Karlsruhe Institute of Technology

Monitoring Energy Entrepreneurship - Descriptive analysis of startup activities within the German energy sector

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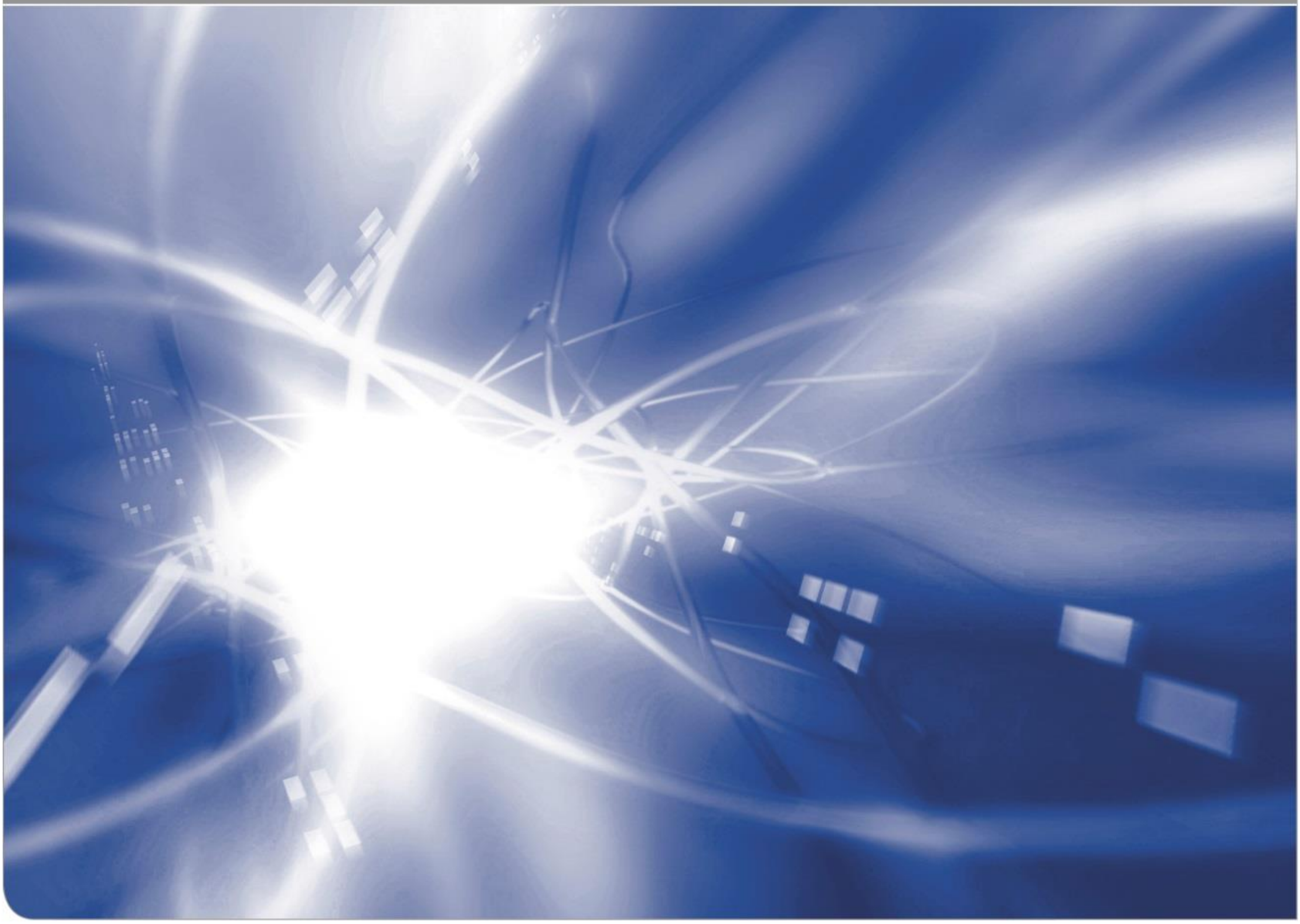

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1 Introduction

By enacting the legislative package for the energy transition in summer 2011, the Federal Government of Germany paved the way from a centrally dominated towards a decentralized structure of the German energy sector and a shift from conventional to renewable energies. This structural change leads to problems of adjustment and restructuring in established corporations in the energy sector. Additionally, current developments in the field of digitalization, e.g. the development of intelligent metering and consumption meters or the connection of decentralized power generators to virtual power plants, new technologies for power storage, or the deep integration of electric vehicles are examples of emerging areas of innovation (Danelius et al. 2012). With these developments, the energy sector has to manage two transformation processes at once - the energy transition and the digitalization of the energy sector. These two processes not only address parts of this sector but the whole energy economic value chain and therefore cause changes along its value creation process. These changes lead to new possibilities that arise for new companies to open up new business areas through innovative business models and technologies (Bersch et al. 2014a).

The following study aims to analyze the impact of these transformation processes on the startup activities within the German energy sector. Therefore, the study addresses the question of how the associated developments trigger startup activities in the field of energy, the so-called Energy Entrepreneurship, in Germany. The aim is to cover the yearly number of startups in different areas of the energy sector which are then analyzed related to the historical development over the years immediately before and after the resolution of the energy transition.

The cross-section of the energy sector, with its numerous industries, markets, and technologies, presents a particular challenge to the statistical collection of these economic structures. Information on the Energy Entrepreneurship in Germany, in particular against the background of the structural change that taking place, has so far not yet been recorded to an adequate extent by the current startup statistics. To close this information gap, a systematic framework of statistical data acquisition was developed to be able to record the Energy Entrepreneurship in Germany statistically.

The data acquisition was conducted in cooperation with the Fraunhofer ISI[1] in October 2015. Some first results of this data acquisition were already presented at the 5th annual conference of the KIT energy center[2] in June 2016. Additionally, the framework design was presented at the 20th Annual Interdisciplinary Conference on Entrepreneurship and Innovation and SMEs (G-Forum)[3] in Leipzig in October 2016. The following working paper describes the methodological framework as well as the results of the analysis in more detail. However, it needs to be noted that some of the results presented in this paper differ from the ones presented at the 5th annual conference of the KIT energy center. This is due to some changes in the framework design and the data acquisition between the time of the presentation at the 5th annual conference of the KIT energy center and the date of publishing of this paper.

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1 The Fraunhofer Institute for Systems and Innovation Research (ISI) focuses on short- and long-term developments of innovation processes and the impacts of new technologies and services on society. For more information see: http://www.isi.fraunhofer.de/isi-en/index.php, 21.11.2016

2 The conference proceedings were not published until the date of publishing of this paper. For more information about the conference see http://www.energy.kit.edu/618.php, 21.11.2016

3 The G-Forum is the largest and oldest entrepreneurship and innovation conference in Germany, Austria, and Switzerland. In 2016, the 20th Annual Interdisciplinary Conference on entrepreneurship, innovation, and SMEs (G-Forum) was held in Leipzig from 05 to 07 October. Conference program: http://www.hhl.de/fileadmin/texte/event/G-Forum/G-Forum_2016_Preliminary-Programm_22-09-2016.pdf, 21.11.2016

2 Demarcation of the Energy Entrepreneurship

At this stage, the statistical covering of the German energy sector is done by the German Federal Statistical Office, using the so-called economic classification (WZ 2008). Via these classifications, the whole German economy is divided and classified in 21 economic sectors with more than 800 sub-sectors. Within this classification, the topic energy is covered by the sector called *Electricity supply*. This sector and its related sub-sectors focus on companies within the energy production and energy transmission. However, this sector does not cover companies dealing with energy services or technologies related to the digitalization of the energy sector. Moreover, this class does not represent current developments, such as the shift from centralized to decentralized production or the increasing use of energy for the transportation sector, for example for electric mobility. Therefore, the statistical covering must be improved and enlarged to address these new trends and developments, by implementing a new framework for collecting and allocating company data. The first step to building such a framework is a broad and robust definition of all relevant sectors, technologies, and services related to energy.

2.1 Lead market approach

There are many different definitions for the term energy economy in the literature. These differ primarily in the depth of the meaning; that is to say specifically, which sectors, technologies, and measurements are part of the energy economy. The number of different definitions indicates that a precise definition of the term energy economy is complicated. The biggest problem is how the energy economy as an economic sector can be defined as comprehensively and as detailed as possible. The present study follows the definition of Böhmer et al. (2015), who defines the energy economy as „all those shares of the added value of the respective industries or sub-sectors of the economic classification [...] whose products or services serve directly or indirectly to the supply of end consumers with electricity, district heating, fuels as well as energy services." This definition is the most likely to allow a statistically well-founded demarcation of the energy economy regarding sectors and sub-sectors of the economic classification. However, this definition also shows the cross-sectoral nature of the energy sector, whose products and services are produced, traded and used across many industry sectors.

Current statistical surveys of the energy sector by the Federal Statistical Office, do not take this cross-section into account. There, the energy sector is composed solely of the sector *Electricity supply*, with its sub-sectors of electricity supply, gas supply, heating and cooling, renewables and coal (DESTATIS 2015). This statistical delimitation allows the collection of data on employment figures, turnover or investments, but also leads to an underrepresentation of areas such as the end use of energy, energy services or the digitalization within the energy sector.

The framework presented in this study, therefore, does improve the approach of the Federal Statistical Office by adding two new pillars to define the relevant sectors of the energy sector. First, the framework recognizes the energy sector as part of the higher-ranking area of the environmental economy. This area is much more pronounced regarding the number of statistical surveys. According to the German Federal Ministry for the Environment, the environmental economy includes all companies that contribute to the reduction and elimination of harmful environmental impacts. These companies offer goods and services in various areas such as rational energy use, renewable energies, environmentally friendly products, climate protection, measurement and control technologies, waste management and recycling, water protection and wastewater treatment, air pollution monitoring and noise reduction (Franz et al. P. 15). This means that in addition to plants for generating electricity from renewable energies (for example wind power and solar systems), the field of environmental technology also covers for example intelligent meters to control the electricity consumption. Moreover, environmental services, such as energy consulting in the energy sector or trading with environmentally-friendly products are taken into account (Franz et al., 2011, p. 15). One of the lead studies for the analysis and statistical demarcation of the German environmental economy is the so-called Environmental Technology Atlas, a study conducted on behalf of the German Federal Ministry for the Environment (Büchele et al., 2014). This study uses a lead market approach with six different lead markets to cover the environmental economy in Germany, namely *Environmentally friendly power generation, storage and distribution*, *Energy efficiency*, *Material efficiency*, *Sustainable mobility*, *Waste management and recycling* and *Sustainable water management*. These lead markets are then subdivided into related market segments which are again divided into several technology lines.

The second pillar is composed by the three primary energy policy objectives of the Federal Government's energy concept - the fostering of renewables, the increase in energy efficiency and the reduction of CO2 emissions within the transportation sector. According to the lead market approach of the German Federal Ministry for the Environment for the environmental economy and the objectives of the energy concept, the present study focuses on the three lead markets *Power generation, storage, and distribution*, *Energy efficiency* and *Sustainable mobility*. Table 1 shows the three relevant lead markets, their market segments, and technology lines.

Table 1: Assembling of the relevant lead markets, Büchele et al. (2014)

	Market segments	Technological lines	
Power generation, storage and distribution	Renewable energy	- Photovoltaics - Solar thermal energy - Biomass use - Wind power (Onshore)	- Wind power (offshore) - Geothermal energy - Hydropower
	Environmentally friendly use of fossil fuels	- Gas and steam turbine power plants - Cogeneration unit - High performance power plants	- Waste Heat utilization - CCS (CO2 capture and storage)
	Storage technologies	- Mechanical storage of energy - Electrochemical storage of energy - Electronic storage of energy	- Power2Gas - Thermal storage of energy
	Efficient grids	- Control technologies for grids - Control technologies for plants	- Heating and cooling networks
	Digital electricity industry	- Virtual powerplants - Trade / Forecasts - Smart Meter - Demand Side Management	- Monitoring / load Management - Virtual Storage - Smart Grid - Smart Home
Energy efficiency	Energy efficient production processes	- ... in metal production - ... in basic chemicals - ... in vehicle construction - ... in trade / logistics	- ... in metal processing - ... in the production of paper / cardboard - ... in food production
	Energy efficiency of buildings	- Thermal insulation - Building automation - Passive houses / Plus energy houses	- Efficient heating, air conditioning and ventilation technology
	Energy efficiency of devices	- Energy efficiency of household appliances - Energy-efficient lighting	- Energy-efficient entertainment electronics
	Cross-Industry components	- Measuring and control technology - Process control technology - Pumping systems - Fans	- Electric drives - Heat exchanger - Compressors, compressed air and vacuum technology
Sustainable mobility	Alternative drive technologies	- Hybrid drive - Electric drive	- Fuel cell drive
	Renewable fuels	- Bioethanol - Biodiesel - Regeneratively generated hydrogen	- Biomethane - Bio-kerosene
	Technologies to increase efficiency	- Efficiency increase of combustion engines - Lightweight construction technologies	- Energy saving tires
	Transport infrastructure and traffic control	- Rail vehicles and rail infrastructure - Public transport - Traffic management systems	- Car Sharing - Petrol station infrastructure for alternative drives

The three relevant lead markets, *Power generation, storage, and distribution*, *Energy efficiency* and *Sustainable mobility*, are derived from the objectives of the energy concept as a delineation of the energy economy. Therefore, companies that are economically active in these lead markets contribute to the achievement of the Federal Government's energy concept by their business purpose. The derived market segments and technology lines are described in the following.

2.1.1 Power generation, storage, and distribution

The desired decarbonization of the energy sector requires an intelligent conversion of the electricity supply in which the technological lines of the lead market *Power generation, storage, and distribution* play a decisive role.

In the area of energy production, the technical progress in systems for the generation of electricity and heat from renewable energy sources is increasingly driving the decentralization. Photovoltaic, wind, hydropower and biomass as well as solar and geothermal energy are therefore important technology lines which can be attributed to the market segment *Renewable energy* (see Table 1).

In addition to the increasing use of such renewable sources, it must be taken into account that coal, natural gas, and oil will stay important for the energy mix over the coming decades (Büchele et al., 2014, p. 36). The second market segment, therefore, covers the *Environmentally friendly use of fossil fuels*. This segment comprises technologies that minimize the consumption of resources and the emission of pollutants in the generation of electricity from these fossil fuels. These include, for example, cogeneration units or a more intensive use of waste heat.

If the proportion of renewable energies and thus the fluctuating and decentralized electricity supply increase, the storage capacities for energy must grow significantly. This expansion can be used to regulate the balance between power generation and demand necessary for grid stability. In this case, storage devices have to store the energy temporarily in the event of an excess and, if there is high demand, feed it back into the grid (Büchele et al., 2014, p. 37). The market segment *Storage Technologies* includes various solutions such as, for example, Power2Gas, battery technologies, a mechanical or thermal storage of energy.

Due to the increasing decentralization and the actual concentration of offshore wind farms in the north of Germany, efficient grids are a critical prerequisite for the security of supply (Büchele et al., 2014, p. 37). The market segment *Efficient Grids* mainly comprises technologies to improve the grid infrastructure and hardware control technologies for networks and systems.

The formerly mentioned digitalization of the electricity sector cannot be understood as the fact that all transactions will be fully digitized or handled exclusively via information and communication technologies (ICT) but that ICT has a support function for the entire production process. This applies to the whole electricity value chain, from generation to trade, transmission, distribution, storage, sectoral linkage to consumption. This includes, for example, the bundling of former, small and medium-sized decentralized electricity generators such as wind turbines and solar plants, hydropower plants and biogas plants into a virtual power plant. These decentralized producers are then able to sell their capacities at the electricity exchange or offer grid operators a spinning reserve (Büchele et al., 2014, p. 25). Additionally, smart metering systems within the industrial as well as the household use will gain greater importance as these devices enable the improved load management or demand side management. Therefore, the market segment 'Digital electricity management' covers some of the major technology lines related to the use of ICT along the electricity value chain.

2.1.2 Energy efficiency

The second primary objective of the Federal Government's energy concept addresses the issue of energy efficiency. In addition to an increased CO2-free electricity supply, an improvement in energy efficiency and the resulting limitation of power consumption contribute to a successful energy transition. The lead market *Energy efficiency*, therefore, covers the main fields of action for an improvement in energy efficiency and is oriented to areas which offer considerable potential for savings.

The market segment *Energy efficient production processes* refer to core processes in various energy-intensive economic sectors, such as metal production, basic chemicals, food production, etc. This segment primarily looks at ways in which companies can reduce energy consumption by optimizing their processes.

Regardless of the industry affiliation, *Cross-sector component technologies* which can lead to energy savings in the case of supporting processes are covered within a market segment. These include, for example, electric drives, pumping systems, compressed air or vacuum systems.

The two market segments mentioned above generally refer to the internal efficiency improvement of companies. However, the market segment *Energy efficiency of devices* addresses mainly the area of private consumers. Technologies for improving the efficiency of household appliances (e.g. "white goods"), lighting and entertainment electronics are being considered.

In Germany, around 35 percent of primary energy consumption was accounted for the provision of space heating and hot water in buildings in 2014. In private households, the proportion of this provision is even 85 percent of the total energy demand (AGEB 2015). These figures clearly show the potential for improvement within the market segment of *Energy efficiency of buildings*. By 2050 the primary energy requirement of buildings in Germany should be reduced by 80 percent compared to the base year 2008 (BMWi 2014). To achieve this ambitious goal, it is necessary to promote the renovation of existing buildings. On the other hand, the most energy-efficient and climate-friendly construction of new buildings should be considered. In addition to the structural measures, the market segment also includes efficiency effects through building automation, thermal insulation, passive houses and plus energy houses.

2.1.3 Sustainable mobility

In Germany, the share of the transport sector in total energy consumption amounted to 29 percent in 2014 (AGEB 2015). In 2010, 20 percent of all CO2 emissions in Germany were attributable to this sector (Kalinowska et al. 2012). The largest share of both energy consumption and emissions apply for motorized individual traffic (Kalinowska et al. 2012). As written in the objectives of the energy concepts, the power consumption is to fall by ten percent by 2020, and until 2050 by 40 percent compared to the level of the base year 2005. The main reason for the high share of CO2 emissions is the dependence on fossil fuel oil. A reduced use of this current critical resource offers great potential for the decarbonization of the transport sector (Büchele et al., 2014, p. 42). Key levers to reduce this dependency are the efficiency enhancement of combustion engines or technologies for environmentally friendly vehicle design. These technologies are combined in the market segment of *Technologies for increasing efficiency*.

Even if vehicles with a conventional drivetrain will make up the bulk of the global fleet of vehicles in the foreseeable future, alternative drive technologies also represent a promising way of reducing the dependency on fossil fuel oil (Büchele et al., 2014, p. 42). Vehicles with purely battery-driven drivetrains or a fuel cell run in the operating phase without any CO2 emissions. If the electricity generated by renewable energies is also used to power electric vehicles, these vehicles operate completely CO2-free and thus make a significant contribution to sustainable mobility (Büchele et al., 2014, p. 30). The market segment *Alternative drive technologies*, therefore, covers all technologies for pure electric, hybrid and fuel cell drivetrains as well as power-to-mobility systems[4].

The market segment *Renewable Fuels* pursues a similar goal as alternative drive technologies. Through renewable alternatives to the fuel oil, the dependence of the transport sector on this resource is to be reduced.

In addition to the purely technical efficiency improvements, the expansion of an innovative transportation infrastructure is a further lever for decarbonization and energy saving. This includes, on the one hand, a better interlinking of private transport with the services offered by local public transport, for example, the expansion of car sharing programs or an expansion of rail transport. On the other hand, the integration of alternative drivetrains is becoming increasingly important through the development of a loading infrastruc-

4 Power-to-Mobility systems allow to store electricity in battery electric vehicles using mostly lithium-ion and nickel metal-hydride batteries. For more information, see e.g. Sternberg et al. (2015).

ture. All of these technologies are attributable to the market segment *Transport infrastructure and traffic control*.

The field of study in this work is thus defined by the technology lines and market segments of the three lead markets *Power generation, storage, and distribution*, *Energy efficiency* and *Sustainable mobility* mentioned and described above.

2.2 Definition of Energy Entrepreneurship

Following the derivation of the relevant lead markets in the energy sector from the lead market approach of the Federal Ministry for the Environment and the objectives of the energy concept, the term startup must also be placed in the particular relation to the energy sector. When using the term startup, the aspects of new and innovative products, technologies or business models are often considered a requirement for such companies. In a broader definition of the term startup, such businesses can also be regarded as relevant without necessarily using or developing new or substantially improved products, processes, marketing methods, organizational structures or institutional aspects. These companies then usually offer improved versions of existing or traditional goods or services. The genuine innovation in this type of enterprise is not a radical change in products or services but in the offer of more economical, efficient, user or environmentally friendly alternatives to the existing ones (Kirkwood and Walton 2014, p. 47; Weiss and Fichter 2013, p. 27). For the present work, it was defined that startups do not necessarily have to bring innovations to the market. Nevertheless, the core business or at least a significant ancillary business of the company must serve to achieve the goals of the energy concept and thus contribute to the energy transition. To allocate such startups, the term of Energy Entrepreneurship is introduced and defined as follows:

"Energy Entrepreneurship refers to startups that contribute with their products, technologies, and services to the power generation, storage, and distribution, to the improvement of energy efficiency or the promotion of sustainable mobility, through their core business or a significant ancillary business." (Own definition based on Weiss and Fichter 2013, p. 27)

The object of study thus results from startups to which the above definition applies. These startups of the Energy Entrepreneurship are summarized in the following work under the term Energy Startups. Whenever this term is used in the following, it refers to new and young companies with a maximum age of eight years.

3 Conceptual framework for monitoring the Energy Entrepreneurship

The next chapter presents the methodical survey concept developed to measure and analyze the formulated research questions by descriptive data. To this end, the structure for the necessary data collection is described, including the definition of the requirements for the survey framework as well as the concretization of the research questions using measurable indicators. Based on this framework, the phase of the data collection is described together with an explanation of the used data sources as well as the selection strategies for the relevant information.

3.1 Requirements for the framework

The structure of the survey framework for the recording of the energy startups follows the delimitations of the field of study. Also, the data collection itself must meet certain requirements to collect the data needed to answer the research questions ultimately. Based on the findings by Weiss and Fichter (2013) regarding the requirements of startup monitors, nine requirements of the survey design have been set for the framework (s. Figure 1).

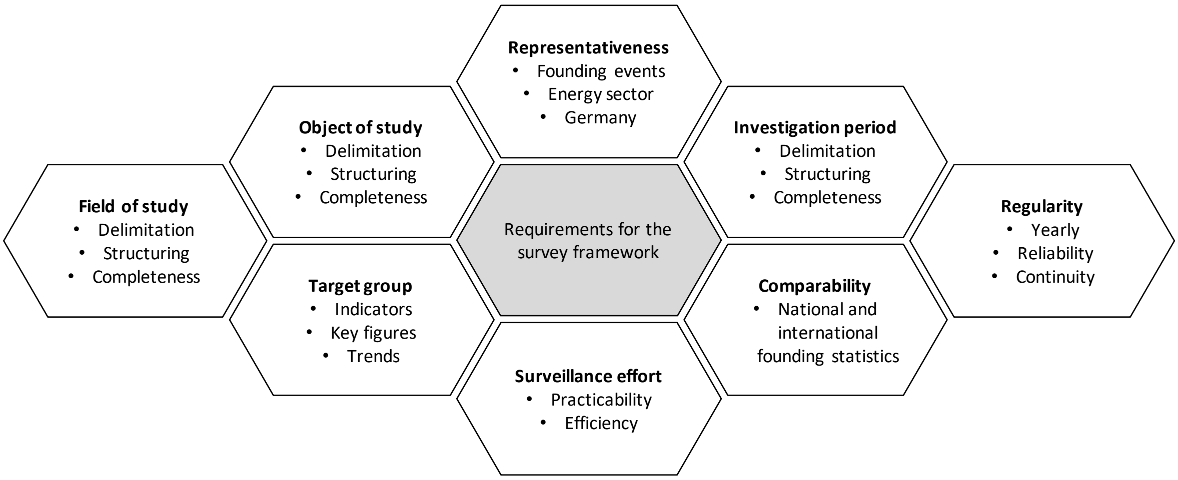

Figure 1: Requirements for the survey framework, own illustration based on Weiss and Fichter (2013)

For a consistent review and analysis, company-specific data must be collected, which reflects both the lead market structure as well as the contribution of the foundations to the goals of the energy concept. The design must, therefore, allow for the classification of the economy and accurate information on the activity and the product portfolio of the startups. Moreover, the study must assure representativeness by reflecting three essential definitions, the ones of the field of study, the investigation period and the object of study. The field of study is defined via the three lead markets *Power generation, storage, and distribution*, *Energy efficiency* and *Sustainable mobility* with their respective market segments and technology lines. Since the present study deals primarily with the effects of the energy concept, the investigation period focuses the years after its introduction, i.e. from 2011 onwards. Also, startups established between 2008 and 2010 are examined, to measure possible short-term effects of this concept on the startup situation in the energy sector. However, at the date of implementation of the present analysis, the year 2015 was not yet completed. Therefore, the investigation period refers to the years from 2008 to 2014. The third definition relates to the proper object of study, in the current case energy startups related to the definition introduced above. The essential criterion for determining the totality of the analysis is the delineation and structuring of the field of study, meaning the three lead markets of Energy Entrepreneurship, which must be as complete as possible. To meet the cross-sectional nature of the energy sector, data sets that contain exclusive information on suppliers of environmental technologies or environmental goods and services are out of the question (Weiss and Fichter 2013, p. 30). Moreover, the framework only allows data sets on startups which permit an individual analysis of their entrepreneurial activities. Regarding the representativeness as mentioned above, the survey design must also allow comparability of the lead markets with other economic sectors. To this end, the framework needs to take a methodological continuity as a basis, which can be extended to other economic areas if necessary. Furthermore, it is desirable for further analyses to make an international comparison possible. For this reason, the design for data on the lead market allocation may not refer to German-specific lines of evidence, but must be based on international sources adaptable to the German market. Also, the data must allow conclusions on measurable indicators, appropriate metrics, and trends to maximize the benefits for the target group. Furthermore, the collection effort needs to be made as efficiently as possible to ensure long-term usability of the framework. Also, the regularity of the design must be guaranteed, thus allowing a continuous and reliable survey.

3.1.1 Indicators of the survey concept

The primary objective of this thesis is to collect and analyze information on startups in the energy sector. Part of this analysis is to answer questions about the economic importance of such energy startups. Other data to be collected refer to their year of incorporation or their regional distribution. Therefore, the research question was specified using indicators which enable the Energy Entrepreneurship to be recorded in a standardized manner and to structure the selection of the necessary data sources. Based on existing startup statistics, specifically the Mannheim startup panel and the Green Economy Monitor (Bretz et al. 2015, Weiss and Fichter, 2013), the following indicators were selected:

- Company structure of energy startups
- Regional distribution of energy startups
- Number of annual energy startups by lead markets
- Number of annual energy startups by economic sectors
- Composition of Energy Entrepreneurship by economic sectors
- Composition of Energy Entrepreneurship by lead markets
- Composition of the lead markets by market segments
- Composition of the market segments by technology lines

3.2 Strategies for data collection

The first step in measuring the indicators set is to choose the right database. This is done primarily by the necessary information, the requirements for the survey design as well as the findings from the analysis of existing studies. It is, therefore, necessary to have a database that contains the most detailed information on company foundations in Germany. These include, in particular, typological features such as the year of incorporation or the location as well as further details on the field of the entrepreneurial activity of the companies, which allows an allocation to the lead markets as well as specific economic sectors.

Some investigations of the startup activities in Germany, for example, the Green Economy Monitor (Weiß und Fichter 2015) or the KfW founding monitor (Metzger 2015), are pursuing the approach of selecting an appropriate sample from the totality of the startups. Based on this sample, they then draw conclusions about the startups in certain economic sectors. The survey framework presented here differs from these sample approaches in the way that the combination of various databases makes an attempt to depict the totality of all company foundations in Germany as accurately as possible. Subsequently, characteristics are then applied to this whole that allow an identification of energy startups.

Many existing company statistics confirm the database of Creditreform as a tried and trusted source to obtain corporate information. This comprehensive database contains data on 14 million companies across Europe. The collection of these data is carried out decentralized by a total of approx. 130 independent branches, which are grouped together in the association Creditreform e.V. (Bersch et al. 2014b, p. 2). Creditreform searches various public registers, in particular, the commercial record, the bankruptcy and settlement reports as well as daily newspapers, annual reports and published balance sheets to collect their data. The systematic evaluation implies that the Creditreform database includes almost all existing companies (Metzger et al., 2010, p. 63 f.). The search always takes place according to the same mode, with the legally independent enterprise as a survey unit (ZEW 2014, p. 116). Further studies by the ZEW show that the Creditreform database maps the entirety of companies without systematic temporal and regional distortions (Licht 1999). In addition to local data of the companies, the Creditreform database also contains information such as organizational data on the legal status, their year of incorporation or the URL[5] addresses of the companies websites. Also, each acquired company is assigned to an economy sector using the economic classification WZ 2008 of the Federal Statistical Office and further described based on a trade description and information about their respective products or services. Moreover, these data are periodically determined and renewed which allows an analysis of the historical development (Bersch et al. 2014b, p. 3).

Due to the aim of depicting the totality of all company foundations in Germany, a second company database, the Hoppenstedt database, is used. Hoppenstedt records similar data as Creditreform. The only significant difference between the two databases is the regional coverage of the companies. Whereas Creditreform analyzes companies across Europe, Hoppenstedt focuses on the markets of Germany, Austria, and Switzerland (Bisnode 2012). Due to the different regional focus, it is entirely possible that the Hoppenstedt database lists companies, for which there are no data in Creditreform and vice versa. A combination of these two databases offers the advantage of being able to cover even more company profiles and to ensure a higher level of detail.

The introduction of the electronic trading register in Germany in 2009 made it possible for the two databases to increase the speed of adding companies subject to registration significantly. Due to this higher rate of collection only small extrapolations are necessary for the current edge of the investigation period (Höwer 2010, p. 7). Since at the time of the data extraction for this study the last year of research has already been closed for ten months, and the combination of both databases as such allows a higher data density, the current analysis does dispense with an extrapolation at the current edge altogether.

As the mixture of these two databases covers more than 15 million company profiles, these initial data must be limited to the actual analysis according to the field, object and period of study. This is intended to ensure that only those companies are analyzed that meet the previously established requirements for startups in the energy sector. To filter companies according to the criteria of the field, object and period of study as well as the required information, four strategies for limiting and selecting data were deployed. The first filter relates to the temporal and geographical limitation of the investigation. The second strategic flaw is the selection of individual economy sectors which are relevant for a consideration of the lead markets. The third strategy is to analyze the trade descriptions and the products and services of the companies. By this analysis, the companies are allocated to the respective technology lines, market segments and thus the three lead markets. Finally, the study placed a focus on genuine startups, by making a distinction between derivative and genuine foundations.

[5] URL = Uniform Resource Locator, referred to the unique address for each document, which is available on the Internet (Lackes 2015)

As can be seen in Figure 2, the aim of these four strategies is to gradually reduce the number of companies by a more precise demarcation while increasing the level of detail of the associated company information. The following chapter describes these procedures in depth.

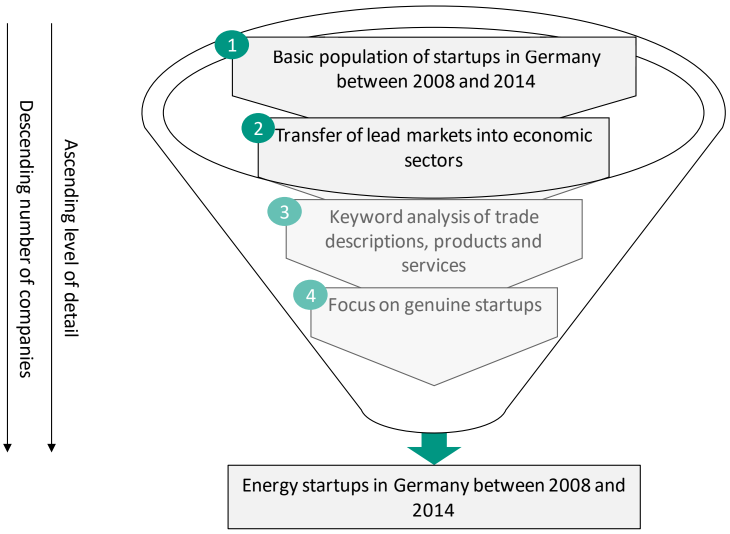

Figure 2: Strategies for delimiting the investigation environment, own illustration

3.2.1 Temporal and geographical boundaries

The framework only considers businesses established from 2008 onwards and recorded in the commercial register of Germany. Although foreign companies have the opportunity to use the German energy sector as a growth market, the present work focuses on the potential and the development of businesses that were founded and reported in Germany. The third criterion is the economic activity of the companies under consideration. This means that the detailed investigation only approves those companies that are economically active in 2014.

3.2.2 Transfer of the relevant lead markets to economic sectors

The essential requirements for the survey design include the regularity and comparability of the data collection. Therefore, a fixed framework for data collection is necessary, which is typically based on international standards and contains data that can be determined periodically. One of the essential prerequisites for this defined framework is the existence of a recognized system for classifying the available evidence. As already mentioned, the Federal Statistical Office of Germany uses the so-called classification of the economic sectors (WZ 2008) to allocate companies within the German economy.

The WZ 2008 describes the production activity of companies and does not differ according to their legal organization or the operating forms of a company since these criteria do not refer to the characteristics of the activity itself. Undertakings or entities which pursue the same economic activity are equally allocated to the economic sectors, whether they are individual companies, (parts of) corporations or public companies, and whether the company consists of several entities or the parent company is a foreign company. Moreover, the classification by economic activity does not distinguish between the pursuit of economic activity by machinery or manual work, in a factory or a private household (Statistisches Bundesamt 2008, p. 9). The classification of the branches of the Federal Statistical Office provides an internationally harmonized demarcation of the economic sectors, which consists of a total of 21 economic sections, again divided into groups, classes, and subclasses. The underlying databases of Creditreform and Hoppenstedt support such a classification of companies according to the WZ 2008. The transfer of the lead markets into the economic sector classification of the WZ 2008, forms a first but rough demarcation of the Energy Entrepreneurship. For example, the WZ 2008 defines the technology line by the production of solar cells and solar modules (WZ 26.11.1) and the production of solar heat collectors (WZ 28.21.1). However, with this technology line, as with the majority of all technology lines relevant for the Energy Entrepreneurship, it is delicate to define a demarcation by such suitable economic sectors. In addition to the production of solar cells, modules, and heat collectors, the WZ 2008 does not explicitly define other industries linked to photovoltaic. These include, for example, all services related to the installation and operation of solar systems. It is, therefore, necessary to find a more sophisticated way of transforming the interdisciplinary lead markets of the Energy Entrepreneurship into economic classes.

For this purpose, the present study uses several existing studies on the subject of classification of some areas of the economy based on the WZ 2008. The primary basis is a study by Prognos AG on behalf of BMWi[6] (Böhmer et al., 2015). The study on the value creation and employment effects of the energy sector includes a detailed statistical demarcation of the German energy sector using the WZ 2008 and based on the known definition of the energy economy by Böhmer et al. (2015). However, since this demarcation places a strong focus on the topics of power generation and energy conversion, the lead markets of *Energy efficiency* and *Sustainable mobility* are not sufficiently represented. To also be able to record these lead markets statistically, the present work makes use of the fact that companies in the area of efficiency improvement are regarded as technology-intensive companies, which are often founded in the high-tech sector (Gehrke et al., 2010). These technology-intensive companies can also include those from the lead market of *Sustainable Mobility*, which are active in the market segments of *Alternative drive technologies* and the *Technologies for increasing efficiency*. In addition to these technology-intensive companies, there are numerous software-based companies in the lead markets. Such companies are usually assigned to the area of knowledge-intensive goods and economic sectors (Gehrke et al., 2010). Both the technology and the knowledge-intensive goods and economic sectors were delineated in the NAV / ISI / ZEW lists based on the WZ 2008 (Gehrke et al., 2013). Accordingly, the present work uses a combination of the list of Prognos (Böhmer et al. 2015) and the NEW / ISI / ZEW lists (Gehrke et al., 2013) as the statistical basis to meet all relevant lead markets equally.

3.2.3 Analysis of trade descriptions, products, and services

Since the Energy Entrepreneurship covers many different technologies and economic sectors, a clear demarcation based on these WZ classes is still too superficial. There is a risk that many companies that are by definition not part of the Energy Entrepreneurship will be involved in the analysis. Because the data collection must explicitly examine companies from the economic sectors for their affiliation with the energy sector, it must be refined accordingly. The necessary information about the company's activities, as well as the products and services it offers can be obtained from the data of Creditreform and Hoppenstedt. Information, describing the business purpose of the companies is stored in the databases in the form of a flowing text. Therefore, the third strategy for data selection investigates these flow texts. Comparable to the ZEW survey (ZEW 2014), a text analysis algorithm searches the company's trade descriptions and descriptions of their main products or services for keywords linking to the lead markets of *Power generation, storage, and distribution*, *Energy efficiency* or *Sustainable mobility*. If this algorithm shows any evidence of an affiliation with the relevant technology lines, the companies are assigned to these technology lines and thus ultimately to the relevant lead markets.

To this end, precise keywords describe the various technological lines. These keywords are identified in a two-step process using two sources. The first source consists of texts from the literature related to the

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6 BMWi = Federal Ministry for Economic Affairs and Energy

technology lines which were examined for frequently used words to describe the technologies. These texts were analyzed by the analysis program RapidMiner[7] subjected to a keyword analysis and a word count. Based on these identified keywords, a thesaurus[8] has been created for each respective technology line, describing the technology as disjoint as possible and consisting of both uniquely identifying keywords as well as combinations of keywords. The biggest problem in analyzing these trade descriptions is that only such terms can be found which are used by the Creditreform and Hoppenstedt employees who write these descriptions. Therefore, the trade descriptions themselves build the second source. These were subjected to a word analysis, in which the words themselves and their quantities were detected. The keywords from the literature were then compared with this word count. As a result, the previous keywords were adapted to the terms used in the descriptions. Thesauri which contain similar or even identical terms were grouped under the respective conceptions of the market segment.

These thesauri form the basis of a specially developed analysis tool, which examines the trade descriptions and the information on the products and services. Before the real analysis was carried out, the quality of the thesauri was tested and improved in an iterative process. For this purpose, a company sample was examined after an initial run of the analysis tool to identify companies that were wrongly assigned to the Energy Entrepreneurship or were not found due to a lack of overlapping of the thesauri and the trade descriptions.

The sample consisted of the companies that were surveyed in the UMFIS database[9] as part of the already mentioned Environmental Technology Atlas. Within the survey of the former mentioned Environmental Technology Atlas, the companies in this database undertook an independent affiliation to the six lead markets for the environmental economy. As the three lead markets of the Energy Entrepreneurship are part of these six lead markets, the aim of the sample investigation was to determine whether all companies which had assigned themselves to one of the lead markets of the Energy Entrepreneurship were also recognized by the analysis tool as such. By the findings, the first version of the thesauri was subsequently modified to prevent misallocations. In the course of this modification, the thesauri were also improved regarding operability and efficiency. For example, several similar terms were replaced by a part of the corresponding word stem, thus reducing the number of word entries and reducing the computing time of the analysis tool. Thesauri which contained similar or even identical terms were grouped under the respective conceptions of the market segment. For this reason, the final assembling of the lead markets used in the analysis slightly differs from the assembling of the field of study described in Chapter 2.1 (see Table 2). In addition to the keywords, a negative list of terms was introduced during the optimization process. This list can be used to prevent the identification of companies which, while overlapping with the thesauri, are not to be assigned to the Energy Entrepreneurship. After the second pass with modified thesauri, the respective technology line and thus the associated lead market are assigned to each identified company of the Energy Entrepreneurship through the analysis tool. With this classification of the companies by the trade descriptions as well as the information on products and services, the existing assignment of the companies using the WZ 2008 was further refined.

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7 RapidMiner is an open-source environment for machine learning, data, text and web mining, originally developed by the Department of Artificial Intelligence of the University of Dortmund (RapidMiner 2015).

8 Thesaurus: "Alphabetically and systematically ordered collection of words of a particular (subject) area" (Duden 2015)

9 The UMFIS database consists of German companies involved in environmental technologies and services and is presented by the German Chambers of Commerce and Industry. The database entries stem from voluntary specifications of the companies. Source: http://www.umfis.de/index_e.html, 21.11.2016

Table 2: Final assembling of the three lead markets, own compilation based on Büchele et al. (2014)

	Market segments	Technological lines	
Power generation, storage and distribution	Renew able energy	- Photovoltaics - Solarthermal energy - Windpow er (on- / offshore)	- Hydropow er - Geothermal energy - Biomass use
	Environmentally friendly use of fossil fuels	- Fossil fuels	- Waste heat utilization
	Storage technologies	- Storage technologies	
	Efficient grids	- Grids and plants for regenerative generation and distribution - Grids and plants for fossil production and distribution	- Netw orks and facilities for heat and cooling production and distribution
	Digital electricity industry	- Virtual pow erplants - Trade / Forecasts - Smart Meter - Demand Side Management	- Monitoring / load Management - Virtual Storage - Smart Grid - Smart Home
Energy efficiency	Energy efficient production processes	- Energy efficient production processes	
	Energy efficiency of buildings	- Plus-energy buildings - Buildingautomation	- Heat insulation - Environmental Consulting
	Energy efficiency of devices	- Energy efficiency of devices	
	Cross-Industry components	- Cross-Industry components	
Sustainable mobility	Alternative drive technologies	- Alternative drive technologies	- Pow er-to-Mobility
	Renew able fuels	- Renew able fuels	
	Technologies to increase efficiency	- Technologies to increase efficiency	
	Transport infrastructure and traffic control	- Infrastructure for Alternative drive technologies - Transport infrastructure	- Car sharing

3.2.4 Delimitation of genuine company foundations

When analyzing the startup activities within this study, particular attention was paid to the structure-creating genuine startups. In the underlying databases, a division of the business startups into derivative and genuine startups is not made explicitly. Also, an identification of the genuine startups is made more complicated by the fact that the chronological development of a company can also include derivative events, such as changes in the legal structure or modifications in the ownership structure due to acquisitions, divisions or mergers (Engel and Fryges 2002, p. 6). Therefore, different approaches are being pursued in this framework to identify and filter out these derivative events. Both Hoppenstedt and Creditreform collect information on company history. These include, for example, previous company names. In the case of simple name changes without amending the legal form, the commercial register entry is retained and the company with a new name still counts as a genuine startup (Handelsregisterverordnung - HRV 2015). This being the case, the legal forms in the previous company names are compared with the current legal forms to determine a possible change. Furthermore, it is checked whether the history of the particular status of the company contains information about possible bankruptcy proceedings, in the course of which a change of legal form or reorganization has taken place. When collecting the data initially both genuine and derivative startups are acquired. After their separation, the subsequent analysis allows to filter out these derivative startups.

3.3 Harmonization and aggregation of data sets

After collecting the raw data from the underlying data sources, the next step was to merge the company-specific data into one database. Since the sources used usually display different formats, names or units of measure, these data needed preparation before the merge. This was done in three steps and is described below. This approach is based on the work of Ehrenfeld (2015, p. 5) but has been adapted to the peculiarities of the data records used.

Step I: Basic Pre-Processing

In a first step, essential preparatory work was carried out for subsequent harmonization. This included the extraction of the data delimited by the selection strategies and the subsequent conversion of the individual data records into a uniform format, in this case, Microsoft Excel.

Step II: Pre-Cleaning

The company databases of Creditreform and Hoppenstedt enable the registration of the commercial register number as well as the corresponding administrative court of the respective companies. By this data, a specially developed company identification number (U_ID) was created for all selected companies of these databases, which enables a precise identification of the companies. As Creditreform uses English terms to describe their information whereas Hoppenstedt uses German terms, these terms were harmonized where necessary to the English format. Some information, however, e.g. the company names were standardized additionally. To do so, the individual data sets were subjected to a pre-cleaning procedure which is based on the work steps of Magerman et al. (2006). In the following, these steps are described following the example of the company names.

First of all, a sign reconciliation took place within the company names. For this purpose, the company name was converted completely into uppercase letters. In the course of this, German umlauts, characters with accents or signs with coding were replaced by their ASCII[10] equivalents. Duplicate spaces in the name and spaces at the beginning or end of the name were removed. Afterward, bracket symbols and spellings for "and" were unified and existing bracket expressions were extracted. In a second step, all non-ASCII characters were removed from the name. The original writings of the legal form were subsequently identified and withdrawn from the company name and extracted as an additional attribute. These procedures are very well suited for assigning slightly different spellings for the same company name. These include, for example, differences in the use of hyphens or blanks that prevent direct assignment.

Further harmonization steps were necessary for all data relating to figures, i.e. date formats. For better allocation and analysis, the date format in all data sources has been reduced to the year; dates for the day and month have been removed.

Step III: Data Linkage

Through the use of deterministic methods, the aggregated data sets from Creditreform and Hoppenstedt were then merged. This was done using the Query Editor from Excel, in which the two data sets were linked using the Left Outer Join. By doing so, the two corporate data records from Creditreform and Hoppenstedt were merged into one data file using the U_ID.

As a result of this harmonization and merger, a database is now available, which contains basic data about the companies and allows and identification of energy startups as well as their segmentation based on the economic classification WZ 2008 and the lead market approach.

10 The American Standard Code for Information Interchange (ASCII) is a character encoding of 128 characters consisting of 33 non-printable and 95 printable characters. The printable characters include the Latin alphabet, the ten Arabic numerals and some punctuation marks (Horn 2011).

4 Startup activities within the Energy Entrepreneurship

The collected data enabled to derive a comprehensive picture of the Energy Entrepreneurship in Germany in the years immediately before and after the decision of the energy transition. As defined in Chapter 2.2, the identified energy startups do not need to be innovative technology- or service- driven companies. Many of the identified energy startups do not create new and innovative products or services but focus on the diffusion of existing technologies and services to contribute to the objectives of the energy concept. Therefore, the following section describes the composition and the chronological development of the Energy Entrepreneurship in more detail. The framework allows two main categorizations of the energy startups. First, it categorizes the identified startups via the economic sectors using the WZ 2008. Second, the framework displays the energy startups using the lead markets and respective market segments and technology lines. This enables a more detailed analysis of the historical development regarding influencing effects and events. Nevertheless, additional structural data of the energy startups was conducted and allowed the first insight into the patterns of the identified companies.

4.1 Structure and regional distribution of energy startups

The inventory shows the Energy Entrepreneurship as a well-established startup field in Germany. Between 2008 and 2014 about 28,000 genuine energy startups were identified. This corresponds to a share of 3.3 percent of all company foundings in Germany during this period. The analysis shows a strong influence of the Energy Entrepreneurship by micro and small enterprises. The share of female entrepreneurs with an average of 11 percent is significantly lower within the Energy Entrepreneurship than the overall average of female entrepreneurs in Germany with 33 percent (Abel-Koch 2014).

By far the most common legal forms in energy startups are the GmbH with 53 percent, followed by the GmbH & Co. KG with 32 percent. According to the frequency of these legal forms, 59 percent of the energy startups have a natural person as the sole owner or largest shareholder, 35 percent an industrial company and three per cent a financial enterprise. Public institutions, research facilities, and the state account for the remaining two percent. Overall, 60 percent of the energy startups have more than one shareholder with an average of 3.9 shareholders. The distribution of the type of shareholders closely resembles the distribution of the owner. Natural persons, for example, account for 70% of the shareholders, industrial companies for 27 percent. The remaining three percent are divided into financial companies and others.

An analysis based on geographical data illustrates the regional distribution of energy startups mainly to the Federal states of Bavaria, Lower Saxony, North Rhine-Westphalia and Baden-Württemberg. This analysis also highlights the importance of Schleswig-Holstein regarding energy startups in the north of Germany. This is mainly due to the increasing importance of wind power stations near the coast as well as the establishment of related installation and maintenance companies or other related services. The substantial presence of companies from the lead market of *Power generation, storage, and distribution* in Bavaria is dominated by operators and installers of photovoltaic plants as well as companies from environmental consulting. In the case of startups from the lead market of *Energy efficiency*, a regional bundling is not visible. On the other hand, the lead market of *Sustainable mobility* shows a clear focus on the major cities and agglomerations. Nearly half of all startups related to car sharing offerings and 30 percent of the startups from the market segment of *Alternative drive technologies* were created in Berlin, the Greater Munich and the Ruhr area.

4.2 The economic sectors of the Energy Entrepreneurship

As stated before, the Energy Entrepreneurship is fed by many different economic sectors. Figure 3 shows the five largest of these economic sectors and again the cross-cutting nature of the energy sector. The biggest share of energy startups with 24 percent does belong to the economic sector of *Electricity supply*. This area is mainly composed of the two large blocks of power generation without (47%) and with (21%) respect to the power distribution. The second most important sector is the one of *Professional, scientific, and technical activities* with a share of 18 percent. The majority of this service oriented sector consists of engineering activities (30%), the administration and management of companies and businesses (27%) and consulting services (12%). The sector of *Construction* with a total of ten percent of the energy startups consists primarily of companies in the electrical installation (29%), the field of gas, water, heat and air-conditioning installation (17%) and other building installations (16%).

The sectors of *Wholesale and retail trade*, as well as *Manufacturing*, allocate for seven percent of the energy startups each. The other 33 percent include companies of other sections of the WZ 2008 which are not further examined here.

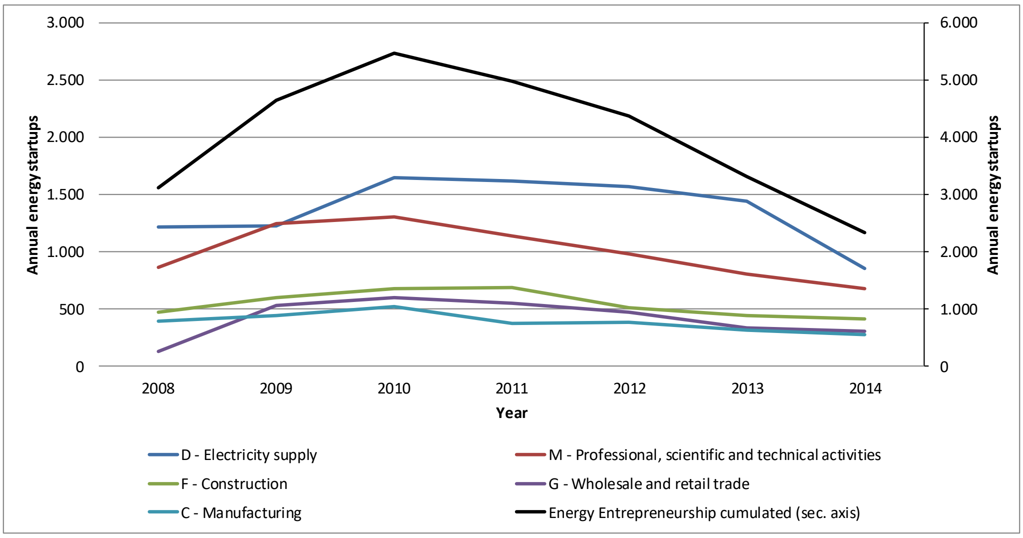

Figure 3: Composition and development of the Energy Entrepreneurship by economic sectors

As the majority of companies accounted for the sectors *Electricity supply* and *Professional, scientific, and technical activities*, these sectors form the main driving forces in the development of the Energy Entrepreneurship. The numbers of annual energy startups in the sector of *Electricity supply* show a sharp increase between 2009 and 2010 and stay almost constant on a level of around 1,600 startups per year until 2012. The analysis showed a noticeable decrease between 2012 and 2013 and again a major decrease from roughly 1,400 startups in 2013 to only 800 annual founded startups in 2014. Startups allocated for the service sector of *Professional, scientific, and technical activities* show an increase between 2008 and 2010, followed by a steady decrease until 2014. This decrease is the main driver for the overall decline of the Energy Entrepreneurship from 2010 onwards.

4.3 The lead markets of the Energy Entrepreneurship

The lead market *Power generation, storage, and distribution* takes on a dominant role within the Energy Entrepreneurship. Around 70 percent of all identified Energy Startups can thus be allocated to the market segments *Renewable energy*, *Environment-friendly use of fossil fuels*, *Storage technologies*, *Efficient grids* and *Digital electricity industry*. 24 percent of the identified energy startups account for the lead market of *Energy* *efficiency* with its market segments *Energy efficient production processes*, *Energy efficiency of buildings*, *Energy efficiency of devices* and *Cross-industry components*. With five percent of the energy startups, the lead market *Sustainable mobility* with the associated market segments *Alternative drive technologies*, *Renewable fuels*, *Technologies to increase efficiency* and *Transport infrastructure and traffic control* accounts for the least amount of energy startups (see Figure 4).

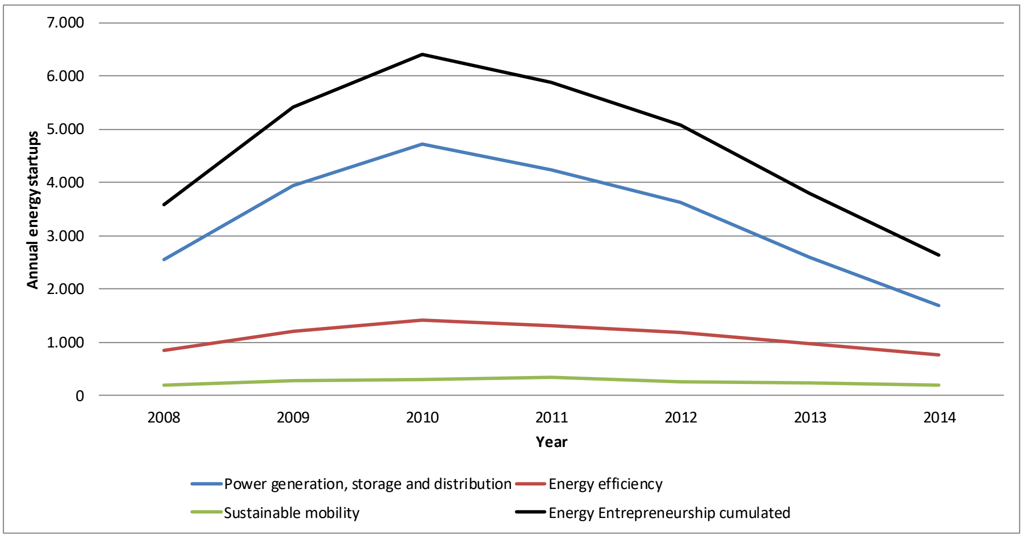

Figure 4: Composition and development of the Energy Entrepreneurship by lead markets

Regarding this percentage distribution of the lead markets it is to be noted that, despite a careful and disjoint selection and composition of the thesauri, the cross-sectional nature of the Energy Entrepreneurship leads to various counts of some startups as they are economically active in more than one lead market. Because of these multiple activities, the overall number of startups within the three lead markets sums up to about 33,000 energy startups. However, the identified startups are only given one particular economic classification by the WZ 2008, no matter if they are active in more than one sector. Therefore, the developments of the Energy Entrepreneurship allocated by economic classification (see Figure 3) and assigned by lead markets (see Figure 4) slightly differ.

4.3.1 Lead market *Power generation, storage, and distribution*

Development of the economic sectors within the lead market

Because of the dominant role of the lead market *Power generation, storage, and distribution*, the annual startup figures for the individual economic sectors within this lead market are nearly identical to the overall development of the Energy Entrepreneurship described before. The only noticeable difference is about the higher share of the economic sector of *Electricity supply*. One-third of the energy startups in the lead market belong to this sector.

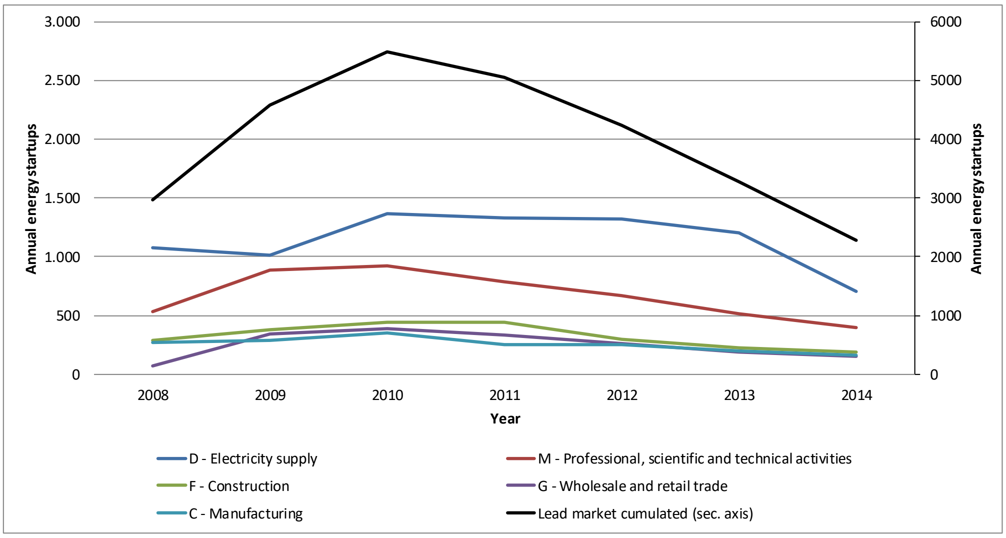

Figure 5: Development of the lead market *Power generation, storage, and distribution* by economic sectors

Development of the market segments within the lead market

With a share of 89 percent of the energy startups within this lead market, the market segment of *Renewable energy* is by far the primary driver for the development (see Figure 6). Within this segment, the annual number of energy startups has redoubled from 2008 to 2010 with an increase from 2,300 to more than 5,000 energy startups per year. In the following years, the number of annual energy startups continually declined until 2014. The course of the market segment *Renewable energy* explains the bell-shaped course of the entire lead market.

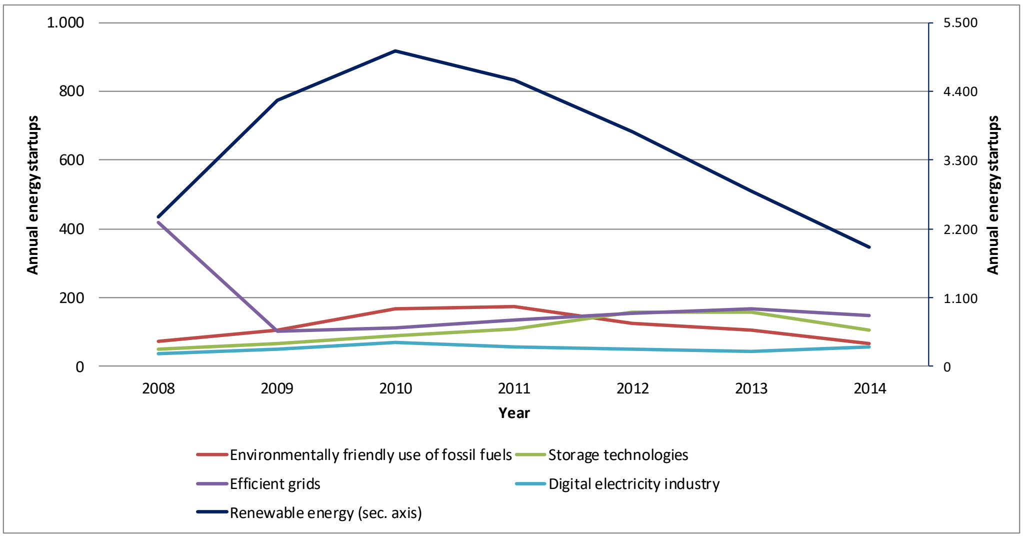

Figure 6: Composition and development of the lead market *Power generation, storage, and distribution* by market segments

Due to its substantial importance, the market segment *Renewable energy* is again analyzed at the level of the technological lines. As shown in Figure 5 especially startups related to photovoltaics define the development of the segment. Throughout the entire period of investigation, nearly half of all startups related to renewables belong to the technology line photovoltaic (see Figure 5). The technologies of wind power (19%) and biomass (18%) account for the same amount of startups. Nevertheless, the development of these two technology lines is very different. Biomass reached its peak in 2010 and then started a big decline until 2014. In contrast, wind power showed a steady increase from 2008 until 2013. Only in the last year of the investigation, this technology showed a first decrease in the annual startup figures. The technology lines of solar thermal energy, geothermal energy and hydropower play only a subordinate role in the entire market segment and represent only four percent of the energy startups in total. The technology line *Others* includes energy startups, which are related to renewable technologies in their activities but do not define them further.

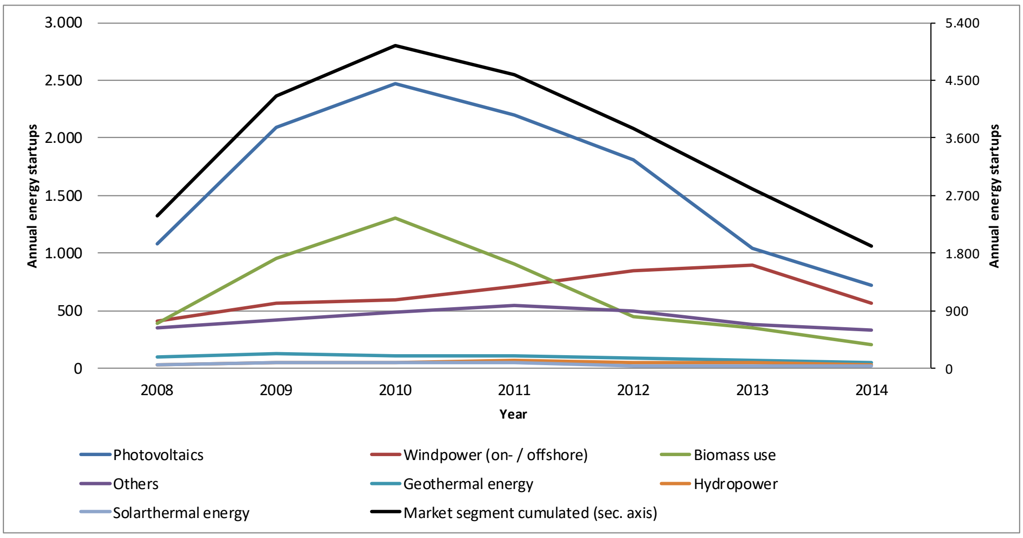

Figure 7: Composition and development of the market segment *Renewable energy* by technology lines

Another market segment that is worth for further analysis is the segment *Digital electricity industry* as it is of particular importance for the interface between digitalization and power generation. A review of the market segment based on the WZ 2008 classification provides information on the heterogeneous composition of the market segment. Thus, the sectors *Professional, scientific, and technical activities* (23%), as well as *Electricity supply* (20%), clearly define the market segment (see Figure 7). The annual startup data for the energy startups from the sector *Electricity supply* show a significant increase between 2009 and 2011. As of 2012, the annual startup figures of this sector were declining and replaced in the following years by energy startups from the service sectors as well as from the sectors *IT and communications* and *Construction*.

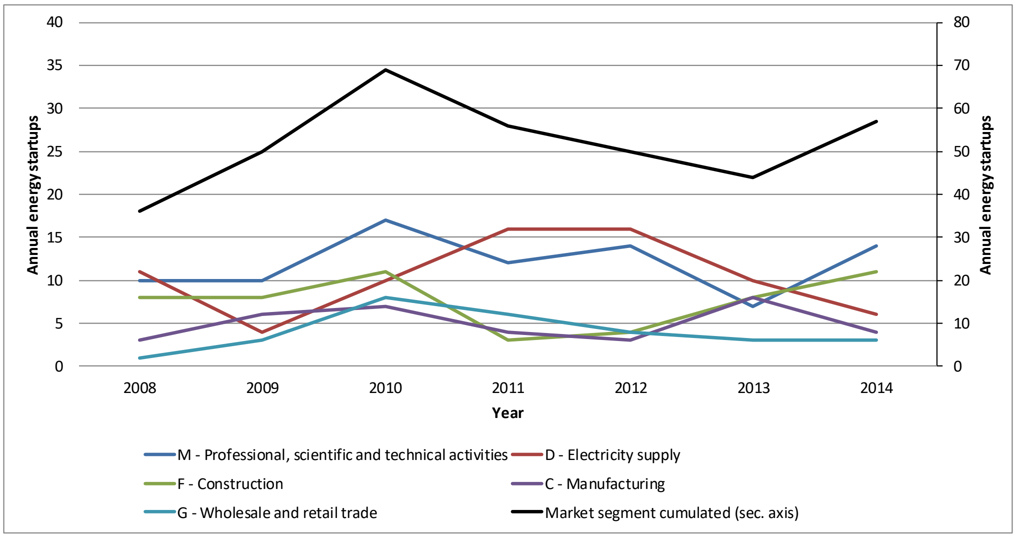

Figure 8: Composition and development of the market segment *Digital electricity industry* by economic sectors

An analysis concerning the corresponding technology lines showed an ascending trend in the market segment since 2013, caused by an increase in the number of startups in the areas of monitoring and load management, smart home applications, and virtual power plants (see Figure 8). With a share of 36 percent of the annual founded energy startups within this segment, technologies in the field of smart grids play a vital role in the development of the market segment. Particularly striking is the decline in the number of annual startups for smart metering technologies since 2012.

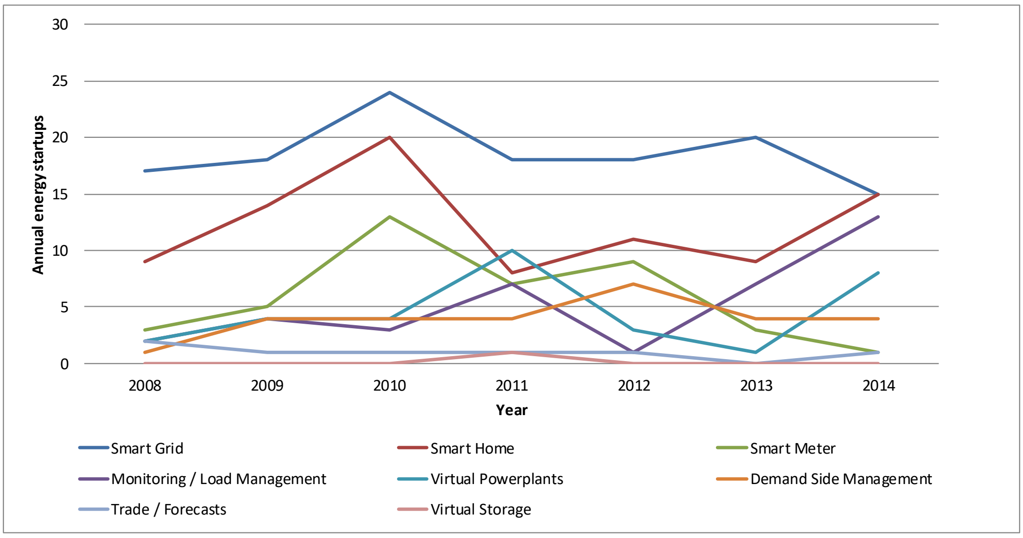

Figure 9: Composition and development of the market segment *Digital electricity industry* by technology lines

4.3.2 Lead market *Energy efficiency*

Development of the economic sectors within the lead market

The consideration of the associated economic sectors of the lead market *Energy efficiency* reveals that the service sectors strongly characterize this lead market with a total share of 30%. As a result, fewer companies from the sector *Electricity supply* belong to this lead market. However, the increased importance of the sector *Construction* with a share of 14 percent is significant.

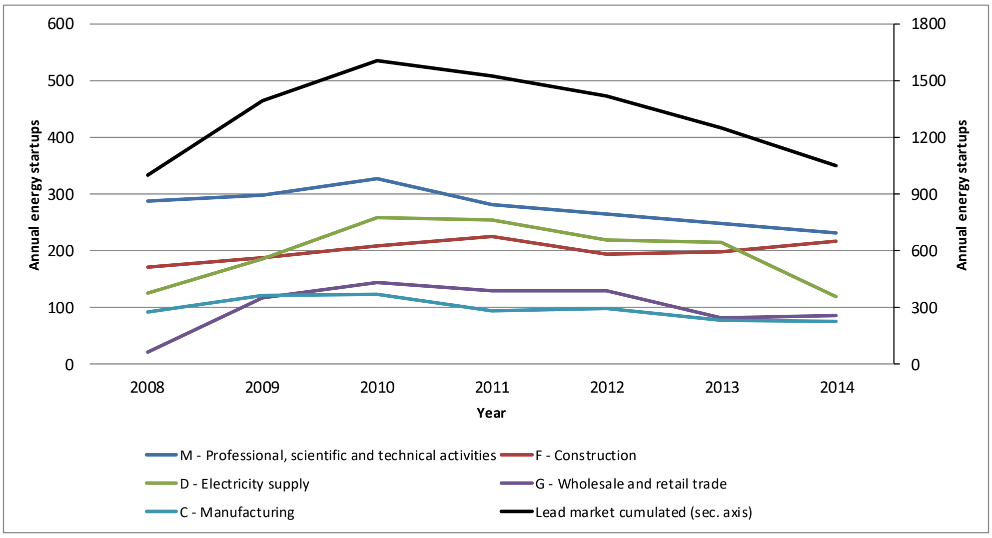

Figure 10: Composition and development of the lead market *Energy efficiency* by economic sectors

Development of the market segments within the lead market

The lead market *Energy efficiency* comprises mainly the efficient use of energy. The largest contributors to this lead market are the market segments *Energy-efficient production processes* and *Energy efficiency of devices* with 37 percent respectively 36 percent of the related startups (see Figure 10). The market segment *Energy efficiency of devices* is very much in line with the general trend of the increase until 2010 and the subsequent decline in the annual startup figures until 2014. In the segment *Energy-efficient production processes*, this decrease occurs starting in 2012.

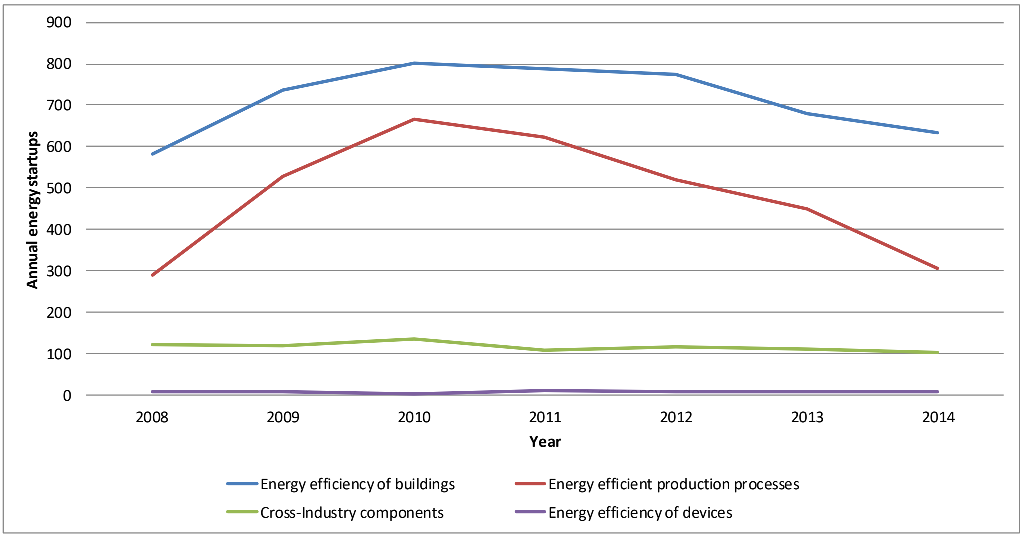

Figure 11: Composition and development of the lead market *Energy efficiency* by market segments

4.3.3 Lead market *Sustainable Mobility*

Development of the economic sectors within the lead market

The lead market *Sustainable mobility* is dominated by the majority of energy startups from the sector of *Professional, scientific, and technical activities* (25%). However, the sector of *Electricity supply* plays only a subordinate role in the lead market for *Sustainable mobility*. On the other hand, the sectors of *Wholesale and retail trade* and *Manufacturing industry* are gaining in importance.

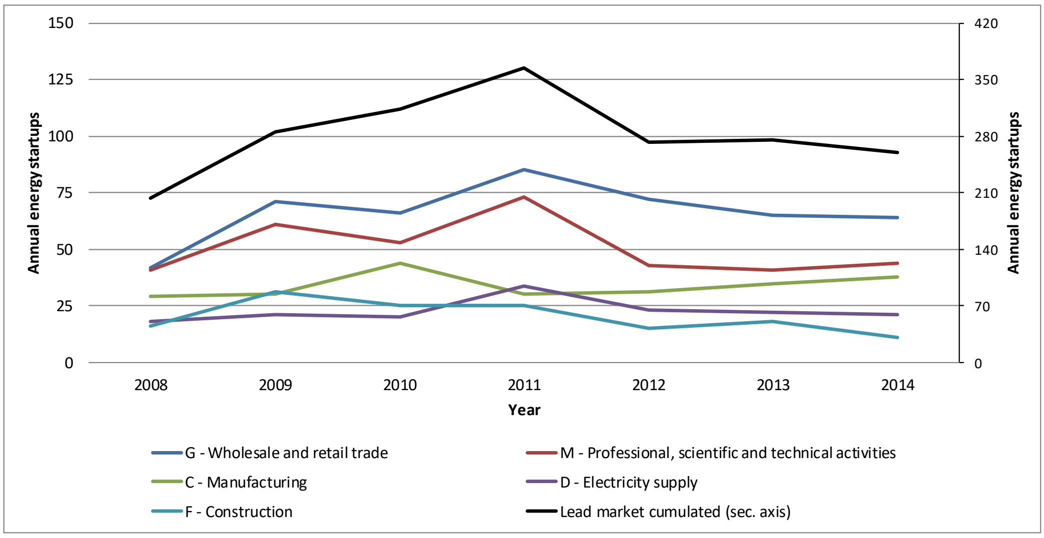

Figure 12: Composition and development of the lead market *Sustainable mobility* by economic sectors

Development of the market segments within the lead market

The lead market *Sustainable mobility* represents the smallest lead market regarding the number of energy startups. The largest share of this lead market is accounted for the market segment *Alternative drive technologies* by 64 percent of all associated energy startups. Therefore, this market segment is crucial for the development of the entire lead market. It reported a step-like development of the annual number of foundations between 2008 and 2014 (see Figure 12). After an increase from 2008 to 2009, the level for 2010 remains constant. The market segment reached its peak after a further rise in 2011. In the following years, the number of annual energy startups declined steadily. The market segment of *Technologies to increase efficiency*, as well as the segment of *Renewable fuels*, show a very similar development, albeit on a much smaller scale.

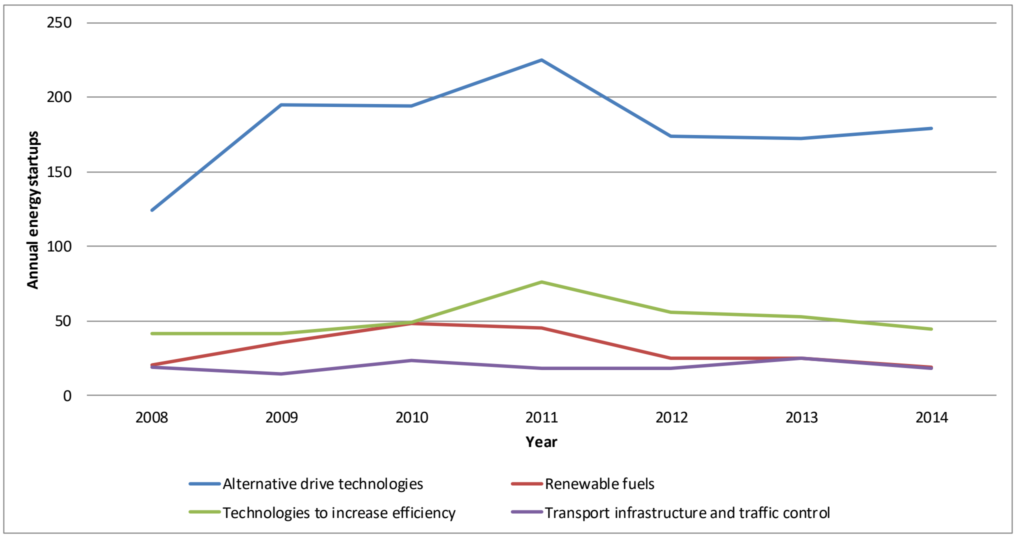

Figure 13: Composition and development of the lead market *Sustainable mobility* by market segments

5 Summary

The overall objective of this work was to answer how the ongoing structural change and the associated events within the German energy sector trigger related startup activities. In the preceding chapters, a framework was developed by which these startup activities within the energy sector in Germany could be initially demarcated, measured and subsequently evaluated.

5.1 Appraisal of results

The present study of startup activities within the Energy Entrepreneurship in the years 2008 to 2014 shows that the annual birth rate is fed in principle from all three lead markets, namely *Power generation, storage, and distribution*, *Energy efficiency* and *Sustainable mobility*. By far the largest contribution to startups of the Energy Entrepreneurship, the so-called energy startups, comes by the lead market *Power generation, storage, and distribution*, with the dominant market segment *Renewable energy*. These size fractions can hardly be surprising in light of the development of the German energy sector. The market liberalization and the promotion of renewables triggered a fundamental change in the framework through which the areas of production and distribution of energy from renewable sources became highly attractive for new players (ZEW 2014, S. 104 f.). Also, it is not surprising that the economic sector of *Electricity supply* plays a central role in the composition of the Energy Entrepreneurship.

But against the backdrop of this strong imprint of Energy Entrepreneurship through this sector, and especially the issue of renewable energy, the chronological development of the Energy Entrepreneurship is surprising. In recent years of the review period, the number of yearly foundations has fallen dramatically. All three lead markets show significant drops in 2010/2011. After the resolution of the energy transmission in 2011, the presumed consequence would have been an increase in energy startups, triggered by the extended funding for renewables. The instead occurred decrease of the startup figures in Energy Entrepreneurship suggests that many potential market participants were uncertain regarding the future conditions within the energy sector. The open questions on topics such as the future of the EEG or the integration and network access for distributed power generators can lead to a lack of predictability that could cause potential actors to refrain from establishing a startup. However, the detailed analysis reveals that the number of energy startups from the sector of *Electricity supply* stayed almost constant between 2010 and 2013. The thesis of a reduction in the startup numbers due to the uncertainty of the market is thus only partially tenable.

Also, the detailed analysis shows that the decline in energy startups from the service sector from 2010 can be seen as the main reason for the general downward trend in the founding figures of the Energy Entrepreneurship. Another explanation for the development of the Energy Entrepreneurship is, therefore, focusing on the development of the service sector. A possible reason for the chronological development of this area can be found in the financial and economic crisis of 2008 and 2009. For example, numerous studies have shown that the number of startups in crisis periods initially rises, including the frequent change from unemployed into self-employment. This could explain the increase in annual service startups from 2008 to 2010. Such a development was for example foreseen in the DIHK founders report of 2009 (DIHK 2009). In the phase of stabilization after such a crisis, the number of foundations is relativizing, which could explain the decline in energy startups from the service sector from 2010/2011 onwards.

Because these possible explanations are only hypotheses at this time, a further and more detailed analysis of the identified startups is necessary. In addition to that, more precise statements can be made regarding the responsible effects for the development of the Energy Entrepreneurship.

5.2 Conclusions and Recommendations

The design of the German energy sector needs profound changes to achieve the ambitious goals of the Federal Government's energy concept. To carry out this much-propagated structural change, the major established companies, as well as the energy startups studied here, both have significant roles. Especially the latter group of energy startups, with its strong connection to services as well as generation, storage and distribution in the field of renewables, can contribute to a decisive step towards this structural change.

With the definition of the three lead markets, the cross-cutting sector of the Energy Entrepreneurship is delineated based on existing boundaries of the overriding concept of the environmental economy. The challenge about the statistical recording and collection of startups and established companies of the energy sector, however, also remains with this lead market approach. These allocation problems are especially noticeable in the case of multi-product companies, as well as in those companies which do not have a relation to the energy sector in all aspects of their entrepreneurial activity. The better statistical coverage of the Energy Entrepreneurship is, therefore, a central recommendation for action. Additional information about the companies, their products, services and business models are needed to improve the prospective analysis of the Energy Entrepreneurship. Based on the concept developed in this study, a further improvement of the analysis algorithm could deliver this more detailed information. The goal is to achieve a more detailed assignment of the startups using a keyword analysis based on information from the company web pages. In the long term, this should not only allow an allocation according to technology, products or services, but also an allocation according to the type of business model. This means that the energy startups can also be divided into technology-driven or service-oriented companies and thus can be distinguished from companies that are primarily active in the diffusion of existing technologies.

Apart from these purely statistical conditions for the collection and promotion of Energy Entrepreneurship, there can be no doubt that the current discussions and uncertainties regarding the shaping of the economic framework of the energy sector and the regulatory measures related to the electricity supply are not an optimal breeding ground for startups. It should be pointed out here that the potentials of energy startups to support and implement the goals of the energy concept can only be fully exploited if the political and regulatory framework conditions are as stable, reliable and long-term as possible. A stable political environment within the German energy sector is crucial to provide energy startups the planning security they need for a successful establishment.

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