine giant), Roche Diagnostics GmbH und software giant SAP AG. The initiative is part of the German Federal Government's high-tech strategy and the OLED initiative is one of it.

The business model of iL aims to establish research platforms for various key technologies. Organic Electronics represents a first step. Each platform has three central elements: applied research, supporting young talents and services, such as acquisition of public funds. The activities of each platform are controlled and managed by independent management.

If researching partners have no interest in commercializing inventions of the research platforms of iL the inventions will be assessed by the unit "Transfer and Incubation" with regard to opportunities and, in case, they will be further developed to reach a market within a "virtual enterprise." iL will not go for commercialization within its own structure. Commercialization is intended by either bringing the project back to one of the research partners or by a spin-off as a new firm and thus iL may act as an incubator.

When looking for "New Instruments for Promoting Innovation," the origin of the "Top Cluster Organic Electronics" was the German Ministry of Education & Research (BMBF) which established a competition for high-level technology clusters. But it did not specify categories or established preconceived boundaries as to the kinds of technologies that were eligible. In 2007, it published a call for entries in the first of a total of three rounds of the German Top Technology Cluster competition. The prize was roughly $260 million for a maximum of five clusters. Out of thirty-eight applicants twelve finalists were eventually invited to make a 10-minute presentation to the prize jury.

Two of the five winners were from the Heidelberg – Rhine-Neckar Rivers (RN) region (Figure I.50). A tight focus helped winning the prize. [Short 2009a]. The organic electronics cluster – Forum Organic Electronics – is managed by InnovationLab GmbH (iL) with a primary focus on products such as luminous wallpaper and solar absorption coatings for energy-efficient heating and cooling. [Short 2009a]. The other cluster BioRN emphasizes biotechnology [Short 2009b].

The heavy focus of BASF on worldwide research cooperations is illustrated in Figure I.188. As similar structures are found also for other German large to giant industrial firms it stresses the concept of a "networked economy" for the German innovation system (Figure I.51).

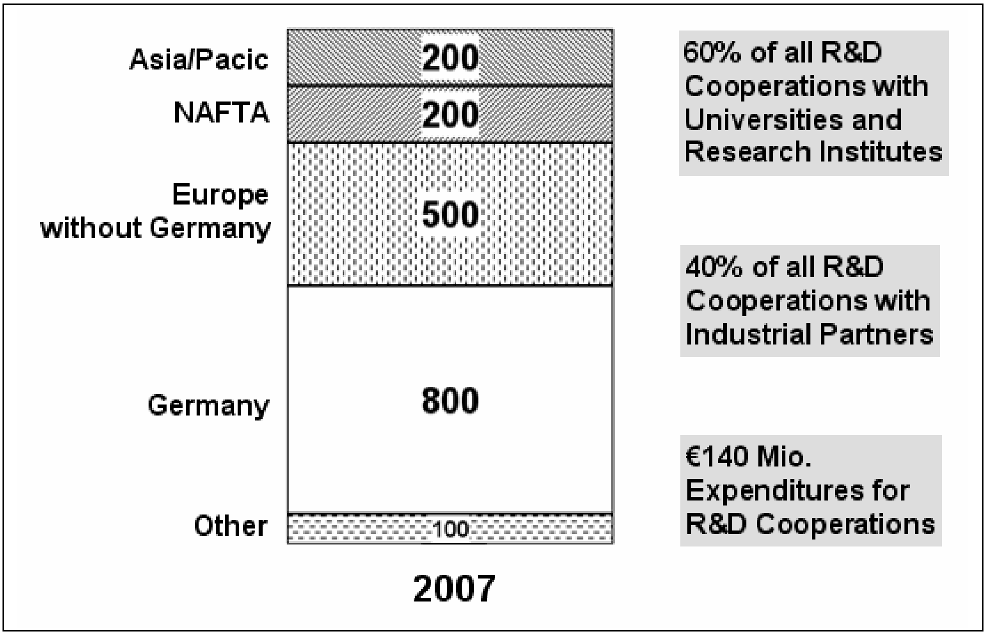


Figure I.188: Quantifying the BASF "Knowledge (now Science) Verbund": 1,800 R&D Cooperations [Jahn 2008].

For German university-industry relationships and technology transfer based on sharing personnel more concepts have been reported, such as "project houses" [Runge 2006:556-557, 575-576] or "science-to-business-centers" [Runge 2006:575; Dröscher 2008].

Moreover, for the chemical industry, in particular, a joint program "Academia-Industry-Exchange (in German Akademia-Industrie-Austausch – AIA) has been set up by the German Chemical Society and the (German) Chemical Industry Association to bring (for two to eight weeks) academics into industrial R&D laboratories or industrial researchers into laboratories of universities or public research institutes. Experiences of an academic in a so-called Innovation Concept Lab of German Merck KGaA in Cambridge (Mass.) have been reported recently [Schneider 2010].

PPP structures similar to those in Germany are also found in the US. The broad areas of industry-academia alliances concern essentially *"entry" into new or emerging technologies*, for the chemical industry, for instance, ionic liquids, nanotechnology, "white and green biotechnology" and biobased or green chemistry or co-evolutionary areas, such as electronic chemicals.

For instance, DuPont had intense cooperative agreements with MIT which started in 2000 with about 30 specific research programs in biotechnology. Each research project at MIT was assigned a DuPont Liaison and projects were regularly reviewed at DuPont. The DuPont MIT Alliance (DMA) was renewed in 2005.

Originally as a five-year $35 million investment, the alliance should receive another $25 million from DuPont to continue funding through 2010. This 10-year, $60 million commitment made the DMA the largest corporate R&D investment at MIT. In the second stage, the alliance planned to expand beyond biobased science to work with nanocomposites, nanoelectronic materials, alternative energy technologies and next-generation safety and protection materials [Runge 2006:690, 691].

Furthermore, DMA also provided an opportunity for DuPont to collaborate with MIT's Sloan School of Management to define *new business models for these emerging technologies*. Another aspect of DMA concerned idea generation. Since its inception, the DuPont MIT Alliance has also asked for *proposals* from the MIT community that draw upon the science, engineering and business expertise at MIT to extend DuPont's reach in the areas of biology, genetics, bioinformatics and catalysis .

Another way for academia-industry relationships targeting compelling topics is used by the US firm HP. Its Innovation Research Program (IRP) [118] is administered by the HP Labs Open Innovation Office, which is responsible for enabling strategic collaborations with academia, the government and the commercial sector to produce mutually beneficial, high-impact research.

HP Labs' IRP is designed to create opportunities at colleges, universities and research institutes around the world for collaborative research with HP. It offers awards in the range of $50,000 to $75,000. Each year IRP sends out open calls for proposals. It is designed to *create opportunities for breakthrough collaborative research with HP*. Proposals will be judged on their potential scientific and societal impact, as well as the caliber of the principal researchers, the availability of matching funds for the project and the quality of the proposed research plan.

Discussing issues of university-industry relationships we can refer again to BASF. Fundamentally, industry at the moment might benefit from getting something into the market quickly, but it also might destroy the free-ranging activity of the professor(s). It is the question over the degree of influence the industry partner firm could exercise over projects chosen. While not opposed to university-industry partnerships to address technical challenges such partnerships might compromise researchers' independence and commitment to the public interest, such as a "green" environment, *unless the program had a clear organizational structure* [Reisch 2007a].

In the US in recent times the partnership between industry and universities has been weakened over difficulties associated with negotiating IP rights in research contracts. Largely as a result of the lack of federal funding for research, American universities have become extremely aggressive in their attempts to raise funding from large corporations. But industry feels that it takes too much time, effort, and money to negotiate an agreement.

Typically at present, negotiating a contract to perform collaborative research with an American university takes one to two years of exchanging emails by attorneys, punctuated by long telephone conference calls involving the scientists who wish to work together. All too often, the company spends more on attorneys' fees than the value of the contract being negotiated. This situation has driven many large companies away from working with American universities altogether, and they are looking for alternate research partners [Johnson 2005; Reisch 2007b].

In 2007 BASF and Harvard University's Office of Technology Investment agreed to form the BASF Advanced Research Initiative. With $20 million from BASF, the five-year program would initially support 10 postdoctoral students and other Harvard researchers, primarily in the School of Engineering & Applied Sciences. However, the initiative would also draw on a network of faculty and students in labs throughout Harvard.

Under the agreement, BASF will have the opportunity to further develop discoveries and innovations. But Harvard faculty investigators reserved the right to distribute and publish any discoveries from the initiative. Although it involves two high-profile names, the announcement of this program set off no obvious alarms, perhaps because it had many of the hallmarks of traditional university-industry research initiatives and involved no debate over public policy. Its focus was on research leading to new products. BASF would decide on the projects it will fund and had pledged to work with Harvard on applying fundamental research to new product development [Reisch 2007a; Reisch 2007b].

A.1.4 Foundation and Development of SAP AG in Germany

German SAP AG is the largest software enterprise in Europe and the fourth largest software enterprise by revenues in the world as of 2009 (behind Microsoft, IBM and Oracle). Its revenues over the last years amounted to €11.6 billion in 2008 (€10.6 billion in 2009 during the Great Recession and €12.5 billion in 2010).

The company now is best known for its SAP Enterprise Resource Planning (SAP ERP) software covering accounting, controlling, distribution, purchasing, production, storage and inventory, and human resources. Describing the foundation and development of SAP AG rely on selected literature [SAP-1; SAP-2; Nonnast 2006, Anonymus 2004; Breuer 2009] with information relevant for entrepreneurship.

In April 1972 five computer experts employed at the IBM office in Mannheim (Germany) founded their own firm with the simple name "Systemanalyse und Programmentwicklung" SAP ("*Systems Analysis & Program Development* in Data Processing*")*, using the simplest legal form (GbR) for a firm in Germany. They rented rooms in a building in Mannheim close to the IBM office. And as they told, these rooms were usually left empty, occupied by just a secretary, to receive calls from customers as the team was off developing software with customers [Nannost 2006].

At that time (mainframe) computers were like big cabinets with many switches and buttons. These mainframes were run by “operators” through stack processing generating a sequence of programs with a meaningful order. Input of data and commands via keyboard monitors did not exist. And IBM did not only provided hardware, but delivered also customized software programs worked off by the computer, for instance, for accounting or payroll.

By the early 1970s, many in the computer industry realized that an affordable video data entry terminal could supplant the ubiquitous punched cards and permit new uses for computers that would be more interactive. At universities (at least in Germany) there was no computer science or informatics, just courses in programming with ALGOL 60 or on analogue calculations.

Dietmar Hopp, an engineer (diploma in telecommunication technology) who after graduation started to work at IBM as a software developer, and then system consultant and account manager and his assistant Hasso Plattner, also an engineer (diploma in telecommunication technology) and having started at IBM as software developer, were engaged in an IBM program for order processing – based on stack processing - for a customer Imperial Chemical Industries (ICI) in Germany, the once British chemical giant, then split and now no longer existing.

Hopp and Plattner, both from the University of Karlsruhe, suggested to ICI that the task could be done much smarter with monitors. ICI agreed and IBM developed an order processing system using monitors which then was much requested also by other customers.

Both developed the *idea of standard software* for accounting whose work processes proceed largely identical in firms. And both were ready to develop a corresponding system for IBM. However, something which is not so rare in big firms happened. Infights with regard to the project between the Mannheim office and the IBM Headquarter in Germany emerged – and Hopp and Plattner were frustrated.

Simultaneously, ICI wanted to have a monitor-based solution for procurement, inventory and invoice-checking. Hopp and Plattner recognized the opportunity: provided ICI with what it wanted and got agreement to distribute the created programs with their own firm. Both convinced other IBM colleagues, mathematician Hans-Werner Hector, graduated physicist Klaus Tschira and economist Claus Wellenreuther, business administration and accounting specialist who also thought about standardization of accounting software, to join the foundation team.

SAP was founded with capital of the founders and ICI was their very first client in 1972. By the end of 1972 there were nine employees and revenues in the first year amounted to DM620,000 (€310,000) leaving a small profit. Their vision and business idea was to *develop standard application software for real-time business processing*, in particular, standardization and unification of all kinds of software that is applied in firms (which later was extended to provide enterprise software applications and support to businesses of all sizes globally). More of their entrepreneurial and innovative approach is described under the heading "value innovation" (ch. 4.3.6, Table I.78).

The five ex-IBMers actually acquired the technology from which they based their software platform from IBM itself which got it from Xerox as a swap deal for a contract Xerox had with IBM. It was called the SDS/SAPE software then and IBM gave the software rights to the five engineers in another swap deal, now, for the five's stock ownership of about 8 percent.

After a short while they came out with the very first financial accounting software. This was the seed from which other components were developed to create the system known as the SAP R/1 where "R" means real time. Thus came to fruition the founding engineer's vision of developing the standard software systems for real time business data processing [SAP-2].

During the first years the founders were simultaneously consultants, developers and salesmen who could complement each other by various personal characteristics. Success factors included that SAP standard ERP software filled a market niche, they had customers and marketing was unnecessary; development was done with the customers and internationalization soon took place. Simultaneously, the founders created a corporate culture of trust and customer-orientation as the basis. For employees they were always addressable. Key was a corporate environment free from fear and accepting error and failure so that innovation could thrive.

The founders focused more on development than sales, but average yearly growth rate in terms of revenues in the first five years remained very strong with ca. 60 percent. Further development was with ups and downs. A serious obstacle occurred when IBM announced its own accounting software. SAP could not sell any accounting software for one year.

SAP lived on software introduction service [Breuer 2009]. And we learn: "In the first half of 1975 we did not grasp any new order." Five years after foundation SAP was still a small firm with 25 employees and DM3.8 million (€1.9 million) revenues [Nannost 2006]. *It took SAP approximately ten years to achieve €10 million in revenues (Figure I.189) which simultaneously represented the inflection point when linear growth changed to exponential growth.*

In 1977 the legal form of the company was converted to a limited liability company ("GmbH," LLC) and the name was changed to "Systeme, Anwendungen, Produkte in der Datenverarbeitung" (SAP GmbH; Systems, Applications and Products in Data Processing) and it moved its headquarters to Walldorf near Heidelberg.

The breakthrough was induced again by the former employer of the team. Early in 1979 IBM launched a new mainframe computer. The new type 4300 was faster by a factor of four compared to the most powerful computers existing so far on the market. Furthermore, the price of the 4300 series was just a quarter of the other high power computers.

And SAP had the right software R/2 which could map many business processes. In the 1980s, SAP released SAP R/2 which boasted of a better stability compared to its predecessors. It also started becoming multilingual and had become multi-currency to accommodate the needs of their international customers.

Only one year later half of Germany's top 100 industrial firms were SAP's customers. SAP's significant growth became more noticed. In 1986 SAP's revenues exceeded DM100 million (€50 million) [Nannost 2006]. By 1995 the global chemical industry had the largest percentage of SAP installations and accounted for 40-50 percent of SAP's annual revenues and Chemical Market Reporter called SAP the "ERP standard among large chemical companies." [Runge 2006:241]

The original foundation team worked together roughly for ten years. In 1982 Claus Wellenreuther left the firm. In 1988, SAP GmbH transferred into SAP AG (a stock-based corporation by German law), and public trading started on the stock exchange by the end of the year. Hans-Werner Hector became responsible for SAP's business in the US. Until its IPO SAP financed its growth by own profits.

After fifteen years in 1987 SAP achieved revenues of €77.7 million with 468 employees, and €1.38 billion with 6,857 employees in 1995, after 23 years (Figure I.189). For comparison, it took Microsoft nine years (until 1983) to reach $50 million in annual revenues and fifteen years to cross $1 billion (1989) (cf. [Bhidé 2000:16] and Figure I.144, Figure I.157).

What was the basis of SAP's success? Contrary to Microsoft or Oracle which, during their early phases, relied essentially on products, tools (programming languages and computer operating system or relational databases), SAP was focused on *business processes* emphasizing industrial customers. And, according to Dietmar Hopp, there was an additional situation: "Simply, at the right time we had the right idea" ("Wir hatten einfach zur richtigen Zeit die richtige Idee").

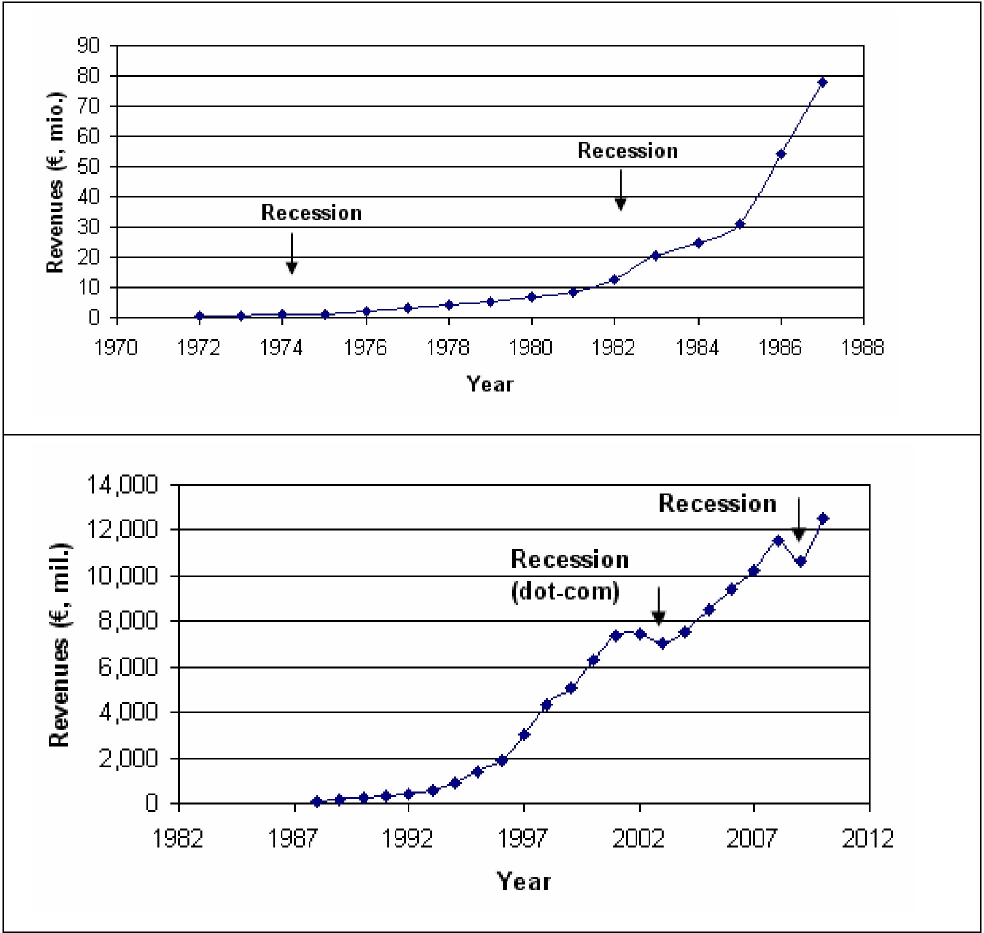


Figure I.189: Developments of revenues of German SAP AG from its foundation.

A.1.5 Entrepreneurship Cases Referring to Ionic Liquids

Referring to the field of ion liquids (ILs) provides exemplary insights into aspects of the birth of (largely) "economic markets" (Table I.15) out of science and the approaches of entrepreneurs to grasp corresponding opportunities based on a *new technology* – which means essentially a *technology push* approach (ch. 1.2.5.1, Figure I.26).

But contrary to biofuels and biobased chemicals (A.1.1) venture capital did not show up here as a financial source. Related cases tackle entrepreneurship perceived as a *disruptive innovation* based on a *platform technology* with broad applicability for many markets. Furthermore, the evolved area after ca. five years had a *limited number of players*.

We shall focus on the fates of two university spin-outs (RBSUs) and one NTBF, two from Germany and one from the UK, over the first 8-10 years of their existence. Only one survived the entry into the new technology area (IoLiTec GmbH, B.2), one was purchased by a large firm (Solvent Innovation GmbH, B.2) and one went bankrupt (Bionics Ltd., B.2). The Bioniqs case contains also a larger discussion of another university spin-out in the UK, Scionix Ltd. founded in 1999, which still exists.

	Solvent Innovation GmbH	**IoLiTec GmbH**	**Bioniqs Ltd.**
Founded	1999	2002/2003	2004
Current State	Purchased by Merck KGaA in 2007, integrated 2008	Still operational; has US subsidiary	Dissolved 2011 in Nov.; liquidation > 12 months

Concerning entrepreneurship it is notable that IoLiTec has been founded by a former employee of Solvent Innovation.

Ionic liquids for broad chemical, pharmaceutical and biotechnological, industrial and research applications emerged only by the end of the 1990s though they were known for decades. They are salts (with negatively charged anions and positive cations), but they are not solid as commonly salts are but liquid at “low” temperatures (usually considered to melt near or below 100 degC) and are relatively low viscous. However, only a melting point below 80 degC allows a broad substitution of conventional organic solvents by ionic liquids – in principle.

Replacing an organic solvent by ionic liquids can lead to remarkable improvements regarding reactivity and selectivity. In many cases the proper choice of the cation/anion-combination allows an optimization of the ionic liquid solvent, especially for a reaction under investigation. Ionic liquids have been used to dissolve not only simple organic compounds, but also enzymes, polymers, even coal and nuclear waste.

The role of ionic liquids as a solvent is not restricted to chemical reactions; it can also be used for extraction reactions. The extraction of metals from different sources will play an important role in times of depleting resources. Selected ionic liquids show a high extraction capacity for some metal ions which will make these ionic liquids interesting solvents.

Researchers from the University of Leuven, Belgium, have used ionic liquids to separate the rare earth metals neodymium and samarium from transition metals like iron, manganese and cobalt – all elements that are used in the construction of permanent rare earth magnets, which are found in electronic devices ranging from hard drives to air conditioners and wind turbines. Hence, recycling old magnets with ILs provide opportunities, so that rare earth metals can be re-used in electronics [Farrell 2013].

China has almost a monopoly concerning rare earths. This degree of dependence gives many Western governments an uneasy feeling, especially when the materials are so crucial to high-tech defense projects. Recycling is at least a partial solution to the supply-risk problem.

China has 37 percent of the world's accessible reserves, according to the British Geological Survey, followed by the former Soviet Republics that make up the Commonwealth of Independent States, then the US and Australia. But China supplies about 96 percent of the world's rare earth elements (REEs). Many green technologies are heavily dependent on the REEs, especially wind turbines and hybrid cars; each Toyota Prius hybrid car is reported to contain as much as 1kg of neodymium in its motor and 10-15 kg of lanthanum in its battery.

"Although less than 1% of rare-earth elements are recycled currently, 20% of global demand could be met in this way. By combining mining and recycling the western world could become largely independent of China in the future." [Farrell 2013]

Ionic liquids are also specified as "*designer solvents*." The choice of the cation or anion can affect other salt properties, including density, viscosity, and water stability and miscibility. Tailor-made ionic liquids were becoming increasingly important.

Ionic liquids form two-phase reaction systems with many organic product mixtures. In this way, *simple product separation* by phase separation and *easy catalyst recycling* is possible. Moreover, the lack of vapor pressure allows destillative separation of the product from the ionic catalyst solution without formation of azeotrops. In some cases the catalyst is even stabilized by the ionic liquid during distillation. Currently a growing variety of ionic liquids is becoming commercially available, a development that has fed the surge of research using these unorthodox liquids [Runge 2006:538-540].

One of the most widely heralded features of ionic liquids is the virtual absence of vapor pressure. Ionic liquids are "the ultimate non-volatile organic solvents." A great deal of attention has consequently been given to the use of ionic liquids as "green" replacements for volatile organic compounds (VOCs), which are being subjected to increasingly stringent regulations [ICB Americas 2004].

By theory about 10^{18} different ionic liquids are conceivable. The numbers of ca. 500-1,000 products for R&D and 10-20 different commercially available industrial scale products [Schubert 2008a] seem to be just a start for the new technical field. This ratio also demonstrates that *design of ionic liquids is a game with gigantic numbers and combinatorics*.

Though being rather fragmented into many relatively small markets this totally new technical area attracted not only some notable startups and NTBFs (Solvent Innovation GmbH and IoLitec GmbH in Germany, Scionix Ltd. and Bioniqs Ltd. in the UK), but also large chemical companies, such as the German firms Merck KGaA (which acquired recently Solvent Innovation GmbH), Cytec and Covalent Associates in the US as well as the chemical giant BASF in Germany.

Ionic liquids can be viewed as a *generic* and *platform technology* (Table I.12, Table I.51) with a very large number of commercially relevant applications as is shown by IoLiTec GmbH founder T. Schubert [2008a]. He lists 26 specific applications clustered into 6 different general areas. A corresponding slide in a presentation (available with the author) was published by IoLiTec already in 2004 [Schubert 2004], one year after its foundation. A corresponding list of applications was later also published by Short [2006].

Having such a *broad choice set of opportunities* requires careful selection and setting priorities. And the setting of priorities means usually making hard choices among conflicting (sub)goals.

But publicizing and illustrating the broad spectrum of applications for ionic liquids was not only meant to show what choices IoLiTec could make from existing options and which ones it finally made. The spectrum of applications was additionally made public to prevent any entrant to patent a particular application and thus constrain IoLiTec's further expansions into other applications of interest to them.

In search for commercial applications of ionic liquids and the necessity to reveal further opportunities ionic liquids startups had to closely watch results of the intense research efforts in the field. In this line startups focused on building broad and intense networks with academia and, in particular, to get leading scientists as members of their Advisory Boards.

Markets

The gross market of ionic liquids comprises research and development in academia and industry as well as components or auxiliaries for technical devices and machines as well as solvents for special technical processes (functional fluids).

Most industry observers reckoned that the chemical industry's interest in ionic liquids, mainly as a solvent, was kick-started only in 1999 by Solvent Innovation GmbH, founded in Cologne, Germany focused on the development, production and marketing of ionic liquids. Soon Degussa AG (now Evonik Industries) through its subsidiary Creavis Technologies & Innovation gained an interest in Solvent Innovation (B.2). Also in 1999 in the UK Scionix Ltd. (in Bioniqs Ltd. – B.2) was established.

"The purpose of the strategic partnership that we have entered with Solvent Innovation is to obtain ionic liquids as a new product category for large-scale production applications." According to a Degussa spokesperson around 2004 the company aimed to produce and market ionic liquids as specialty chemicals, particularly for technical applications, such as pigment-sensitized solar cells, high-capacity batteries, fuel cell membranes, plastics additives and special functional coatings. Degussa was rumored already to have commercialized a hydrosilylation reaction using ionic liquids [ICB Americas 2004].

Chemical giant BASF SE entered the field in 2002 and in the same year also the formation of IoLiTec GmbH occurred (in Cologne/Aachen, Germany).

Most of the applications of ion liquids that do come to fruition in 2006 were estimated to be relatively small. "Everybody is looking for the blockbuster – but it won't happen. There will be $1 million here and $5 million there, a lot of different uses in a lot of different markets." It was expected that in this way the worldwide ionic liquids business could add as much as $50 million annually in a very short time [Short 2006].

Sales projections by market entrants were understandably still vague in a business that was less than a decade old. For his startup IoLiTec (B.2) Schubert [2004] estimated the total market for R&D environments in 2004 to be €2.5 million per year and distribution to be via chemicals' catalogs of dedicated firms, such as German Merck KGaA or Sigma-Aldrich. These firms sell (and produce) its chemical and biochemical products and kits that are used in scientific and industrial research, biotechnology, pharmaceutical development, the diagnosis of disease, and as key components in high technology manufacturing. On the other hand, Schubert envisioned applications for sensors (for the detection of moisture, the use of gases and dangerous materials) to reflect a total market of €25 million per year.

Most ion liquids may have *very high prices*, €400 - €2,000 per kilogram. Economies of scale for ionic liquids would not exist soon, and their expense would slow their adoption. Costs, however, may be surmountable.

It was pointed out that "the price might look bad in the beginning, but it is always price-to-performance that is important." If the performance of an ionic liquid is 20 times that of the material it aims to replace, for example, a customer would need much less of the ionic liquid. Furthermore, one hears "*You always need to help a customer differentiate a product* from a competitor's or make a technology leap." "If the improvement is only incremental, you'd better forget about it." [Short 2006]

Experts fast dampened expectations arising from early research into ionic liquids – particularly when it came to forecasting widespread applicability. "Most of the ionic liquids that academia is playing with are new chemicals. They are not listed in regulatory framework. They can be used in research but can't be used in large quantities without *being registered with the authorities around the world*. And that, will involve considerable amounts of time and money." [Short 2006]

"In Degussa," the German large specialty chemicals company renamed to Evonik Industries, "researchers have some degree of freedom to work on potential projects and to be innovative. But once something becomes a bigger, controlled project, questions come up: Toxicity? Raw materials? Availability? Listing? These questions do kill some projects."

The willingness of large companies, such as Evonik, to encourage the use of ionic liquids will be a key to their widespread adoption.

More specific ionic liquids market segments and their magnitudes are described in the context of the cases of Solvent Innovation GmbH (B.2) and IoLiTec GmbH (B.2).

After 2005 large or giant global German firms like Evonik (Degussa), Merck KgaA or BASF looked for large-scale applications of ionic liquids and had increased their in-house production capacities to the multi-ton level for selected applications.

Some ionic liquids are not miscible in organic solvents, a property that BASF made the foundation of its BASIL technology. For example, the company produces alkoxy-phenylphosphines at multi-ton scale by reacting phenyl-chlorophosphines with alcohols [ICB Americas 2004].

Merck KGaA began working with ionic liquids for battery applications already in the mid 1980s, though the project was ultimately dropped, said its Urs Welz-Biermann. In 1999, the company was one of the co-founders of the QUILL network (Solvent Innovation GmbH, B.2), in which it took a fairly passive role, following developments and considering how it might use ionic liquids. In 2002, however, Merck restarted its own ionic liquids program. “We decided we would try to sell compounds and see if there was interest,” said Mr. Welz-Biermann.

Merck began a Web site offering a list of compounds, at that time over 250, many of them based on building blocks patented by the company. “We’ve put a lot of effort into analytics,” he adds. “We’re doing the business a different way from other companies-not just putting together a catalog of compounds, but also giving specific data like melting point, solvation, etc., to help customers begin working with new compounds.” [ICB Americas 2004]

Merck made most of its ionic liquids in-house at its headquarter in Darmstadt, Germany. Large volumes were not a problem, according to Mr. Welz-Biermann – a new multi-purpose facility built for the company’s liquid crystal business was also available for manufacturing ionic liquids in the hundreds of kilograms.

While large firms, such as BASF SE and Merck KGaA, have multi-purpose plants for large production levels economies of scale as, for instance, found for biofuels (A.1.1) or solar cell manufacturing (Figure I.154), this did not exist for NTBFs and their ionic liquids. Without economies of scale the related little reductions of expense and price of ionic liquids also slowed adoption of their offerings.

“The success of ionic liquids will not necessarily be equated with large-scale chemistry,” noted Prof. Robin D. Rogers, at the University of Alabama, Tuscaloosa. As most applications will be small, usually only a couple of tons of ionic liquid per application per year, a micro-reactor that can quickly be configured to produce different types of ionic liquids on a kilogram-per-day scale could be an advantage. For IL NTBFs scaling-up via micro-reactor technology (MRT) has turned out to be the *technology of* *choice for small and mid-sized companies to face the challenges of scale-up* (IoLiTec GmbH, B.2).

In their early phases ionic liquids startups usually relied on joint production alliances with large firms (mostly Merck KGaA) to produce larger volumes of ILs, say more than 1 metric ton. But concerning the issue of scaling-up startups also considered limiting themselves concerning production capacities.

For instance, Claus Hilgers, the co-founder of Solvent Innovation GmbH said [Short 2006]: “We could extend up to 50 or 100 metric tons, but that’s it. We won’t go beyond that. We are positioned between the global players and the small guys.” If his company needs significantly larger quantities, he added, it would work with Degussa (Evonik), BASF, or another large company to actually produce the compounds.

Entrepreneurial Startups in Ionic Liquids

The *industry’s concept of what ionic liquids can do* has evolved significantly over the last years. Advanced materials and functional compounds, such as high-performance lubricants, thermal fluids, and dispersion of nanoparticles, became major directions.

In 2010 the ionic liquids markets worldwide was forecasted to reach $3.4 billion by 2020 from 300 million that year. Catalysis and synthesis are seen as the biggest applications by value. German and US companies lead the market and developments with a share today of 70 percent [Helmut Kaiser Consultancy 2010].

Generally, IL startups could take advantage from the *general interest in the field* in academia *and* industries – at least in Germany. A serious entry of startups into commercialization began around 2005.

Around 2006-2007, for instance, to push growth in *promising technical directions* and development of the markets by sales professionals Solvent Innovation looked to catch €2 million of investment capital (B.2) and IoLiTec looked for €3.5 million investment capital. In parallel, *scientific research* on ionic liquids progressed with fast pace. A host of known academic groups was busily expanding the limits of what is known about ionic liquids.

As a consequence, IL startups must *keep knowledge about the developments* of new classes of materials, including their applications and potential markets.

Computer-supported prediction of the performance and properties and simulation of ILs turned out to be mandatory to manage the myriad of continuously created new data and also to respond to *customized solutions for clients*. IoLiTec and Bioniqs run (ran) related computer systems. The issue here is often a trade-off between properties, for instance, hydrophobicity (water-repellent; tending to repel and not absorb water), thermal stability and price versus biodegradability and corrosiveness [Sahin and Schubert 2012].

> "If a new material is to be accepted as a technically useful material, the chemists must present reliable data on the chemical and physical properties needed by engineers to design processes and devices." – Lowell A. King, Pionier of Ionic-Liquids-Research

The startups had to continuously adapt to their environments by changing their *business model*s and *organizational structures*, having sufficient *financial resources* and establishing *networks* with appropriate universities and public research institutes and *cooperation* with industrial partners which are potential customers and participate in corresponding *project consortia* – utilizing public R&D and public financial support.

They had to continuously work on *reducing the price* levels of the offerings, but simultaneously *keeping the quality*. For ILs quality is associated with purity, and purity usually translates into performance of the ILs. *Collaborative projects* are a preferred method of *introducing materials to the market place as an optimized process solution*.

Furthermore, in the sense of *"technology push*" (ch. 1.2.5.1) and commercialization of the technology startups had to *develop their market*s and fight for market share. If ILs occur in the market as a *new technology* or if ILs appear as an *enhancing* or *generic technology*, fight is against other, often well established technologies in the market.

The above requirements represent important factors and conditions against which the fates of the startups mentioned in the introduction can be discussed, considering additionally the role of the Great Recession.

Solvent Innovation GmbH

The *RBSU* Solvent Innovation GmbH (B.2) survived the Dot-Com Recession around 2001, as did Scionix Ltd. in the UK.

Solvent Innovation GmbH (SI) was founded in 1999 by Claus Hilger and later Prof. Peter Wasserscheid, a worldwide renowned pioneer and expert in ionic liquids, as a spin-out of the Technical University (RWTH) Aachen in Germany.

By January 2008 the German firm Merck KGaA :took over SI with ten employees at that time and integrated it into Merck's Performance & Life Science Chemicals unit, but it continued to operate as "Merck Solvent Innovation GmbH." In this regard Solvent Innovation shared the fate of another spin-out of the Technical University (RWTH) Aachen, Puron AG, which also was acquired by a large firm after a couple of years ([Runge 2006:95-96]; Table I.41, Figure I.73).

Before foundation of Solvent Innovation in 1999 availability of ionic liquids in commercially relevant quantities did not exist. A small number of systems for laboratory experiments could be purchased from catalog firm Sigma-Aldrich [Wagner and Hilgers 2008]. Furthermore, Cytec, Acros and other "catalog firms" had supplied the laboratory market with ionic liquids for years.

Having the adequate entrepreneurial mind-set Claus Hilgers went in 1998 to the Technical University (RWTH) of Aachen. Under the leadership of Dr. Peter Wasserscheid a working group emerged that dealt with the synthesis and applications of ionic liquids and Hilgers performed his doctoral thesis in this group. At that time industry became more interested in ILs. And as they were not commercially available, Wasserscheid's workgroup received an increasing number of requests for samples.

Talks with industry professionals indicated that *people wanted the ionic liquids and were willing to pay for ILs*. When development of demand reached a certain level, Wasserscheid und Hilgers recognized the opportunity for a business and founded Solvent Innovation GmbH.

Such an entrepreneurial situation starting already with industrial or academic customers is often observed with RBSUs, such as WITec GmbH (B.2), Attocube AG (B.2), Nanion Technologies GmbH (B.2) in Germany or Cambridge Nanotech (B.2) in the US.

The company's founders were both pioneers in the development and application of new ionic liquids with enhanced efficiency. The most significant research results of Wasserscheid and Hilgers were combined to form a unique technology platform, the AIMFEE™ technology (Advanced Ionic Materials for Enhanced Efficiency), which was seen as the basis and a powerful tool for numerous potential applications in life science and chemical synthesis as well as catalysis and material science.

SI's *technology was protected by a number of patents* (or patent applications, respectively).

In the early days Solvent Innovation viewed itself as a partner for systems solutions in the field of ionic liquids rather than only a producer. I*t also offered custom synthesis of specialties and contract research.* Early customers included the big names in the chemical and petrochemical industry.

For foundation and further developments SI followed the typical entrepreneurial path of a German RBSU.

Solvent Innovation did not need external financing during its startup thrust phase (ch. 4.3.2; Figure I.125), its first three to four years of existence [Hilgers 2006]. On the one hand, the founders could utilize the laboratories and the infrastructure of the university. Furthermore, after Hilgers' scholarship for his thesis ended the program PFAU ("Programm zur Finanziellen Absicherung von Unternehmensgründern aus Hochschulen") of the State Government of Northrhine-Westphalia secured his cost of living.

The program financed founders of the state universities for a maximum of two years by a quasi-salary. Hence, Hilgers did not need to make revenue, but could concentrate on developing the business. Hilgers was supported by PFAU for the period July 1, 2000 until June 30, 2002.

The time of the PFAU scholarship was used essentially for generating a technical Proof-of Concept (PoC), developing concepts for financing and distribution and market tests. During that period also two new processes were developed with the claim to reduce production cost by 35 percent and increasing quality and SI submitted these as patent applications.

Solvent innovation could not finance growth which required also a new location by sufficient own revenues (profits) and, hence, looked for an investor. As there where already contacts with the German large specialty chemicals firm Evonik Industries (named Degussa at that time) Hilgers succeeded in getting Evonik on board as a third (minority) partner for the GmbH (LLC) in 2003. It complemented its growth financing deal together with capital from a public investment organization.

In February 2004 Solvent Innovation moved to its new site at the Biocampus Cologne, a sort of technology park. Since 2004 Solvent Innovation manufactured its products in Cologne and had an option on the neighboring building so that its site could be extended without problems.

Business orientation was driven essentially by the fact that published research results indicated that the unique character of ionic liquids could open up new “solutions” for catalysis and organic synthesis emphasizing the “green” character of *ionic liquids for chemical processes* in terms of

- replacing volatile organic solvents,
- minimizing the consumption of catalyst,
- enhancing the overall activity and selectivity of chemical processes.

In order to meet *rising market demands for ionic liquids in larger quantities*, in 2005 Solvent Innovation increased its capacities distinctly with the acquisition of a new 100 l plant. Together with the already existing 25 l plant and two 20 l reactors at that time Solvent Innovation had an annual production capacity of more than 5 metric tons.

Between 2005 and 2007 within Solvent Innovation a *business re-orientation* emerged. The industry’s concept of what ionic liquids can do had evolved significantly. Therefore, Hilgers changed the business model. Over time it had turned out *that positioning and commercialization of ionic liquids as a replacement of organic solvents for syntheses were not sufficient for distinct growth.* Solvent Innovation should no longer be viewed as only a producer of solvents – mainly used by academic research

SI turned to *materials and functional compounds* – for industrial customers.

And there was a new business model. Organizationally, SI could expect its impressive list of persons on the Advisory Board to be helpful for the re-orientation. Products would be sold directly via a *catalog business* or via *distributors*. SI then focused on the fields of

- Separation
- Analytics
- Organic Synthesis
- Enzymatic Biocatalysis
- Electrochemistry
- New Materials.

This shift of emphasis away from the solvent aspect was associated with addressing a *different type of customers*. And the firm had to learn that for the market of functional materials the times from first contact to applications with the existing customers were significantly shorter. Until an industrial customer replaces a solvent in a running process an extremely long time will pass. Other applications of ionic liquids can be implemented within one or two years [Hilgers 2006].

Solvent Innovation strove for becoming *a systems and solutions provider*; it offered the complete portfolio of *customer services, joint development, consultancy*, and so on.

Solvent Innovation offered two kinds of products [Wagner 2006a, 2007]:

- Platform products – pure ionic liquids
- Integrated products – finished formulated products and masterbatches.

A masterbatch is a product in which components (often pigments and/or other additives) are already optimally dispersed in a carrier material that is compatible with the main target/material in which it will be used. Integrated product classes of SI with market potentials of €300 million to €500 million were, for instance,

INNOLUBE™ High-performance lubricants and electrically conductive lubricants	INNOLUBE™ acts as an electrically conductive lubricant for a bearing in frequency-controlled motors
INNOVAC™ Liquid for vacuum pumps and compressor fluid for screw compressors	INNODISPERS™ Dispersing agents for nano-particles
INNOSTAT™ Anti-static agents for plastics and coatings	AMMOENG™ acts a dispersing agent, for instance, for homogenization of color pigments

However, it appeared that most of the products had still the status of *prototypes*. For instance, the prototype INNOSTAT™ anti-static agents, such as INNOSTAT™PU or INNOSTAT™PVC or INNOSTAT™PC targeted the polymers and plastics commodity markets of polyurethanes, polyvinylchlorides and polycarbonates which, however, are produced since decades on a million tons level relying on an established set of highly competitive suppliers of processing aids and additives.

To replace existing anti-static agents for well established and optimized manufacturing processes would mean that “technical specification of customers met,” as noted by Wagner [2007] for INNOSTAT™PU, does not suffice. SI had to fight against switching costs and convenience and customers taking the risks these additives to function not only in a laboratory or 500 kg level pilot plant, but in a multi-million tons plant.

In 2006 SI targeted an institutional investor to finance finishing its “products” and the development of the market by sales professionals.

According to SI’s Head of Marketing & Sales M. Wagner the biggest risk was associated with the *challenge of efficient market penetration* for the newly developed products INNOLUBE™ and INNOSTAT™.

By January 2008 the German firm Merck KGaA acquired SI. The takeover meant *acquisition of technical know-how and experience*. Furthermore, Merck obtained additional production capacities and products to access new markets with the high-performance lubricants and antistatic agents for plastics.

SI was slow in transforming science into businesses providing sufficient revenues compared with its direct German competitor IoLiTec whose most important co-founder was a former employee of SI. It lacked sufficient financial resources to drive pilot products into commercial offerings and lack of human resources to sufficiently support the successful entry into lucrative markets by technically versatile professionals.

Bioniqs Ltd.

As Solvent Innovation GmbH in Germany also in the UK the *RBSU* Bioniqs Ltd. (B.2) was founded (in December 2004) by an *entrepreneurial pair* consisting of a scientific co-worker or graduate, respectively and a professor.

It provided designs and developed proprietary ionic liquids (ILs) which aimed to facilitate and improve *biochemical and biocatalytic processes in industry*, particularly in the chemical, pharmaceutical, paper and textile sectors. It addressed a heterogeneous set of industrial processes, from bioconversions and chemical synthesis to analytics (chromatography), extraction of natural products and decontamination/cleaning.

Bioniqs was set to be profitable by the end of 2007 [RSC 2007]. However, Bioniqs went bankrupt and was dissolved in November 2011.

Founding Bioniqs had a biological origin and perspective. It was essentially *science-driven* based on attitudes and activities of Adam Walker who wanted to work at the interface between biology and chemistry. For a study for a PhD to find a way to integrate biological catalysts into the preparation of an opioid analgesic Walker joined Neil Bruce, then at the Institute of Biotechnology at the University of Cambridge, UK.

Walker realized that the intermediates in the path to that analgesic are poorly water soluble, but enzymes only function in a water-based environment. In the attempt to solve the problem Walker came across using ionic liquids as solvents. Eventually he succeeded in chemically modifying an ionic liquid to make it resemble water more closely, so that his enzymes and drug intermediates remained stable in one solvent.

Towards the end of his PhD, Walker had the business idea that *replacing water with modified ionic liquids as solvents for industrial applications* would be commercially viable – and a related startup would not seriously interfere with other IL startups operating already in the UK and Germany

And he decided to set up a spin-out company, Bioniqs, with Neil Bruce. The University of Cambridge filed the patents for their "designer solvents," but before Walker and Bruce could set up a spin-out company in Cambridge, Bruce was offered a position as chair of biotechnology at the Centre for Novel Agricultural Products (CNAP) at the University of York, UK.

Bruce and Walker moved to CNAP and they "designed an ionic liquid that would mimic water, but would not hydrolyze enzymes" – "Second Generation Ionic Liquids." They thought they can *develop tailor-made ionic liquids at a competitive price*.

They positioned their technology as an *enabling technology* (Table I.12) which means, *you can do things that you cannot do using existing processes.* Furthermore, the new company would be based upon a *strong patent portfolio* arising from work performed at the Universities of York and Cambridge.

Bioniqs aimed to *generate revenues through design and process development (royalty stream on sale of licensed products), not manufacturing* – hence, exploiting opportunity by alliance rather than competition with major IL manufacturers. Bioniqs also offered *contract research and consulting services.* Its major target *markets* were in the *pharmaceuticals and fine chemicals sectors*.

By type there were two customer segments, industrial customers (*solvents for industrial enzymes*) and customers from academia and public research institutes. But, *de facto* the consultancy element of what Bioniqs did was really helping the firm to understand and develop its own products rather than generating a stream of revenue.

To fill roles of CEO and director of operations for growing a company quite literally from scratch and *pushing new technology into almost non-existing markets*, a "technology push" situation, Walker had to master a steep learning curve.

CNAP in York took a very proactive approach to spin-outs. In the *York Science Park* as its location Bioniqs had an analytical room where ionic liquids were designed and a synthesis suite, where the resulting liquids were produced in small scale. In York they also found a partner in Amaethon Ltd., a technology commercialization company specifically created to commercialize CNAP research. *Financing* was through *own and public sources* as well as *private investors*.

IL research of the then founders of Bioniqs was also funded by the ProBio Faraday Partnership and BBSRC (Biotechnology & Biological Sciences Research Council).

In 2006 Bioniqs could take advantage of Connect, Yorkshire's Fast Invest Scheme – a program that offered technology businesses loans of up to £50,000 combined with business mentoring (at January 2007: 1 £ = 1.52 € = 1.96 $). To help Bioniqs' transformation from a purely development focus to one of sales and growth, Fast Invest allowed Bioniqs to recruit a business development manager, an experienced commercial director on a consultancy basis.

Also in 2006 Bioniqs established a partnership agreement with the large German chemicals firm Merck KGaA (Darmstadt). Through this partnership, *Merck KGaA manufactured and distributed through its catalog a selected range of Bioniqs' proprietary ammonium based ionic liquids.*("catalog business").

In 2007 the Yorkshire Forward Bioscience award for the "Young Company of the Year" was given to Bioniqs.

By 2006/2007 with ionic liquids as solvents and its application in the chemical and pharmaceutical industries Bioniqs put its focus largely on production processes via production and distribution alliances with *IL as solvents or auxiliaries* for *decontamination and cleaning* of process reactors and recycling processes as well as *extraction of natural products from biomass* and *biocatalysis*.

It hoped to *take advantage from the "green chemistry" and CleanTech trends* which emerged clearly by 2005/2006. As a differentiator, Bioniqs *positioned* its offerings on identification and design of environmentally friendly solvents that offer performance and efficiency improvements over many hazardous materials and as a *timely service* – as many conventional solvents were becoming more difficult and expensive to use due to increasingly stringent environmental and safety legislation, such as the so-called REACH registration for Europe. This would tend to require replacing substances and solvents because of their negative environmental impact.

As there was (and is) much discussion about the notion and the understanding of "green solvents" as a *marketing tool* Bioniqs introduced and promoted a green solvent certification (named "*econiqs*") in response to confusion over the reality of claims made about "green chemicals" and many novel solvents.

As a *further marketing instrument*, ahead of its 2009 product catalog, Bioniqs launched three solvent kits – "Product Catalogue Starter kit," "Low Viscosity kit" and "Hydrophobic kit." These offered a representative selection of ammonium salts and would *address researchers who are new to protic ionic liquids* (PILs).

The *cleaning business* promised to be multi-scale tons envisioning tailor-made ionic liquids for dissolving poorly soluble active pharmaceutical ingredients off the walls of reactors.

In 2008/2009 Bioniqs was successful in winning funding from the UK government to design solvents that will enable some *plastics (high performance polymers) to be re-*

cycled more efficiently. The related HiPerPol project aimed to enable polymers to be separated from plastic waste-streams.

As Bioniqs strived for assisting the customers in developing increasingly sustainable, safe and ecologically efficient working practices it used its “solventS” service to work with their customers to develop solvents which they claim are *optimized for their technical, economic and environmental performance*.

This service was made by the *high-throughput screening and design capabilities* of Bioniqs *solvent modeling software* and proprietary *database* of over 12 million solvent permutations (including both ionic and molecular solvents). The ROSETTA solvent simulation database [Newton 2009] combined advanced structure-property alignment tools with a series of databases to evaluate the performance and properties of solvents along with other requirements, such as cost and toxicity/environmental impact.

Concerning the potential of “*extraction of natural products*” for ionic liquids Bioniqs had, for instance, successfully extracted *artemisinin (*also called *artemesinin*), the anti-malaria drug precursor (Table I.99, Amyris), from both fresh and dried plant material following an *in silico* solvent design process (performed on computer or via computer simulation) from a database of some 350 proprietary ionic liquids. In 2008 Bioniqs had secured £50,000 of investment to enable continuing to fund its work with artemisinin.

But, Bioniqs’ approach to artemisinin extraction turned out to be a scientific investigation rather than a recipe for implementing a real process – it was not a demonstration of the artemisinin extraction process at scale and fulfilling the commercial potential of Bioniqs’ ionic liquid. The study revealed that further fine tuning can lead to the end product of an ionic liquid optimized for the needs of the real process. A set of process parameters were revealed and it was recommended that these parameters are used as the basis for a final product specification and that multi-parameter screening is used. In addition, the involvement of chemical engineering specialists was recommended (B.2).

On foundation in 2004 Bioniqs consisted of three people, but was growing to employ eight people in 2007. But the financial decline of Bioniqs towards a financial collapse was already reflected by some financial indicators, such as “cash at bank” and “net worth,” comparing 2006 and 2007 data. After five years of existence, Bioniqs was no longer viable, the liquidation process started by the mid of 2009 (B.2).

There were still tremendous *issues of market entry* in terms of *cost of ILs* and *replacing existing processes* including a fight against switching cost and attitude and risk aversion of customers to implement a totally new technology – industrial customers did not want to act as the “guinea pigs.”

Bioniqs Ltd remained largely a *curiosity-driven research endeavor* with (probably) meager revenue in an entrepreneurial environment relying on perceived potential or unexpected commercial opportunities without a clear identification and focus on its major markets and executing related market entry – or, at least, convincing demonstrations.

Over its time of existence Bioniqs can be assumed to have had little direct, sufficient contacts with the market and its customers. Competing with other IL startups concerning contract research and consulting services for revenue generation may have suffered from the same services offered by the more established other IL startups. The end was a state of the firm without enough cash and probably no chance for further financing due to the Great Recession.

IoLiTec GmbH (and Scionix Ltd.)

Ionic Liquids Technologies (IoLiTec) GmbH (B.2), founded in 2002/2003, has been cited already in various contexts in this book as an example to illustrate particular entrepreneurial situations. The current discussion shall focus on IoLiTec's development and position in emerging markets based on its technology push approach. IoLiTec emerged as a rather successful NTBF and the most successful of the ionic liquids startups.

IoLiTec is engaged in top value technology (TVT, Table I.1). Its founder reported several times that *IoLiTec made always a profit since its foundation*. It shows continuous growth by various indicators. For instance, after six years of existence it had 12 employees, whereas on average the number of TVT startups' employees after 6-8 years is 8 (Table I.70). The Compound Annual Growth Rate (CAGR, Equation I.10) of employees between 2005 and 2012 is 17.8 percent.

Contrary to all other IL startups which are university spin-outs (RBSUs) IoLiTec GmbH is an "academic startup" (Table I.2) and is special by four facts.

- It started with a customer, which eased getting further financings via banks.
- It comprised a team of experienced founders in the ionic liquid fields and in industry.
- The key founder Thomas Schubert worked as a "post doc" with Professor Peter Wasserscheid at the Technical University (RWTH) in Aachen (Germany), a worldwide renowned pioneer and expert in ionic liquids, and worked already for 18 months for Solvent Innovation as a Leader of Distribution, with responsibilities for technical synthesis and marketing of ionic liquids. In Aachen he also met one of the then co-founders of IoLiTec.
- The founder team fell apart rather soon, but without serious troubles. Thomas Schubert replaced one of the co-founders by an angel investor in 2004 who took over responsibilities for taxes, finances and law. In 2006 the second co-founder left IoLiTec to further pursue his scientific career at a university (with Professor Peter Wasserscheid).

The firm was born in a climate of excitement about ionic liquid technologies in Germany and also the UK (Scionix Ltd. in the Bioniqs Ltd. case, B.2) that was shared between academia and industry and embedded in a “green” attitude of society and policy. There was (and is) much support by related joint projects (ch. 1.2.6, Figure I.40, Table I.92) financed by federal and state governments and non-governmental organizations (NGOs), such as the Deutsche Bundesstiftung Umwelt (DBU; The German Federal Environmental Foundation).

DBU is one of the largest foundations in Europe. It promotes and funds innovative and exemplary projects for environmental protection. And IoLiTec’s development projects represented what in Germany is called “*sustainability innovation*” (ch. 1.2.5.1; [BMBF 2007]) – or, at least, paths to sustainability innovations.

IoLiTec had to successfully respond to a number of issues associated with ionic liquids and to achieve competitive advantage.

- A *technology push* situation with very many fragmented rather small markets
- A *science-driven environment* in which technical developments by firms are continuously associated with external scientific developments. It was not to use just one key scientific effect or result which had to be commercialized as a technical solution and subjected to further developments
- Success of ionic liquids will not necessarily be equated with large-scale production
- Economies of scale for ILs do not exist yet for ionic liquids as, for instance, for biofuels (A.1.1) or solar cell manufacturing (Figure I.154). Hence, their slow reduction of expense and *high prices* will also slow their adoption
- A *special situation for scale-up* of production.

IoLiTec founders selected carefully the *location* of the firm in the city of Freiburg and its BioTechPark, having had in mind networking with academia in the science-driven field.

> Massive networking with academia, public research institutes, and industrial firms as *external resources* (Figure I.125, Figure I.170) became a typical feature of IoLiTec’s further development.

During its first three to four years of existence, its *startup thrust phase* (ch. 4.3.2; Figure I.125), IoLiTec was in search for lucrative applications and markets and developing “experimentally” its business model. *Major customers were from academic and industrial research groups* [Schubert 2006a].

IoLiTec elaborated a rather large *opportunity options set* (Box I.13, ch. 5.1) of a *platform technology* from which to select the most promising opportunities for the firm. The options were related to the various broad application fields matching relevant properties of the ionic liquids technology. Furthermore, *priorities* had to be established.

The derived technology strategy and associated marketable products and strategy evolvement over time, consequently adapting the firms organization to the strategy and implementing and executing the strategy, represented the framework for IoLiTec's development over its first ten years of existence.

Evolvement of IoLiTec's organizational and network structures are presented by graphics in the case description (B.2). These reflect the increase of complexity of the firm, changing functions and roles for the leadership team and developing applications (businesses). In the case description (B.2) it is also exemplified how IoLiTec achieved a competitive advantage.

In its early days around 2004 IoLiTec's offerings had two components.

- (Bio-)analytical applications (IoLiTec offered new materials that could make the life of biochemists and scientists from other disciplines much easier.)
- Consulting and custom R&D.

Additionally, anti-static fluids – functional fluids for the use on glass-surfaces – were offered. Activities in nano-particles and sensors were planned.

Concerning *intellectual properties* (IPs) by 2005 IoLiTec had submitted eight patent applications and owned some trademarks (for instance, IoLiTive®, IoLiTherm® and IoLiSens®).

Around 2005 IoLiTec decided to focus on the following five areas for commercialization:

1. Contract R&D services
2. Special Chemistry (Ionic Liquids)
3. Sensor technology
4. Energy
5. Nanotechnology

IoLiTec ran own R&D, but contract R&D to generate revenues.

> Since then, fundamental and necessary R&D for all these areas was partially pursued by *participating in publicly funded projects*, essentially the typically German joint projects ("Verbundprojekte"; ch. 1.2.6, Figure I.40).

Joint projects cover universities, public research institutes, and small and mid-sized firms. They are often initiated out of "*competence networks*" (Figure I.39) in which IoLiTec also participated. This did not only broaden the scope of IoLiTec's network, but provided also many contacts to and cooperation with potential customers and was used to enlarge its group of Scientific Advisors. Project money always represented *an important revenue stream* for IoLiTec.

Running almost continuously R&D projects, publicly financed by the German Federal Ministry of Education and Research (BMBF), Federal Ministry for Economics (BMWi) and the Deutsche Bundestiftung Umwelt (DBU), was (and is) central for financing IoLiTec and running its own internal applied R&D.

IoLiTec *increased systematically its knowledge base* and set up *computer-supported technology intelligence* focusing on literature and patent search activities. These are the basis of knowing the state of the art und current awareness about new developments. The *systematic activity* of “current awareness” and “state-of-the-art” knowledge based on the scientific literature and patents became the basis for related databases – and to provide an IoLiTec newsletter as well as consulting activities and design of new ILs or customized ILs.

As a *marketing instrument for technology push* IoLiTec launched its free newsletter “Ionic Liquids Today” already in March 2005. It does not only provide news about IoLiTec’s products and their applications and cooperation set up by IoLiTec, but reports also on scientific and technical progress in ILs.

In 2005 IoLiTec moved out of BioTechPark Freiburg to a new location in Denzlingen very close to Freiburg due to more favorable cost of needed facilities. And since 2006 IoLiTec acted also as *a distributor for other IL firms*. It made phosphonium ionic liquids of the US firm Cytec Industries available.

Within a huge joint project (called NEMESIS) IoLiTec engaged intensively itself with the scaling-up technology via micro-reactor-systems. Micro-reactor technology (MRT) is the *technology of choice for small and mid-sized companies to face the challenges of scale-up*. Another aspect during the project was the development of concepts for efficient *recycling of used ionic liquids*. One micro-reactor was set up in 2008, in 2009 IoLiTec built its second micro-reaction system.

Furthermore, micro-reactor technology was assumed to be not only the means for scale-up, but also for *quality management* and to *reduce the prices of ILs*.

By 2007/2008 IoLiTec had a growth strategy in place with a corresponding organizational structure and a related requirement of investment (Figure 4 and Figure 5 in the case description, B.2). As T. Schubert did not succeed getting finances from banks he turned to an investment firm, the “Zukunftsfonds Heilbronn” (ZFHN). The venture capital fund acquired a 30 percent stake in the technology firm and IoLiTec had to move its location from Denzlingen to that of the investor, to Heilbronn (Germany).

Preparing for the move to Heilbronn had consequences for the original plans of IoLiTec. Activities in R&D projects were reduced and its intention to establish a subsidiary in the US was delayed. Though in 2009 IoLiTec, Inc. was incorporated as a one-man-firm in the Business Technology Incubator at the University of Alabama in Tuscaloosa. But it started the operative business only in April 2010. The selection of the location in Tuscaloosa followed very rational arguments.

After Europe the US is the most important market for ILs – and simultaneously there was no IL startup. Out of a small office the IoLiTec representative is contacting North

American companies, universities and researchers interested in ionic liquids. ILs are shipped to Tuscaloosa from Germany, and IoLiTec Inc. then fills the orders for North American customers.

Having established its distribution organization for ILs, marketing and sales of ionic liquids *have remained tough as they remained expensive* due to the difficulty of manufacturing them. Much of the difficulty is associated with purification. Hence, *recycling* of ILs played an important role to support sales. But, in 2010 IoLiTec opened another revenue stream, i*onic liquids rental service*. IoLiTec claimed to be an industry first with renting ionic liquids to customers.

By the end of 2011 IoLiTec achieved a status concerning the level of progression from R&D via piloting to commercialization of offerings which is depicted in Figure 6 of the case description (B.2) and which also indicates the state of *executing the strategy*.

IoLiTec has positioned its ionic liquids in the "*low volume, high value*" segment of specialties. The diversified orientation of offerings and industry segments makes *IoLiTec rather independent from economic ups and downs* of the addressed industries. Growth of the number of employees across the period of the Great Recession (Table 2 of the case description, B.2) corroborates this.

Several metrics for IoLiTec show that the firm grew considerably and healthy and since 2006/2007 has accelerated its development. Characteristics of IoLiTec's growth are:

- *Innovation persistence* (ch. 4.2.3, Figure I.115, Figure I.127)
- Strong *customer orientation*
- *Execution* of a longer term strategy and
- *Diversification* of applications and continuous expansions of its basis of ILs as its *platform technology*.

Concerning the competitive landscape, as described in the IoLiTec case (B.2), there was no serious competition with the very few large firms active in ILs except probably with Merck KGaA which acquired the NTBF competitor Solvent Innovation GmbH in 2008. IoLiTec operates in lucrative niches and for large firms like BASF the related markets and volumes of production are too small to be of interest. IoLiTec operates complementary to the large firms.

Concerning the IL startups during its life-time Bioniqs Ltd. (B.2) has never been a competitor of IoLiTec. Bioniqs focused largely on ionic liquids as solvents and on application in just the chemical and pharmaceutical industries.

The remaining competitor from the UK, Scionix Ltd. (in case Bioniqs Ltd, B.2), shows few fields that could become competitive areas, if Scionix would leave its two key markets

- Electrochemistry (metal deposition and electropolishing, metal recovery) and
- Process technology (metal extraction including catalyst recycling).

Scionix' ionic liquids are essentially based on choline chloride promising mass product related ionic liquids which could be assumed to be applicable to large scale processes. One basic orientation of Scionix is ILs to offer *a clean way to carry out chemical processes avoiding strong acids* (removing harsh acid-based processes).

Scionix is a joint venture between the University of Leicester and Genacys Ltd. (a wholly owned subsidiary of the Whyte Group Ltd). The company was set-up in 1999 to commercialize the industrial use of a novel class of solvent systems, focusing on ILs.

Scionix pursued *an entrepreneurial process which is quite different from IoLiTec's approach*. It follows the narrow path of a university/industry cooperative organization. This Private-Public-Partnership (PPP; A.1.3) allows fundamental and applied research to be carried out at the university while providing the production, marketing and licensing capability by the private organization. The essential structure in case of Scionix attributed a dual role to Prof. A. Abbott of the University of Leicester (UK) to be a research leader at the university and as a co-founder to act as the Research Director of Scionix.

The PPP construct involves Whyte Group Ltd. which is Britain's largest privately owned chemical company and has a number of diverse activities, including manufacturing, distribution and R&D. The flagship of the group is Whyte Chemicals Ltd., one of the largest private distributors of chemicals and polymers in the UK and it also manufactures pharmaceuticals – and ultimately also ILs.

The interrelations between Leicester University and Whyte Group are mediated by Genacys Ltd. Genacys is a special external organization of the Whyte Group acting as a *corporate venturing company (CVC)* and on the basis of bringing together research ideas and entrepreneurial spirit, targets to turn early-stage technologies into separate successful corporate entities through collaborations, strategic partnerships and joint ventures.

Contrary to IoLiTec which pursues many links with industrial firms and universities and public research institutes Scionix concentrates essentially on only the University of Leicester and Whyte Group. This means, Scionix' access to external resources for research, development and commercialization and competitive strength are rather small compared with those of IoLiTec.

With regard to the IL NTBFs IoLiTec's *competitive advantage* is discussed in the case description in terms of the VRIO attributes of a resource-based view (RBV) (ch. 4.3.3,Table I.75):

A final remark concerns entrepreneurship and innovation with high priced offerings. In contrast to, for instance, German Smart Fuel Cell (SFC) AG (now SCF Energy AG) which could sell its fuel cells systems in niche markets (such as leisure, recreation vehicles, military) with customers with high purchasing power [Runge 2006:331-335] for ILs there are no such opportunities. An entry into a broad industry segment through a market with high purchasing power occurred also when William Henry Perkin (A.1.2) introduced his synthetic mauve dyestuff [Runge 2006:293-294].

A.1.6 Formalization of Structures of Founder Teams and Architectures of New Firms

Dealing with “architectures,” “configurations” (ch. 4.3.2; Figure I.124) and ultimately taxonomies of new technology ventures (Figure I.128) relates to several complementary aspects of subjects or objects of a set: “identification,” “distinction” and “similarity.”

Such concepts play an important role to describe the development of new firms in terms of biological analogies. The discipline that provides *metaphoric explanations* of firm or industry segment growth is Developmental Biology [Runge 2006:7; Bhidé 2000:249].

Developmental biology relates to three key concepts, similarity, homomorphism and heritage versus analogy (actually function-analogy). Two structures are *homologous*, if they *look similar* and the *similarity* is due to descent from a *common ancestor* possessing the ancestral version of the part in question (Figure I.190). If two structures are *analogous* there is *no common ancestry* and the parts look similar as the pressure of natural selection has forced a convergence of structure to meet *the need for similar function*. In biology *identity* of form or shape or structure is termed isomorphism.

Fundamentally we dealt with sets of n entities, objects or states, and their representations in terms of the “Diagram Lattice” (with Young Diagrams) which are related to *partitions of an integer n* (Figure I.73, upper right). This means decompositions of n into a sum of integers and is related to permutation algebra to deal with structures of founder teams and discuss *issues of coordination* (Figure I.72 – Figure I.74).

In essence, there was a proposition that structures and attributes can be associated with meaning. For instance, in Figure I.73 we have introduced a binary differentiation of weak and strong *coupling of (structural) subjects* based on the subjects’ attributes. Sharing the same attribute has been *interpreted* as “strong coupling” requiring much less efforts of coordination – for instance, by reference to effects of “boundary spanning” (ch. 1.2.3).

Using Young Diagrams, in a similar way as coordination, one could also represent and discuss *social ties* of the members of a founder team (social coupling, Figure I.71).

Furthermore we used *partial orders* of Young Diagrams (Figure I.74) which are related to moving boxes within a Young diagram and illustrated that in Figure I.73 (lower right). The WITec GmbH case (Figure I.73, lower right) provides a special example for dealing with *homology* without changing the number n of objects due to a common ancestor (here the column with three boxes).

In discussing development of new ventures Young Diagrams [119] provide also a mode of (structural) relations of relevance for mappings and representations of the current subject of interest. That is, the relations generated by adding or removing a box providing *relations for build-up processes*.

> From a systems point of view in the realm of entrepreneurship we are dealing with small numbers of components (2-30), often numbers between 1 and 8-12. For systems of such smallness (the lowest level of "organized complexity") one can expect that adding or removing just one component may have a significant effect for a team and/or the firm.

To discuss structures and similarities of teams we shall understand a partition diagram of a Ruch lattice as a histogram (bar chart, Figure I.191) or, in other words, a finite discrete distribution with a partition diagram being comparable to an intra-system state.

Without needing to go into the details of (mathematical) group theory, particularly of the symmetric groups S_n and their irreducible (non-decomposable) representations (mathematically homomorphisms), Zhao [2009] provides sufficient information to be utilized for our purpose.

One needs to know that irreducible representations of the symmetric group S_n are in a one-to-one correspondence with Young Diagrams having n boxes. And a representation of the symmetric group on n elements, S_n, is also a representation of the symmetric group on (n − 1) elements, S_{n-1}.

Furthermore, one can describe a basis of each irreducible representation using standard Young Tableaux, which are numberings of the boxes of a Young Diagram with 1; 2; …; n such that the rows and columns are all increasing. For instance, the bases of the standard representation of S_3 correspond to the following two standard Young Tableaux relating to the partition (2,1) (Figure I.73) which are the only standard tableaux for (2,1).

1	2
3	

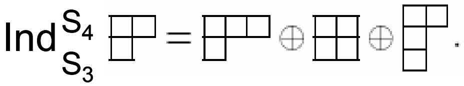
1	3
2	

A general example of a standard tableau would be

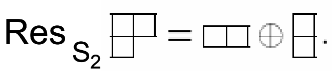
1	2	4
3	5	6
7	8	
9		

.

There are interesting connections for further discussions following essentially a *visual approach*. Suppose we have an irreducible representation in S_n and we want to find its induced representation in S_{n+1}. It turns out that the *induced representation* is simply the *direct sum* of all the representations corresponding to the Young Diagrams obtained by adding a new box to the original Young diagram! For instance, the induced representation of the standard representation from S_3 to S_4 is simply



Similarly, the *restricted representation* can be found by removing a box from the Young diagram



These relations and corresponding extensions become lucidly visualized by another approach interconnecting Young Tableaux and representations of S_n. In addition to partial order of Young Diagrams by the Diagram Lattice (Figure I.74) relations in terms of the "Young Lattice" *generalize the addition or removal of boxes*.

Following Zhao [2009] let the symbol λ ↗ μ denote that μ can be obtained by adding a box to λ. To create a Young Lattice at the nth level all the Young Diagrams with n boxes are drawn. In addition, λ to connected to μ if λ ↗ μ., Figure I.190 displays the bottom portion (n = 4) of the Young Lattice which will extend infinitely upwards (∅ is the NULL).

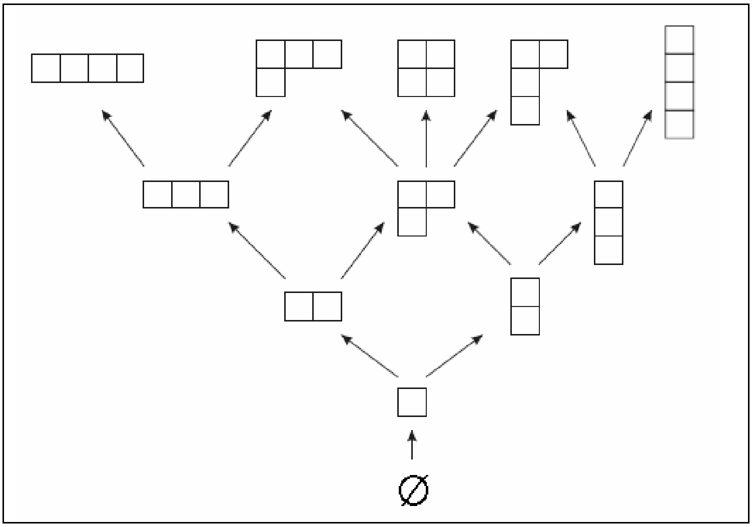


Figure I.190: The bottom of the Young Lattice [Zhao 2009].

We can think that a Young Diagram is a pile of bricks and the Young Lattice is the order in which bricks are placed.

The issue of firm development can be related to the question: What was the shape of this pile of bricks in the past and what would be a favorable shape for the pile in the future? Or could there be an adequate interpretation of the shapes when building a pile? In essence rows of the Young Lattice can represent homologies in biology.

To be useful with regard to the last question one must ask, can there be any meaning attached to the relation $\lambda \nearrow \mu$ with regard to “directions” or strategies chosen for further development of new firms?

To answer the last question one can use the example of entrepreneurship with the number of founders being $n \leq 4$ which covers almost all situations of technology entrepreneurship or we can use sources of financing (essentially $n \leq 8$).

For our purposes the discussion refers primarily to *structural characteristics*, such as looking at a founder team with three members as equivalent subjects. On secondary consideration we shall introduce *attributes of property or function* (“roles”) of the structural entities, such as personal operational competencies of the individuals of founder team (Figure I.72). Adding attributes in this discussion is similar to using “colored symmetries” as displayed in Figure I.2.

If we attribute numbers to the boxes in Figure I.190 (which has nothing to do with Young Tableaux) all boxes in a row reflect only one entity (for instance, one member of a team) having a set of relevant attributes (for instance, personal operational competencies) which equals the number of the boxes in the row. In this view the outer left part of the Young Lattice (Figure I.190) means “*growth by learning*,” adding an attribute to the same entity, such as learning of new subjects like a competency or chunk of knowledge.

As the extreme a single entrepreneur (Figure I.72) has all the needed personal competencies to found and develop a new firm. A lucid example coming into one’s mind would be William Henry Perkin (A.1.2). In a related way concerning financial sources of a new firm one can define the attribute of a source of capital, for instance, as ten percent per box (Figure I.193).

Hence, one can view the left part of a Young Lattice with attributes, symbolized by $\lambda \,{}_L{\uparrow}\, \mu$, to put the emphasis on rows as “*centralization*” (“monopolization”) of attributes and the right part focusing on columns, $\lambda \uparrow_R \mu$, as “decentralization” (“diversity”). In a Young Diagram the length of the leftmost column is the maximum number of non-equivalent objects/subjects. Hence, $\lambda \uparrow_R \mu$ may represent, for instance, adding a further person to a team with a particular useful competency or knowledge.

Furthermore, Ruch’s Diagram Lattices allows a general description of comparing frequency distributions as an order relation. This can be extended to discuss a firm’s organization or sub-states on the basis of Ruch’s [1975] concept of the “*mixing character*,” distinction of objects by relating classification to mixing character.

Accordingly, the mixing in the set of n objects is certainly at a maximum, if the number of distinguishable objects is maximal. This suggests that increasing mixing character should be defined by a *mixing process*. The *mixing character* allows comparing sets of differing mixing character. That is, a judgment can be obtained of “more” or “less mixed,” at least for comparable (compatible) cases.

The **mixing character** denotes the composition of a set of partly equivalent objects or the distribution of objects among different states. Two sets are “*mixing-equivalent*,” if the partition of the classes (structure) is the same for both. In Figure I.73 the founder teams of Puron AG and JPK Instruments AG would be structurally mixing-equivalent, but attributively different.

Generally, according to Ruch [1975], a statement that a set M is more mixed than another one, M’, implies that the comparison must be restricted to pairs of sets such that M is obtainable by mixing together sets of mixing character of M’. We must define M to be more mixed than M’ if M can be obtained by mixing sets with the same mixing character as M’. If the set finally obtained has a partition of objects which is an integral multiple of a partition of n, we may consider a corresponding set of n objects as equally mixed.

We can characterize all “mixing-equivalent” sets by a sequence of integers ν_l (including zero) in a column matrix or graphically by means of diagram-like figures in which rows with ν_l boxes are arranged along a vertical scale with indices l = 1, 2, …n denoting the different kinds of objects or the distribution of objects among different states.

Figure I.191 illustrates how to address *similarity* (including equality) for multi-dimensionality of underlying criteria. It provides an example of structurally mixing-equivalent sets of three subjects and of the representative diagram and the binary relationships which these exhibit with regard to structurally and attributive characteristics. In so far, these considerations may provide an option to discuss aspects of *heterogeneity* which is important concerning competencies or traits of members of a founder team or resources of a startup or NTBF, respectively.

Attributes refer, for instance, to personal operational competencies. Here we can differentiate *inequivalency* and *incompatibility*. However, we regard the structurally mixing-equivalent, but attributively mixing-inequivalent constellations having the same set of attributes as *similar*. For our purposes in the realm of small numbers, usually $n \leq 8$, graphics will suffice to work with issues of mixing characteristics.

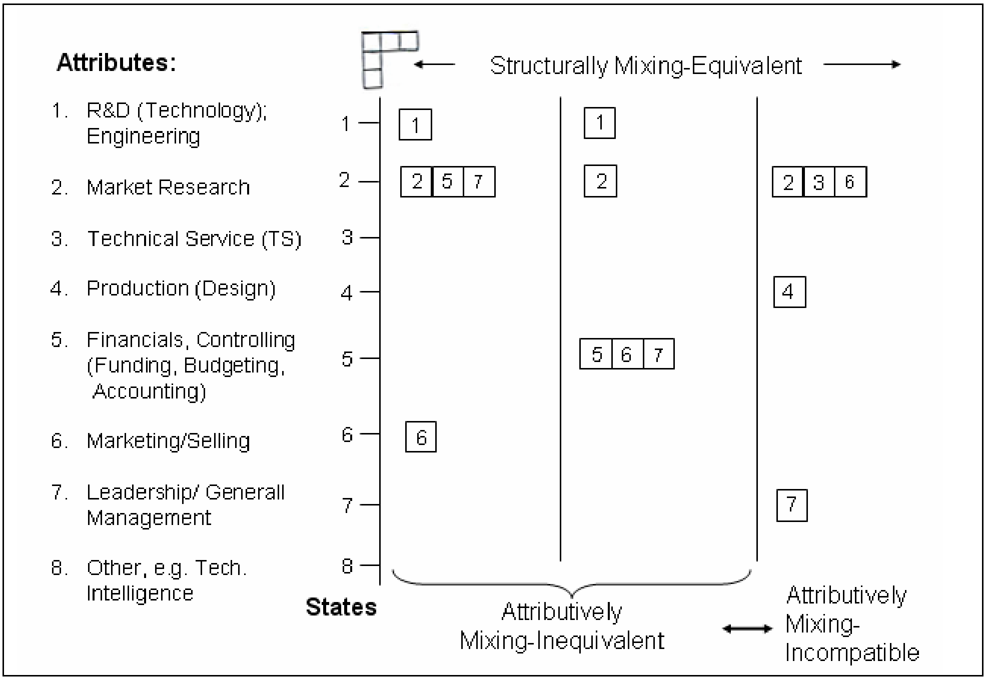
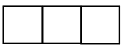


Figure I.191: Illustrating structural and attributive features with regard to their mixing characteristics referring to an entrepreneurial triple with regard to the personal operational competencies for firm foundation**.**

For future applications it should be noted that Young Diagrams allow also a mapping to (state) vectors which is shown in Figure I.192. The integers of the example partition can be mapped to a 2-dimensional vector. To obtain vectors with the same dimension within a Diagram Lattice one expands the 2-dimensional vector with zero elements.

Correspondingly, one could also separate structure and attributes denoting structure by a Young Diagram and attribute by a vector, respectively, reflecting the different attributes' value by a 1 and otherwise a 0 for the related vector's coordinates. For instance, for state 2 in Figure I.191 with attribute values (2,5,7) out of eight attributes one can write a binary value row vector:

 **(2,5,7) $\rightarrow$ (01001010)**

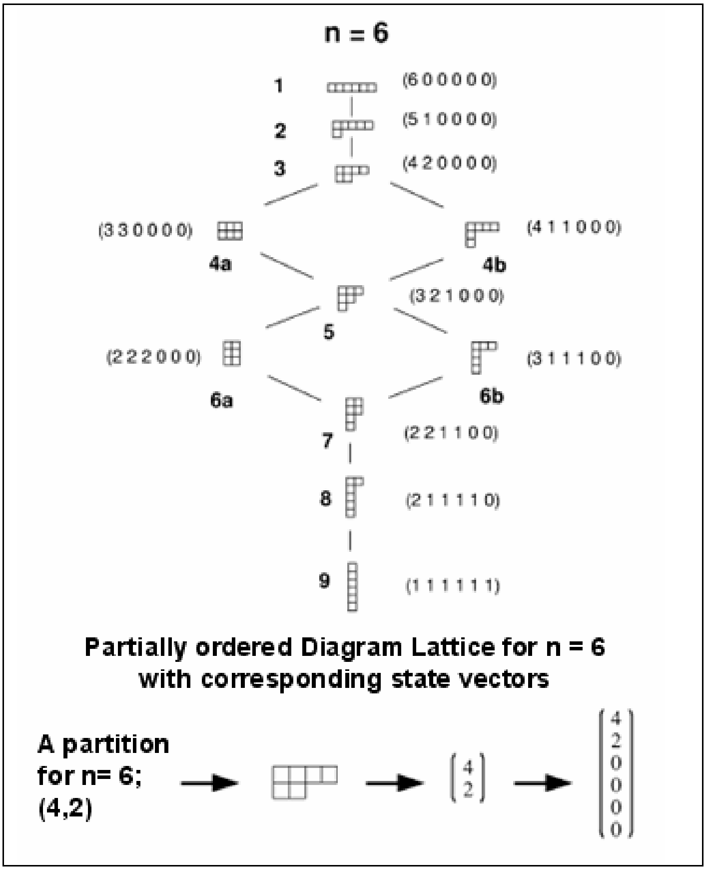


Figure I.192: Representation of Young Diagrams as vectors based on their partitions.

It is immediately evident that in Figure I.193 the founder teams concerning experience of the team members are equal in structure and attributes. To quantify "similarity" of entities with regard to attributes generally vector calculus can be utilized.

The related non-systemic and component-oriented *cosine similarity* may provide a rough measure. Cosine similarity is a measure of similarity between two vectors by measuring the cosine of the angle between them. The cosine of 0 is 1, and less than 1 for any other angle; the lowest value of the cosine is -1. For our case, however, the cosine similarity will be restricted to $0 \leq 1$.

The cosine of the angle between two vectors thus determines whether two vectors are pointing in roughly the same direction. In Euclidean space, the dot product of two unit vectors is simply the cosine of the angle between them. This follows from the formula for the dot product, since the lengths are both 1. Hence, we could measure cosine similarity by creating n-dimensional vectors, normalizing them to unit vectors, and then calculating the cosine similarity.

For instance, in Figure I.193 we compare operational competencies of two startups founded by an entrepreneurial triple. And we deal with eight-dimensional vectors. In the first step we construct the attribute vectors of the related Young Diagrams starting with (3,1,1) versus (2,2,2) and then add the three related vectors in the usual way to get in the first case (1,1,0,0,1,1,1,0) and 0.4472·(1,1,0,0,1,1,1,0) as the unit vector. Creating the second unit vector and multiplying both leads to cosine similarity = 0.73 for attributes – a rather high (quantitative) similarity. This, however, does not tell anything about the actual performance of the two startup teams. At best it is an indicator that both have a similar potential of performance.

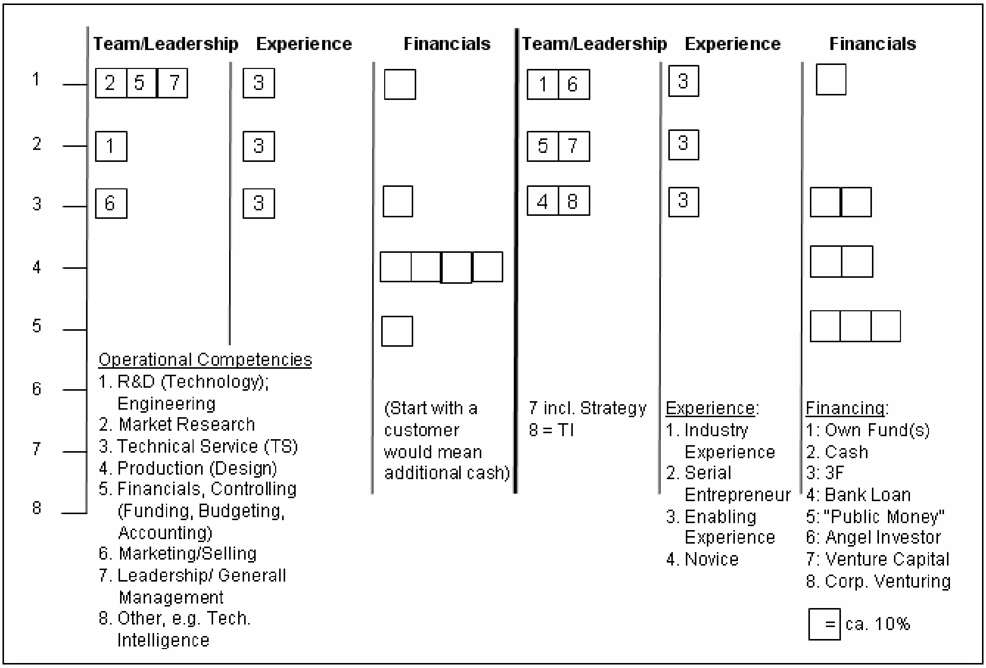


Figure I.193: Comparing architectures of two startups founded by an entrepreneurial triple focusing on selected resources.

One can extend this approach to deal with finances as another key resource of a startup. For the financial attributes we assume for simplicity equally weighted financial sources quantified by financial contributions expressed in multiples of 10 percent. Figure I.193 allows comparisons between the financial states of two startups. However, an immediate question arises concerning the underlying attributes, the origins of the money and the consequences for the founder(s) in terms of control over the start-up.

For instance, debt and equity financing (Table I.28) will mean incompatible attributes if equity means also external control of the firm by VCs. Hence, it would not allow comparing startups with related financial sources. The financial states of the two new firms in Figure I.193 show compatible financial attributes which puts them into the same class of startups (Table I.74). They are structurally mixing-inequal.

For quantitatively assessing rough cosine similarity we give characterization of the financial sub-states by vectors with non-binary-valued coordinates (Figure I.192). This would mean (row) vectors (1,0,1,4,1,0,0,0) and (1,0,2,2,3,0,0,0) for the two firms and attributive cosine similarity = 0.70.

The outlined approach may be used to visualize architectures or even configurations of startups (ch. 4.3.2) which means *the firm's genetics* for a particular state in time. For instance, in Figure I.193 the initial configuration of two NTBFs or the startup thrust phase was displayed referring particularly to *resources* (knowledge/competencies, business experiences or foundation experience, respectively, and financial endowment).

A more elaborate visualization of architectures may connect structures and attributes to block forms of their dimensions as given in Figure I.194. It is envisioned that the firm is in the startup thrust phase (ch. 4.3.2) and having a customer for its foundation (initial configuration) means generating cash as part of the financial structure.

The NTBF's architecture given here shall not be discussed in detail. It should be noted how further resources may be integrated into such a diagram, such as classes of technology underlying the firm's offerings. And network partners and type of networking activity indicate how to tackle the firm's environment to represent also configurations of new ventures in a related manner.

Finally, also relationships between the firm's offerings, business activities and its revenue model (Table I.3) can be visualized by such block forms. And if we focus on the early stage of startups with say less than 15 employees one can envision also to deal with organizational states in terms of specialization as discussed in Table I.69 or given by their value chains (Figure I.7) including an advisory board.

Variations on a Theme

The preceding outlines focused on identifying *generic* relationships, where the attribute "generic" will be viewed as an "operational definition": the limited or even unlimited number of structural variations based on one particular selection of structural features/units or one particular function (application).

For entrepreneurship from a GST and permutation perspective corresponding variations (Figure I.194) can be related metaphorically to music, to V*ariations on a Theme*.

In music, variation is a formal technique where "content" is repeated in an altered expression (theme-and-variation form) and is recognizable by the addressee. Variation forms show up as “free-standing” pieces for solo instruments or ensembles, or can constitute a movement of a larger piece. Most jazz music is structured on a basic pattern of theme and variations.

Most famous and very illustrative for the current context are Johann Sebastian Bach’s Goldberg Variations (BWV 988) and the first movement of the Piano Sonata in A Major (K. 331) or the finale of the Quintet for Clarinet and String Quartet in A Major of Wolfgang Amadeus Mozart.

These examples have been chosen as there are lucid demonstrations available referring to perception of variation on the *acoustical* and *visual* levels (inspecting the sheets of music) and to get a feeling for the “systemic nature” of the underlying patterns [Denk 2012].

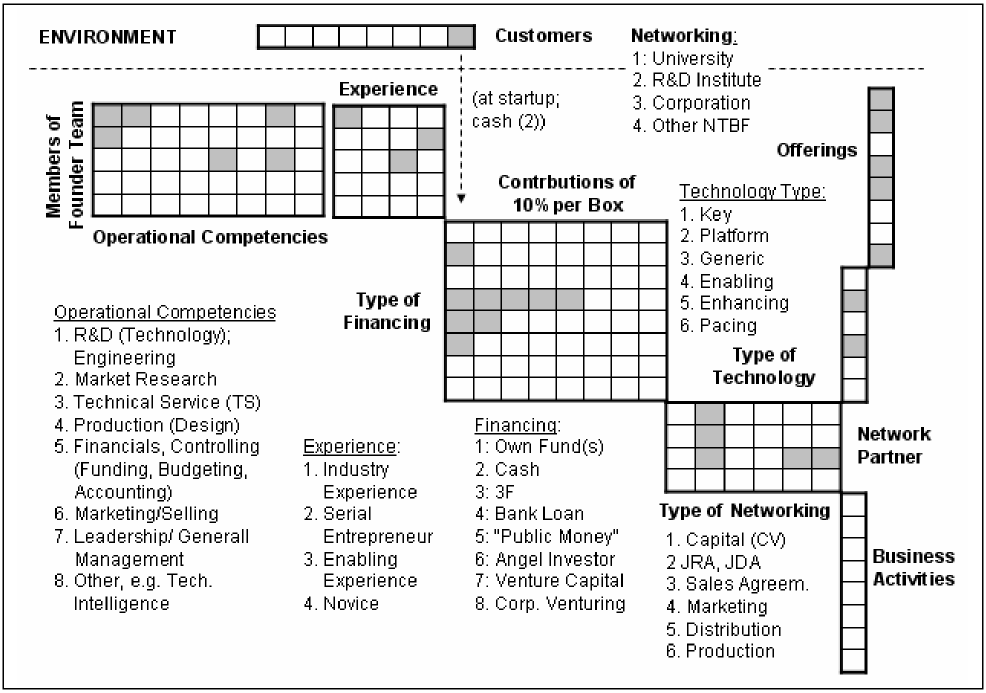
Furthermore, the topic allows also to see that composers use pieces of other composers to generate variations, for instance, Johannes Brahms wrote “Variations on a Theme by Haydn.” All this establishes interconnections to Faltin’s [2007] article entitled “Founding successfully – The Entrepreneur as an Artist and Composer.”

The Goldberg variations do not follow the melody of the aria, but rather use its bass line (and chord progression) and even without any music education and even if you cannot read music or have little feelings for music variations of the baseline are easily grasped by inspecting visually the notes or/and hearing them and recognizing the four eight notes sequences as “similar patterns.”
(http://en.wikipedia.org/wiki/Goldberg_Variations)

> In music variation can concern a number of elements. In its most literal sense, for music a *melody* is a sequence of pitches (in German Tonhöhe) and durations of tones and a *theme* is the material, usually a *recognizable melody*. A *chord* is a sound created by a set of three or more different notes from a specific key that sound. A *rhythm* is the variation of the length and accentuation of a series of sounds or other events – also a matter of execution.

Hence, *variation* is a formal technique where material is altered during repetition: *reiteration with changes*. And changes may involve, for instance, the theme/melody, chords or rhythm or a contrast of major/minor mode.

Similarly, the realization of the *systemic character of a founder team* depends on the “measuring device” to bring it up. *Viewing* three music notes arranged vertically upon each other on a music note sheet may realize three individual “music note components.” However, pressing on a piano the three related piano keys, the “chord.” one *hears* a tone which do not allow most of us to discern the individual constituting tones of the notes – it is a “whole” (Figure I.193).



Offerings:
1. Product(s)
2. Tech. Processes
3. Services
4. Consulting
5. Contractual R&D
6. Analytics, Tests
7. IPR, Licenses
8. Knowledge

Early Phase Business Activities:
1. Business Development
2. Product/Process Development
3. Application Development
4. Project Management
5. Purchasing, Procurement
6. Selling Products/Processes
7. Managing Patents and Licenses
8. Stakeholders Relationships

Figure I.194: Architectural outline of an NTBFs startup thrust phase as block diagrams using related dimensions of involved entities (business activities not specified).

Chords can be related to collections of attributes of a single entity, such as a person with personal traits, experiences, attitude towards risk etc. or a financing structure of a firm (as seen in Figure I.193 and Figure I.194).

Correspondingly, for the core-shell model the “core-entrepreneur” or the new venture (Figure I.16) chords can be viewed to be transformed to particular extended chords (via interactions with super-systems) and variations may occur by changing the original chord (initial architecture) by additional systemic “notes” and accentuation (strengths of interactions of the systems) establishing configurations.

Entrepreneurship then is shaped by *environmental rhythm* (ch. 1.2.1) of the shells which provide the relevant exogenous variables (parameters), the drivers from the set of given shells in Figure I.13, for firm development over time.

A.1.7 Special Networking Effects for Entrepreneurship: The "PayPal Mafia"

According to Wikipedia [120] the "PayPal Mafia" is an informal term for a network of American business people, actually (serial) entrepreneur-investors, centered in Silicon Valley, who were founders or early employees of *PayPal* before founding a series of other technology companies. The PayPal Mafia are often credited with inspiring Web 2.0 and for the re-emergence of *consumer-focused Internet companies* after the dot-com bust of 2001. Some commentators consider these credits to be exaggerated or partly mythologized.

This group of serial entrepreneurs and investors represents a new, but special generation of wealth and power. In some ways they are classic characters of Silicon Valley, where *success and easy access to capital breed ambition and further success* [O'Brien 2007].

PayPal grew to serve the broader *market of electronic currency*, used in particular for online auctions. It went public in 2002 and was bought by eBay later that year for $1.65 billion, after eBay gave up on its own competing service, BillPoint. A number of serial entrepreneurs from the group worked with each other in the following years to form new companies, venture funds, and to make private equity investment in each other's companies, particularly in the field of social networking. Figure I.195 shows which companies dealt with in this treatise can trace their ancestries to PayPal.

It is not uncommon for a company's employees to leave and start successful new companies of their own after their old company is acquired. PayPal's former employees launched more successful companies in a shorter time than almost any other company in history. Apart from the networking effect the diversity of skill-sets among the former employees ensured that the social group has a full range of financiers, engineers, designers, operations experts, marketers and others available to help each other start new companies.

The group's name for itself, "PayPal Mafia" was already a minor cultural meme, but gained wide exposure due to a 2007 article in Fortune Magazine [O'Brian 2007] that used the term in its headline and featured most of the members posed at San Francisco's Tosca Cafe in gangster outfits. Members included and startups are listed in note 120.

Peter Thiel and PayPal's Development

At the center of the network there is Peter Thiel with a story of a money manager extraordinaire and special personality and the foundation of PayPal. While at high school, Peter developed into both a math genius and a chess prodigy. He achieved and has maintained his US Chess Master rating up to the present.

He picked nearby Stanford, deciding to major in philosophy, and became a free-market libertarian, believing that people should be permitted to do as they wished, assuming they did not impinge on the freedoms of others [Thomas 2010].

Following Thomas [2010], after graduating in 1989, Thiel decided on law school at his alma mater and earned his JD from Stanford. He clerked as a corporate lawyer for several organizations, but after a couple of months he resigned because of total boredom. Thiel needed the excitement and thrill of “the deal” to keep his considerable professional juices flowing. Finance has always been more his thing.

He decided to polish his totally theoretical investment skills by joining the firm of CS Financial Products, now part of the Credit Suisse Group. He quickly decided it was time to follow his own map, not someone else’s. In California, he somehow raised $1 million from friends and family, beginning his first macro fund, Thiel Capital Management. With no experience, Peter faced daily struggles to raise funds and investors, but by 1998, he did have more than $4 million in his management portfolio.

This was about the time Thiel had the fateful meeting with Max Levchin, a Ukrainian-born American computer scientist. While he was conducting a finance lecture at Stanford, the young software engineer, Max Levchin, dreaming about an Internet startup, walked into his class by chance.

During a later meeting for breakfast of the two, Levchin asked if Thiel would invest in his idea to offer a secure method of allowing handheld computers to communicate. Peter liked the idea. Originally believing he would have a short-term relationship Thiel eventually froze his fledgling hedge fund career, dedicating the next four years to the new company – which eventually grew into PayPal. Thiel even joined the new venture as a co-founder and its CEO in December 1998, but together Thiel and Levchin set out to “*create the new world currency*.” [O’Brien 2007]

A staunch libertarian, Thiel figured a Web-based currency would undermine government tax structures. Getting there, however, would mean taking on established Industries – commercial banking, for instance – which would require financial acumen and engineering expertise [O’Brien 2007].

Thiel had invested $240,000 in the new company after his meeting with Levchin. Only eight months after PayPal’s IPO it was sold to the giant auction site eBay for $1.65 billion and Thiel realized a very attractive payout. Only 34, he rode off into the sunset with $60 million [O’Brien 2007].

Only weeks after the PayPal sale to eBay in 2002, Thiel decided to found a hedge fund firm, Clarium Capital Management, LLC, in his apartment. And, indeed, he became a successful hedge fund manager in the US. In 2005 Thiel started a San Francisco-based venture capital investment firm, The Founders Fund, with fellow members. Peter Thiel and the firm’s six partners have been founders of or early investors in numerous companies, such as Facebook, PayPal, Napster, and Palantir Technologies. Founders Fund launched four suites of funds by 2010 with more than $1 billion in aggregate capital under management [Thomas 2010] [120] .

The amazing success of PayPal was not without problems and serious issues. Shortly after PayPal began fulfilling the dream of its becoming the "new currency for the world economy," Thiel had to face a number of challenges. Russian hackers managed to pirate millions of dollars from the new venture by cribbing credit card numbers. Credit card processing companies claimed that PayPal was in violation of their regulations. Customer-service complaints flooded the phone lines and in-boxes and were often dealt with by simply not answering the phone or doing a mass deletion. Louisiana temporarily banned PayPal from doing business in the state; MasterCard threatened to pull the plug because of the high number of chargebacks [Thomas 2010; O'Brien 2007].

At one point, PayPal had enough funding to survive only another two months while still losing around $10 million a month. Shortly after, because of what was then the dot-com zenith, Thiel tried to raise money for PayPal, then valued at around $500 million by VC's even though losing money at a rapid rate. NASDAQ had just broken its own record, hitting 5,048, and the majority of investors thought the dot-com phenomenon would last forever [Thomas 2010].

Thiel already realized what the market came to know shortly thereafter: There was very little substance to the majority of dot-com "superstars." Nonetheless, he capitalized on the opportunity presented to him, worked feverishly to locate interested VCs and jumped through numerous obstacles to close the deal so quickly and rose $100 million to fund these hard times for PayPal. The closing for the deal was March 31, 2000. This was critical as the very next day the NASDAQ began its famous freefall [Thomas 2010].

Thiel established PayPal as the leading company to handle purchase payments over the "Net" and was successful at branding his company as the expert in this area. As a result, he began positioning the company for an IPO, which he registered only weeks after the World Trade Center ("9/11") tragedy. Again his strategy was successful.

Thiel was not always successful. He missed the opportunity to invest in the highly successful YouTube, bought by Google for $1.65 billion, (Thiel said, "It just kind of fell through the cracks." [Thomas 2010]). But he was very high on Facebook, founded by Mark Zuckerberg in 2004. Thiel backed the startup and advised Zuckerberg to relocate to Silicon Valley. Calling Thiel his mentor, Zuckerberg did just that. He said goodbye to Harvard University, where he was a student, and headed west (Box I.15).

In the context of the expected IPO of Facebook (in 2012) Facebook's first outside investor Peter Thiel led a $500,000 investment in Facebook in late 2004. He has 44.7 million shares that could be worth more than $2 billion. Accel Partners, whose principal partner, Jim Breyer, invested in the startup seven years ago (Box I.15), holds

201.4 million shares. Accel could have a thousandfold return on some of its investment [Bilton and Rusli 2012].

PayPal's Corporate Culture

For PayPal's development Thiel and Levchin had to bring in several hundred employees to what would become PayPal. They signed up more than 20 million users and burnt $180 million in funding before breaking even and selling out to eBay. The eBay deal indicated a remarkable factor of PayPal's success – obviously unique corporate culture and networking conditions. Most of PayPal's key employees left eBay, but they stayed in touch. [O'Brien 2007].

It is hypothesized by O'Brien [2007] that PayPal's success comes back to the early hires. Thiel and Levchin began recruiting everyone they knew at their alma maters. "It basically started by hiring all these people in concentric circles," Thiel rememberd. "I hired friends from Stanford, and Max brought in people from the University of Illinois."

They were looking for a *specific type of candidate*. They wanted competitive, well-read, multilingual individuals who, above all else, had a proficiency in math. Thiel and Levchin also wanted workaholics who were not MBAs, consultants, frat boys, or, God forbid, and jocks (an American term for a stereotypical male athlete). In other words, they were *looking for people like themselves*. For instance, Levchin lives to work. The company was male-dominated; nearly all employees were young men. [120]

"The difference between Google and PayPal was that Google wanted to hire PhDs, and PayPal wanted to hire the people who got into PhD. programs and dropped out," said Roelof Botha, PayPal's onetime CFO. "Most of them were very introverted anyway," Levchin recalled. "They'd come in, eat crappy food all day, and sleep under their desks." [O'Brien 2007]

Thiel's leadership style was as unconventional as his worldview. All employees, not just managers, were made aware in detail of company finances, performance etc. His management at PayPal (at least, pre-IPO) was the all-hands open-book session. Customer logs, revenue flow, fraud losses, burn rate: He showed it all for every employee to see. This access to information, coupled with the lack of offices, created a flat structure where any idea could win the day.

Company decisions were made according to reasoned arguments ("Good decision-making flows out of details") rather than executive experience. It was allowed and even encouraged for low level employees to criticize executive decisions and lobby for their own positions.

Reid Hoffman, a former executive VP, loved PayPal's meritocracy. "The group was very analytical," says Hoffman. "It was all about, 'Here are my arguments; here's my perspective.' You could never say, 'In my experience,' because experience wasn't there as a variable."

And O'Brien [2007] continued that the former COO David Sacks further opened the culture by establishing a no-unnecessary-meetings policy. He became a meeting cop. Anytime he saw a closed-door discussion happening, he had sit in for three minutes. If he considered the meeting to be valueless, he would declare it adjourned. Sacks recalled how the lack of meetings helped create a culture of many workers and few managers. Prestige was measured "by how few people there were above you who could prevent you from doing what you wanted to do."

Not everyone liked the PayPal vibe. Chief among the dissenters was Elon Musk. Musk who came to PayPal not through Levchin/Thiel's regime but during the company's merger with his Internet bank, X.com. Despite having perhaps the greatest entrepreneurial streak of all the PayPal mafia (see last paragraphs), Musk was purged from PayPal like some kind of toxin. Soon after the merger, Thiel resigned. Musk became CEO of the combined company and decided it was time for a technological overhaul. Specifically, he wanted to toss out Unix and put everything on a Microsoft platform.

That may sound innocent enough to laypeople but not to Unix zealots like Levchin and his team. A holy war ensued. Musk lost. The board fired him and brought back Thiel while Musk was on a flight to Australia for his first vacation in years. "That's the problem with vacations," Musk deadpanned. It was not just Musk; anyone who did not mesh with the Levchin/Thiel culture ran into trouble. X.com had a number of people from the banking industry who did not last long. And that awkwardness turned into total dysfunction and warfare. Most X employees ended up leaving or getting fired.

The infighting eventually stopped. It had to, because there were too many other issues to deal with. PayPal problems and losses were multiplying as described above.

Networking – The Soil of Entrepreneurship

By then, the PayPal Mafia was well established. PayPal's founders encouraged *tight social bonds among friends* who continued to trust and support one another despite their relatively short time together at PayPal. They call upon one another when they need money or advice – and when they need both, they go to Thiel, who seems to be at the center of it all (Figure I.195).

Many of PayPal employees were mining new territory. Chad Hurley, Steve Chen and Jawed Karim founded the ever more successful video sharing Web site YouTube, Inc, finally selling it to Google for $1.65 billion.

The now-famous Max Levchin founded Slide, a popular photo-sharing website. Reid Hoffman, Executive VP, started the successful LinkedIn Corp. for business networkers (ch. 3.4.2.1, B.2), while Vice President Jeremy Stoppelman began Yelp, helping people find restaurants, entertainment, businesses and shops in their local area [Thomas 2010]. Slide was sold to Google in August 2010 for $182 Million and, in August, Levchin joined as Vice President of Engineering. In August 2011, Google announced it was shutting down Slide, and that Levchin was leaving the company.

And both YouTube and Yelp learned a valuable lesson from PayPal: The *first idea is not always the best*. YouTube started as a video dating play. CEO Hurley rememberd his PayPal days as an education in business. When he arrived in California with a degree in art from Indiana University of Pennsylvania, building a successful company seemed like something other people did. “You never think it could happen to you,” said Hurley. “But seeing Peter and Max and the guys come up with ideas and seeing how to make things work gave me a lot of insight. You may not have a business degree, but you see how to put the process into effect. The experience helped me realize the payoff of being involved in a startup.” [O’Brien 2007].

Yelp, Inc. is a company that operates yelp.com, a social networking, user review, and local search Web site. Yelp.com had more than 54 million monthly unique visitors as of late 2010. Yelp was one of three projects, including Adzaar and Slide, to come out of the San Francisco incubator, MRL Ventures. The project arose out of research into the local services market by David Galbraith, who worked with Jeremy Stoppelman on the early stages of the project. Stoppelman and Russel Simmons, both of whom were early software engineering employees at PayPal, spun the service off as a separate company. After an aborted start as an email recommendation service, Yelp launched its namesake Web site into the San Francisco market in October 2004. [121]

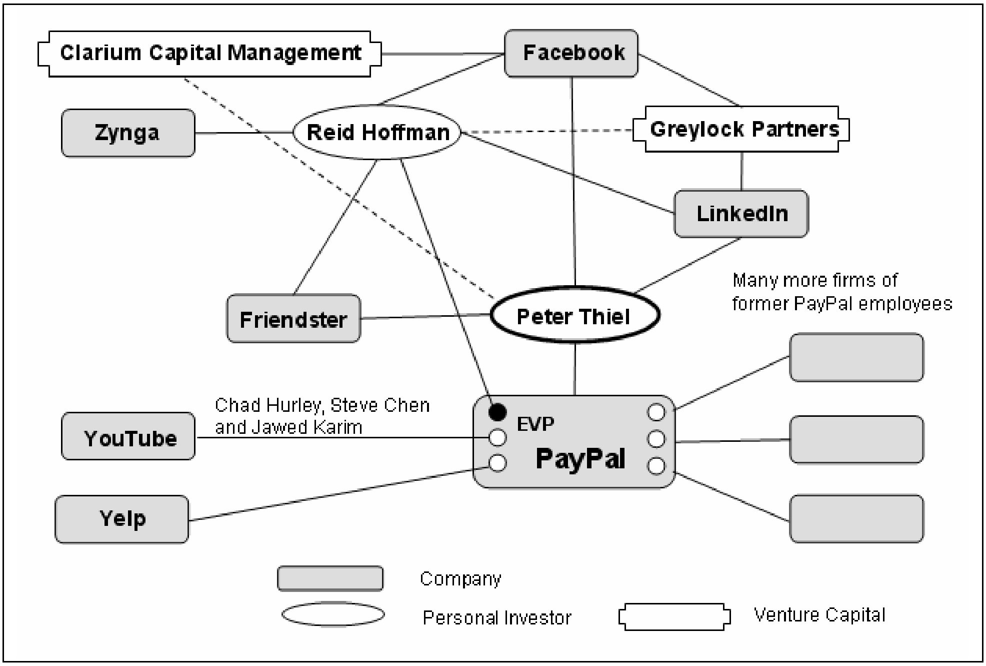


Figure I.195: Significant interrelationships of selected persons and new firms involng the “PayPal Mafia.”

In the context of the entrepreneurship of the PayPal context the aspect of "negative thinking" is notable.

Many successful businesspeople reject the idea of setting firm goals, but assume that sometimes the best way to address an uncertain future is to focus not on the best-case scenario but on the worst ("negative thinking") [Burkeman 2012].

"Positive thinking," by contrast, is the effort to convince yourself that things will turn out fine, which can reinforce the belief that it would be absolutely terrible if they did not. Prof. Saras Sarasvathy interviewed 45 *successful entrepreneurs*, all of whom *had taken at least one business public* ("serial entrepreneurs"). Almost none embraced the idea of writing comprehensive business plans or conducting extensive market research.

They practiced instead what Sarasvathy calls "effectuation." Rather than choosing a goal and then making a plan to achieve it, they took stock of the means and materials at their disposal, then *imagined the possible ends*. Effectuation also includes what she calls the "affordable loss principle." [Burkeman 2012].

With an emphasis on technology entrepreneurs and in the context of PayPal in this book a short addendum on *Elon Musk* is required. [127] Elon Musk (born 1971), who was born in South Africa and came to the US to study at the University of Pennsylvania received a BS in physics and BA in economics from the University of Pennsylvania, was not only a co-founder of PayPal. Before PayPal's sale to eBay he was the company's largest shareholder, owning 11.7 percent of PayPal's shares.

Drawing inspiration from innovators such as Thomas Edison and Nikola Tesla, Musk considered three areas he wanted to get into that were "important problems that would most affect the future of humanity," as he said later, "One was the Internet, one was clean energy, and one was space."

In June 2002, Musk founded his third company, Space Exploration Technologies (SpaceX) of which he is currently the CEO and CTO. SpaceX develops and manufactures space launch vehicles with a focus on advancing the state of rocket technology.

NASA selected SpaceX to be part of the first program that entrusts private companies to deliver cargo to the International Space Station (ISS). In December 2008, SpaceX was awarded a $1.6 billion NASA contract for 12 flights of their Falcon 9 rocket and Dragon spacecraft to the ISS, replacing the Space Shuttle after it retired in 2011. In seven years, SpaceX had designed the family of Falcon launch vehicles and the Dragon multi-purpose spacecraft from the ground-up.

Musk was also co-founder and head of product design at Tesla Motors, where he led development of the Tesla Roadster, the first production electric sports car. Musk's interest in electric vehicles extends long before the creation of Tesla. He originally went to Silicon Valley to do a PhD in Applied Physics and Materials Science at Stanford, where his goal was to create ultracapacitors with enough energy to power electric cars.

Musk provided almost all of the capital for Tesla's first two funding rounds and continued to invest in every subsequent financing round. As a result of the financial crisis in 2008 and a forced layoff at Tesla, Musk agreed to assume the additional responsibility of CEO.

Tesla Motors after having built an electric sports car and having shipped over 2,200 vehicles to 31 countries expected to be in production with its four-door Model S sedan by July 2012. In addition to its own cars, Tesla sold electric powertrain systems to Daimler for the Smart EV and Mercedes A Class, and to Toyota for the upcoming electric RAV4. Musk was also able to bring in both companies as long term investors in Tesla.

Finally, Musk provided the initial concept for the firm SolarCity, founded in July 2006 by brothers Peter and Lyndon Rive, where he remains the largest shareholder and chairman of the board. SolarCity is the largest provider of solar power systems in the US. His cousin Lyndon Rive is the CEO and co-founder. Musk's underlying motivation for funding both SolarCity and Tesla is to help combat global warming.

The aerospace industry reached a milestone in May 2012, when Space Exploration Technologies Corp. (SpaceX) became the first private company to dock a spacecraft with the ISS. The accomplishment also helped buttress plans by the NASA to pay private companies to transport cargo and crew to the orbiting station. But SpaceX was assumed to face huge challenges to turn its achievement into a thriving, long-term business – one that could help birth an industry of privately funded space ventures [Pasztor 2012].

The major question is whether Musk and his management team can transform SpaceX from a boutique development outfit into a low-cost, relatively high-volume production house, said aerospace industry officials and space experts. "Will they be able to reliably repeat this, and do it at the price they promised?" asked a former senior NASA official [Pasztor 2012].

APPENDIX B

B.1 Background Information on the NTBF Selections

Concerning NTBF selection we differentiate providing information on startups or other firms only in a specific context of the book's content or on those firms which were selected intentionally and elaborated as cases. The majority of selected cases cover critical early histories of mostly successful entrepreneurs whose firms had survived and grown through 8 – 12 years. This alone would reflect a "survival bias" and "hindsight bias" for the selections. Therefore, we looked also at some cases that showed NTBFs' failures to survive. Admittedly, many of them were wiped out during or after the Great Recession.

Concerning inter-cultural and socio-economic effects the emphasis is on German and US startups and existing firms with some firms from the UK allowing differentiating situations of culture in the US and UK which both follow Anglo-American capitalism for their economic systems.

Rationales for selection of cases according to technical subjects are given in Table I.1; for software/Internet startups the focus was on social networks (ch. 3.4).

Further selection criteria for cases referred to

- "Competitive groups" to inquire into competitive strategies, but also to provide more insights into related industry segments the new firms are operating in and
- "Strategic groups, particularly the so-called German "Hidden Champions" (ch. 4.1.1) and outstanding representatives (such as Enercon GmbH, Prominent Group and SAP AG).

Finally, on secondary thoughts, NTBFs were also selected to cover a broad range of modes of financing by the various sources available to technology ventures (ch. 1.2.7).

The focus of cases of new ventures with three or more representatives was

- Biofuels and biobased chemicals/materials
- Lighting/Optoelectronics (LED/OLED)
- Nano coatings/films
- Nano-tools/Scientific Instruments
- Ionic Liquids
- Specialty/fine chemicals and polymers and plastics
- I&CT = Informatics (HW/SW)/Consumer/Web Services/ incl. Bio- and Cheminformatics.

Out of the global ca. 350 “plant-based biomass” firms and 200 algae-related startups we have, for instance, selected ca. 40 NTBFs for detailed discussions in the text, not as cases, but rather detailed in a specific context, the *biofuels industry* (A.1.1). Most of these NTBFs are “promising” biofuel firms. For their identification reference was made to Biofuels Digest which published on the Web the “50 Hottest Companies in Bioenergy” Here, “hottest” does not mean “best,” “biggest” or “most significant” – it means the companies that are, in the readers’ judgment, the *most worthy of attention*.

Selection of biofuels firms focused, furthermore, on representatives for biomass type, used conversion technologies and their interrelations, entrepreneurial history, interconnections with agricultural, oil, chemical and automotive industries, financing models and diversity of business models.

The selection of “successful” technology startups relied on assessments of NTBFs regarded as “technology pioneers,” “most promising,” “fast or strong growing,” “high expectation” etc. expressed in terms of being awarded or nominated in contests for prestigious national or international awards and prizes provided by international NGOs, national governmental representatives, technical or business magazines, entrepreneurship-oriented for-profit firms like savings banks in Germany or big industry firms or consulting firms.

Approximately 80 percent of founders invited giving guest lectures within the author’s Technology Entrepreneurship curriculum [1] were either rewarded with or nominated for a highly prestigious award or prize, respectively.

The most important of these assessments often referred to in this book (following [Bhidé 2000]) is the ranking of *Inc.* Magazine which is for the people who run growing privately held companies. The magazine publishes an annual list with rankings of the 500 (5000) fastest-growing private companies in the US, the “*Inc.* 500.” or 500/5000 list categorized by industries. In addition to rankings by growth rates, since 2009 in *Inc.* Magazine a new ranking will also determine which small businesses have generated the most jobs. Most industry classes of *Inc.*, however, do not belong to the industries covered by technology entrepreneurship.

Another US magazine in this category with a focus on practice is “Fast Company.” Through identification of the very creative individuals sparking change in the marketplace the magazine and Web site intends to uncover best and “next” practices, and thus may help new leaders work smarter and more effectively.

In any Systems Design (ch. 5.1) one is faced with the problem of determining the extent to which certain variables can be quantified and measured (ch. 4.1; Box I.17). Therefore, when making selections of NTBFs, we did not only utilized the various organizations which publish lists and/or rankings to select “successful” firms, but looked also into the basis, the criteria of their assessments, to gain insights into what features and data are regarded as relevant. The major sources for NTBF selection and their criteria are given and discussed in Box I.17 and sub-chapter 4.3.6.

B.2 List of NTBFs and Other Companies Surveyed by the Author

Startups/NTBFs investigated in detail for or during the preparation of the treatise as cases in separate documents are listed in Table I.102. The corresponding case documents that were publicly available when this treatise was published are listed in sub-chapter B.3.

Sharing entrepreneurial stories widely does not only create impacts for learning-by-example of founders or to-be founders but may also provide impacts on national policy issues.

The cases of the NTBFs will refer usually to no more than the first twelve years of their existence.

The typical gross structure of the cases is as follows:

- The Technology and the Market
- The Entrepreneur(s)
- Awards and Publicity
- Business Idea, Opportunity and Foundation Process
- Innovation Persistence, Expansion and Diversification
- Vision/Mission, Business Model and Risks
- Intellectual Properties
- Key Metrics
- Competition
- References and Notes.

Table I.102: Case documents prepared specifically for this book.

Firm Name (Country) [1, 5)]	Type of Technology	Industry / Customers	Prod. [2)] (yes/no)	VC [3)] (yes/no)
Bioniqs Ltd (UK) 5, 6)	Ionic liquids	Various industries, industrial and academic research	No	No
IoLiTec GmbH (DE) 5)	Ionic liquids	Various industries, industrial and academic research	Yes	No
Solvent Innovation (DE) 4)	Ionic liquids	Various industries, industrial and academic research	Yes	No

Table I.102, continued

Xing AG (DE)	Social networks (for professionals)	Industry, universities, research institutes	No	No
LinkedIn Corp. (US)	Social networks (for professionals)	Industry, universities, research institutes	No	Yes
Gameforge AG (DE) (Flaregames) 5)	Games on computers and mobile devices	Social network, consumers	Yes	Yes
Zynga, Inc. (US)	Games on computers and mobile devices	Social network, consumers	Yes	Yes
hte AG (DE) 4, 5)	Hard-/software; high throughput screening	Industry	Yes	Yes
CeGaT GmbH (DE) 5)	Genomics, bioinformatics, high throughput screening	Academic research, consumers, industry	No	Yes
Nanion Technologies GmbH (DE) 5)	Nano-tools, high throughput	Academic and industrial research: medicine, pharmaceutical industry	Yes	No
Nanofilm LLC (US)	Nano-coatings, nano-films	Industry, consumers	Yes	No
Nano-X GmbH (DE) 5)	Nano-coatings, nano-films	Industry, consumers	Yes	No
Nanopool GmbH (DE) 5)	Nano-coatings, nano-films	Industry, consumers	Yes	No
Industrial Nanotech, Inc. (US)	Nano-coatings, nano-films	Industry, consumers	Yes	No
InovisCoat GmbH (DE)	Multi-layer coatings, photographic films	Industry, consumers	Yes	Yes
WITec GmbH (DE) 5)	Nano tools, scientific instruments	Academic, industrial R&D	Yes	No

JPK Instruments AG (DE)	Nano tools, scientific instruments	Academic, in-dustrial R&D	Yes	Yes
Cambridge Nanotech, Inc. (US) 6)	Nano tools, scientific instruments; ADL	Academic, in-dustrial R&D	Yes	No
Attocube AG (DE) 4)	Nano tools; scientific devices and instruments	Academic, in-dustrial R&D	Yes	No
Vitracom AG (DE) 5)	Image processing; shop monitoring	Industry, communalities	Yes	Yes
ATMgroup GmbH (DE) 5)	Process, automa-tion, measuring and inspection techno-logies, industrial image processing	Industry	Yes	Yes
SiGNa Chemistry, Inc. (US)	Fine chemicals, reagents, hydrogen	Academic, in-dustrial R&D	Yes	?
ChemCon GmbH (DE) 5)	Fine chemicals, APIs, CRO	Academic, in-dustrial R&D	Yes	No
ASCA GmbH (DE)	Fine chemicals, APIs, CRO	Academic, in-dustrial R&D	Yes	No
Polymaterials AG (DE) 5)	Polymer, plastics, compounding	Industry	Yes	?
Novaled AG (DE) 4))	OLED, Displays, liighting	Industry	No	Yes
Zweibrüder Optoelectronics GmbH (DE) 4, 5)	LED, Lighting	Professional customers, consumers	Yes	No
MineWolf AG (DE/CH) 4)	Mine cleaning	Military, Governments, NGOs	Yes	?
Torqeedo GmbH DE)	Electromobility	Consumers	Yes	Yes
SunCoal GmbH (DE)	Bioenergy, biomass-to-coal	Industry, communalities	Yes	Yes
Renmatix, Inc. (US)	Biobased chemicals and biofuels	Industry	Yes	Yes
Enercon GmbH (DE)	Wind power, wind turbines	Industry	Yes	No

Quiet Revolution, Ltd. (UK)	Wind power, wind turbines	Professional customers, consumers	Yes	Yes
TimberTower Gmbh (DE) 5)	Wind power, wind turbines	Industry, Professional customers	Yes	Yes
SkySails GmbH & Co. KG (DE)	Wind power, energy efficiency, shipping	Industry	Yes	Yes
Marrone Bio Innovations, Inc. (US)	Biopesticides	Farmers, consumers	Yes	Yes
Heppe Medical Chitosan GmbH (DE)	Raw materials, natural products	Industry, chitosan for pharmaceuticals, cosmetics	Yes	Yes
Aluplast GmbH	PVC windows	Industry, professional customers and consumers	Yes	No
KWO Kunststoffteile GmbH (DE)	Plastics	Industry	Yes	No
Nanosolutions GmbH (DE) 6)	Nano-pigments, in ink jet printers or fountain pens	Consumers, industry	No	No
Zoxy Energy Systems AG (DE) 6)	Batteries	Industry	Yes	Yes
MnemoScience GmbH (DE) 6)	Special plastics (with shape memory)	Industry, medicine	Yes	Yes

1) DE = Germany; 2) firm with production or anticipated production; 3) early financed by private venture capital including corporate venturing 4) acquired by a large firm; 5) presentations available on the Technology Entrepreneurship Web; 6) insolvent or bankrupt by 2012.

The startup of some firms is described in individual sub-chapters including Perkin & Sons (UK, founded in 1856, A.1.2), SAP (DE, founded in 1972, A.1.4) and PayPal (US, founded in 2000, A.1.7, ch. 4.3.2). The situation of four startups in ionic liquids with an emphasis on a technology push situation and the competitive constellation is presented in sub-chapter A.1.5.

Larger discussions in context are provided for the birth of Microsoft Corp., Cisco Systems, Inc. and Q-Cells AG.

Startups/NTBFs presented in tabular form or tackled in large text blocks in particular contexts with or without associated figures or in text boxes ("short stories") are given in Table I.103.

Table I.103: Startups/NTBFs tackled by larger descriptions in the text.

Firm Name (Country) [1)]	Technology	Firm Name (Country) [1)]	Technology
Verenium Corp (US)	Biofuels	Cobalt Biofuels, Inc. (US)	Biofuels
Virent Energy Systems, Inc.	Biofuels	Cilion, Inc. (US)	Biofuels
BlueFire Ethanol Fuels, Inc. (now BlueFire Renewables)	Biofuels	Range Fuels, Inc. (US)	Biofuels
CHOREN Industries GmbH (DE)	Biofuels	Mascoma Corp. (US)	Biofuels
Süd-Chemie AG (DE)	Biofuels	Coskata Energy, Inc. (US)	Biofuels
Bio Methanol Chemie Nederland BV (BioMCN) (NL)	Biofuels	Gevo, Inc.	Biofuels
ZeaChem, Inc. (US)	Biofuels	LS9, Inc.	Biofuels
Cellana, LLC (US)	Biofuels	Amyris Biotechnologies, Inc. (US)	Biofuels
Solazyme, Inc. (US)	Biofuels	HCL CleanTech Ltd. (now Verdia) (US)	Biofuels
Algenol Biofuels, Inc. (US)	Biofuels	KiOR Inc. (US)	Biofuels
Cyano Biotech GmbH (DE)	Biofuels	LanzaTech (US/NewZealand)	Biofuels
Sapphire Energy, Inc. (US)	Biofuels	Nanophase Technologies Corp. (US)	Nanotechnology

IGV GmbH (Institut für Getreideverarbei-tung) GmbH (DE)	Biofuels	Scionix. Ltd. (UK) 2)	Ionic liquids
Bioprodukte Prof. Steinberg GmbH" (BPS) DE	Biofuels	Google, Inc. (US)	Search engine and electronic media
Solix Biofuels (now Solix BioSystems) , Inc. (US)	Biofuels	First Solar	Photovoltaic, solar cells
ButylFuels, LLC (US)	Biofuels	US LED Ltd. (US)	LED, Lighting
Green Biologics Ltd. (GBL) (UK)	Biofuels	Albeo Technologies, Inc. (US)	LED, Lighting
OHB AG (DE)	Aerospace	MetroSpec Technology, LLC (US)	LED, Lighting

1) DE = Germany, 2) more detailed in Bioniqs case document.

NTBF cases including historical firms' foundations' dealt with in the author's previous book [Runge 2006] and updated as appropriate are listed in Table I.104.

Table I.104: Other case stories of firm foundations by Runge [2006].

Firm Name (Country, Foundation Year) [1)]	**Original Type of Technology**
BlueBioTech GmbH (DE, 2000)	Algae based additives to nutrition, cosmetics. Fine chemicals
Nanogate AG AG (DE,1999)	Nano-coatings, nano-films
SFC Energy (Smart Fuel Cell) AG (DE, 2000)	Fuels Cells (Direct Methanol Fuel Cells, DMFCs)
Puron AG (DE, 2001) 1)	Water treatment, membranes
Prominent GmbH (DE, 1960)	Water treatment, pumps, filters, chemicals
Osmonics, Inc. (US, 1969) 1)	Membrane separations, water treatment
vH&S GmbH (DE, 1971)	Aerospace, instruments, devices

Closure Medical Corp. (US, 1971; 1997) 1)	Adhesives, medical adhesives
Perkin & Sons (UK 1856)	Organic dyes
Bayer,AG (DE, 1863)	Organic dyes, pharmaceuticals
The Dow Chemical Company (US, 1897)	Chemicals
Avery Dennison (US, 1935)	Adhesives, pressure-sentive adhesives (PSA)
Henkel AG & Co. KGaA (1876)	Washing, adhesives
The Eastman-Kodak Company (US, 1899)	Photography, apparatus and films
Röhm & Haas (DE, 1907); Rohm & Haas (US)	Chemistry
Perstorp Holding AB (SE, 1881)	Chemistry
The Prussian (Berlin) Blue Endeavor (DE, 1704)	Inorganic dyes/pigments

1) Acquired by a large firm

B.3 Publicly Available Case Documents of Companies

Table I.105 provides the list of documents of NTBF case stories of those firms of Table I.102 that are published together with the treatise (on the KIT EnTechnon Web site – Downloads). Other documents will follow regularly over 2014/2015.

For firms marked with an asterisk corresponding presentations of founders are also available on the Technology Entrepreneurship Web. [1]

Table I.105: Published case stories of firms.

<table>
<tr><th>Firm Name
(Country) 1)</th><th>Firm Name
(Country) 1)</th><th>Remarks Concerning the Cases</th></tr>
<tr><td>IoLiTec GmbH *)</td><td>Gameforge AG</td><td rowspan="5">The pairs Gameforge vs. Zynga and Xing vs. LinkedIn allow comparing Germany vs. US
IoLiTec, Bioniqs (including Scionix) and Solvent Innovation is a competitive group of startups</td></tr>
<tr><td>Solvent Innovation GmbH</td><td>Zynga, Inc. (US)</td></tr>
<tr><td>Bioniqs Ltd. (UK)</td><td>Xing AG</td></tr>
<tr><td>Nanion Technologies GmbH *)</td><td>LinkedIn Corp. (US)</td></tr>
<tr><td>Novaled AG *)</td><td>Nanopool GmbH 2)</td></tr>
</table>

1) German firms if not stated otherwise; 2) as a presentation.

Glossary

This glossary is an alphabetical list of terms in a particular broad area of knowledge with the definitions for those terms. The list includes terms that are either newly introduced or specialized and aims to cover several domains of knowledge accounting for the many scientific and technical disciplines which are relevant for technology entrepreneurship.

It is also a reference to notions in the text for which definitions are used that are sometimes differently understood in various scientific disciplines or sometimes have slight differences in a particular discipline to have the basis for common understanding among disciplines.

Cross-references to other terms in the glossary are indicated in the list by italics face.

Apart from the many possibilities to look up definitions, notions and terms on the Web the work of Dorf and Byers [2007] provides a glossary directed toward business administration vocabulary.

Advisory board (or board of advisers):
A group constituted to provide advice and contacts ("networking") to a venture by members with distinct skills and knowledge – and by level of reputation of its members it may also add credibility to a venture.

Agent:
Participants who play a role in achieving the objectives or changes of a system; attendees of the various programs.

Ascribed value (or imputed value):
A systemic category which is generated by consensus or common interests and behavior of a social group in attributing value. It refers usually to valuating or perceiving value of a current situation or object or specifically a firm and the expectation that it will provide future socio-economic benefit – often related to (technology) speculation.

Asset:
Something with economic value that an individual, corporation or country owns or controls with the expectation that it will provide future benefit.
Assets are acquired to increase the value of a firm or benefit the firm's operations.

Backward-integration:
Means the situation in which on a corporate basis a plant or business (of a firm) is interrelated to an *upstream* plant or processing facility for producing its offerings (cf. *forward-integration*).

Book value:
The net worth (net asset value) of a firm according to accounting rules, calculated by total assets minus intangible assets (patents, goodwill) and liabilities.

Breakeven:
Is the point at which cumulated income (revenues, sales) equals loss (expenses, cost).

Brand:
A combination of name, sign or symbol that identifies the goods or services sold by a firm.

Business model:
A business model is an organization's core logic for creating value; a hypothesis how to create value for all its stakeholders.

Business plan:
A business plan is a structured document that includes a current and projected description of a new venture or a business of an existing company, its offerings like products and/or services and related market(s) and how the business will achieve its goals in a particular environment.

Cannibalization:
Processes of introducing offerings, mostly products that will compete with, usually even replace, existing products of a firm.

Cash flow:
Means the transfer of cash into or out of a business, project or financial product (note that the word cash is used here in the broader sense, where it includes bank deposits). It is usually measured during a specified, finite period of time.

Complement:
A product that improves or perfects another product.

Certainty:
Under certainty there is complete knowledge of the value of the outcomes and of the occurrences of the states (of the system).

Closed-loop system:
A self-regulated system is called a closed-loop system and it has its output coupled to its input.

Cluster:
Here, a cluster is a network of interconnected companies and/or organizations with spatial proximity of the nodes (organizational components) and similar or related activities of the nodes.

Communication:
Covers interactions of entities (people or things) and behavior; with regard to people it may relate to actions to work together for a given goal, purpose, function or effect.

Competitive advantage:
An advantage that a firm has over its competitors; how a firm could gain and sustain an advantaged position at potential customers. There can be many types of competitive advantages including the firm's cost structure, product offerings, distribution network and customer support.

Cognitive framework:
Cognitive psychology explains human behavior broadly by examining the "cognitive frameworks" that are used to interpret (how to see) the world and change attitude, behavior and activities accordingly.

A (holistic) system of reciprocation which is a relation of mutual dependence or action or influence over time. A cognitive framework of an individual appears as an internal mental counterpart of a state which is induced by perceiving a situation as the external counterpart.

Complexity:
Complexity in the context of systems expresses a condition of the number of components in a system and the numerous forms of relationships among the components. The numbers may be very large or even infinite, but remain enumerable in the mathematical sense.

Configuration:
In the context of a system, particularly a firm, its situation or state, respectively, characterized by endogenous (system-internal) variables combined with exogenous (external) variables (called "parameters") of supersystems. All the factors are interdependent and interacting, such that their effects may be enhanced or diminished.

Control:
The purposive influence or enforcing power toward a predetermined goal involving continuous comparison of current states to future goals ("is" versus "shall" assessment).

Coordination:
For living systems comprising components and/or subsystems coordination together with sub-ordination in the system exists or is developed to produce an output or outcome or achieve a goal. It is seen as a source of competitive advantage.

Core competency:
It is the one thing that a company can do better than its competitors; an area of specialized expertise that is the result of orchestrating complex streams of technology and work activities and processes, including building and keeping unique relationships with customers, suppliers, research, development or marketing partners, and operational agility or unique business practices.

Customization:
Provision of a product or service designed to meet a customer's or user's preferences or specifications.

Decision-maker:
A decision-maker is someone who is internal to a system and who can change the performance of the parts. Responsibilities for the guidance of the system toward achievement of its objectives are with decision-makers, managers and agents.

Directed Evolution:
Describes a set of *techniques* for the iterative production, evaluation and selection of variants of a biological sequence, usually a protein or nucleic acid (http://dbkgroup.org/direvol.htm);
Directed evolution allows exploring enzyme functions never required in the natural environment and for which the molecular basis is poorly understood. Its purpose is, for instance, to produce useful biocatalysts. With directed evolution one now has the abil-

ity to tailor individual proteins as well as whole biosynthetic and biodegradation pathways for biotechnology applications.
Francis H. Arnold Research Group. Evolution, Synthetic Biology, Protein Engineering, Biocatalysis, Biofuels.
(http://www.che.caltech.edu/groups/fha/, http://www.che.caltech.edu/groups/fha/).

Discovery:
Describes a novel observation or finding of something already existing, often of a natural phenomenon or effect of a (natural) product.

Driver:
Is a relevant endogenous variable or exogenous parameter of a model which provides sufficient power ("strength") or influence to explain (and probably "predict") a system's state and development. Drivers are those combinations of factors which suffice to determine an observable response of the system.

Dominant Design:
Means that, after a technical innovation and a subsequent era of digestion and progressive developments in an industry, a basic architecture of a product or process becomes the accepted market standard.

Due diligence:
A process of gathering and verifying facts, data and information in plans or purposive documents, such as a business or project plan or description of a firm to be acquired, before making a commitment to the terms of an investment, or firm merger or acquisition.

Entry barrier (barrier of entry):
A factor that keeps a firm from entering an industry or a market.

Dynamic capability:
The ability to build and develop firm-specific capabilities and, simultaneously, to renew and re-configure the firm's competencies in response to key factors and conditions of the environment.

Economics:
Economics is the social science that analyzes the production, distribution, and consumption of goods and services (http://en.wikipedia.org/wiki/Economics) and sharing of information. Information may have economic value because it allows individuals to make choices that yield higher expected payoffs or expected utility than they would obtain from choices made in the absence of information.
Economics is "the science which studies human behavior as a relationship between ends and scarce means which have alternative uses." The subject thus defined involves the study of choices as they are affected by incentives and resources (http://en.wikipedia.org/wiki/Scarcity).

Efficacy:
A measure of the extent to which a system contributes to the purposes of a high-level system of which it may be a subsystem.

Entity:
An entity is something that has a distinct, separate existence, though it need not be a material existence. In general, there is also no presumption that an entity is animate. Entities are used in system developmental models that display communication and internal processing of, say, documents compared to order processing (http://en.wikipedia.org/wiki/Entity.

Equifinality:
Means a system can reach the same final state from different initial conditions and by a variety of paths (the ability to reach a goal from myriad ways and beginning at various locations). For open systems this option of finding equally valid ways is the expression of equifinality.

Equivocality:
The state or quality of being ambiguous in meaning or capable of double interpretation. It is viewed as the existence of multiple and conflicting interpretations about an organizational situation or situations where multiple meanings information or information patterns exist among people (striving for the same objectives).

Environment:
In a systems approach any system is viewed in relation to all other systems larger than and interfacing with itself. Such a “Whole System” comprises all the systems deemed to affect or to be affected by the problem at hand. Within a Whole System the environment is defined as comprising all the systems (subsystems and supersystems) over which a decision-maker of a given system has no control.

Environmental rhythm:
The environment within which the entrepreneur operates may have certain regularities or patterns. An environmental rhythm exists when patterns in the environment vary over time with some regularity. Its recognition, however, is perhaps not simple or easy.

Epistemology:
Is the theory of knowledge and the branch of philosophy concerned with the nature and scope (limitations) of knowledge focusing on 1. What is knowledge? 2. How is knowledge acquired? 3. What do people know? 4. How do we know what we know? (http://en.wikipedia.org/wiki/Epistemology).

Escalation:
An expression of a binary relation originating with a special phenomenon or event and showing up either as a significant increase or rise, lifting something’s extent, volume, number, intensity or scope stepwise to a higher level or a corresponding decrease.

Established business ownership:
Percentage of population aged 18-64 years who are currently owner-manager of an established business, for instance, owning and managing a running business that has paid salaries, wages, or any other payments to the owner for more than 42 months (according to Global Entrepreneurship Monitor).

Exit:
The way investors or entrepreneurs get their money out of a venture making a significant profit.

Expert:
A person with considerable experience (and knowledge) in a certain field – someone who knows the most serious mistakes one can make in a field and how to avoid them.

Factor market:
A market where the factors of production (conversion) are bought and sold, such as the labor markets, the capital market, the market for raw materials and the market for management or entrepreneurial resources.

Feedback:
The regulatory mechanism of *closed-loop systems*. It is the modification or control of a process or system by its results or effects; output of an action is "returned" (fed-back) to modify the next action.
"*Negative* feedback" is a process in which an initial change will bring about an additional change in the opposite direction. A "*positive* feedback" is a process in which an initial change will bring about an additional change in the same direction. In positive feedbacks, a small initial perturbation can yield a large change which is *self-reinforcement*. A produces more of B which in turn produces more of A.

Feedforward:
It is a control mechanism that can be measured but not controlled. The disturbance is measured and fed forward to an earlier part of the control loop so that corrective action can be initiated in advance of the disturbance having an adverse effect on the system response.
In industrial processes when some output of an earlier step is fed into a step occurring down the line; self-fulfilling prophesy: if people believe the stockmarket is going to rise, their purchases drive up the stock prices thus creating the very situation they believed will happen

Finality:
A term used to describe the goal-seeking nature of systems, that is, achieving a predefined future state. Open systems have equally valid alternatives easy of attaining the same objectives from different initial conditions (cf. *equifinality*).

Forward-integration:

The situation in which on a corporate basis a plant or business (or a firm) is interrelated to a *downstream* plant or processing facility for producing its offerings (cf. *backward-integration*).

Function:
Means that something is used for; serve: serve a purpose or *role*; a form/structure or activities of a system to achieve a particular purpose or goal or a specific subsystem to contribute to purpose/goal achievement of the supersystem, usually associated with an order of processes (cf. also the division/department/function of a firm).

Gatekeeper (Boundary Spanner):
Someone acting as an interface, if "differences" between intervening parts are too large to allow direct contact and communication between the parts. For instance, a "technical gatekeeper" interconnects various scientific and technical disciplines or corporate-internal and external research.

Genetic Engineering:
Genetic engineering, recombinant DNA technology, genetic modification/manipulation (GM) and gene splicing are terms that apply to the direct manipulation of an organism's genes.
Genetic engineering uses the *techniques* of molecular cloning and transformation to alter the structure and characteristics of genes directly.
(http://en.wikipedia.org/wiki/Genetic_engineering)

Genome:
A genome is the total of all an individual organism's genes. Thus, "genomics is the study of all the genes of a cell, or tissue, at the DNA (genotype), mRNA (transcriptome), or protein (proteome) levels." (US Environmental Protection Agency).

Genomics:
A branch of genetics that studies organisms in terms of their *genomes* (their full DNA sequences) – (http:// wordnetweb.princeton.edu/perl/webwn);
a branch of biotechnology concerned with applying the *techniques* of genetics and molecular biology to the genetic mapping and DNA sequencing of sets of genes or the complete genomes of selected organisms, with organizing the results in databases, and with applications of the data (as in medicine or biology).
(http://www.merriam-webster.com/dictionary/genomics)

Goal: – *Objective*
A goal is where you want to be; it focuses on a qualitative statement. It is a broad, general, tangible, and descriptive statement. It does not say how to do something, but rather what the results will look like.
Some common business goals are: being always profitable, achieving sustainable competitive advantage, customer loyalty, etc.

Goodwill:
In law and accounting, an intangible asset constituting a value over and above the valuation of the tangible assets of the business, and representing all benefits derived from the distinctive location, trademarks, credit rating, reputation, and patronage of the business.
On the sale of a business, a charge usually is made for the goodwill as one of the assets. Sometimes goodwill may be sold by itself without the transfer of any other assets; for example, a business that is moving to another locality may sell the right to use its name and to occupy its former premises.
(http://encarta.msn.com/encyclopedia_761567903/Goodwill.html)

Hard system: – Soft System
A characterization of a system with regards to determining the extent to which certain variables can be quantified and measured and lines of reasoning. "Hard" systems usually will admit formalized reasoning processes where logico-mathematical and analytical-mechanistic derivations, causality and quantitative approaches using the "Scientific Method" are prevalent. Typical domains cover physical sciences, engineering and chemistry and systems are usually treated as "closed" ones.

Human-activity system:
A social system and open system dealing primarily with *goal-seeking subjects*. It is a *purposeful* system directed toward the achievement of a final state, the *goal* – usually a man-machine system with “subjects” and “objects” and characterized by exhibiting *organized complexity*.

Implementation:
Is the use or adoption of change; the actions of accomplishing some goal or executing some order; to put into practical effect; executing given procedures.

Impact value (in German Wirkwert)**:**
A value that is not directly associated with a tangible or intangible entity *per se*, but emerges in a particular situation or constellation and may be related to a particular time period. (Shakespeare, Richard III: “A horse, a horse, my kingdom for a horse!)

Indicator:
In social sciences the decision how to relate measurement to a particular “observable” (“metrics”) is often associated with its operational definition, an indicator assumed to reflect a variable.

Influence:
A capacity to change the behavior of other individuals, to get them to do something that they would not otherwise do.

Information asymmetry:
A state of social group interactions where one or several individuals of the group has more or better information than the other ones; or, at least, one party has information relevant for a subject under consideration whereas the other(s) do not. This could lead to imbalance for decision-making or power which may become counter-productive for the group.

Intangible:
Nonmaterial: lacking material qualities, and so not able to be touched or seen (http://encarta.msn.com/encnet/refpages/search.aspx?q=intangible);
Antonym – Tangible: able to be realized, capable of being given physical existence tangible – financial benefits.

Intelligence:
“Intelligence is knowledge and foreknowledge of the world around us – the prelude to {Presidential} decision and action” (US CIA Factbook on Intelligence).

Interdisciplinarity:
Interdisciplinarity “is based on the integration of ideas from across fields and directed towards a common goal. In this regard it is essential that those involved have a fundamental understanding of the core concepts of the area, its research traditions or themes and the basic questions under consideration.”
A multi-disciplinary approach – that is often confused with interdisciplinarity – generates little or no cooperation between areas.
(A Moral Tourism Industry? Release: Jul. 29, 2010.
http://www.hotelmule.com/html/72/n-3072-3.html

Intervening variable:
In social science intervening variables ((“latent variables”) are *hypothetical* internal states (constructs) that are used to explain relationships between observed variables, such as independent and dependent variables. They are not real things; they cannot be seen, heard, or felt. They are *interpretations of observed facts*, not facts themselves. But they create the illusion of being facts. Typical examples include personality, traits, memory or learning.

Leadership:
Is a process of social *influence* in which one person (or a coherent group) can enlist the aid and support of others in the accomplishment of a common goal. Leadership is reflected by *a purposive collective or group process* and is ultimately concerned with fostering change directed toward some future end or condition which is desired or valued. Leadership is about people (and “doing the right things”).

Learning Curve:
A learning curve shows the rate of improvement in performing a task as a function of time, or the rate of change in average cost (in hours or €/$) as a function of cumulative output.
It is a (graphical and/or mathematical) representation of the common sense principle that the more one does something the better one gets at it (the more times a task has been performed, the less time will be required on each subsequent iteration).

Management:
Management is a process and the art, or science or practice, of setting and achieving *objectives* utilizing and coordinating appropriate *resources* including people in order to attain them with least cost and minimum waste which means attaining the best return on such resources by getting things done efficiently. Management is about business results and processes (and “doing the things right”).

Measurement:
Is the assignment of numbers (or numerals) to represent attributes (properties). Numerals possess order only because of arbitrary assignment or mere convention. One of the first requirements of measurement is the determination of the appropriate scale in which the attribute in question could be mapped. Prevalence of measurement scales differs for hard and soft sciences.

Mental model:
Mental models are representations (for instance, connected information), about a particular topic or subject. Mental models include not only cognitive information, but also feelings and motives in regard to the particular topic. The subject of mental models often involves aspects of the self (for instance, self-concept in regard to spelling), and aspects of the world (for instance, beliefs about a competitive firm).

A mental model is an explanation in someone’s thought process for how something works in the real world; it reflects conscious or subconscious perceptions of reality.

Metabolic engineering:
Metabolic engineering is the practice of optimizing genetic and regulatory processes within cells to increase the cells' production of a certain substance. Producing beer, wine, cheese, pharmaceuticals, and other biotechnology products often involves metabolic engineering (http://en.wikipedia.org/wiki/Metabolic_engineering).
Means targeted and purposeful alteration of metabolic pathways found in an organism in order to better understand and use cellular pathways for chemical transformation, energy transduction, and supramolecular assembly.
(http://www.metabolicengineering.gov/)

Network: – *Cluster*
An interconnected system of entities denoted as "nodes" (such as people, firms or things) irrespective of distance. Interconnections may be "hard" like electric lines in a computer network or "soft" via human relationships, interactions and communication as for a *social network*.

New Technology-Based Firm (NTBF):
An entrepreneurial organization with the goal to actively create, develop, and/or commercialize offerings based on technology and/or research, particularly innovative products, processes, applications and services, which is no more than 12 years in operation and which is usually still led by the original founder or founder team or, at least, one member of the founder team.

Objective:
An objective or *goal* is a projected state of affairs that a person or a system plans or intends to achieve – a personal or organizational desired end-point in some sort of assumed development. Many people endeavor to reach goals within a finite time by setting deadlines (http://en.wikipedia.org/wiki/Objective_(goal));
but, an objective is a specific, measurable, actionable, realistic, and time-bound situation that must be attained in order to accomplish a particular goal. Objectives define the actions that must be taken within a time period to reach the goals. For example, if an organization has a goal to "grow revenues," an objective to achieve the goal may be "introduce 2 new products by the third quarter (Q3) of 20xy." Other examples of common objectives are, increase revenue by x% in 20xy etc.
(http://www.fastcompany.com/blog/dan-feliciano/lean-six-sigma-rock-star/do-you-know-difference-between-goal-and-objective)

Open system:
An open system has an *environment* with which it has inflows and outflows, for instance, of material, energy, information – or people. It possesses other systems with which it relates, exchanges and communicates (for instance, shares information). All systems with living components are open systems. In particular, man-machine systems with "subjects" and "objects" are open systems.

Opportunity:
A timely and favorable juncture of circumstances providing a good chance for a successful venture [Dorf and Byers 2007:28] (in German often translated as "unternehmerisches Handlungsfeld").

Organizational learning:
Comprises the acquisition, application, and mastery of new information and intelligence, tools and methods that allow more rapid decisions and improvement of those processes which are critical to the success of an organization.

Organized complexity: – *Complexity*
Organized complexity has as the main feature that there are only finite, relatively small numbers of components and relationships in the system. Organized complexity is what we usually encounter dealing with new firms (with "small" numbers of employees, say number is < 30).

Outcome: – *Result*
An outcome is any result or consequence, good or bad, intended and unintended, desired or undesired.

Parameter:
An observable or measurable factor exogenous to a system forming one of a set that influences or defines the conditions of the system's operation in the sense of a variable.

Partnership:
A *legal* partnership is created when two or more people work together with a view to make a profit. Legal partnership means that partners are jointly and separately responsible for all the partnership's debts and liabilities.

Performance:
Is the quotient of Actuality (A) and Potentiality (P) when A corresponds to the current achievement of a system using existing resources and constraints and P is what could be achieved by developing resources and removing constraints (Performance ~ A/P).
Performance is a relation between "what is" and "what could be," or verbalized "more with the same or even more with less." Change of productivity is an indicator of performance. In essence, in the current context performance can be related to the first derivative of *productivity*.

Plan: – *Strategy*
When you know *what you want to do* and exactly *how to do it*. A plan is characterized by knowing what the next step will be.
Each step is designed by taking into account the next step.

Positive feedback*:* – *Self-reinforcement*
Positive *feedback* occurs in a feedback loop when the mathematical sign of the net gain around the feedback loop is positive. That is, positive feedback is in phase with the input, in the sense that it adds to make the input larger. Positive feedback is a process in which the effects of a small disturbance on a system can include an increase in the magnitude of the perturbation. Positive feedback tends to cause system instability.
(http://en.wikipedia.org/wiki/Positive_feedback)

Procedure:
A specified course of action intended to achieve a result; a *prescribed* process; a *structured* process by an explicitly given, often documented order of activities according to steps, rules and execution conditions;
how to execute a process, is repeatable.

Process:
Ordered activities to achieve a goal, purpose or function; steps may be sequential (finite, prescribed steps (for 1 to n) or not prescribed, parallel, may be branched (if …then; case x = 1, …case x = n), looping (do …while) or facultative (do X out of Ys).

Productivity:
An economic measure of output per unit of input. Inputs include labor and capital, while output is typically measured in revenues, for instance, revenue per number of employees. Capital and labor are both scarce resources, so maximizing their impact is always a core concern of modern business (cf. *performance*).

Program:
A program is coded or prearranged information (actually "instruction") that controls a process (or behavior) leading it toward a given end; it is a planned sequence and combination of activities designed to achieve specified goals, also a planned series of future events.

Program structure:
Is a classification scheme relating the activities of an organization according to function they perform and the objectives they have been designed to meet. The program structure may cut across formal organizational (and other) boundaries.

R&D intensity (research intensity):
The proportion of R&D expenses in relation to the overall revenues (sales) of the firm in percent.

Recursion:
In mathematics a recursive definition (or inductive definition) is used to define an object in terms of itself. Most recursive definitions have three foundations: a base case (basis), an inductive clause, and an extremal clause.
The base case satisfies the definition without being defined in terms of the definition itself. The factorial function n! ($0! = 1$, $n! = n\cdot(n - 1)\cdot \ldots 2\cdot 1$) is a typical example.
(http://en.wikipedia.org/wiki/Recursive_definition)

Red Tape:
"Red tape is excessive regulation or rigid conformity to formal rules that is considered redundant or bureaucratic and hinders or prevents action or decision-making. It is usually applied to governments, corporations, and other large organizations."
(http://en.wikipedia.org/wiki/Red_tape)

Reflexivity:
In social sciences a circular relationship between cause and effect. A reflexive relationship is bidirectional; with both the cause and the effect affecting one another in a situation that renders both functions cause and effect.

Research-Based Startup (RBSU):
Also called an academic spin-out; is mostly viewed as a new for-profit and independent company based on the findings of a member or by members of a research group at a university or public research institution.

Resource:
A source of aid or support that may be drawn upon when needed.

Result:
A result is the final consequence of intended actions or of events
(There are explicit references to actions/activities or events).

Regulation:
In the context of control rather than law means that the interrelated subjects and objects constituting a system must be regulated in some way so that the *goal* can be achieved. Regulation implies that deviations must be detected and corrected (cf. *feedback*).

Revenue:
Sales of offerings of a firm after deducting all returns, rebates, and discounts.

Revenue model:
Specifies by which kinds of offerings the firm will earn *revenue* to make more money than it spends. In business, a revenue model is generally used for mid and long-term projections of a company's profit potential and operation.

Risk:
In situations of risk the decision-maker knows the value of the outcomes and the relative probabilities of the states (of the system). For a given situation it relates to hazard.

Role:
A function: the actions and activities assigned to or required or expected of a person or group or thing ("acting as"); "the function of a manager";
a role is a set of behaviors, rights and obligations conceptualized in a social situation.

Routine:
A course of action to be followed regularly, not necessarily by an explicitly defined or prescribed given order;
a series of steps followed in a regular definitive order to accomplish something; also a set of instructions designed to perform a specific task; a standard *procedure*.

Scale-up:
Is the process of transfer of materials from preparation in the lab ("lab scale") to large scale or mass production or from small models and prototypes of machines, devices or vehicles to actual size machines/devices/vehicles and their production in large numbers as for automobiles. Here often science is connected with development and engineering to ultimately "Production/Manufacturing."

Self-reinforcement:
It represents a mechanism, a *positive feedback* mechanism, by which a system's output or state is enhanced or brought into a more favorable situation.

Positive feedback is in phase with the input, in the sense that it adds to make the input larger. Positive feedback is a process in which the effects of a small disturbance on a system can include an increase in the magnitude of the perturbation.
(http://en.wikipedia.org/wiki/Positive_feedback)

Self-employment:
In the technological context self-employment refers to a restricted aspect of entrepreneurship related essentially to an autonomy orientation ("be one's own boss," perceived freedom).

Securities:
Securities are financial instruments that can be traded freely on the open market and representing ownership (stocks), a debt agreement (bonds), or the rights to ownership (derivatives); they are broadly categorized into debt securities (such as banknotes, bonds and debentures) and equity securities, for instance, common stocks; and derivative contracts, such as forwards, futures, options and swaps.
(http://useconomy.about.com/od/glossary/g/securities.htm)

Serendipity:
Is finding something unexpected and useful while searching for something else entirely.

Social network:
In its simplest form, a social network is a system of specified ties between individuals as network nodes being observed or studied concerning relationships and social interactions ("edges"), such as friendship, kinship, common social values or interest, relationships of beliefs, knowledge or prestige.
Functionally, it is currently understood as an Internet-based service that allows interacting with others. They play a critical role in socialization into norms and determining the way problems are solved, organizations are run, and the degree to which individuals succeed in achieving their goals.

Soft system: – *Hard System*
A characterization of a system with regards to determining the extent to which certain variables can be quantified and measured and lines of reasoning. "Soft" systems, typically covering biology and life sciences, psychology, cognitive, behavioral and social sciences, focus more on qualitative approaches, perceived causal relationships, intuition, discontinuities with low level of replication, etc. They are usually treated as "open" systems.

Spillover effect:
In economics neglecting the effects of one system upon another one is often referred to as "spillover effects." In systems theory it is related to *sub-optimization*.

Spin-off:
Is a new organization or entity directly formed by a split from a larger one, such as a new company formed from a large firm being still governed by the parent company.

Spin-out:
Is a firm formed when an employee or group of employees leaves an existing entity to form an *independent* startup firm. This can refer to a university or a research institute, directly or mediated by a business incubator. Spin-outs typically operate at arms length from their parent organizations (formally and legally independent, but usually

with certain ties) and have independent sources of financing, products, services and customers.

Strategy: – *Plan*
When you know what goal you want to achieve, but you are not sure exactly how to do it. A strategy is characterized by not knowing what to do at the next step until you have results from the previous step.
Each step of a strategy is realistically influenced by what was learned from the previous step.

Stakeholder:
A stakeholder (in German Einflussnehmer, Anteilsnehmer) is a person (or a group) who has a stake or interest in the outcome of a system's activities, operations and conversion processes, but also one who is or may be affected by a firm's projects;
all the parties that have an interest, financial or otherwise, in a company, including shareholders, creditors, bondholders, employees, customers, management, the community, government and even media.

Sub-optimization:
Sub-optimization refers to issues of improving or even optimizing the performance of open systems. Optimization is only possible for closed systems! Open systems can, at best, only be partially optimized – we have sub-optimization. Moreover, optimizing the subsystems does not guarantee that the total system optimum is reached, whereas the optimization of the total system (if it could ever be reached) does not guarantee that all the subsystems can be optimized at the same time. It is related to *spillover effects*.

Supply chain:
The supply chain (or *value system*) is a "supplier-to-end-users *value chain."* Specifically, *a supply chain is a system* of organizations, people, technology, activities, information and resources involved in moving an offering, product or service, from supplier to the "end-user customer".

Synthetic Biology:
The design and construction of new biological parts, devices, and systems, also the re-design of existing, natural biological systems for useful purposes.
(http://syntheticbiology.org/).
It is a new area of biological research that combines science and engineering in order to design and build ("synthesize") novel biological functions and systems.
Engineers view biology as a technology. Synthetic Biology includes the broad redefinition and expansion of biotechnology, with the ultimate goals of being able to design and build engineered biological systems that process information, manipulate chemicals, fabricate materials and structures, produce energy, provide food, and maintain and enhance human health and our environment.
One aspect of Synthetic Biology which distinguishes it from conventional genetic engineering is a heavy emphasis on developing foundational technologies that make the engineering of biology easier and more reliable.
(http://en.wikipedia.org/wiki/Synthetic_biology).

Task:
A task is an activity or set of activities (that might be defined as part of a process) that needs to be accomplished within a defined period of time.
Skill is the ability to perform a task.

Tacit knowledge:
Tacit knowledge (as opposed to formal or explicit knowledge) is a kind of knowledge mainly ingrained in people rather than documented or encoded and represents correspondingly an issue for “knowledge or technology transfer” or also “licensing” of technology.
With tacit knowledge, people are often not aware of the knowledge they possess or how it can be valuable to others. It is usually gained through personal experience in particular fields and environments of activities (cf. *learning curve*).

Tacit technology:
Is not codified or not documented practical knowledge of and experience with technical fields of people and, hence, an important competitive advantage of a firm and part of its core competencies – as long as the firm can keep the people. Tacit technology is often brought to bear as and when it is required (cf. *resource*).

Technique:
Represents an applicable element of a *technology*. Techniques constitute what is also called instructional (practical) knowledge. Like any recipe they comprise essentially instructions that allow people to “produce” or “re-produce,” respectively. A technique is a *procedure* used to accomplish a specific activity or *task*.

Technology:
Technology has more than one definition, but generically it refers essentially to the body of know-how about the means and methods of producing tools, goods or services. Technology comprises a system of application-oriented statements about means and ends. Technology comprises often a set of *techniques*. Correspondingly, this notion does not require an interconnection to science; it may related to “art, skill and craft” and “useful arts” to create some value. Current definitions often refer explicitly to science, in particular when focusing on “high technology.”

Technology implementation:
Technology implementation means selecting the *techniques* to target a given goal related to tools, goods or services.

Teleology:
Teleology anticipates future existence of systems. As an analytical method it is associated with purpose. Related to *finality*, it represents an antithesis to causality and linear thinking in terms of causes and effects, which is prevalent in natural sciences.

Trade-off (or tradeoff):
A trade-off (or tradeoff) is a situation that involves losing one quality or aspect of something in return for gaining another quality or aspect. It implies a decision to be made with full comprehension of both the upside and downside of a particular choice. Trade-offs are regarded as “compromises” or exchanges which decision makers must effect when all their *objectives* cannot be carried out at the same time. As the extreme one has to be sacrificed totally at the expense of the other, for instance, either quality or low price, but not both.

Trait:
Traits are multiple, thematically-related personality features that collectively reflect the operation or characteristic functioning of a particular area of person, a characteristic way in which an individual perceives, feels, believes, or acts.
For example, the trait of intelligence describes the level of functioning of broad areas of the cognitive system. Traits typically emerge from many diverse contributors.

Transcriptomics: – *Genome*
The study of the complete set of RNA transcripts produced by the genome (transcriptome) at a given time.

Uncertainty:
Under uncertainty, the values of the outcomes may be known but no information on the probability of (occurring) effects or events is available.

Utility:
In the context of systems theory utility can be used as valid guides for *decision-making*. Utility is assigned expected utility values to choices and represents, to a certain degree, the behavioral (psychological) characteristics of decision makers, who are faced with choice situations under risk **[**Gigch 1974:107].
In economics, utility is a measure of the relative satisfaction from, or desirability of, consumption of various goods and services. Given this measure, one may speak meaningfully of increasing or decreasing utility, and thereby explain economic behavior in terms of attempts to increase one's utility. (http://en.wikipedia.org/wiki/Utility)

Value chain:
A value chain is a sequence of activities that a firm operating in a specific industry performs in order to deliver something valuable, such as a product or service.

Value proposition:
Is a statement how customer value will be created summarizing why a customer should buy an offering (product or service). This statement should convince a potential customer that one particular product or service will add more value or better solve a problem than other similar offerings (if they exist).

Value system:
It is the network of organizations and the value producing activities involved in the production and delivery of an offering. The value system consists of value adding components which correspond to supplier/channel-customer bunches. It is an interconnection of processes and activities within and among firms that creates benefits for intermediaries and end-users (consumers).

Verbund (German)**:**
The Verbund principle enables a firm to add value as one company through efficient use of its internal and external resources.

Verbundprojekt (according to the German BMFB ministry):
It is a pre-competitive, division of labor and cooperation of several independent partners from industry and academia with independent contributions to the solution of a research and development task. (Ein Verbundprojekt ist eine vorwettbewerbliche,

arbeitsteilige Kooperation von mehreren unabhängigen Partnern aus Wirtschaft und Wissenschaft mit eigenständigen Beiträgen zur Lösung einer Forschungs- und Entwicklungsaufgabe.) – usually translated as “cooperative project” or joint project.”

Verbund system:
A Verbund system creates efficient value chains that extend from basic input right through to high-value-added offering like products. The Verbund principle extends beyond production and technology to embrace the firm’s employees and also their interconnections of knowledge, experience and expertise to other internal or external people (Employee Verbund, Technology Verbund, …, Customer Verbund).

Window of Opportunity:
Is a short time period during which an otherwise unattainable opportunity exists.

Zeitgeist:
The Zeitgeist (spirit of the age or spirit of the time) is the intellectual fashion or dominant school of thought which typifies and influences the culture of a particular period in time. According to the German philosopher Georg Wilhelm Friedrich Hegel (1770-1831) “no man can surpass his own time, for the spirit of his time is also his own spirit.” (http://en.wikipedia.org/wiki/Zeitgeist)
In an extension of this view, systems theory would allow to use the notion also in a restricted sense, such as how to do business at a particular time period and location (region, country) or “prescriptions” how to innovate or found a firm.

Zeitgeist – Goethe:

Faust – 575-577	Translation *)
„Was ihr den Geist der Zeiten heißt, das ist im Grund der Herren eigner Geist, in dem die Zeiten sich bespiegeln.”	The spirit of the ages, that you find, In the end, is the spirit of Humankind: A mirror where all the ages are revealed. What you call “spirit of the ages” Is after all the spirit of those sages In which the mirrored age itself reveals.

*) http://www.poetryintranslation.com/PITBR/German/FaustIScenesItoIII.htm; http://goethe.holtof.com/faust/Faust_I_02.htm.

Acronyms

ALD	Atomic layer deposition
AUTM	Association of University Technology Managers
B2B	Business-to-business
B2C	Business-to-consumers
B2G	Business-to-government
B2P	Business-to-public
BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)
BMVh	Bundesministerium der Verteidigung (Federal Ministry of Defense)
BMWi	Bundesministerium für Wirtschaft und Technologie (Federal Ministry of Economics and Technology)
BOS	Balance-of-System (Cost)
CAPEX	Capital expenditures
CEO	Chief Executive Officer
CFO	Chief financial officer
CdTe	Cadmium telluride
CFD	Computational fluid dynamics
CHP	Combined heat and power plant (in German Blockheizkraftwerk – BHKW)
CIGS	Copper indium gallium diselenide
CMP	Chemical mechanical planarization
COO	Chief operating officer
CoP	Communities of practice”
COTS	Commercial-off-the-shelf (products, components)
CRADA	Cooperative Research and Development Agreement
CSF	Critical success factor
CSO	Chief-science-officer

CTO	Chief-technology-officer
CV	Corporate venturing
CVC	Corporate venture company
DFG	Deutsche Forschunsgemeinschaft (German Research Foundation)
DIY	Do-it-yourself
DOD or DoD	(US) Department of Defense
DOE or DoE	(US) Department of Energy
DPMA	Deutsches Patent- und Markenamt (German Patent and Trade Mark Office)
DSO	Days Sales Outstanding
EEG	(Germany) Erneuerbare Energie Gesetz – Renewable Energy Act
EERE	(US) Office of Energy Efficient and Renewable Energy
EGC	Entrepreneurial growth company
EH&S	Environmental health and safety
EISA	(US) Energy Independence and Security Act of 2007
EMEA	European Medicines Agency
EPA	(US) Environmental Protection Agency
EPC	Engineering, procurement and construction
EPO	European Patent Office
ERP	Enterprise resource planning
ESA	European Space Agency
ESTCP	(US) Environmental Security Technology Certification Program
EU	European Union
EU27	European Union comprised of 27 members
EV	Electric vehicle
F2P	Free-to-play
FCV	Fuel cell vehicle
FFE	Fuzzy Front-End

FFV	Flex Fuel Vehicle
FhG	Fraunhofer Gesellschaft (Society)
GAAP	Generally Accepted Accounting Principles
GDP	Gross Domestic Product
GDR	German Democratic Republic
GEM	Global Entrepreneurship Monitor
GMA	General morphological analysis
GmbH	Gesellschaft mit beschränkter Haftung (cf. LLC)
GMO	Genetically modified organism or object
GP	General Partner(ship)
GST	General Systems Theory
HAP	Hazardous air pollutant
HR	Human Resource(s)
HAWT	Horizontal axis wind turbine
HTS	High throughput screening; high-temperature superconductor
HVT	High value technology
HW	Hardware
I&CT	Information and communication technology
IC	Intellectual Capital
ID	Identification (mark, sign, signal, code etc.)
IHK	Industry und Handelskammer (Chamber of Industry and Commerce)
IP	Intellectual property
IPO	Initial Public Offering
IPR	Intellectual property right
IT	Information technology
JD	Juris Doctor (degree), Doctor of Jurisprudence
JDA	Joint development alliance
JRA	Joint research alliance

JV	Joint venture
KAI	Kirton Adaptive Innovative (instrument)
KDT	Knowledge discovery in text databases
KIBS	Knowledge-intensive business service (firm)
KIT	Karlsruhe Institute of Technology (Germany)
LCF	Lignocellulose feedstock
LED	Light emitting diode
LLC	Limited Liability Company (cf. German GmbH)
LP	Limited Partner(ship)
M&A	Mergers & Acquisitions
MBI	Management buy-in
MBO	Management buy-out
MBTI	Myers-Briggs Type Indicator
MD	Medicinae Doctor (Doctor of Medicine)
MIT	Massachusetts Institute of Technology
MMOG	Massively Multiplayer Online Game
MPG	Max Planck Gesellschaft (Society)
MPI	Max Planck Institut
NAFTA	North American Free Trade Agreement
NAICS	North American Industry Classification System
NASA	(US) National Aeronautics and Space Administration
NASDAQ	National Association of Securities Dealers Automated Quotation
NBD	New Business Development
NGO	Non-governmental organization
NIH	National Institutes of Health; not invented here
NPD	New Product Development
NREL	(US) National Renewable Energy Laboratory
NSF	National Science Foundation (of the US)

NTBF	New technology-based firm
NVCA	(US) National Venture Capital Association
NYSE	New York Stock Exchange
OLED	Organic light emitting diode
OPEX	Operational expenditures
OPV	Organic photovoltaic
OTC	Over-the-counter
P2P	Pay-to-play
PARC	Palo Alto Research Center
PDA	Personal digital assistant
PoC	Proof-of-concept
PPP	Private-public-partnership
PR	Public Relations
PV	Photovoltaic
RBV	Resource-Based View
RES	Renewable energy source
RFS	Renewable Fuel Standard (of US EPA)
RI	R&D intensity (or research intensity)
ROI	Return on investment
S&T	Science & Technology (System)
SBA	Small Business Administration (in the US)
SBIC	Small Business Investment Company
SBIR	Small Business Innovation Research
SME	Small and medium-sized enterprise
SOL	Society for Organizational Learning
SSBIC	Specialized Small Business Investment Company
STVP	Stanford Technology Ventures Program
STTR	Small Business Technology Transfer

SW	Software
SWOT	Strengths, Weaknesses, Opportunities and Threats
Syngas	Synthesis gas
TBS	Technology-based service
TIM	Technology and Innovation Management
TOI	Timing of industrialization
TS	Technical service
TFT	Thin film transistor
TVT	Top value technology
UIRC	University-industry-research centers
USDA	US Department of Agriculture
USP	Unique selling proposition; Unique selling point
USPTO	US Patent and Trademark Office
VAWT	Vertical axis wind turbine
VC	Venture capital (or venture capitalist)
VOC	Volatile organic compound
WWI	World War I
WWII	World War II

INDEX

Indexing is rather detailed including hierarchies following Figure I.1, Figure I.5 and the Table of Contents. This is intended to facilitate working with this book, such as "answering questions", preparing a presentation, a course and reading list or looking for background for a research issue.

A page number for an index entry may be the start covering a range of following pages associated with that index term.

For the index term "Definition/Explanation" the page number of the key definition will be given in **bold** face.

For an index term in a figure or a company description in a sub-chapter, table or box the related page number may be given in *italics*. A company name and directly associated page in italics means a detailed description of the company in a box, sub-chapter or table.

Company Index

Subject Index

TECHNOLOGY ENTREPRENEURSHIP

This treatise is the first coherent and comprehensive presentation of the important sub-field of technology entrepreneurship emphasizing the science and engineering perspective.

It uses Applied General Systems Theory (GST) as a framework for an interdisciplinary approach and the provision of a "theory-into-practice" approach. This allows consistently treating entrepreneurship for firm formation as well as entrepreneurship in existing firms (intrapreneurship) within one framework.

It is a unique presentation of (technology) entrepreneurship as an inter-cultural approach referring to the US and Germany. This situation is used to elaborate generic and country-specific features of entrepreneurship. Adding also a historic approach allows differentiating time-independent generic and time-dependent specific features of technology entrepreneurship.

The book integrates micro- and macro aspects of technology entrepreneurship. A large number of company cases (and two selected industries) generated by the author reflecting the broad diversity of new technology-based firms is interconnected with existing macro-level research results from the literature for technology entrepreneurship. The book provides additionally a totally new semi-quantitative approach to growth of new technology ventures.

Based on principles of GST, such as self-reinforcement and cybernetic processes, for instance, verbalized by the saying "growth breeds growth," and redefining principles of "bracketing" from social theory and sociology as well as metaphorical references to the very basics of quantum theory and physics of light for quantifications "A Bracket Model of New Technology Venture Development" is presented and illustrated by many examples.

The large number of documented cases in the context of the book provides also useful learning examples for to-be entrepreneurs and entrepreneurs having a firm in an incubator or in the early phase of development.