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ETHICAL ASPECTS OF CLIMATE ENGINEERING



Gregor Betz / Sebastian Cacean

Ethical Aspects of Climate Engineering

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by

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Preface

This book is a slightly modified and updated translation of a study commissioned by the German Federal Ministry of Education and Research (BMBF) on Ethical Aspects of Climate Engineering. Parallel to this ethical assessment, further scoping reports on natural and social science as well as legal aspects of CE were compiled. The highly focused reports were eventually merged into a single interdisciplinary assessment, which is also available in English (cf. Rickels 2011). We have profited enormously from discussions with experts in charge of the other scoping reports and are indebted to the BMBF for providing the opportunity to carry out this study.

The BMBF report has been finalised in spring 2011, and it is roughly the state of the CE debate at that point in time which is analysed in this book. This holds in particular for the commented bibliography, compiled by Sebastian Cacean, but applies to the arguments as well. The CE controversy, though, is advancing rapidly; ISI web of knowledge counts 44 new articles on “geoengineering” in 2011 alone. We thus conceive our assessment as a first, preliminary argumentative analysis only, which calls for more detailed investigations and continuous updates as the debate goes on.

Last but not least, we would like to thank Heidemarie Knierim from Karlsruhe Institute of Technology for providing an excellent translation of the original German version.

Gregor Betz, Sebastian Cacean
Karlsruhe, May 2012

Summary

1 Introduction

The term “climate engineering” (CE) refers to large-scale technical interventions in the climate system with the objective of offsetting anthropogenic climate change. One distinguishes roughly between solar radiation management (SRM) and carbon dioxide removal (CDR) technologies. The main questions in dispute are whether CE technologies should (a) be researched into and (b) be deployed where appropriate. (1.1)

This study investigates the ethical aspects of deploying and researching into climate engineering. An ethical analysis assesses the moral reasons in favour of or against taking certain action or policies. Moral reasoning appraises actions or policies from an unbiased point of view which takes the interests of all persons involved equally into account. Moral arguments differ fundamentally from economic or legal ones. (1.2)

In this study, the moral reasons in favour of and against R&D into and deployment of CE methods are analysed by means of argument maps. These argument maps give a transparent overview of the CE controversy. Besides structuring the extremely complex debate, they help, moreover, to determine and evaluate the positions held by proponents. (1.3)

Argument maps consist of arguments (filled-in boxes) and theses (framed boxes) which may support and attack each other (green and red arrows, respectively). (1.4)

2 The Macrostructure of the Overall Debate

The analysis of the CE controversy carried out hereunder uses placeholders. Instead of referring to specific CE methods, the reconstructed arguments speak generically of the CE technology “T” – which, later, must be specified when evaluating the argumenta-

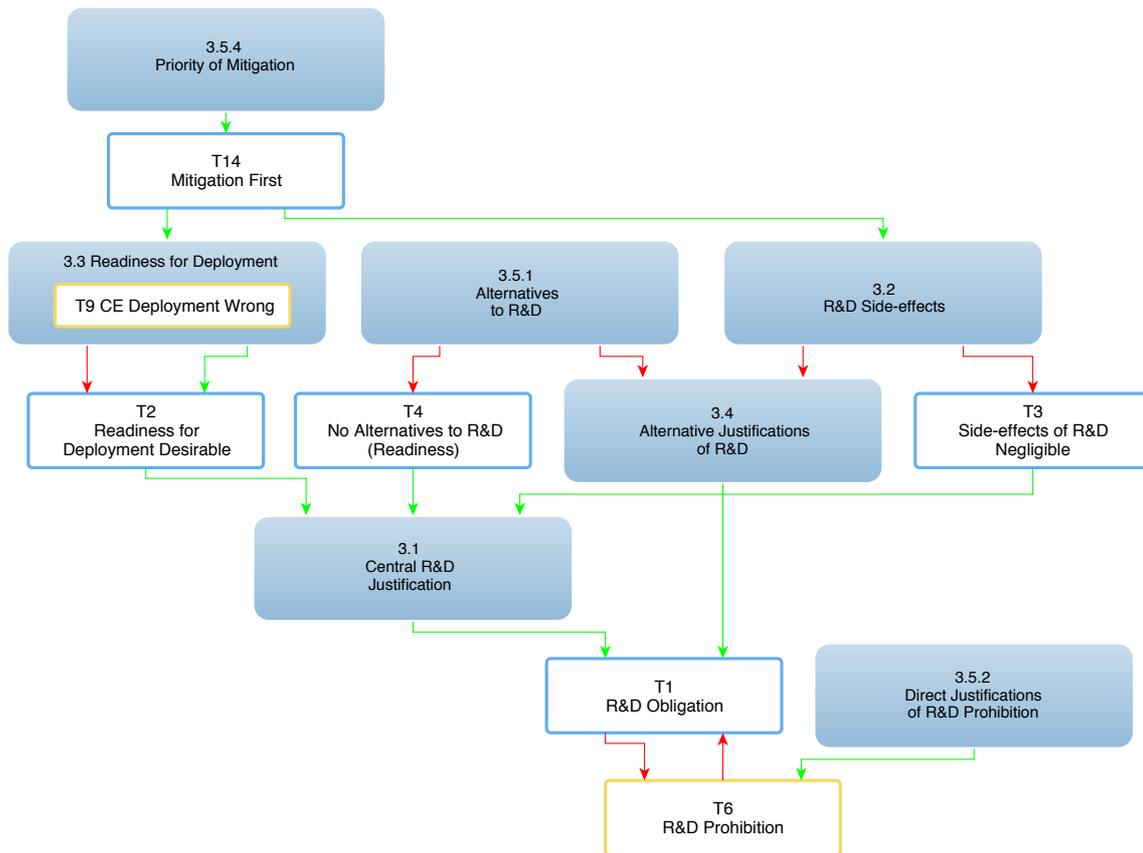
tion. The central thesis of the controversy holds that R&D into the CE technology T ought to be carried out immediately (T1). This R&D obligation is contradicted by the R&D prohibition thesis T6. The central justification of research obligation T1 relies on three further theses:

[T2 READINESS FOR DEPLOYMENT DESIRABLE] The CE technology T should be ready for deployment at a future point in time.

[T3 SIDE-EFFECTS OF R&D NEGLIGIBLE] The side-effects of R&D into the CE technology T under the aspect R are negligible as compared to T being [probably] ready for deployment in time.

[T4 NO ALTERNATIVES TO R&D (READINESS)] There are no more appropriate alternatives to immediate R&D into the CE technology T under the aspect R which bring about that T is probably ready in time.

Each of these theses ignites a more or less extensive sub-controversy. In these sub-controversies, the contentious thesis that mitigation policies have priority over CE methods is of decisive importance (T14). Moreover, the R&D prohibition thesis is being justified through an alternative argumentation that does not require the controversial thesis T2. Finally, the CE controversy also contains direct justifications of the R&D prohibition. (2)



Argument Map A (see also Chapter 2): This map visualises the overall structure of the reconstructed CE controversy. Besides central theses (framed boxes), it mainly displays argument clusters, which group individual arguments. The argument clusters represent sub-debates of the controversy and exhibit a more or less complex internal argumentative structure. Argument clusters are numbered corresponding to section numbers in this book. Green and red arrows indicate argumentative impacts (supportive or critical) of the reasoning set forth in the corresponding sub-controversies.

3 The Detailed Structure of the Sub-debates

The central justification of R&D represents a consequentialist argument. R&D into CE technologies is claimed to be a suitable means for reaching the goal that CE methods be ready for deployment in the future. This argument rests essentially on theses T2 – T4. (3.1)

Thesis T3, which holds that the side-effects of R&D into CE are negligible, is challenged in the controversy by pointing out possible or probable harmful side-effects such as, in particular, the impact on mitigation policies (moral-hazard objection), the inevitable

deployment of the technologies researched into, the commercial control of CE methods, risky field tests, and the risk of unilateral use. (3.2)

The most extensive sub-controversy is based on thesis T2. Three different arguments justify why readiness for deployment of CE is desirable: At some future point in time, the deployment of CE methods could be the lesser of two evils, and we should prepare for that case (lesser-evil argumentation); without using CE methods, ambitious climate policy targets cannot be achieved anymore (two-degree target/350 ppm argumentation); CE methods are more efficient and can be implemented more easily than extensive mitigation policies (efficiency and feasibility considerations). These arguments in favour of T2 are countered by numerous objections to T2. To start with, critical arguments based on the ethics of risk stress that the deployment of CE is accompanied by massive, irreducible hazards. The prominent termination problem belongs to this category of objections, too. The arguments from justice and fairness point out the uneven regional consequences of CE deployment. Geopolitical concerns arise because of the dual use problem and the fear that a “global thermostat” could induce new conflicts. Finally, several fundamental objections are raised in the controversy: They either rest on a general critique of technology and civilization or consist in religious, existentialist, or environmental-ethics considerations. (3.3)

Although alternative research justifications consider R&D into CE methods as being a suitable means for a given end, they differ from the central justification by specifying an altogether different purpose of research. According to these alternative arguments, research does not aim at making CE methods ready for deployment. Rather, research should help, for example, to avoid hasty CE deployment by pointing out the real risks and hazards involved. (3.4) Further arguments of the CE controversy are related to the lack of alternatives to CE R&D (T4), provide direct justifications of the R&D prohibition, broach the issue of national bans, and give reasons for the priority of mitigation measures over CE methods. (3.5)

4. Central Issues, Principles, and Problems

Weighting of side-effects represents a common issue that occurs throughout the CE controversy. The proponents of the controversy do not explicitly address (e.g. tackle through further arguments) the question as to how a series of side-effects, which are partly certain, partly probable, and partly possible, are to be evaluated and weighted against each other. Depending on which weighting is made by the proponents, they will endorse or not endorse the corresponding arguments and objections. (4.1)

The CE controversy takes place against the background of massive uncertainties. Not only are the side-effects of R&D and deployment poorly understood, but, what's more, we can't even reliably predict the effectiveness of CE methods. That's why more or less all arguments in the debate concern – in one or another way – the ethics of risk. A central question that arises in this context is how rational decisions can be made at all in spite of massive ignorance. The arguments where that decision-theoretic problem arises are reconstructed, in this study, such that they use variants of the precautionary principle. (4.2)

The priority of mitigation policies (T14) is taken for granted by various arguments, in particular by the moral-hazard objections and the alternative justifications of CE research. Conversely, though, some arguments contradict more or less explicitly the thesis that mitigation policies take, in general, priority. This holds especially for the efficiency and feasibility argumentation, which considers CE methods a favourable substitute for mitigation policies. Most of the arguments of the CE controversy, however, are compatible with the priority of mitigation policies. (4.3)

Within the CE controversy, moral and extra-moral considerations seem to be deeply interwoven. This is mainly due to the fact that the moral arguments also make use of descriptive premisses such as forecasts of an action's consequences. (4.4)

One may broadly distinguish two types of arguments in the CE controversy: Those which make controversial ideological assumptions, and those which do not rely on strong normative premisses but which involve, at most, contentious descriptive assumptions or basically shared principles whose concrete application is controversial. The first category comprises, in particular, the religious,

existentialist, and environmental-ethics arguments, the efficiency and feasibility consideration, the arguments that rely on a critique of technology and civilization, the research neutrality reasoning, the arguments from fairness, and some arguments belonging to the sub-controversy about R&D side-effects. (4.5)

5 Coherent Positions and their Logico-argumentative Implications

Analysing a complex controversy as an argument map allows to check proponent positions (actually or possibly held) for coherence. A core position, which consists in accepting or rejecting certain arguments and theses, has logico-argumentative implications that go beyond the core position itself because (i) one is bound to accept the logical consequences of the sentences one accepts and (ii) one must reject the direct objections to one's core position. Proponents endorsing R&D into some CE method, thus, are obliged to reject the relevant objections to R&D into CE; proponents rejecting CE R&D have to specify on which points they disagree with the diverse research justifications. It is these very considerations that are relevant when drafting coherent political positions.

For illustrative purposes, the following positions can be checked for coherence: Endorsement of SRM research for reasons of easiness and efficiency; endorsement of R&D into ocean fertilization to detect the associated risks; rejection of SRM R&D on account of basic considerations from democratic theory and fairness; endorsement of CDR development for the purpose of achieving ambitious climate targets in the future. (5)

1 Introduction

1.1 Geoengineering – Climate Engineering

The term “climate engineering” (CE) refers to large-scale technical interventions in the climate system with the objective of offsetting anthropogenic climate change. One distinguishes roughly between solar radiation management (SRM) and carbon dioxide removal (CDR) technologies. The main questions in dispute are whether CE technologies should (a) be researched into and (b) be deployed where appropriate.

Man is changing the climate. Although both the exact extent and the details of anthropogenic climate change are still uncertain, *the fact that* we massively affect the climate system, in particular by increasing the concentration of atmospheric greenhouse gases, is not seriously argued anymore (IPCC WGI 2007). Recent observations even indicate that the IPCC climate projections rather under- than overestimate anthropogenic climate change (WBGU 2006; WBGU 2009; Allison et al. 2009). The ethical issues resulting from these long-term impacts of human action have long since been acknowledged (cf. Gardiner 2004, 2010a) and have triggered philosophical controversies concerning our responsibility towards future generations (Birnbacher 1995), the acceptability of discounting future damage and benefits (Birnbacher 2001; Ott 2004), the appropriate evaluation of the impacts of climate change (Broome 2004, 2006), the handling of risks and uncertainties (Gottschalk-Mazouz et al. 2003), and the fair distribution of emission rights (Shue 2008; Ott et al. 2008). These ethical investigations are mainly concerned with the design of and our moral obligation to implement mitigation and adaptation policies. Recent developments of

the climate policy debate are, however, posing new challenges to climate ethics.

In his 2006 article *Albedo Enhancement by Stratospheric Sulfur Injection: A Contribution to Resolve a Policy Dilemma?*, atmospheric chemist and Nobel laureate Paul Crutzen suggests compensating anthropogenic climate change by targeted large-scale interventions in the climate system (Crutzen 2006). Indeed, such so-called geoengineering measures had occasionally been discussed before Crutzen's article was published (Schneider 1996; Keith 2000, 2001a); and, not least against the background of military considerations, technical interventions for deliberate weather modification had been thought about time and again in the course of the 20th century (Fleming 2010). Crutzen's deliberate plea for research into measures such as these, however, has made the controversy a permanent issue in scientific journals and the public media. So as to differentiate between the concepts underlying the latest proposals that are aimed at offsetting anthropogenic global warming and previous proposals for large-scale restructuring of the environment, we will refer below to "climate engineering" instead of using the term "geoengineering". Basically, there are two kinds of climate engineering measures (CE measures): Those intervening in the global carbon cycle to reduce the concentration of atmospheric carbon dioxide (Carbon Dioxide Removal, CDR) and those intervening directly in the radiation balance of the Earth, for example to increase the share of the reflected incident solar radiation (Solar Radiation Management, SRM). In September 2009, the British Royal Society published a report that introduces and examines the different proposals (Royal Society 2009). A second report by the Royal Society, published in 2011, focuses on governance schemes for CE research (Royal Society 2011). Another survey, although limited to policies influencing the radiation balance and to drafting a tentative research agenda, is given by Blackstock et al. (2009).

Two central questions are raised by the proposal to offset anthropogenic climate change by CE measures:

[Deployment] Should CE measures be *deployed*? (Under which conditions would deployment be appropriate, and how

is one supposed to differentiate between the various CE technologies?)

[R&D] Should CE measures be *researched* into? (What would be the time frame for such research? What should be the dedicated purpose of research into the relevant technologies? How do we set research priorities?)

These two issues represent the central focus and starting point of the reconstruction of the CE controversy put forward in this study.

1.2 An Introductory Note on Ethics

This study investigates the ethical aspects of deploying and researching into climate engineering. An ethical analysis assesses the moral reasons in favour of or against taking certain action or policies. Moral reasoning appraises actions or policies from an unbiased point of view which takes the interests of all persons involved equally into account. Moral arguments differ fundamentally from economic or legal ones.

This study investigates the ethical aspects of deploying and researching into climate engineering. What, though, is understood by “ethical aspects”? And which form can ethical expertise assume at all?

“Ethics” is understood as the systematic theory of moral evaluation and reasoning. It is thus a scientific discipline focusing on morals as the subject of investigation. But then, what does “moral”, or “morals”, mean? The adjective “moral” describes a certain manner of evaluating, arguing, and acting. While ethical considerations are mainly academic, all of us – more or less - reason and act morally. To be more precise, an action is evaluated as *morally* right or wrong if evaluation is made from an unbiased point of view, i.e. from a viewpoint considering, in particular, all relevant interests of all persons that may be involved. Moral evaluations are characterised by their detachedness. Obviously, this is a rather general (or philosophically spoken “purely formal”) explication of the concept of morality: Such an abstract explication is, for instance, not capable of deciding matters of moral disagreement and does in no way

provide definite moral evaluations of a specific situation or action. Moral disagreement is resolved by giving and taking concrete arguments that are related to the corresponding particular case – and not by recourse to abstract definitions of what is morally right or wrong.

Moral reasoning and evaluation clearly differ from other manners of analysing and evaluating political measures. Legal evaluation, for example, assesses whether, in accordance with applicable laws, bans may have to be imposed on a certain technology. Apparently, however, conformity with applicable law does not imply that the relevant action is also permissible from an unbiased point of view that takes into account the interests of all persons involved. Also, geopolitical and economic analyses must be distinguished from moral evaluations. If, as a political-science analysis may reveal, some policy is – allegedly – in the national interest of a country, it is thereby shown to be beneficial from a narrow and biased perspective (which acknowledges the country's interests) only, but not yet from an unbiased moral point of view. In the same way, economic analyses, assessing the effects of political measures on economic factors, do not reveal whether some specific measure considers all relevant interests adequately. It is necessary to distinguish between moral, on the one hand, and legal or social-science analyses and reasoning on the other hand. Nevertheless, as will be shown below, the results of the two latter may pass on, as assumptions, into moral arguments.

This said, we may now turn to the function and nature of ethical expertise. First of all, ethical expertise is a type of scientific policy advice. Consequently, it is based on and must fulfil the same standards as natural science, legal or economic policy advice. In democratic societies, these standards include, in particular, the ideal of value-freedom. Accordingly, it is not the scientific expert but the democratically legitimised decision-maker who must determine which targets are to be pursued and realised through policy measures. Scientific policy advice must hence be free from (non-epistemic) normative assumptions. Now, ethical expertise deals inevitably with normative (namely moral) considerations, which, however, it must not assume to be correct according to the ideal of value-freedom. Therefore, ethical expertise can only set forth *con-*

ditional normative recommendations (Grunwald 2008:317 et seq.). In other words, ethical advice makes explicit the basic moral assumptions without asserting them, e.g.: If the basic normative assumptions A are shared and the forecast F is accepted, then the objection O is defeated and the policy measure P should be taken; if, in contrast, the basic normative assumptions A' are shared and the prediction F' is accepted, then the objection O' is defeated and the policy measure P' should be taken. Ethical expertise strives to make as transparent as possible the manifold relations between our normative beliefs against the background of a given, more or less certain factual knowledge. It thus seeks to enable decision-makers and the public alike to grasp the relevant moral aspects of an upcoming decision and to found their choices on a coherent basis of normative beliefs.

1.3 Methods Applied

In this study, the moral reasons in favour of and against R&D into and deployment of CE methods are analysed by means of argument maps. These argument maps give a transparent overview of the CE controversy. Besides structuring the extremely complex debate, they help, moreover, to determine and evaluate the positions held by proponents.

So as to clarify the manifold moral aspects and assumptions pertaining to CE, along with their interrelations, this study has applied the method of argument mapping (Betz 2010). Notably, the results presented below have been obtained from the following steps:

1. Compilation of a commented bibliography of texts addressing ethical aspects of CE.
2. Mapping of the logico-dialectical landscape of the CE controversy in the form of argument maps, based on the respective text sources.
3. Presentation of intermediate results on the occasion of a symposium on ethical aspects of CE (*Ethische Aspekte des CE*) held in Greifswald, Germany (September 2010) and during a separate workshop (November 2010) within a scoping project

of the German Federal Ministry of Education and Research; revision of argument maps in the light of the feedback received.

Without doubt, step 2 is the most comprehensive one, and the corresponding approach requires detailed explanation.

Firstly, complex argumentation can be analysed and mapped at different levels of detail. In a relatively coarse-grained analysis, the respective arguments and theses are identified, the basic ideas of the arguments are outlined in a few sentences, and the assumed relations between the theses and arguments (support or attack) are sketched. The analysis becomes, in contrast, far more exact if the individual arguments are reconstructed as premiss-conclusion structures. Such, and only such, reconstruction can make the hidden assumptions explicit and reveal how the arguments are actually related to each other. This study sketches the entire moral controversy about CE, which is documented in the commented bibliography. By contrast, only a few selected arguments are reconstructed in detail. The argument maps presented hereunder must hence be regarded as preliminary results that can be revised more or less extensively through further detailed analyses.

Secondly, the reconstruction of the CE controversy makes use of placeholders. As a matter of fact, there are more than one dozen different CE technologies that vary substantially regarding, for example, their respective operating cost or the extent of potential side-effects. Hence, the arguments in favour of and against one CE measure may differ radically from the arguments that pertain to another CE measure. This would suggest to reconstruct separate argument maps for each individual CE technology. Since such argument maps would share some albeit not all arguments, the already complex reconstruction below would probably have become impenetrable. Now, the placeholder method offers a solution. Instead of referring to a specific CE technology, e.g. ocean fertilization, the reconstructed arguments remain abstract and speak of CE technology T. As a consequence, full-fledged arguments that, for example, can be checked for soundness (i.e. whose premisses and conclusions may be true or false) are not obtained unless all occurrences of placeholder “T” are substituted by a concrete technology

such as ocean fertilization or air capture. Arguments that may become very convincing through one such substitution may well become implausible through another. And yet, without any substitution whatsoever, the argument maps can reveal how the different types of considerations are related to each other argumentatively. Now, the placeholder method has not only been used for taking the different CE technologies (placeholder “T”) into account but also for dealing with the variety of R&D strategies and targets. In fact, there are quite different ways of conducting research into a technology: Research may, for example, prepare future deployment of a technology – in which case we would also speak of “technology development”. In contrast, technologies can also be researched into by just taking a closer look at risks and side-effects. The R&D mode is abbreviated in the arguments and theses through placeholder “R”. This second placeholder, too, requires substitution (e.g. “technology development”, “risk assessment”, etc.) before the arguments can be evaluated for soundness and theses can be checked for plausibility and truth.

Thirdly, argument reconstructions are always interpretations. This being definitely true for coarse-grained analysis, it is also fact that, when compiling a detailed argument reconstruction, there is always room for interpretation that one can fill in one way or another. Hence, there is no such thing as the one and only correct reconstruction of a controversy. This, in turn, does not imply that argument reconstructions are completely arbitrary. In particular, the analysis carried out within this study is based on the principle of charity, i.e. it attempts to render the arguments as strong and convincing as possible. This is to ensure that reasons are not being prematurely rejected merely due to a biased interpretation. In addition, any whatsoever room for interpretation presents a much smaller impediment to controversy assessment (as compared to reconstruction) than may first be assumed. For sure, it is a matter of interpretation how accurately a proponent’s consideration is represented. Whether, however, given the reconstructed debate, a position is still coherent at all remains largely unaffected by issues of interpretation and can be determined objectively relative to the arguments identified.

Fourthly, and finally, the reconstruction itself does not judge or value and can never be concluding or complete: It does neither decide on who is right nor on who has the final say in a debate.

On the one hand, the reconstruction is not judging: Firstly and directly, the reconstruction itself entails only if-then claims: If certain statements are true, then certain other statements that occur in the debate must also be true. The argument map does not reveal which statements are true; it is, thus, neutral and open to different evaluations (depending on which statements one considers to be true, false or uncertain). In other words, the argument map discloses the questions to be answered in order to adopt a position in the debate and merely points out the consequences of different answers to these questions.

Because of this, a thesis that is supported by many arguments is not necessarily true. And, by the same token, a thesis that is attacked by many arguments is by no means bound to be false. This applies equally to arguments: An attack on an argument does not imply that the very argument is definitely refuted. It may be, for example, that the attacking argument itself implies – from an evaluative perspective – absurd premisses that can easily be criticised by adding further arguments.

Argument maps can be used to determine positions proponents may adopt and to check these positions for coherence (cf. Chapter 5). Moreover, argument maps can be important tools for coping with conflicting positions. As a matter of fact, dissent can have two causes: (i) The proponents have overlooked arguments put forward by their respective opponent. (ii) Some arguments and theses are evaluated differently. Ad (i): Should it be found that dissent arises, among other things, from not yet having considered certain arguments, the argument maps should be completed by the corresponding considerations and the positions held by the opponents should be re-evaluated thereupon. At best, dissent is dissolved right after that. Ad (ii): If there is dissent in spite of agreement on the set of relevant arguments, one may proceed as follows. Using the maps, one firstly identifies the theses and arguments mutually agreed on by the opponents. Based on this common ground, one then tries to determine or develop consensual policies. In other words: The argument maps can be used for developing robust proposals for ac-

tion, i.e. proposals that are compatible with many different positions and sets of basic moral assumptions.

1.4 How to Read Argument Maps

Argument maps consist of arguments (filled-in boxes) and theses (framed boxes) which may support and attack each other (green and red arrows, respectively).

Arguments are (i) roughly sketched in a few sentences (coarse-grained analysis) or are (ii) reconstructed as deductively valid premiss-conclusion structures (detailed analysis). The dialectical relations (attack, support) between arguments are either sketched (coarse-grained analysis) or are determined as follows (detailed analysis): An argument supports another one if the supporting argument's conclusion figures as premiss in the supported one. And an argument attacks another one if the attacking argument's conclusion negates a premiss of the attacked one.

An argument map visualises these relations. It contains two types of elements: Simple sentences (e.g. central theses) are visualised as framed white boxes while arguments (containing sentences as premisses and conclusions) are shown as filled-in boxes. To ensure clear arrangement, the maps do not show all the sentences occurring in the arguments as sentences but only visualise the sentences that are of special relevance in the debate (e.g. are referred to in multiple arguments).

If a sentence that has been visualised in the argument map at the same time occurs in an argument as premiss, this is indicated by a green arrow pointing from the sentence towards the argument. If the negation of such a sentence occurs as premiss in an argument, this is visualised by a red arrow. In the same way, the relations between arguments are represented: If an argument supports another argument, this is shown by a green arrow; a red arrow indicates that one argument attacks another.

The outlined and reconstructed arguments and theses are consecutively numbered. In the running text, "T1", "T2", etc. refer to the respective theses while "A1", "A2", etc. point to the respective

arguments. Brief designations (e.g. “T1 READINESS FOR DEPLOYMENT DESIRABLE”) of the arguments or theses may be given in addition to facilitate readability. The appendix lists all argument abbreviations and titles and compiles all argument sketches and reconstructions. Individual premisses and conclusions, numbered also, are referred to as “(n)”, where n is the corresponding sentence number if the sentence is found in the argument listed last. “(m.n)” with n being the sentence number and m the number of the argument is used otherwise; “(23.4)” hence refers to the sentence numbered 4 of argument A23.

2 The Macrostructure of the Overall Debate

The analysis of the CE controversy carried out hereunder uses placeholders. Instead of referring to specific CE methods, the reconstructed arguments speak generically of the CE technology “T” – which, later, must be specified when evaluating the argumentation. The central thesis of the controversy holds that R&D into the CE technology T ought to be carried out immediately (T1). This R&D obligation is contradicted by the R&D prohibition thesis T6. The central justification of research obligation T1 relies on three further theses:

[T2 READINESS FOR DEPLOYMENT DESIRABLE] The CE technology T should be ready for deployment at a future point in time.

[T3 SIDE-EFFECTS OF R&D NEGLIGIBLE] The side-effects of R&D into the CE technology T under the aspect R are negligible as compared to T being [probably] ready for deployment in time.

[T4 NO ALTERNATIVES TO R&D (READINESS)] There are no more appropriate alternatives to immediate R&D into the CE technology T under the aspect R which bring about that T is probably ready in time.

Each of these theses ignites a more or less extensive sub-controversy. In these sub-controversies, the contentious thesis that mitigation policies have priority over CE methods is of decisive importance (T14). Moreover, the R&D prohibition thesis is being justified through an alternative argumentation that does not require the controversial thesis T2. Finally, the CE controversy also contains direct justifications of the R&D prohibition.

As already indicated in the introduction, the term “climate engineering” subsumes various different technologies which all aim at large-scale interventions in the climate system, but which, at the

same time, substantially differ from one another regarding risks, effectiveness, side-effects, and costs of deployment. Since these aspects are also relevant to the moral assessment of the corresponding technologies (i.e. of their R&D and deployment), the following problem arises for the argumentative analysis: To do justice to the different CE technologies, the question of whether, for instance, ocean fertilization should be further researched into would have to be discussed separately and independently from the question of whether, let's say, cloud-albedo enhancement should be researched into as well. This applies, *mutatis mutandis*, to the remaining technologies as well. Accordingly, not only one but a rough dozen CE controversies, each dealing with a different technology, would have to be differentiated and reconstructed. Since the results of such an analysis would be extremely comprehensive and, in addition, redundant in many respects, this study uses a placeholder method (cf. Section 1.3).

The central theses of the CE controversy, which directly address the key questions of the debate (see Section 1.1), and their logico-argumentative interrelations can be outlined as follows. The thesis

- [T1 R&D OBLIGATION] R&D into the CE technology T under the aspect R ought to be carried out immediately.

answers the central R&D question positively. It is contradicted by the thesis

- [T6 R&D PROHIBITION] R&D into the CE technology T under the aspect R must not be carried out.

Three further theses fuel the central justification of the R&D obligation (T1), as Section 3.1 explains in more detail.

- [T2 READINESS FOR DEPLOYMENT DESIRABLE] The CE technology T should be ready for deployment at a future point in time.
- [T3 SIDE-EFFECTS OF R&D NEGLIGIBLE] The side-effects of R&D into the CE technology T under the aspect R are negligible as compared to T being [probably] ready for deployment in time.
- [T4 NO ALTERNATIVES TO R&D (READINESS)] There are no more appropriate alternatives to immediate R&D into the CE

technology T under the aspect R which bring about that T is probably ready in time.

Taken together, the three theses T2-T4 constitute a sufficient reason for R&D into the CE technology T. Reversely though, each of these theses represents a necessary condition for R&D obligation, as pointed out in Section 3.1: Should one of these theses be false, it would be wrong to carry out R&D into technology T, at least as regards achieving readiness for deployment.

Theses T2-T4 are the starting points of more or less comprehensive sub-debates of the CE controversy. Based on these theses, the overall debate can thus be clearly structured into sub-controversies.

The expected R&D side-effects and their assessment are the subject of the sub-debate that is associated with T3. Within that part of the debate, the side-effects of R&D are weighted and compared to the target of achieving readiness of deployment (cf. Section 3.2).

Thesis T2, according to which readiness for deployment at a future point in time is desirable, triggers the most comprehensive sub-debate of the CE controversy (see Section 3.3). It contains various pro and con arguments of different types. These arguments are either directly related to thesis T2 (i.e. support or attack it) or back up the assumption

- [T9 CE DEPLOYMENT WRONG] A future deployment of the CE technology T is in any case (morally) wrong.

T9 is closely connected with T2: If T9 were true, then T2 would be false – for why should technologies whose deployment would be morally wrong be ready for deployment in the first place? The arguments supporting thesis T9 thus indirectly attack T2.

T4, too, appears to be contestable (cf. Section 3.5.1). According to the findings of the authors, though, hardly any arguments have been put forward so far in order to settle the question whether there are no alternatives to immediate R&D, should the appropriate CE technologies be ready for deployment in time. The thesis T4 is only challenged by few arguments.

Irrespective of the issue of the future readiness for deployment, several further reasons are given in favour of the R&D obligation T1 (cf. Section 3.4). These alternative justifications do not depend

on the highly contentious thesis T2 and, thus, circumnavigate the most comprehensive sub-controversy of the overall debate. However, the alternative justifications of T1, too, make use of premisses that, in line with T3 and T4, hold that R&D side-effects are negligible and that there are no alternatives to immediate R&D. T3 and T4 thus turn out to be the actual touchstones of any position whatsoever which embraces R&D into CE technologies.

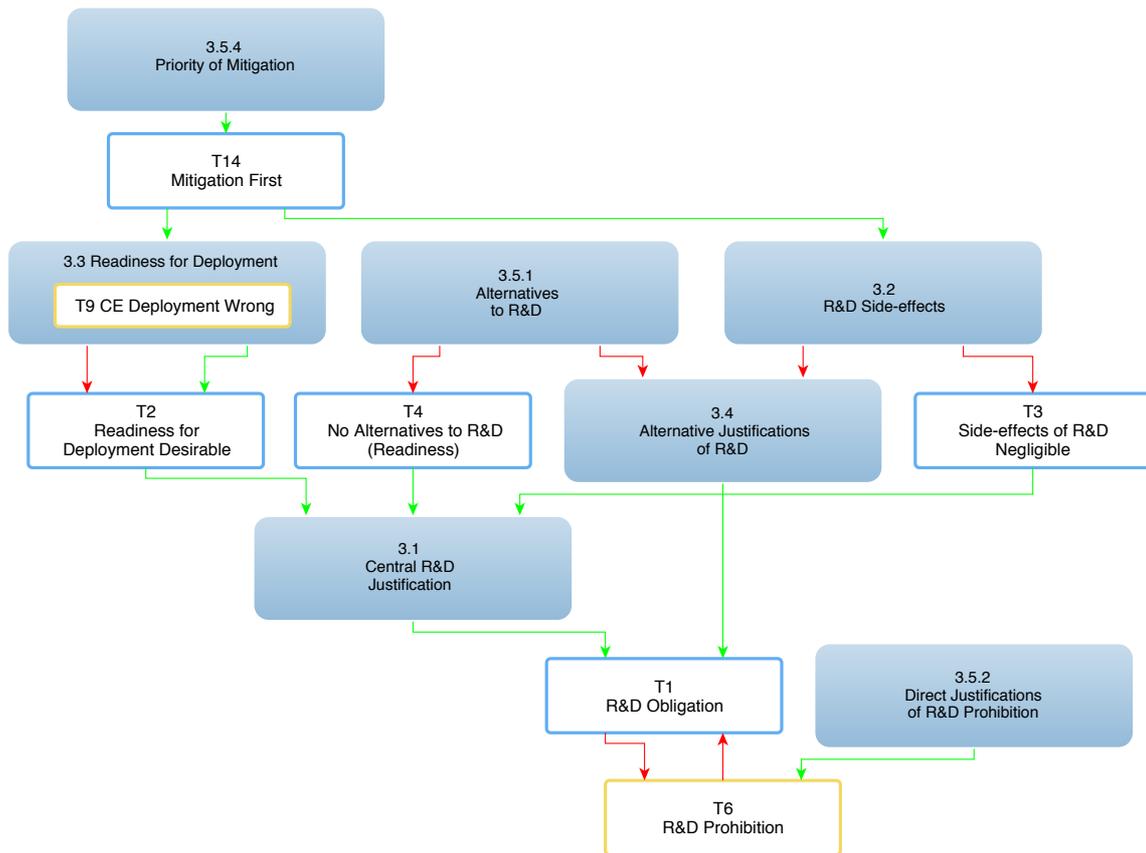
The critique of R&D into CE technologies is not limited to attacking theses T2-T4. Independent of the objections to T2-T4, T6, which proscribes R&D, is supported by a number of ethical arguments that have already been discussed in some detail in the current debate (see Section 3.5.2).

Another important thesis which, although conceded by most of the proponents, mainly supports the arguments of the critics, asserts that mitigation policies, which try to prevent anthropogenic climate change through emission reduction, have priority over CE measures.

- [T14 MITIGATION FIRST] Mitigation, as a climate policy option, is preferable to CE deployment.

Thesis T14 represents the starting point of various arguments in the CE controversy (cf. Section 4.3) and can itself be justified in different ways (see Section 3.5.4).

In line with the above, the macrostructure of the entire reconstructed CE controversy can be visualised as follows.



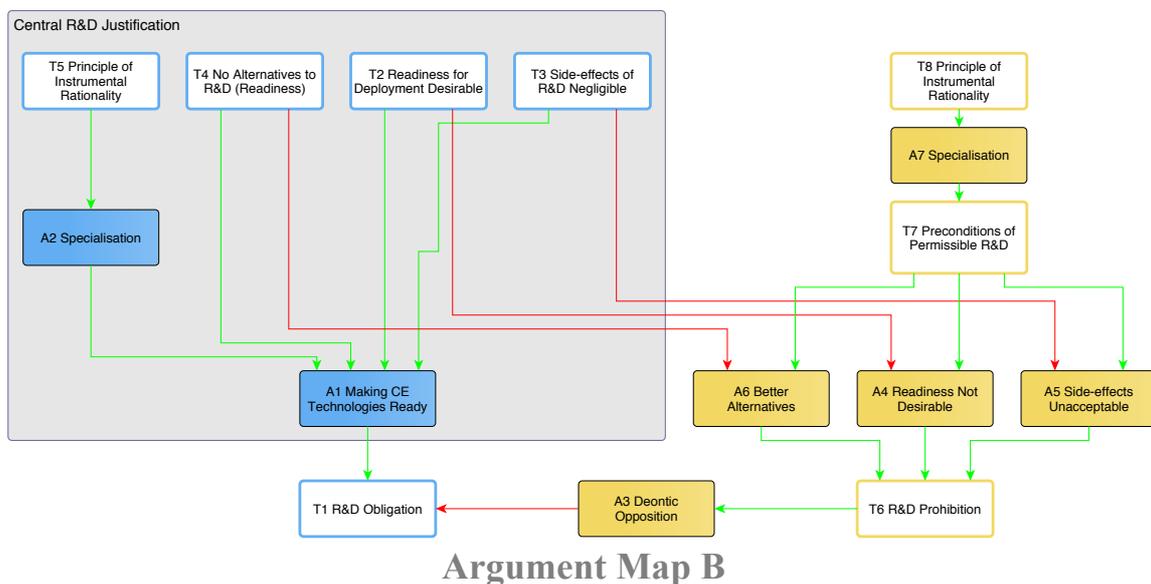
Argument Map A: This map visualises the overall structure of the reconstructed CE controversy. Besides central theses (framed boxes), it mainly displays argument clusters, which group individual arguments. The argument clusters represent sub-debates of the controversy and exhibit a more or less complex internal argumentative structure. Argument clusters are numbered corresponding to section numbers in this book. Green and red arrows indicate argumentative impacts (supportive or critical) of the reasoning set forth in the corresponding sub-controversies.

3 The Detailed Structure of the Sub-debates

3.1 The Central Justification of R&D

The central justification of R&D represents a consequentialist argument. R&D into CE technologies is claimed to be a suitable means for reaching the goal that CE methods be ready for deployment in the future. This argument rests essentially on theses T2 – T4.

The argument map below shows the dialectical structure of the central justification of R&D.



The central argument in favour of R&D into CE technology T justifies thesis T1 by saying that R&D is required to have CE technologies ready for deployment in the future. Accordingly, this justification infers appropriate means from a desired end and can be reconstructed as a so-called consequentialist argument, A1 MAKING CE TECHNOLOGIES READY,

- 1) The CE technology T should be ready for deployment at a future point in time. [T2]
 - 2) Immediate R&D into the CE technology T under the aspect R [probably] brings about that T is ready in time.
 - 3) There are no more appropriate alternatives to immediate R&D into the CE technology T under the aspect R which bring about that T is ready in time while at the same time being more appropriate than immediate R&D into the CE technology. [T4]
 - 4) The side-effects of R&D into the CE technology T under the aspect R are negligible as compared to T being [probably] ready for deployment in time. [T3]
 - 5) R&D into a technology ought to be carried out immediately if the following conditions are met: 1. The technology should be ready for deployment at a future point in time; 2. Immediate R&D [probably] brings about that the technology will be ready for deployment; 3. There are no alternatives which bring about that the technology is ready in time while at the same time being more appropriate than immediate R&D; 4. The side-effects of R&D are negligible as compared to the technology being ready for deployment.
-
- 6) THUS (from 1-5): R&D into the CE technology T under the aspect R ought to be carried out.

Besides assuming theses T2-T5, the central argument relies on the thesis that research is in fact effective (i.e. it is at least likely to bring about that the respective technology becomes ready for deployment, premiss 1.2), as well as on a means-end principle in premiss (1.5) which is a special case of a more general principle of instrumental rationality (T5).

The prohibition of R&D (T6) contradicts the obligation to carry out research (T1), as argument A3 makes explicit. Negating one of the three theses T2-T4, which are assumed in R&D justification A1, yields immediately a justification of the R&D prohibition (cf. arguments A4-A6). The decisive general premiss that these arguments are based on establishes the necessary normative conditions of R&D into a technology,

- [T7 PRECONDITIONS OF PERMISSIBLE R&D] R&D into a technology under the aspect R may be carried out only if each of the following conditions is met:
 1. There is a chance of achieving readiness for deployment.
 2. The direct costs of R&D are reasonable.
 3. The readiness for deployment of the technology outweighs, considering the probability that such readiness be actually achieved, the expected certain, probable, and possible side-effects of R&D.
 4. It is desirable to have the technology ready for deployment.

These preconditions, once again, can be derived from a more general principle (argument A7) if one assumes that the purpose of R&D consists in achieving readiness for deployment (premiss 7.3).

Theses T2-T4 thus constitute jointly sufficient and individually necessary conditions for the R&D obligation (T1). Hence, they represent decisive statements and focal points of the debate. It is therefore not surprising that these theses are suited for structuring the overall debate as explained in Section 2.

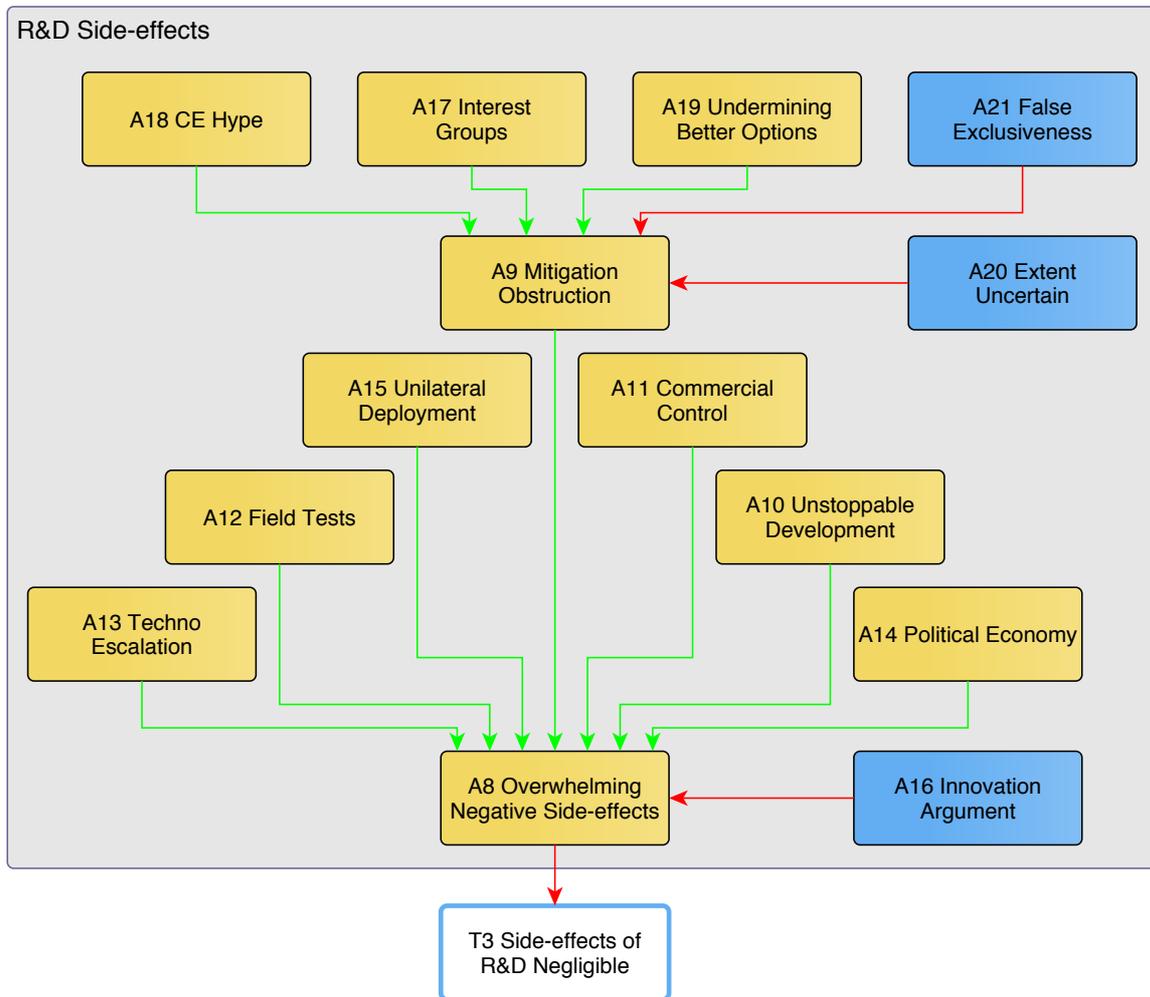
The argument map introduced under Section 3.1 reconstructs the core of the CE controversy. That core, however, remains by and large implicit in the current debate. It seems that most participants in the debate tacitly conceive R&D to be justified along the lines of A1 MAKING CE TECHNOLOGIES READY. But this is only revealed through further considerations (supporting arguments and objections) made by the proponents which can be related to the premisses of A1. So, since the central argument of the debate is hardly ever made explicit, Section 3.1, unlike the following sections, cannot be backed by references.

3.2 Side-effects of R&D

Thesis T3, which holds that the side-effects of R&D into CE are negligible, is challenged in the controversy by pointing out possible or probable harmful side-effects such as, in particular, the impact on mitigation policies (moral-hazard objection), the inevitable deployment of the technologies researched into, the commercial

control of CE methods, risky field tests, and the risk of unilateral use.

The sub-debate about the negligibility of R&D side-effects can be represented as follows:



Argument Map C

Here, thesis T3 is challenged by the central argument A8 OVERWHELMING NEGATIVE SIDE-EFFECTS which (i) points out the diverse side-effects of R&D into CE, (ii) assesses them as being harmful, and (iii) weighs them against the intended R&D objective (achievement of readiness for deployment). The decisive premiss within argument A8 is

- 8) The possible and probable negative side-effects SE1-SE7 clearly outweigh the sum of all [certain, probable, and possi-

ble] useful side-effects and the [probable] intended effect that technology T is ready for deployment.

Arguments A9 to A15 in argument map C identify the alleged, harmful side-effects of R&D.

One of the most frequently mentioned and, thus, most prominent objections to CE argues that the very R&D into such technologies could cause a substantial reduction of mitigation efforts (cf. e.g. Keith 2000:276; Royal Society 2009; Gardiner 2010b:292; Jamieson 1996:333 et seq.; Robock 2008a,b; ETC 2009:34). Carrying out R&D into CE, the argument warns, might suggest that there is a technical solution to the climate problem, and this in turn could prevent public and private stakeholders from implementing more or less painful mitigation measures. This argument, A9, which is sometimes also referred to as “moral-hazard objection”, identifies a potential side-effect of mere R&D into CE and, thus, supports argument A8. But why should there be a trade-off between mitigation on the one side and R&D into CE on the other one? Critics suggest different mechanisms which, should CE be researched into, could at least potentially affect mitigation policies in a negative way:

- [A17 INTEREST GROUPS] With larger sums going into CE R&D, lobby groups that tend to be opposed to ambitious mitigation policies will be established and strengthened.
- [A18 CE HYPE] R&D into CE could trigger an outright CE hype. And the discussion of CE alone could undermine the motivation for realising costly mitigation and adaptation policies.
- [A19 UNDERMINING BETTER OPTIONS] The financial and cognitive resources that are used for R&D into CE are not available for preparing and implementing mitigation policies.

Still, the argument of mitigation obstruction has also been criticised. While the Royal Society (2009) and Corner & Pidgeon (2010) point out that the actual extent of the assumed trade-off is uncertain (A20), David Keith et al. (2010) accuse the argument of presuming false exclusiveness and say that R&D and mitigation may well coexist. Whether, however, these objections definitely

affect the argument of mitigation obstruction (A9) can only be determined through a detailed reconstruction and, thus, has to be settled in future research.

The arguments below identify further assumed side-effects of R&D into CE:

- [A10 UNSTOPPABLE DEVELOPMENT] Research into CE might create an internal dynamic which inevitably leads to deployment even if deployment is dispensable. Yet, one must be able to halt R&D into risk technologies at any moment. (Jamieson 1996:333 et seq.)
- [A11 COMMERCIAL CONTROL] CE technologies might ultimately be controlled by big business that acts purely on the basis of commercial interest. This would lead to problems similar to those experienced in the pharmaceutical sector. (Robock 2008a; ETC 2009:29,34)
- [A12 FIELD TESTS] R&D into the CE technology T under the aspect R inevitably goes along with large-scale field tests which actually lead to deployment of T before T has been thoroughly probed. (Elliott 2010:11; Robock 2010)
- [A13 TECHNO ESCALATION] R&D into CE may sanction technical interventions into nature on any scale whatsoever. (cf. Keith 2000)
- [A14 POLITICAL ECONOMY] CE promotes the military-industrial sectors and the business branches that are the most reactionary in terms of climate policy. (Ott 2010a,b,d)
- [A15 UNILATERAL DEPLOYMENT] R&D into CE might lead to unilateral deployment with catastrophic impacts. (Goodell 2010:195-7)

While arguments A9 to A15, via A8, challenge the thesis of the negligibility of side-effects of R&D by listing potential negative side-effects, the positive side-effects of CE R&D counterbalance, in principle, such criticism. If the positive and negative side-effects were balanced, they could, in sum, turn out to be negligible indeed. Yet, proponents of the current debate, as analysed in this study, hardly advance positive side-effects of R&D at all. It is only Ott (Ott 2010a,b,d) who mentions a useful side-effect:

- [A16 INNOVATION ARGUMENT] R&D into new technologies such as CE triggers spin-offs and creates jobs.

This argument, however, rests on fairly strong assumptions, as the detailed reconstruction reveals, A16,

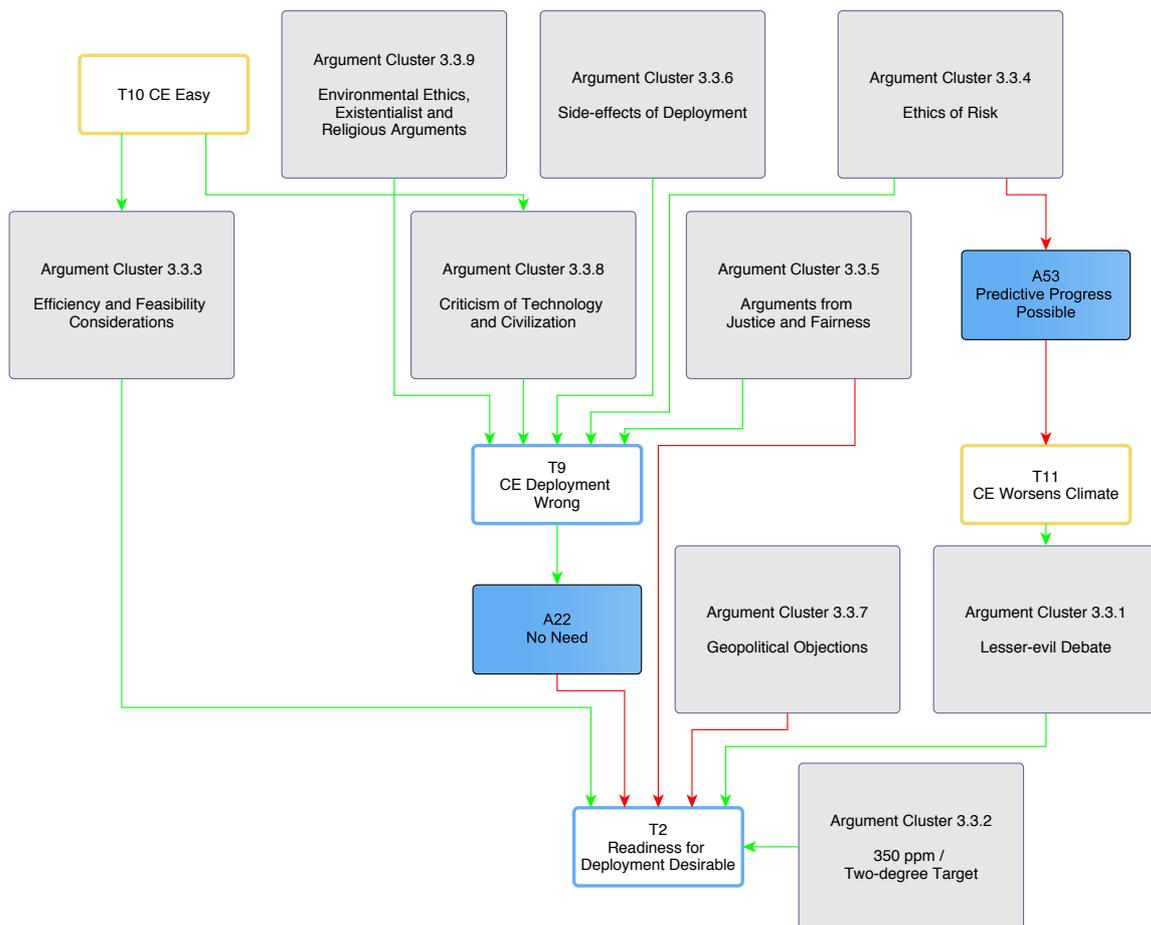
- 1) As a possible positive side-effect, R&D into the CE technology under the aspect R might lead to the creation of spin-offs and jobs.
 - 2) The potential creation of spin-offs and jobs, together with the intended achievement of readiness for deployment, outweighs the possible and probable negative side-effects SE1-SE7.
-
- 3) THUS (from 1,2): It is not true that: The possible and probable negative side-effects SE1-SE7 clearly outweigh the sum of all [certain, probable, and possible] useful side-effects and the [probable] intended consequence that technology T is ready for deployment.

3.3 Readiness for Deployment

The most extensive sub-controversy is based on thesis T2. Three different arguments justify why readiness for deployment of CE is desirable: At some future point in time, the deployment of CE methods could be the lesser of two evils, and we should prepare for that case (lesser-evil argumentation); without using CE methods, ambitious climate policy targets cannot be achieved anymore (two-degree target/350 ppm argumentation); CE methods are more efficient and can be implemented more easily than extensive mitigation policies (efficiency and feasibility considerations). These arguments in favour of T2 are countered by numerous objections to T2. To start with, critical arguments based on the ethics of risk stress that the deployment of CE is accompanied by massive, irreducible hazards. The prominent termination problem belongs to this category of objections, too. The arguments from justice and fairness point out the uneven regional consequences of CE deployment. Geopolitical concerns arise because of the dual use problem and the fear that a “global thermostat” could induce new conflicts. Finally, several fundamental objections are raised in the

controversy: They either rest on a general critique of technology and civilization or consist in religious, existentialist, or environmental-ethics considerations.

The sub-controversy about the readiness for deployment is ignited by thesis T2 READINESS FOR DEPLOYMENT DESIRABLE. It is the most comprehensive sub-debate within the CE controversy. The mesostructure of this sub-debate is illustrated in the argument map below, where argument clusters are combined into groups.



Argument Map D

Thesis T2 is supported by three argument clusters. These pro arguments are discussed in Sections 3.3.1-3.3.3. The objections to T2 either target T2 directly (cf. geopolitical considerations, Section 3.3.7, and some of the justice-theory arguments, Section 3.3.5) or indirectly oppose it by supporting T9 CE DEPLOYMENT WRONG (this holds for argument clusters 3.3.4, 3.3.5, 3.3.6, 3.3.8, 3.3.9). According to T9, the deployment of CE is morally wrong anyhow,

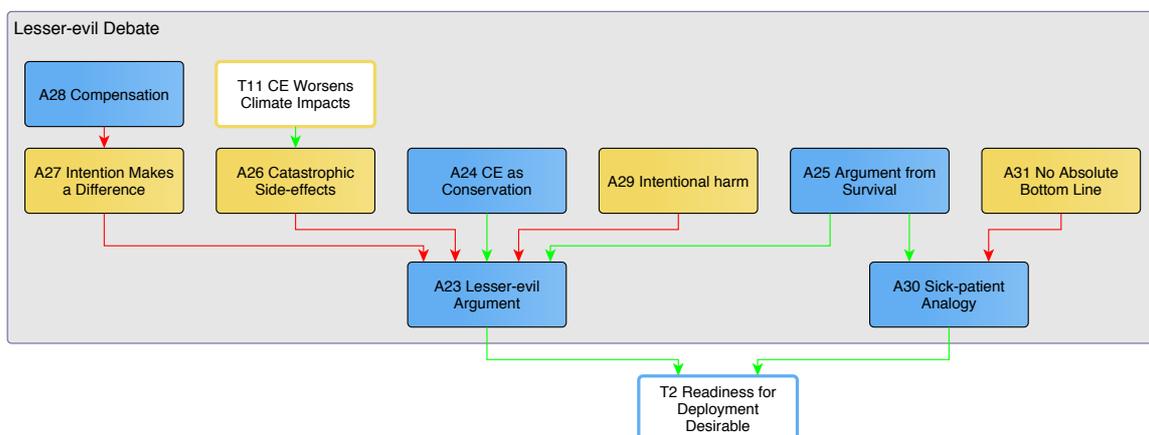
and, thus, readiness for deployment is not desirable (A22). Considerations from ethics of risk, moreover, give rise to an objection to the lesser-evil argumentation (via T11, A53). In addition, the feasibility considerations, on the one hand, and objections based on a fundamental critique of civilization, on the other hand, make use of one and the same premiss:

- [T10 CE EASY] Implementation of the CE technology is comparatively easy.

Hence, what in some arguments and for some proponents represents a reason in favour of readiness for deployment becomes a principal objection to deployment in other arguments and for other proponents.

3.3.1 Lesser-evil Argumentation (Pro)

The lesser-evil argument is certainly among the most important justifications of thesis T2, and, consequently, of the central R&D obligation in general. It already figures prominently in early articles by Stephen Schneider and Dale Jamieson, which include cautious pleas in favour of R&D into CE (Schneider 1996, Jamieson 1996). The mesostructure of the lesser-evil argumentation, together with closely related arguments and direct objections, is shown below.



Argument Map E

The central lesser-evil argument, A23, justifies thesis T2 by saying that there may be future situations (e.g. if climate sensitivity turns

out to be very high or if our mitigation efforts prove to be insufficient) where the (admittedly extremely risky) deployment of the CE technology T may be considered the lesser evil – since, without CE deployment, we would face uncompensated catastrophic climate change. The lesser-evil argument holds that, in view of such possible climate emergency, the CE technologies should, as a precautionary measure, at least be ready for deployment. A detailed reconstruction of this important argument reveals that, simple as it may seem, it builds on subtle decision-theoretic considerations, A23 LESSER-EVIL,

- 1) At some future point in time t, we may end up in a situation where (a) the worst possible impacts of the deployment of the CE technology T are clearly less severe than the worst possible consequences of not deploying it; where (b) relevant probability forecasts are not at our disposal; and where (c) the worst possible consequences of not deploying CE would in fact be catastrophic.
- 2) If relevant probability forecasts are unavailable and if the worst possible consequences of a decision are actually catastrophic, one should choose the option for action with the comparatively best worst possible consequences. (version of the precautionary principle)

- 3) THUS (from 1,2): At some future point in time t, we may get into a situation where we should deploy the CE technology T.
- 4) If we may get into a situation where a technology T ought to be deployed, the technology T should be ready for deployment in the future, provided that there are no more significant moral reasons against T being ready for deployment. (precautionary reasoning)
- 5) There are no such more significant moral reasons against the readiness for deployment of the CE technology T.

- 6) THUS (from 3-5): The CE technology T should be ready for deployment at a future point in time.

The lesser-evil argument is based on a (complex) possibility forecast, which already entails a normative assessment (23.1), as well as on two precautionary principles (23.2 and 23.4) and the general normative assessment that the moral objections to readiness for de-

ployment do not outweigh the precautionary considerations (23.5). The possibility forecast that the deployment of CE could be the lesser evil in case a climate emergency occurs is backed up in different ways. High climate sensitivity and failure of emission reductions may lead to CE being the only remaining possibility of saving unique ecosystems (A24, e.g. D. Keith in Goodell 2010:39). The argument A25, discussed by Pidgeon & Corner (2010:32), goes much further, still: Climate emergencies may well endanger the survival of the entire human species; that's why the worst possible consequence of uncompensated catastrophic climate change would be worse than the worst possible consequence of CE deployment (23.1).

The lesser-evil argument is criticised in different ways. While argument A26 is directed against the complex possibility forecast (23.1), the counter-arguments A27 and A29 attack premiss (23.5). Argument A26 asserts that CE deployment could further aggravate harmful climate impacts, rather than alleviating them. Because this uncertainty is irreducible, the objection goes, premiss (23.1) is false. In contrast to what (23.1) assumes, not deploying CE might actually be the lesser of the two evils. Argument A26 is based on

- [T11 CE WORSENS CLIMATE IMPACTS] It is certain that the future deployment of CE technologies might even worsen the most catastrophic anthropogenic climate impacts instead of alleviating them.

Thesis T11 itself is justified or defended by arguments that are assigned to the ethics of risk argument cluster (cf. Section 3.3.4). At first sight, the formulation of T11 and, hence, of argument A26, seems to be unduly sophisticated. Does it not suffice to simply say that CE deployment may worsen the whole situation? Well, actually no, that would not suffice – strictly spoken – to attack the above-reconstructed lesser-evil argument. The criticism A26 of the lesser-evil argument thus directly brings up the question as to how far the uncertainties of CE technologies (concerning effectiveness and side-effects) can be reduced through future research.

The further arguments A27 and A29 both attack premiss (23.5) by claiming that the moral reasons against readiness for deployment outweigh the precautionary considerations:

- [A27 INTENTION MAKES A DIFFERENCE] Intentional interventions into the climate system are (morally) worse than unintentional ones. (Keith 2000)
- [A29 INTENTIONAL HARM] Deploying CE involves harming some (rather than other) people; this reduces the ethical value of our lives. (Gardiner 2010b:304)

By making use of the ethical principle of double effect (cf. also K.C. Elliott 2010:18) and by thus assuming that there is a substantial moral difference between bringing about a consequence and not preventing it, argument A27, in fact, becomes vulnerable. Here, different counter-arguments that defend the lesser-evil argument can be anticipated. Referring to R. Elliot's environmental ethics (1982, 1997), one could, for instance, argue that the principle of double effect no longer applies in the case of renaturation measures that are considered compensations: In such cases, we would definitely be obliged to act and provide compensations, whereas passive inaction would be morally wrong (A28).

The sick-patient analogy (A30) spells out the basic idea of the lesser-evil argument by using a metaphor: The Earth could become a terminally ill patient whom we prescribe a highly risky, hardly understood therapy for she is apparently doomed to die anyway (cf. Lovelock in Goodell 2010:106). Just like the lesser-evil argument, the sick-patient analogy justifies the central thesis T2 READINESS FOR DEPLOYMENT DESIRABLE. A detailed reconstruction of this argument by analogy reads, A30 SICK-PATIENT ANALOGY,

- 1) A terminally ill patient ought to be prescribed a highly risky therapy if such therapy is found to be the only treatment option.
- 2) If, in the coming decades, greenhouse gas emissions remain unabated and if the climate sensitivity exceeds 6°C, the Earth, by about 2050, will resemble – in every relevant respect (especially as regards the fact that the situation cannot worsen) – a terminally ill patient for whom the only treatment option consists in a highly risky therapy (i.e., in analogy, in the deployment of a CE technology).
- 3) If two situations are equal in every morally relevant respect, an option for action in one of these situations ought to be tak-

en whenever the analogous option ought to be taken in the other situation.

- 4) THUS (from 1-3): If, in the coming decades, greenhouse gas emissions should remain unabated and if the climate sensitivity should exceed 6°C, CE technology T ought to be deployed by about 2050.
 - 5) It is possible that, in the coming decades, greenhouse gas emissions will remain unabated and climate sensitivity will exceed 6°C.
 - 6) If it is possible to get into a situation where a technology T ought to be deployed, the technology T should be ready for deployment in the future, provided that there are no more significant moral reasons against T being ready for deployment. (precautionary consideration)
 - 7) There are no such more significant moral reasons against the readiness for deployment of the CE technology T.
-
- 8) THUS (from 4-7): The CE technology T should be ready for deployment at a future point in time.

Argument A25, according to which climate change might endanger the survival of the entire human species, can be used to justify the analogy statement (3.2). This very premiss (3.2) represents the crucial assumption of argument A30. Any relevant difference between the two situations considered could defeat the sick-patient analogy. Such a difference is pinpointed in argument A31.

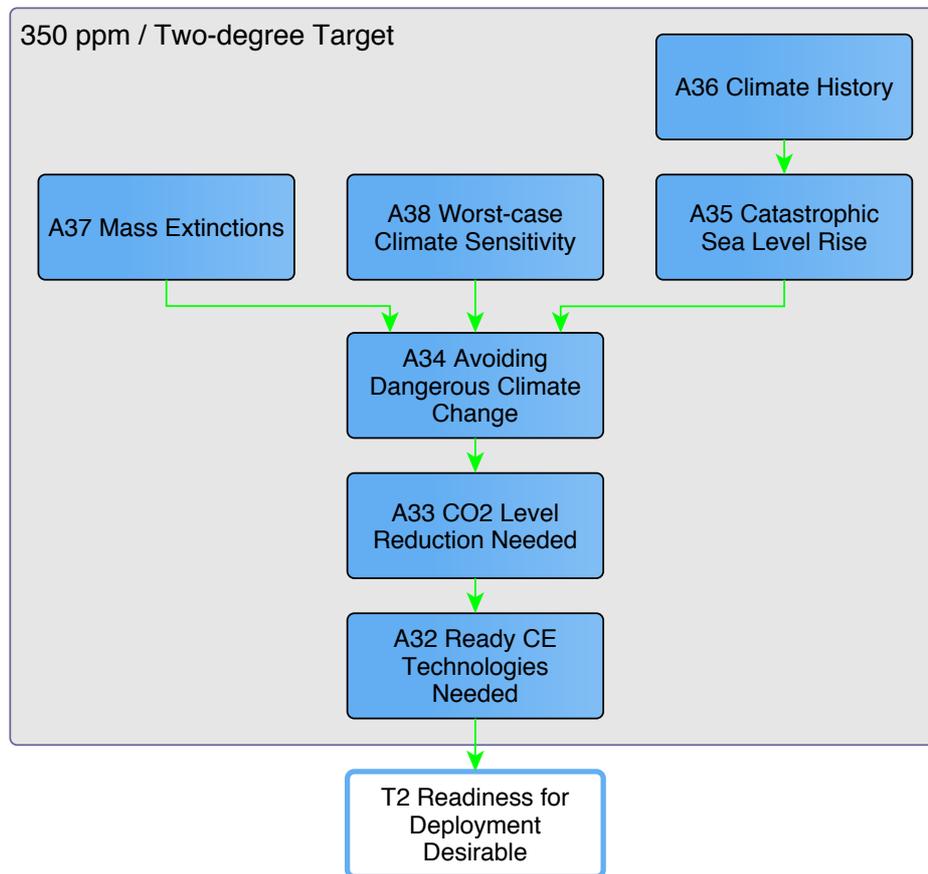
- [A31 NO ABSOLUTE BOTTOM LINE] In contrast to a terminally ill person, who, at worst, dies, anthropogenic climate impacts, no matter how bad they are, can always become worse.

The analogy assumed in A30, this objection says, is therefore severely flawed.

3.3.2 Two-degree Target / 350 ppm Argumentation (Pro)

A second argumentation in support of thesis T2 READINESS FOR DEPLOYMENT DESIRABLE results from the stipulation to stabilize the atmospheric CO₂ concentration at a value of at most 350 ppm (cf. Hansen 2009, Greene et al. 2010). (In analogy, the argument

cluster could be reconstructed based on a global 2° or 1.5° target.) Since the present concentration, however, is clearly above that value, the 350 ppm target demands a large-scale removal of carbon from the atmosphere. The mesostructure of that line of reasoning is as follows:



Argument Map F

The argumentation's structure is comparatively straight. The obligation to have CE technologies ready for deployment (T2) results from

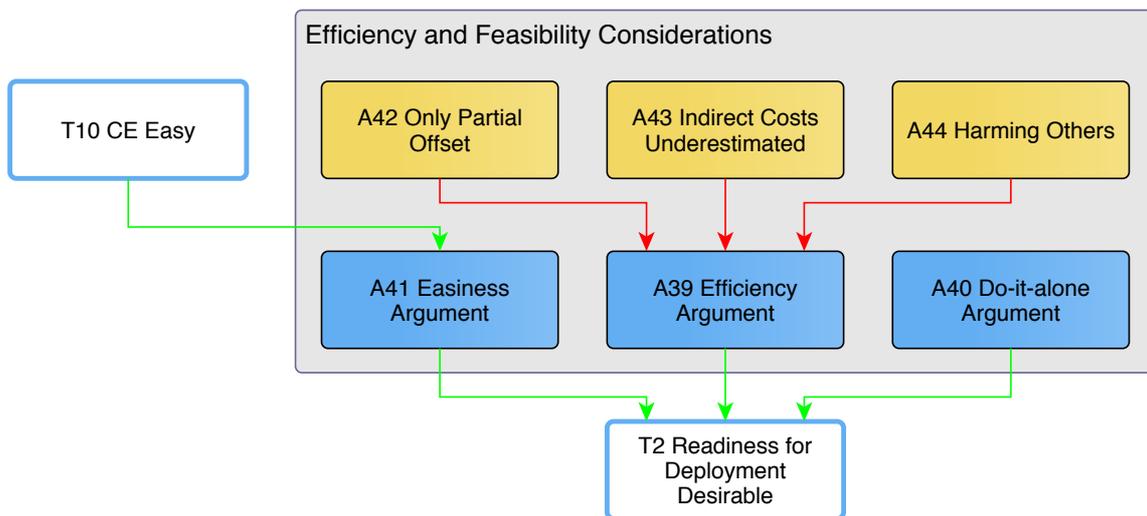
- [A32 READY CE TECHNOLOGIES NEEDED] Only with the help of a ready CE technology T can the atmospheric CO₂ level be reduced to 350 ppm. (Hansen 2009; Greene et al. 2010)

Arguments A33 and A34 point out that a reduction of the CO₂ concentration to 350 ppm is required to avoid dangerous climate change (Hansen 2009). The following independent evidence is provided to substantiate this claim:

- Values above 350 ppm may lead to a melting of the ice sheets and a catastrophic sea level rise (A35) – a scenario corroborated by palaeo-climatic data (A36).
- Values above 350 ppm may cause mass extinctions (A37).
- At values above 350 ppm, the radiation budget of the Earth is not balanced, which could trigger extreme global warming if climate sensitivity were high (A38).

3.3.3 Efficiency and Feasibility Considerations (Pro)

A third cluster of arguments that support T2 READINESS FOR DEPLOYMENT DESIRABLE is made up of efficiency and feasibility considerations.



Argument Map G

The efficiency argument A39 and the closely related do-it-alone (A40) and easiness arguments (A41) underline that the deployment of CE technologies would be easier and more cost-effective than burdensome mitigation or adaptation measures. All of these arguments thus consider CE a substitute for instead of a potential complement to mitigation policies.

- [A39 EFFICIENCY ARGUMENT] The direct and indirect costs of the deployment of CE are clearly below those of mitigation and adaptation. (Ott 2010a,b,d; Gardiner 2010b:287; Elliott 2010:20; Wood in Goodell 2010:129)

- [A40 DO-IT-ALONE ARGUMENT] If necessary, CE technologies can be deployed by a small group of determined nations to the benefit of the entire world. (Ott 2010a,b,d)
- [A41 EASINESS ARGUMENT] CE allows avoiding dangerous climate change without changing life styles, habits, and the current mode of our economy. (Ott 2010a,b,d)

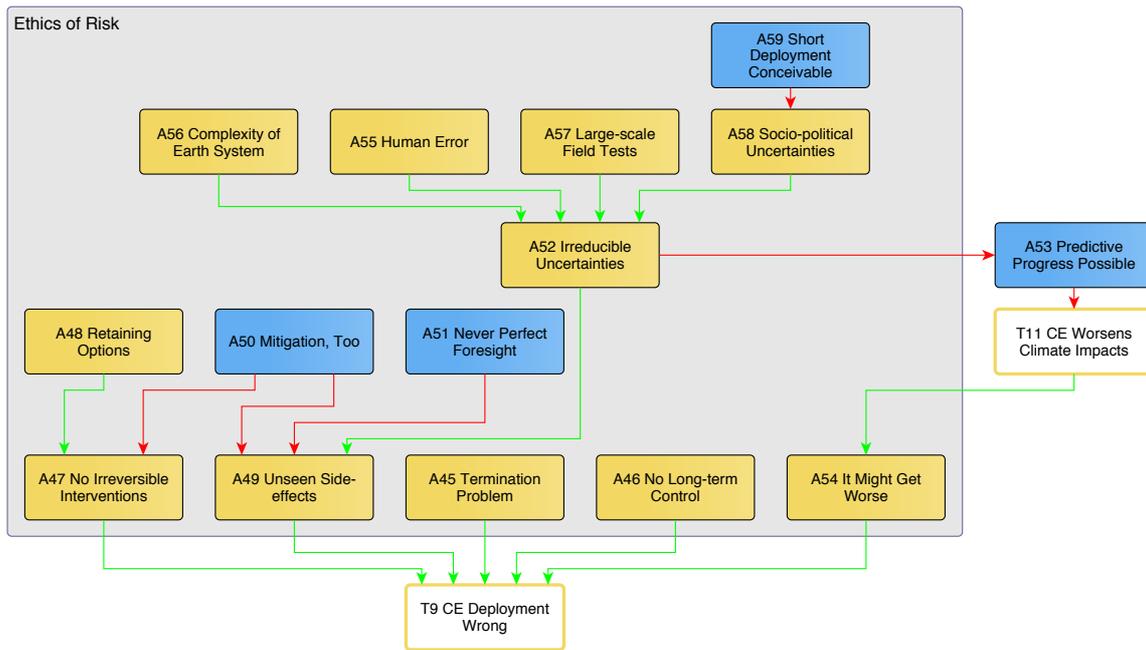
Having said this, the easiness argument portrays a certain CE feature as advantageous (T10) that critics consider as disadvantageous (cf. Section 3.3.8).

The efficiency argument has been discussed and criticised extensively in the current ethical debate. In particular, the following reasons have been invoked against argument A39:

- [A42 ONLY PARTIAL OFFSET] The CE method T often neutralises only a fraction of all anthropogenic climate impacts, e.g. not ocean acidification. In principle, its benefits are obviously smaller than those of mitigation. (Gardiner 2010b:288; Robock 2008a,b; ETC 2009:19)
- [A43 INDIRECT COSTS UNDERESTIMATED] The CE method T is anything but cheap, if one considers all indirect costs that arise due to unintended side-effects. (Gardiner 2010b:288)
- [A44 HARMING OTHERS] We do not compensate for harming others by merely providing them with technologies which might be used to moderate the harm we have caused. (Gardiner 2010b:293)

3.3.4 Arguments from Ethics of Risk (Contra)

Incalculable side-effects and imponderables constitute one of the main reasons against CE technology deployment. Arguments from ethics of risk, which point out uncertainties in future deployment, are primarily supporting thesis T9 CE DEPLOYMENT WRONG and make up an argument cluster with a comparatively complex dialectical structure.



Argument Map H

Before taking a closer look at some of the relevant arguments, a broad outline of the argumentation’s mesostructure is given. There are five arguments from ethics of risk which justify that deploying CE technologies – today as in the future – would be morally wrong (A45, A46, A47, A49, A54). Three of these arguments, namely A47, A49, and A54, are further supported and attacked. The unseen side-effects argument (A49), in particular, is based on the premiss that the uncertainties of CE deployment are irreducible, i.e. cannot be reduced substantially through further R&D. This claim, in turn, is supported by argument A52. The irreducibility of CE uncertainties is substantiated through several arguments (A55-A58), which all support A52. Argument A52, however, is also dialectically related to the it-might-get-worse argument (A54). This is because the latter is based on thesis T11, and T11 is attacked by argument A53 according to which further R&D could eliminate the uncertainties. Argument A52, finally, rebuts this progress-of-R&D objection by pointing out irreducible uncertainties.

The first three justifications of thesis T9 can be outlined as follows:

- [A45 TERMINATION PROBLEM] CE measures do not possess viable exit options. If deployment is terminated abruptly, rap-

id and catastrophic climate change ensues. (Ott 2010a,b,d; Robock 2008a,b)

- [A46 NO LONG-TERM CONTROL] Our social systems and institutions are possibly not capable of controlling risk technologies on long time scales and of ensuring that they are handled with proper technical care. (Corner & Pidgeon 2010:31)
- [A47 NO IRREVERSIBLE INTERVENTIONS] CE represents an irreversible intervention.

The prohibition of irreversible interventions, which A47 assumes, is justified by:

- [A48 RETAINING OPTIONS] Irreversible interventions narrow the options of future generations in an unacceptable way. (Jamieson 1996:330 et seq.)

A47, in turn, is attacked by:

- [A50 MITIGATION, TOO] Mitigation, too, is, at least to some extent, an irreversible intervention with unseen side-effects. (Corner & Pidgeon 2010:28)

In fact, this objection may also be understood as attacking the following argument, which supports T9 CE DEPLOYMENT WRONG:

- [A49 UNSEEN SIDE-EFFECTS] As long as the side-effects of CE technologies cannot be reliably predicted, their deployment is morally wrong. (Jamieson 1996:326 et seq.; ETC 2009:34)

A51 is another argument which, just like A50, is only vaguely articulated in the debate:

- [A51 NEVER PERFECT FORESIGHT] We do never completely foresee the consequences of our actions. (Goodell 2010:135)

A detailed reconstruction of A49, however, shows that arguments A50 and A51 may fail to gain traction, A49,

- 1) It is not true that: Further R&D into the CE technology T may (a) ensure its effectiveness and (b) exclude catastrophic side-effects of its deployment.
- 2) If further R&D into the CE technology T cannot exclude catastrophic side-effects of its deployment for sure, then side-

effects of deployment cannot be predicted reliably at any future point in time.

- 3) As long as the side-effects of a risk technology cannot be reliably predicted, its deployment is morally wrong.
- 4) The CE technology T is a risk technology.
- 5) THUS (from 1-4): A future deployment of the CE technology T is in any case (morally) wrong.

None of these premisses seems to be challenged by A50 or A51. Claiming that some uncertainties of CE are irreducible, premiss (49.1), moreover, is backed by argument A52.

- [A52 IRREDUCIBLE UNCERTAINTIES] There are major irreducible uncertainties regarding the effectiveness and side-effects of CE deployment (Cf. Keith 2000:277; Robock 2008a; Bunzl 2009)

Further reasons are given to support that argument:

- [A55 HUMAN ERROR] Complex technical interventions that are sustained on longer time scales are susceptible to human error and are hence unpredictable. (Robock 2008a; ETC 2009:34)
- [A56 COMPLEXITY OF EARTH SYSTEM] As a consequence of the earth system's complexity, we will never be in a position to grasp, let alone quantify, all side-effects of large-scale interventions. (Grunwald 2010; ETC 2009:34)
- [A57 LARGE-SCALE FIELD TESTS] Only large-scale field tests, which effectively amount to full-fledged deployment, can robustly demonstrate the effectiveness and reliability of CE methods. Hence, we will know whether CE works only once we have deployed it. (Robock 2010)
- [A58 SOCIO-POLITICAL UNCERTAINTIES] The effectiveness and reliability of CE presuppose a stable institutional framework over several decades. Such boundary conditions are unpredictable.

This last-mentioned argument, however, is qualified by:

- [A59 SHORT DEPLOYMENT CONCEIVABLE] In case mitigation efforts are carried out and highly effective CDR methods are

available, SRM might be deployed for no longer than a decade. (Wigley in Goodell 2010:133)

A fifth justification of thesis T9 CE DEPLOYMENT WRONG in the ethics of risk cluster says that:

- [A54 IT MIGHT GET WORSE] In the worst case (which is the decisive one), CE aggravates catastrophic climate impacts.

The detailed reconstruction shows that A54, similarly to the lesser-evil argument (A23), employs a precautionary principle, A54,

- 1) It is certain that future deployment of CE technologies might even worsen the most catastrophic anthropogenic climate impacts instead of alleviating them.
 - 2) There are no relevant probability forecasts available regarding the impacts of a future deployment of CE technologies.
 - 3) If relevant probability forecasts are unavailable and if the worst possible consequences of a decision are actually catastrophic, one should choose the option for action with the comparatively best worst possible consequences. (version of the precautionary principle)
-
- 4) THUS (from 1-3): The CE technology T should not be deployed in the future.
-
- 5) THUS (from 4): A future deployment of the CE technology T is in any case (morally) wrong.

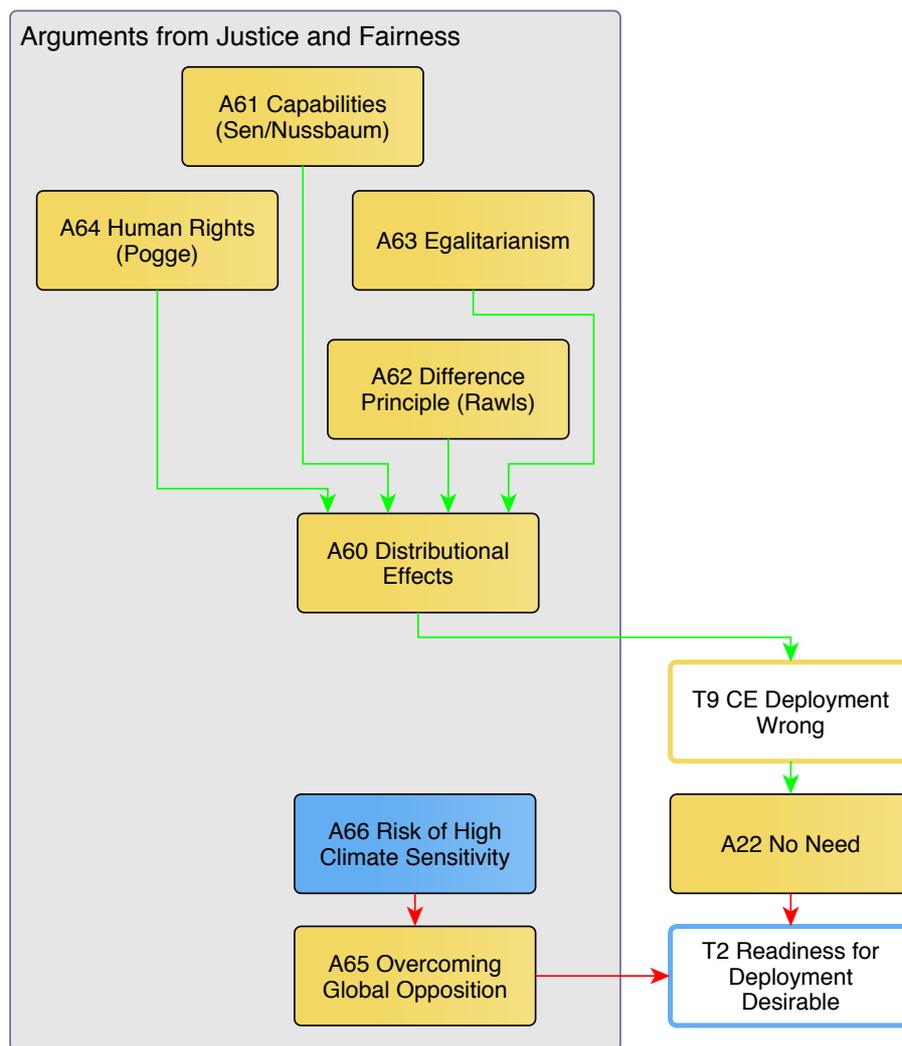
Premiss (54.1), which is also shown as thesis T11 CE WORSENS CLIMATE IMPACTS in the argument map, is obviously incompatible with the view that scientific progress and acquisition of further knowledge are possible in the context of CE:

- [A53 PREDICTIVE PROGRESS POSSIBLE] Scientific research might advance our understanding so that we will be in a position, when actually deploying CE, to robustly rule out the worst case that CE aggravates climate impacts.

Once again now, considerations about irreducible uncertainties arise because the argument A52 IRREDUCIBLE UNCERTAINTIES, supported by A55-A58, refutes precisely that further research could lead to a substantial reduction of uncertainties.

3.3.5 Arguments from Justice and Fairness (Contra)

The fact that consequences of CE may vary widely on a regional scale – both as regards compensation of climate impacts and non-intended effects – constitutes the starting point of another significant group of arguments against the deployment of CE. On the basis of such regional differences, arguments that stress justice and fairness considerations support thesis T9.



Argument Map I

In general, arguments from justice and fairness have not yet been discussed or elaborated fully in the current CE controversy. The common basis of different fairness arguments, which is also referred to in the literature, reads:

- [A60 DISTRIBUTIONAL EFFECTS] The uneven distributions of regional climate offsets (benefits), costs, and negative side-effects that go along with CE deployment are deeply unjust. (Keith 2000:276; Robock 2008a; ETC 2009:34)

On the one hand, spelling out of such an argumentation requires precise details of the diverse regional impacts of CE deployment. On the other hand, the arising regional differences must be assessed normatively according to a given theory or principle of justice. Such an assessment can be carried out on the basis of the below-mentioned theories, for example. Each of these four theories might provide independent arguments in support of A60 (note that these arguments are anticipated by the authors of this study as the corresponding theories have not yet been explicitly applied to assess CE):

- [A61 CAPABILITIES] CE deployment will bring about that less people possess elementary capabilities to lead a successful, good, flourishing human life. (Nussbaum/Sen 1993)
- [A62 DIFFERENCE PRINCIPLE] CE deployment will even aggravate the situation of those who are globally already worst off. (Rawls 1975)
- [A63 EGALITARIANISM] CE deployment widens the existing global socio-economic inequalities instead of reducing them.
- [A64 HUMAN RIGHTS] CE deployment alters the global institutional and economic conditions such that human rights will be realised to a lesser degree. (Pogge 2002)

Another argument from fairness which, however, does not support T9 CE DEPLOYMENT WRONG but directly opposes T2 READINESS FOR DEPLOYMENT DESIRABLE has been introduced by Stephen Gardiner:

- [A65 OVERCOMING GLOBAL OPPOSITION] Getting global legitimisation (in terms of factual consent and acceptance) for CE deployment is no less difficult than winning broad support for mitigation; if the former could be achieved, global mitigation efforts would not be blocked anymore and the prime reason for CE would fade away. (Gardiner 2010b:294)

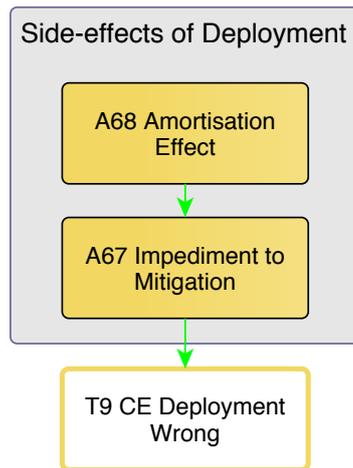
Being based on the idea of procedural justice, the argument voiced by Gardiner can be understood in two ways. Its first version implies that the central motivation for CE deployment gets lost as soon as the problems of achieving concerted multilateral implementation are overcome. As a matter of fact, should the community of states be able to agree on the deployment of CE it could as well agree on mitigation policies. With global mitigation on the way, Gardiner asserts, there would be no more demand for CE. This first version though can be opposed by:

- [A66 RISK OF HIGH CLIMATE SENSITIVITY] Even with ambitious mitigation policies, we might fail to achieve the two-degree target such that CE deployment is the lesser of two evils. (Keith et al. 2010)

In the second version, Gardiner's A65 is based on the pessimistic assumption (of one of the variants) of the lesser-evil argument and of some supporters of CE that, due to insurmountable clashes of interest, the international community will not agree on binding mitigation targets and policies anyway. But then, the argument goes, there will be no multilateral CE consensus for analogous reasons, either. And without such consensus, deployment will cease to be desirable.

3.3.6 Side-effects of Deployment (Contra)

Arguments pointing out the (uncertain) consequences and side-effects of CE deployment are already found in the cluster referring to ethical risks. Another side-effect argumentation, bearing a great similarity to the moral-hazard problem (cf. A9 MITIGATION OBSTRUCTION), has been identified by Klepper und Rickels (2011).



Argument Map J

Not only R&D into but also the deployment of CE could undermine further mitigation measures:

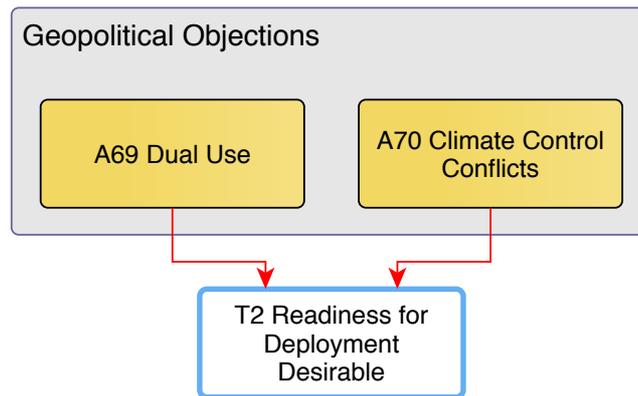
- [A67 IMPEDIMENT TO MITIGATION] The deployment of CE makes it highly unlikely that far-reaching mitigation policies are implemented and sustained.

The negative impact on mitigation stems supposedly from the high capital intensity of CE measures:

- [A68 AMORTIZATION EFFECT] Significant investments, required by capital-intensive CE technologies upfront, will amortize only in case the technology is deployed for a sufficiently long period of time. This requires not reducing CO₂ emissions too much.

3.3.7 Geopolitical Objections (Contra)

Geopolitical and military strategic effects of having CE technologies ready for deployment represent the starting points of consequentialist objections to T2 READINESS FOR DEPLOYMENT DESIRABLE.



Argument Map K

A69 refers to a problem that is also known from other technology debates, e.g. the nuclear energy controversy:

- [A69 DUAL USE] The CE technology T may potentially serve as (the basis for) weapons of mass destruction. (Keith 2000:275; Corner & Pidgeon 2010:30; Goodell 2010:210-2; Robock 2008a; ETC 2009:34)

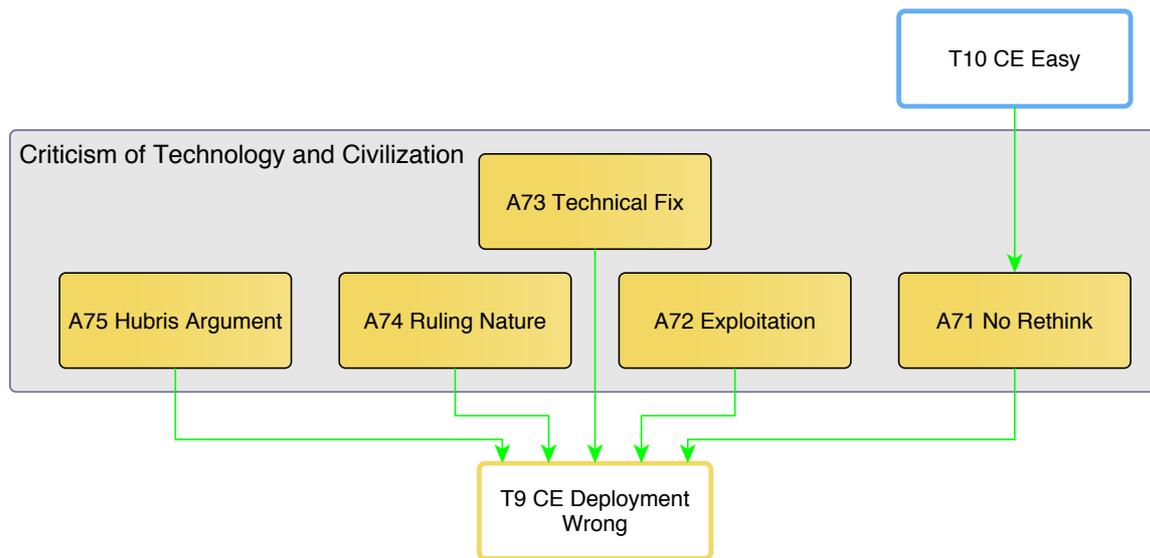
Yet another prominent argument of the CE controversy states:

- [A70 CLIMATE CONTROL CONFLICTS] CE puts future generations in a position to control the climate. This ability generates new conflicts and might even bring about climate wars. (Hulme 2010:351; Robock 2008a)

According to that argument, a global thermostat would generate more risks and problems than it solves.

3.3.8 Critique of Technology and Civilization (Contra)

Objections of a completely different kind are compiled in the argument cluster on fundamental critique of technology and civilization.



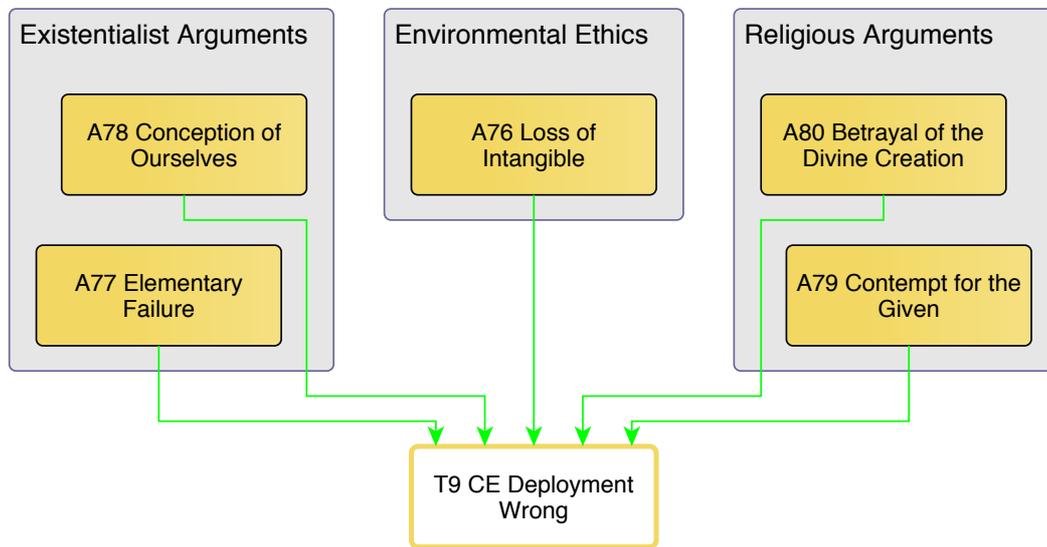
Argument Map L

Based on more or less radical normative premisses that express a critical attitude towards the scientific-technical civilization, these arguments reason that the deployment of CE would be deeply wrong.

- [A71 NO RETHINK] The deployment of CE prevents and postpones the urgently needed rethinking in our societies and the inevitable reforms of our economies. (Corner & Pidgeon 2010:32)
- [A72 EXPLOITATION] CE is just a cover for our ongoing exploitation of other people, generations, and species. (Gardiner 2010b:304)
- [A73 TECHNICAL FIX] CE is a “technical fix”, tinkering with symptoms instead of resolving the causes. As such, it is fundamentally flawed. (Keith 2000; Gardiner 2010b:303; ETC 2009:5)
- [A74 RULING NATURE] CE methods are but another means for ruling nature and point into a fundamentally wrong direction. (Gardiner 2010b:288)
- [A75 HUBRIS ARGUMENT] CE belongs to a tradition of large-scale interventions which have ignored the boundaries of technical manipulation. It testifies to arrogance and a form of self-deceit that will heavily backfire. (Ott 2010a,b,c,d; Gardiner 2010b:303; Jamieson 1996:332; Fleming 2010)

3.3.9 Religious, Existentialist, and Environmental-ethics Arguments (Contra)

Arguments that are based on highly specific ethical assumptions are outlined in the next argument map.



Argument Map M

Environmental-ethics considerations emphasize the large-scale loss of wilderness through CE deployment and contribute a prominent argument to the CE controversy:

- [A76 LOSS OF INTANGIBLE] The deployment of CE triggers a loss of wilderness, originality, and intangibility on unprecedented scales. (Ott 2010a,b,d; Keith 2000:277 et seq.; Robock 2008a)

In connection with that argument, attention is sometimes called to perceptible large-scale changes such as noticeably different sunsets. Focusing on the value of wilderness, originality, and naturalness, the environmental-ethics argument, however, does not depend on such *perceptible* side-effects of CE (concerning the environmental-ethics debate about the value of wilderness, cf. also Birnbacher 2006). Reference to changed sunsets or the loss of blue skies (due to SRM) may as well, however, arise from aesthetic considerations.

Stephen Gardiner articulates two arguments against CE deployment that appeal to our self-conception as moral persons and may thus be called “existentialist”:

- [A77 ELEMENTARY FAILURE] CE testifies that mankind has failed to meet an elementary challenge: To live and to survive on this planet as we have found it. (Gardiner 2010b:304; Jamieson 1996:332)
- [A78 CONCEPTION OF OURSELVES] CE risks undermining our conception of ourselves as moral beings. (Gardiner 2010b:303)

The latter argument is only hinted at by Gardiner as he asks what the decision to implement CE or research into it may tell about us: What are humans like that make such decisions? Which are the virtues that guide their actions?

Two religious arguments have been anticipated from statements by the Catholic and Protestant churches, specifically from a social encyclical by Pope John Paul II and from the report by an EKD (Evangelische Kirche in Deutschland – Evangelical Church in Germany) working group on genetic engineering. Although both arguments have not yet been introduced into the debate, they establish an inferential connection between religious beliefs and CE:

- [A79 CONTEMPT FOR THE GIVEN] By deploying the CE technology T, we would not perceive and respect nature as what is given to humans; rather, nature would become something we create intentionally by way of technical reproduction (cf. Zimmerli et al. 1997, III.1)
- [A80 BETRAYAL OF THE DIVINE CREATION] By deploying the CE technology T, man subjects the Earth without restraint to his will and betrays its prior God-given purpose. (According to Pope John Paul II, *Centesimus annus*, IV, 37; WCC 1998)

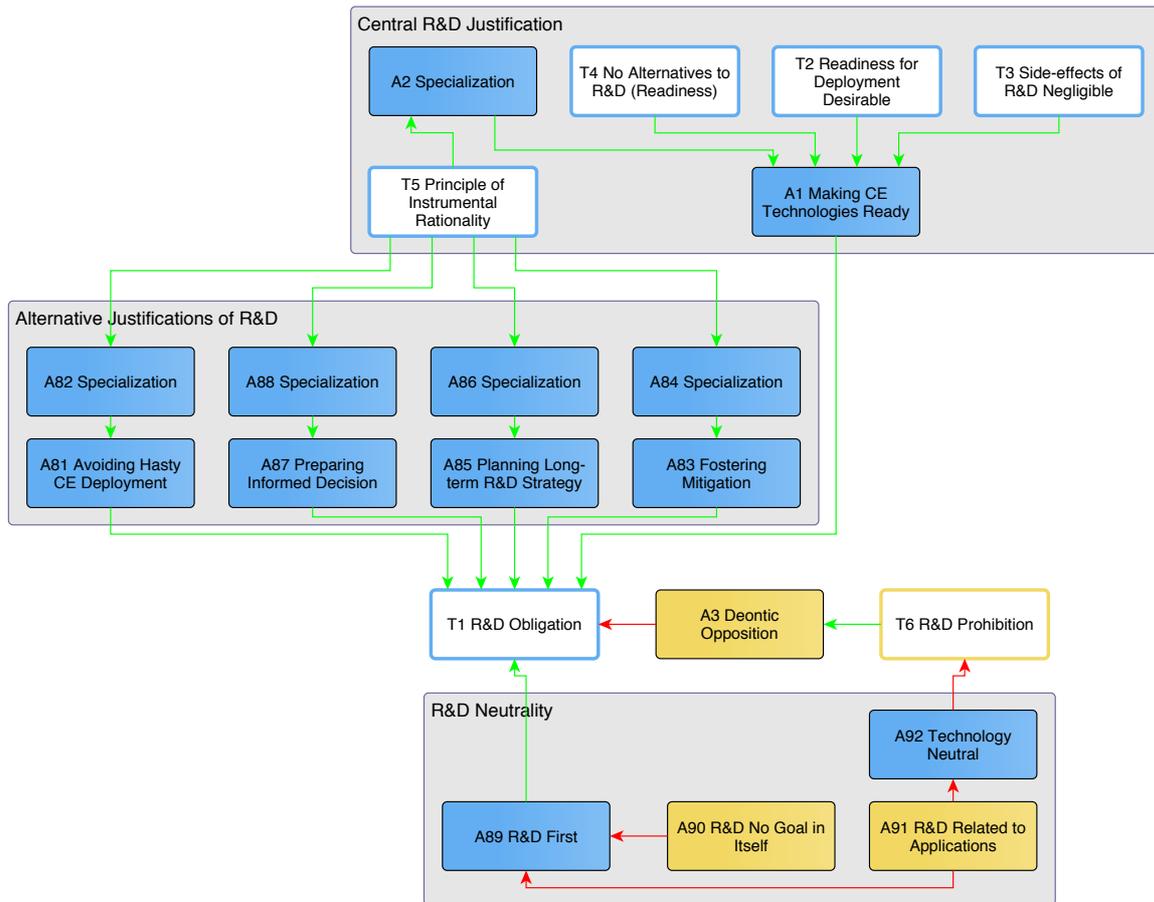
It is important to note that the genetic engineering statement made by the EKD working group draws an extremely differentiated picture and suggests acting carefully without flatly denouncing each and every genetic engineering method. In line with this, EKD could be assumed to be evaluating CE measures in a likewise differentiated way and be supposed not to argue generally against all

CE measures with A79. Ultimately, however, such predictions remain purely speculative.

3.4 Alternative Justifications of R&D

Although alternative research justifications consider R&D into CE methods as being a suitable means for a given end, they differ from the central justification by specifying an altogether different purpose of research. According to these alternative arguments, research does not aim at making CE methods ready for deployment. Rather, research should help, for example, to avoid hasty CE deployment by pointing out the real risks and hazards involved.

Not least because of the numerous objections to the central R&D justification A1 MAKING CE TECHNOLOGIES READY, the CE controversy has turned to the question as to whether there may not be other reasons in favour of R&D that are entirely independent of such contentious issues as CE deployment or readiness for deployment. Such alternative research justifications are compiled in the argument map below.



Argument Map N

Just like the central justification, each of the alternative justifications of R&D represents a means-end argument and realises the general consequentialist inference pattern T5. The alternative arguments A81-A88 merely differ from the original one by citing other targets than deployment readiness to be pursued through CE R&D, namely:

- Avoidance of hasty CE deployment. [A81, A82] (cf. Leisner and Müller-Klieser 2010; Keith et al. 2010)
- Fostering of mitigation policies. [A83, A84] (cf. Keith et al. 2010; Lovelock in Goodell 2010:107)
- Planning of a long-term R&D strategy. [A85, A86]
- Preparation of an informed decision (on deployment in the future). [A87, A88]

The latter of these four variants (A87) comes closest to the central justification of R&D. In fact, to prepare an informed decision on future deployment, it takes more than just compiling relevant information: The respective technologies must, in addition, be devel-

oped to maturity. Hence, A81, A83, and A85 seem to be the only genuine alternatives. Each of these alternative arguments evidently claims that (i) the respective target shall be reached, (ii) R&D into the CE technology contributes to reaching the target, (iii) there are no alternatives to R&D in that respect, and (iv) R&D side-effects are negligible. In view of these claims, the alternative justifications obviously also imply variants of theses T3 SIDE-EFFECTS OF R&D NEGLIGIBLE and T4 NO ALTERNATIVES TO R&D (READINESS). Unlike the central R&D justification A1 MAKING CE TECHNOLOGIES READY, these alternatives, however, steer clear of the comprehensive sub-controversy on readiness for deployment (T2). Nonetheless, arguments A81, A83, and A85 are partially based on other problematic assumptions. Since the allegedly lacking alternatives to R&D will be discussed separately (cf. Section 3.5.1), we confine ourselves at this point to questions of effectiveness. It is all but obvious why R&D into CE should contribute effectively to avoiding hasty deployment (A81) and to fostering mitigation policies (A83). In fact, the relevant arguments are rather based on the assumption that the risks and side-effects of CE are currently systematically underestimated and that a closer scientific investigation of such technologies reveals their limitations (as regards feasibility, effectiveness, and acceptability of side-effects). The basic idea behind A83 holds that such revelations would keep the international community from relying prematurely on CE and losing sight of mitigation policies.

Finally, there remains one last kind of justification, which is briefly mentioned for completeness' sake. Gardiner discusses an argument that emphasizes the neutrality of R&D:

- [A89 R&D FIRST] R&D should not be constrained; once technologies have been developed, a decision can be taken as to their deployment. (Gardiner 2010b:288 et seq.)

However, he discards the argument immediately on the following grounds:

- [A90 R&D NO GOAL IN ITSELF] R&D is no intrinsic goal and not for free, either: Research projects compete for limited

funds, requiring a choice as to which projects to pursue. (Gardiner 2010b:288 et seq.; Jamieson 1996:333 et seq.)

- [A91 R&D RELATED TO APPLICATIONS] R&D cannot be separated neatly from its potential results' applications because of psychological as well as socio-economic mechanisms. Frequently, automatic applications cannot be avoided. (Gardiner 2010b:288 et seq.)

Also, these objections rebut the following attack against the R&D prohibition:

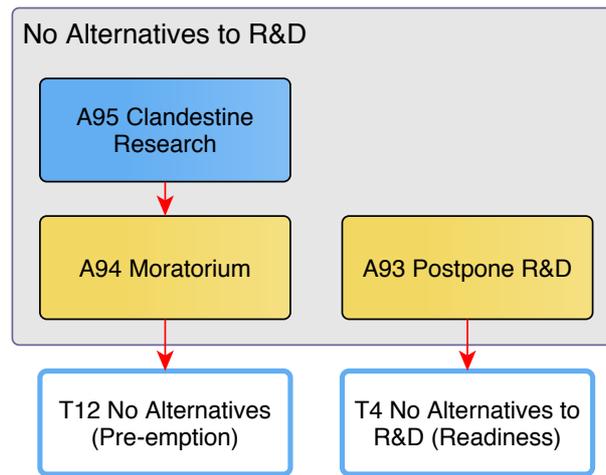
- [A92 TECHNOLOGY NEUTRAL] The CE technology T is, in itself, neutral and may be applied for good or bad purposes. Its mere development cannot reasonably be prohibited. (Goodell 2010:192)

3.5 Further Arguments

Further arguments of the CE controversy are related to the lack of alternatives to CE R&D (T4), provide direct justifications of the R&D prohibition, broach the issue of national bans, and give reasons for the priority of mitigation measures over CE methods.
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3.5.1 Lack of R&D Alternatives

All R&D justifications decisively depend on the assumption that no means are more appropriate for achieving the presumed purpose (e.g. readiness for deployment in time) than immediate R&D into CE technology T (T4). In spite of its central importance, this prerequisite is – as opposed to theses T2 and T3 – hardly paid attention to. The following argument map compiles considerations that are directed against T4 or variants thereof.



Argument Map O

Thesis T4 is a premiss of the central R&D justification. In this context, Gardiner makes the following objection:

- [A93 POSTPONE R&D] Preparing a technical intervention which is to be carried out in 50 years is a waste of resources: The technological means upon which the intervention will ultimately rely are not available today at all. (Gardiner 2010b:288 et seq.)

In line with this, R&D with the goal of developing the respective technology to maturity in time may as well be postponed. This objection obviously presumes that, if at all, the technology T shall not be deployed until the remote future (in several decades).

The premiss of R&D justification A81 AVOIDING HASTY CE DEPLOYMENT, however, which claims that there are no alternatives to R&D if hasty deployment of the CE technology T is to be avoided (T12), is opposed by the following obvious consideration:

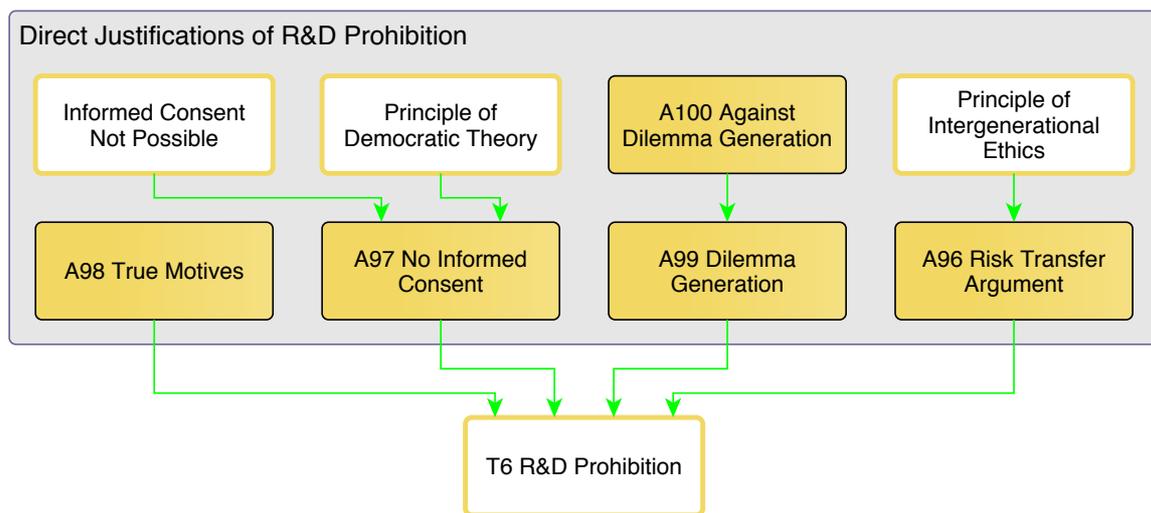
- [A94 MORATORIUM] Hasty and premature deployment of CE technologies might be avoided (alternatively) by an international moratorium.

A moratorium of that kind has recently been recommended unanimously by the Convention of Biological Diversity (CBD) (cf. Tollefson 2010). But not only does such a moratorium undermine one of the premisses of R&D justification A81, it also weakens the analogous assumption of argument A83 FOSTERING MITIGATION. Concerns that a moratorium would hardly be effective and would not inhibit R&D lead up to the following objection:

- [A95 CLANDESTINE RESEARCH] A moratorium would merely push research activities „underground“. (Goodell 2010:200)

3.5.2 Direct Justifications of R&D Prohibition

So far, the justification of the R&D prohibition thesis (T6) has been linked up with the criticism of theses T2 to T4. Should one of the latter be wrong, it follows, through A4-A6, that R&D ought to be refrained from. This assumes, though, that the objective of research consists in the development of ready-for-deployment technologies (cf. Section 3.1). If R&D is being endorsed (thesis T1) for alternative reasons, arguments A4-A6 cease to apply. The CE controversy, however, contains further arguments that can be understood as direct justifications of the thesis T6.



Argument Map P

Several authors argue that mere CE planning already represents part of an unacceptable transfer of risks from present to future generations:

- [A96 RISK TRANSFER ARGUMENT] Planning for deployment and carrying out R&D today means transferring risks to future generations. (Ott 2010a,b,d; Gardiner 2010b:293; Jamieson 1996:331)

However, argument A96 must (presumably) assume that CE measures are conceived as alternatives to mitigation policies or, at

least, that such mitigation measures will not be implemented because of CE planning.

While A96 is based on a principle of intergenerational ethics, A97 is founded on democratic theory:

- [A97 NO INFORMED CONSENT] R&D into CE requires a broad and well-informed consent of those potentially affected, which is not given. (Jamieson 1996:329 et seq.; Ott 2010a,b,d; Gardiner 2010b:293 et seq.; Elliott 2010:19)

The following justification of the R&D obligation, in contrast, shows parallels to objections that are critical of civilization and technology (cf. Section 3.3.8):

- [A98 TRUE MOTIVES] R&D into CE is but a rationalisation for “passing the buck” on to future generations and for not addressing the CO₂ problem in earnest. (cf. Gardiner 2010b:295)

Eventually, Ott has developed another variant of the risk transfer argument where he denounces R&D into CE for possibly burdening future generations with a fatal dilemma:

- [A99 DILEMMA GENERATION] R&D into CE is likely to lead to future dilemmata. (Ott 2010c)

Dilemmata, however, curb the rights of future generations in an unacceptable way (A100).

3.5.3 The Problem of National Bans

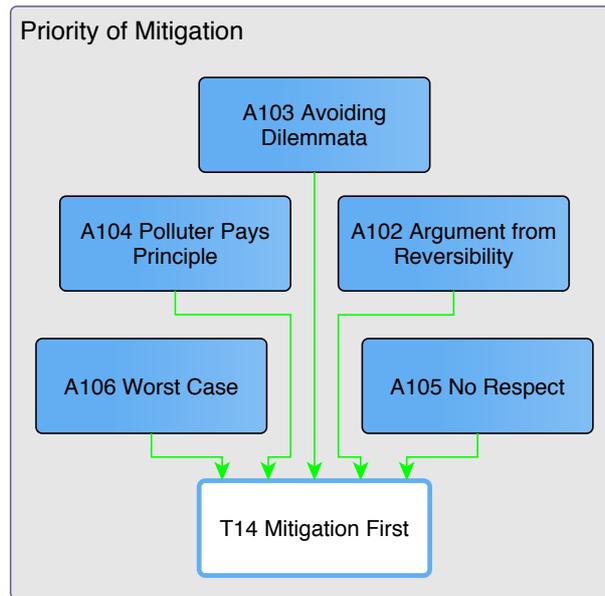
A particular ethical problem, which has not been discussed explicitly in the current debate but is of relevance nonetheless, pertains – in a broad sense – to the problem of free-riding: How can limited, for example national, bans still be justified if, on a global scale, numerous stakeholders do not abide by comparable prohibitions anyway? Or, do universal norms which have been justified under the assumption that they be collectively accepted and adopted lose their authority – for everybody – once sufficiently many agents don't comply? Picking up on these questions, the argument below takes for granted the universal research prohibition T6 and con-

cludes that it would be wrong to enforce such a prohibition on a small (e.g. European) scale, A101,

- 1) R&D into the CE technology T under the aspect R ought not to be carried out (immediately). (thesis T6)
 - 2) Some nations and businesses get away with defying R&D prohibition.
 - 3) If an action A is prohibited (or morally forbidden) to all stakeholders but some get away with defying the related rules, it seems unjust to uphold the prohibition for the remaining stakeholders.
 - 4) Any prohibition whatsoever ought not to be unjustly upheld and imposed on any stakeholder.
-
- 5) THUS (from 1-4): The prohibition of R&D into the CE technology T ought not to be upheld towards German or European stakeholders.

3.5.4 Priority of Mitigation Policies

Many objections to R&D into CE, but also numerous justifications thereof, are based on the assumption that, *prima facie*, mitigation – rather than CE – represents the more appropriate means for avoiding dangerous climate change (cf. Section 4.3). This comparative assessment (thesis T14) is justified in different ways in the CE controversy.



Argument Map Q

Several independent reasons are given to substantiate the priority of mitigation:

- [A102 ARGUMENT FROM REVERSIBILITY] Changes in behaviour (induced by mitigation policies) are much more reversible than technical interventions. (Jamieson 1996:331)
- [A103 AVOIDING DILEMMATA] We should avoid upfront to end up in a situation where we are compelled to choose between two evils. (Gardiner 2010b:300 et seq.; Elliott 2010:13)
- [A104 POLLUTER-PAYS PRINCIPLE] Problems should be solved by those (generations) who have caused them; therefore, mitigation is preferable to CE. (Jamieson 1996:331)
- [A105 NO RESPECT] An initial act of pollution would even be morally wrong if perfect neutralisation of negative impacts were possible *ex post*, because it is an expression of a lack of respect. (Hale 2009; Hale and Grundy 2009)
- [106 WORST CASE] No matter whether CE technologies are carried out or not: The worst case, given mitigation policies are carried out, is comparatively better than the worst case without mitigation.

4 Central Issues, Principles, and Problems

After having introduced the macrostructure of the CE controversy and the detailed structure of its sub-debates in the previous chapters, we shall identify and discuss some common questions and problems in the chapter below. Since each of these issues pertains to several arguments set forth in the CE controversy, they are particularly relevant to assessing the debate in terms of coherent positions (cf. Chapter 5).

4.1 Weighting of Side-effects

Weighting of side-effects represents a common issue that occurs throughout the CE controversy. The proponents of the controversy do not explicitly address (e.g. tackle through further arguments) the question as to how a series of side-effects, which are partly certain, partly probable, and partly possible, are to be evaluated and weighted against each other. Depending on which weighting is made by the proponents, they will endorse or not endorse the corresponding arguments and objections.

Consequentialist arguments essentially involve a weighting of the side-effects of alternative actions while taking the intended consequences into account. In doing so, the positive and beneficial (certain, probable or merely possible) effects are compared with the negative and harmful (certain, probable or merely possible) ones.

In the CE controversy, one finds two types of argumentation that refer to an action's consequences. To begin with, some of the arguments single out presumably crucial positive or negative consequences on the basis of which they then argue for or against R&D and deployment. Argument A45 TERMINATION PROBLEM, for example, alludes to the lack of an exit option – a single potential harmful effect of CE deployment – to justify T9 CE DEPLOY-

MENT WRONG. Arguments from fairness, to give another example, denounce CE deployment because of the expected distributional effects. Arguments A67, A69, A70, A76, and A96 fall into that group, too. Such arguments, which claim that a single consequence of some action – let us call it I_A – is decisive for the action’s assessment, characteristically consider the further consequences of that action (intended and unintended ones) negligible. All such arguments thus must be based on a premiss saying that:

- There are no moral reasons that outweigh I_A and speak against (or in favour of) the corresponding action.

In effect, that premiss implies a hidden, more or less complex weighting of consequences, which can be challenged and disputed by the proponents of the debate.

The second way of arguing for or against an action in terms of its consequences consists in specifying all relevant effects and weighting them against each other. Such explicit and comprehensive weighting of consequences is found in the central argument of the sub-debate on R&D side-effects (A8 OVERWHELMING NEGATIVE SIDE-EFFECTS). A8 does not simply confine itself to assessing just one single side-effect. Instead, it lists the entire range of harmful side-effects and declares them to outweigh, *in toto*, the whole range of positive effects. Sentence (8.8) represents the decisive premiss of A8. To oppose such a premiss, it suffices, in principle, to point out that some relevant consequences have not been considered at all. However, the more comprehensive and exhaustive the list of positive and negative consequences (for each of the decision options), the more difficult it becomes to criticise such an argument in this way. The evaluation of consequentialist arguments that are based on a (presumably) comprehensive list of consequences is, in fact, tricky. For a proponent who rejects a side-effect-predicting premiss of such an argument does not necessarily disapprove of the weighting carried out and of the inference that is drawn from the weighting. Quite the contrary: She may as well believe the remaining side-effects to provide a sufficient reason for refraining from (carrying out) the corresponding action.

4.2 Ethics of Risk: Possibilistic Predictions and the Precautionary Principle

The CE controversy takes place against the background of massive uncertainties. Not only are the side-effects of R&D and deployment poorly understood, but, what's more, we can't even reliably predict the effectiveness of CE methods. That's why more or less all arguments in the debate concern – in one or another way – the ethics of risk. A central question that arises in this context is how rational decisions can be made at all in spite of massive ignorance. The arguments where that decision-theoretic problem arises are reconstructed, in this study, such that they use variants of the precautionary principle.

So far, the reconstruction of the CE controversy has revealed that uncertainties and imponderabilities of CE deployment are paramount in the debate. As a matter of fact, limits of scientific understanding do not only play a decisive role in the argument cluster on ethics of risk. Ultimately, all arguments that refer to consequences of CE R&D and deployment must take uncertainties into account. The detailed reconstruction of the debate reveals clearly, among other things, that the question as to whether current uncertainties can be reduced is of special significance (cf. A52 IRREDUCIBLE UNCERTAINTIES).

In a decision situation, the characterisation of one's uncertain foreknowledge determines crucially the way in which one may argue in favour of or against a certain choice. If, for example, reliable probability forecasts are available, the expected utility of alternative choices may be calculated and compared. Yet, no one would seriously claim that faithful probability forecasts of the effects of CE R&D and deployment can be made at present. It is due to that fact that this study's reconstruction has been largely based on the assumption that, today, CE measures must be assessed with a view to their *possible* effects. Stakeholders face decisions under uncertainty, or "deep uncertainty" (Knight 1921, Kandlikar et al. 2005). How to make and justify a choice in such a decision situation is, indeed, controversial (Rawls 1975, Harsanyi 1975). Many moral philosophers, following Rawls, have argued in favour of a worst-

case principle, provided certain additional conditions are met (Gardiner 2006, Sunstein 2004, Shue 2010). This rule reads:

If relevant probability forecasts are unavailable and if the worst possible consequences of a decision are actually catastrophic, one should choose the option for action with the comparatively best worst possible consequences. (version of the precautionary principle)

This decision rule, moreover, represents a variant of the *Principle of the Priority of Bad over Good Prognoses* formulated by Hans Jonas (Jonas 2003, p. 70 et seq.). According to Jonas, “it is in particular in matters of a certain magnitude, i.e. matters of apocalyptic potential, that greater weight must be given to the prognosis of doom than to that of bliss” (p. 76, own translation).

The above worst-case principle is explicitly assumed in the reconstructed arguments A23 LESSER-EVIL and A54 IT MIGHT GET WORSE. In addition, many other arguments that could not be reconstructed in detail yet (for example A60, A69, A70, A106) presumably rely on it, as well. It is noteworthy that the worst-case rule figures both in arguments that tend to be in favour of CE as well as in arguments that speak against it. This means that a commitment to risk-averse precautionary thinking alone does not settle the CE controversy.

4.3 The Priority of Mitigation Policies

The priority of mitigation policies (T14) is taken for granted by various arguments, in particular by the moral-hazard objections and the alternative justifications of CE research. Conversely, though, some arguments contradict more or less explicitly the thesis that mitigation policies take, in general, priority. This holds especially for the efficiency and feasibility argumentation, which considers CE methods a favourable substitute for mitigation policies. Most of the arguments of the CE controversy, however, are compatible with the priority of mitigation policies.

As already indicated in Section 3.5.4, various arguments of the CE controversy assume that the avoidance of a dangerous climate

change through drastic CO₂ reduction is generally to be preferred to the deployment of CE technologies, which merely aims at *ex post* compensation of impacts. That thesis, which is supported by arguments A102-A106, enters, in particular, into the below considerations:

- The moral-hazard argument (A9), which is one of the most frequently cited objections to R&D into CE, implicitly assumes that mitigation policies are to be preferred to CE deployment. For otherwise, triggering a reduction of mitigation efforts would not provide a reason against the preparation of (i.e. the research into) CE measures.
- By the same token, argument A67 IMPEDIMENT TO MITIGATION, according to which CE deployment hampers emission reduction, presumes that priority is given to mitigation.
- The priority of mitigation strategies, however, figures also in one of the alternative justifications of R&D into CE, namely in A83 FOSTERING MITIGATION. This argument favours CE R&D for the very reason that it may strengthen mitigation efforts.

Hence, there are both justifications of and objections to CE R&D which rely, more or less explicitly, on the claim that mitigation measures take priority.

Still further arguments are closely related to the justifications of the priority of mitigation. Instead of assuming thesis T14 as a premiss, they – or very similar considerations – actually support T14:

- Arguments A71-A75, which express a fundamental critique of technology and civilization, seem to be based on far-reaching normative assumptions from which the priority of mitigation measures could be deduced as well.
- The direct justifications of the R&D prohibition – A96 RISK TRANSFER ARGUMENT and A98 TRUE MOTIVES – are based on variants of the polluter-pays principle which can also be drawn upon to support thesis T14 (cf. A104).

Next, there are some arguments in the controversy which explicitly contradict thesis T14 MITIGATION FIRST: namely the efficiency and

feasibility argumentation (A39-A41). These arguments consider CE measures a (potential) substitute for mitigation, which possesses diverse advantages (efficiency, feasibility, easiness). Correspondingly, they reject the thesis that mitigation is generally to be preferred.

In summary, some arguments rely on T14, others seem to imply it, and a third group of arguments contradict T14. Nevertheless, the great majority of arguments of the controversy are independent of T14. They can be coherently adopted no matter if one accepts T14 or not. In particular, the main justifications of T2 READINESS FOR DEPLOYMENT DESIRABLE, i.e. the lesser-evil argumentation and the 350 ppm argumentation, don't conflict with T14 – whereas they are not based on it, either. These two justifications remain intact, even if one believes mitigation policies to be generally more appropriate and better than CE deployment.

4.4 The Entanglement of Moral and Extra-moral Arguments

Within the CE controversy, moral and extra-moral considerations seem to be deeply interwoven. This is mainly due to the fact that the moral arguments also make use of descriptive premisses such as forecasts of an action's consequences.

It is evident from the reconstruction of the CE controversy that there is a profound entanglement of moral and extra-moral considerations in more than just one respect.

Firstly, the diverse arguments always make both normative and descriptive assumptions. Accordingly, they can be refuted for two kinds of reasons: factual or normative ones. The arguments from fairness (A60-A64), for instance, claim, on the one hand, that CE deployment would have very different regional effects. That claim constitutes a descriptive premiss which concerns mere matters of fact. On the other hand, the assumed regional differences are claimed to be unjust, which, in turn, represents a normative premiss of the argument. Both, descriptive and normative premisses, are found as well in the deontological arguments, which do not assess

actions on the basis of their respective consequences. The religious arguments (A79, A80), for example, claim that (a) CE deployment falls under a certain type of action (descriptive) and that (b) any action of that type is morally wrong (normative). Finally, to give one last example, the lesser-evil argument (A23), too, relies on both (mainly) descriptive (23.1) and normative premisses (23.2, 23.4, and 23.5). In general, the descriptive premisses give rise to expert debates about specific matters of fact and data. Hence, this is where the moral controversy smoothly connects with scientific controversies in different disciplines.

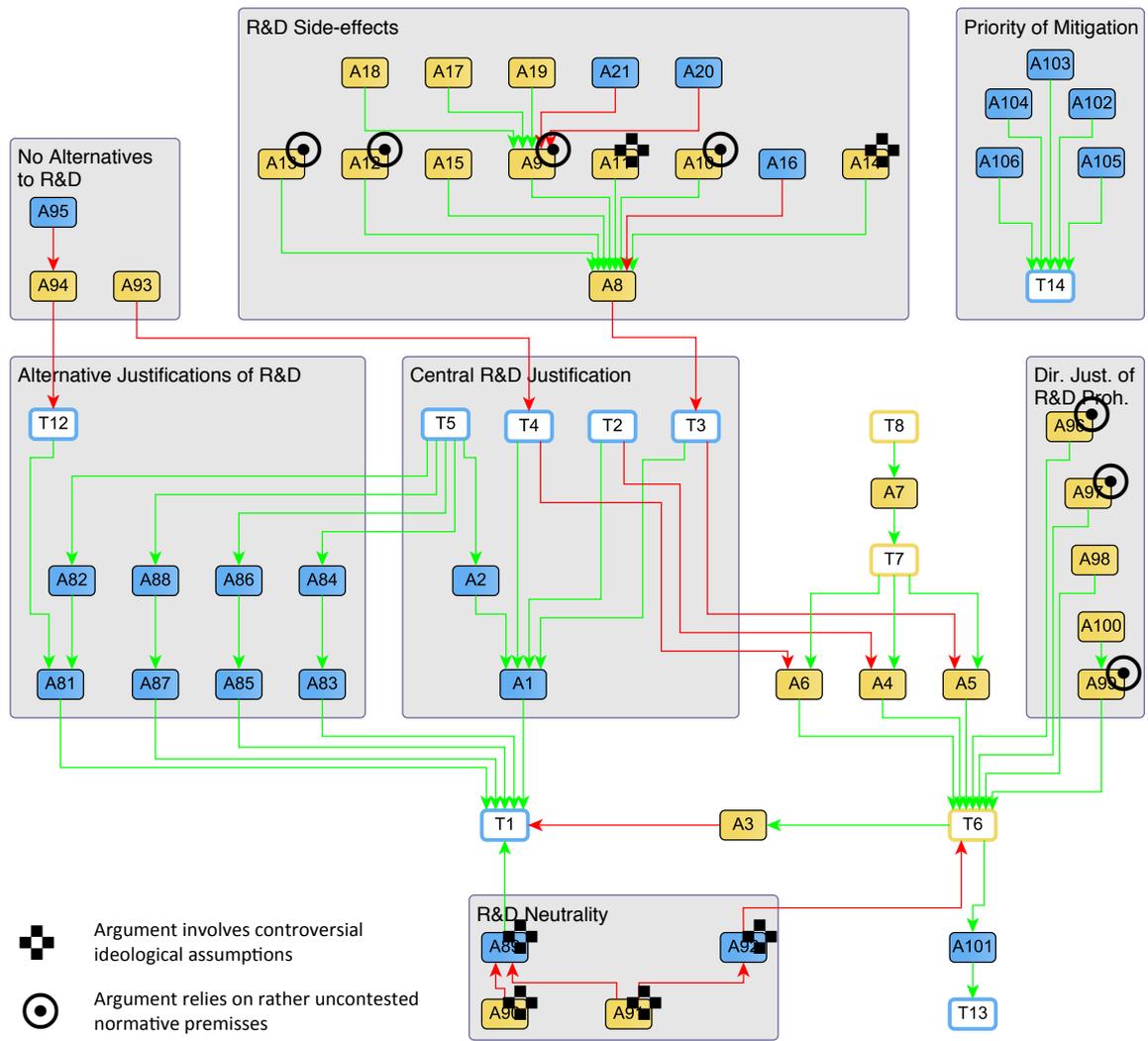
Secondly, the central normative theses are supported by moral arguments as well as legal arguments and arguments based on special interests, or so it seems. There are presumably reasons other than the moral ones that support R&D into CE and that's why moral and extra-moral considerations are entangled in the debate. However, one needs to be careful here. This study's reconstruction solely considers a moral "ought", i.e. refers to moral obligations and prohibitions only. The thesis that there is a moral obligation to research into CE, however, must in no way be confounded with the claim that e.g. legal arguments or economic reasons make research into CE compulsory (cf. also Section 1.2). Strictly speaking, such arguments warrant not one and the same, but refer to different and independent theses. For the sake of clarity, we should add the attribute "moral" – at least mentally – whenever an argument or thesis speaks of "ought", "must" or "may" – of obligations or prohibitions. Moreover, such a conceptual differentiation finally reveals that for some arguments of the CE controversy, there may well be alternative interpretations which do not necessarily imply *moral* obligations or prohibitions. The efficiency argument (A39), for instance, can be re-interpreted as a justification of an economic advice: Economic reason demands that ... And such a claim would be nothing but a hypothetical imperative: If maximisation of economic benefit is the only target we pursue, then we ought to ... Once more: It is essential to bear in mind that such a statement is entirely different from the moral thesis T2. The dual-use argument (A69), too, can be re-interpreted in a non-moral way. Accordingly, it justifies a geopolitical recommendation: If the achievement of peace and international stability is the only target we pursue, then ... Un-

like interpretations that do not invoke any moral concepts, the moral reconstructions are based on important additional premisses through which the intended moral claim can be derived (cf. 4.1). In this sense, the moral reasons that have been reconstructed in this study represent the more sophisticated arguments.

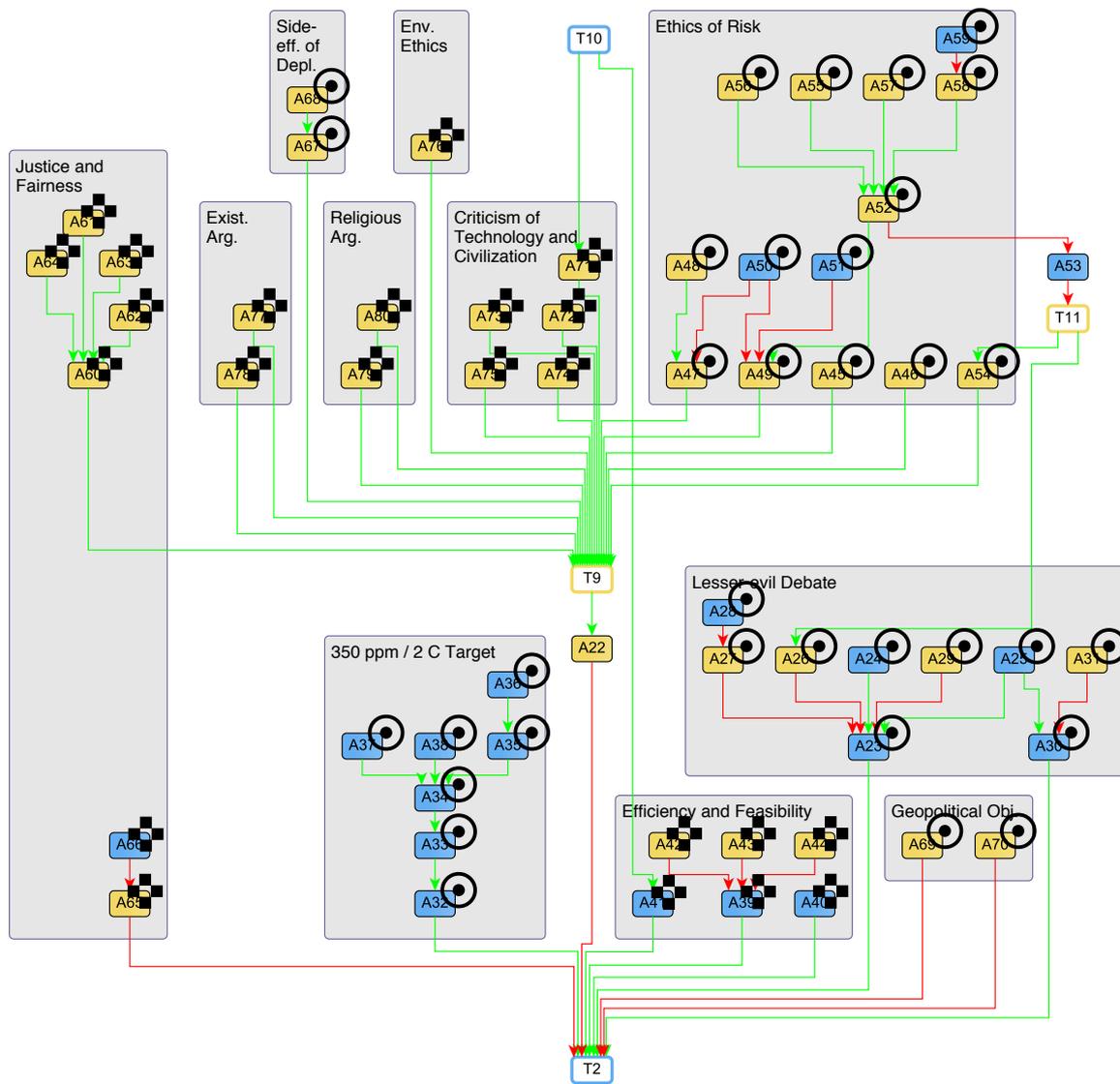
Thirdly, and finally, there is an intricate relationship between legal and governance issues on the one hand and the moral argumentation that has been reconstructed on the other hand. Thus, it depends – among other things – on institutional set-ups whether the factual premisses assumed in the moral arguments turn out to be true or false. Whether, for example, R&D into CE *de facto* results in a reduction of mitigation efforts depends, not least, on the legal conditions under which R&D is being carried out. That's why the reconstructed moral controversy may well provide a touchstone of legal and governance structures: A suitable legal and institutional framework for CE R&D should ideally ensure that the premisses of relevant objections to CE research become false. And legal or political-science analyses may investigate for which institutional provisions this is the case.

4.5 Fundamental Assumptions and Weltanschauung

One may broadly distinguish two types of arguments in the CE controversy: Those which make controversial ideological assumptions, and those which do not rely on strong normative premisses but which involve, at most, contentious descriptive assumptions or basically shared principles whose concrete application is controversial. The first category comprises, in particular, the religious, existentialist, and environmental-ethics arguments, the efficiency and feasibility consideration, the arguments that rely on a critique of technology and civilization, the research neutrality reasoning, the arguments from fairness, and some arguments belonging to the sub-controversy about R&D side-effects.



Argument Map R



Argument Map S

As discussed in the previous section, the arguments of the CE controversy are made up of both descriptive and normative – or, to be more exact, moral – premisses. Two types of arguments can be roughly distinguished according to their specific moral assumptions (cf. argument maps R and S):

1. Arguments that rely on disputed normative assumptions (tied to a specific Weltanschauung) – be it in the form of a general moral rule or in the form of a value theory (axiology) that is used to assess consequences of an action. Such assumptions, for example, may pertain to the just organization of our society or the role of technologies and markets.

2. Arguments that don't rely on strong normative premisses but that possibly make contentious descriptive assumptions or that assume basically shared normative principles whose concrete application, though, might be disputed.

Of course, these two types of arguments cannot in any way be separated neatly. Moreover, the following classification is partly based on the authors' subjective judgment.

The first category of ideological considerations includes: Religious, existentialist, and environmental-ethics arguments (Section 3.3.9), efficiency and feasibility considerations (Section 3.3.3), the critique of technology and civilization (Section 3.3.8), research neutrality arguments (cf. Section 3.4), arguments from justice and fairness (Section 3.3.5), and the arguments "Commercial Control" (A11) and "Political Economy" (A14) from the sub-controversy about R&D side-effects. The authors of this study take it that these arguments and considerations are based on normative premisses on which consensus can hardly be obtained.

The second category of arguments, in contrast, comprises: The lesser-evil argumentation and the 350 ppm argumentation in favour of thesis T2 (cf. Sections 3.3.1 and 3.3.2); the arguments "Mitigation Obstruction" (A9), "Unstoppable Development" (A10), "Field Tests" (A12), and "Techno Escalation" (A13) from the sub-controversy about R&D side-effects; the "Termination Problem" (A45) and other considerations from ethics of risk (cf. Section 3.3.4); the military-geopolitical objections (Section 3.3.7); the assessment of deployment side-effects (section 3.3.6); and the direct justifications of the R&D prohibition, namely the arguments "Risk Transfer" (A96), "No Informed Consent" (A97), and "Dilemma Generation" (A99). While consensus is likely to be achieved on the normative premisses of these arguments, the descriptive assumptions tend to be controversial.

The above classification of arguments, however, by no means implies that arguments classified as (rather) ideological may be neglected or are of little significance: Firstly, the normative premisses of the type-one arguments could still be less controversial than the descriptive premisses of the type-two arguments. And, secondly, it is always conceivable that proponents in a debate, while starting

from different ideological assumptions, will nonetheless agree with regard to the central thesis – albeit for different reasons. The arguments that are based on strong ideological premisses, thus, are not necessarily less significant than other arguments when it comes to assessing the overall controversy.

5 Coherent Positions and their Logico-argumentative Implications

Analysing a complex controversy as an argument map allows to check proponent positions (actually or possibly held) for coherence. A core position, which consists in accepting or rejecting certain arguments and theses, has logico-argumentative implications that go beyond the core position itself because (i) one is bound to accept the logical consequences of the sentences one accepts and (ii) one must reject the direct objections to one's core position. Proponents endorsing R&D into some CE method, thus, are obliged to reject the relevant objections to R&D into CE; proponents rejecting CE R&D have to specify on which points they disagree with the diverse research justifications. It is these very considerations that are relevant when drafting coherent political positions.

For illustrative purposes, the following positions can be checked for coherence: Endorsement of SRM research for reasons of easiness and efficiency; endorsement of R&D into ocean fertilization to detect the associated risks; rejection of SRM R&D on account of basic considerations from democratic theory and fairness; endorsement of CDR development for the purpose of achieving ambitious climate targets in the future.

Argument maps serve to structure controversies and reveal how different considerations are related to each other. In addition, they can be used to check positions, which proponents do or might adopt in a controversy, for coherence. Argument maps, however, do not mark out one single position as being particularly plausible or well-founded. Quite the contrary: There are always various admissible (coherent) points of views between which argumentation analysis (and, hence, ethics) cannot further decide. In this context, to say that a position is not coherent means that it does not

acknowledge the logico-argumentative consequences resulting from its concessions or that it gets tangled up in contradictions.

For scientific policy advice, checking the diverse positions in a debate for coherence may very well represent the most important benefit of argument analysis. Such checking enables political stakeholders to trace whether they have taken into account all relevant considerations with a view to their own position. In particular, argument analysis can be of significant help already in the initial process of setting up a position. At this stage, provisional and partial positions can be pictured and thought through tentatively based on the argument maps. That's what this concluding chapter is all about: It aims to point out how the argument maps of the CE controversy can be used to clarify particular positions. The procedure of checking positions for their coherence is demonstrated by examples, i.e. by mapping out four arbitrary, merely illustrative positions. These positions do not have any special status; in particular, the argument maps don't show these positions to be extremely important, well-founded or anything like that. They have been chosen such that they give at least an idea of the broad spectrum of conceivable coherent positions.

Proponents can assume positions by accepting or rejecting the arguments and theses in a controversy. In that context, acceptance and rejection are defined as follows:

- Acceptance of a thesis =_{def} the thesis is accepted as true;
- Acceptance of an argument =_{def} all premisses as well as the conclusion of the argument are accepted as true;
- Rejection of a thesis =_{def} the thesis is considered to be false;
- Rejection of an argument =_{def} at least one premiss is considered to be false.

It is important to bear in mind that in order to (coherently) reject an argument, it suffices to say which of its premisses one does not accept; it is not necessary to justify why the respective premiss is believed to be false.

To describe a position assumed in the CE controversy, it is not enough, however, to state which arguments and theses of the above-presented reconstruction are being accepted or rejected. This is because, strictly speaking, the arguments are not made up of sen-

tences that can be true or false – the argument maps merely contain argument patterns which employ two types of placeholders (cf. Section 1.3). So, before one can adopt a position by accepting or rejecting arguments and theses, two things have to be done: First, one has to specify which CE technologies one addresses (placeholder “T”) and, second, one has to determine which kind of R&D one considers (placeholder “R”). Consequently, the four exemplary positions are described hereunder by (1.) specifying the CE technology “T” and the type of R&D “R”, (2.) pointing out the core position (acceptance and rejection of theses and arguments), and (3.) explaining the logico-argumentative obligations arising from the core position.

5.1 First Position: SRM is More Efficient than Mitigation

The first illustrative position discusses the technologies of cloud-albedo enhancement (Royal Society 2009, p. 27) and recommends developing them immediately for reasons of efficiency (cf. argument maps T and U). The SRM technology of cloud-albedo enhancement is aimed at increasing oceanic cloud formation by injecting particles into lower atmospheric layers to increase the direct reflection of incident sunlight.

Subject Matter of the Position

- T = Cloud-albedo enhancement
- R = Technology development

In essence, the position justifies immediate R&D into cloud-albedo enhancement by saying that measures of that kind are more efficient than emission reduction (mitigation). Hence, besides the central R&D justification (A1 MAKING CE TECHNOLOGIES READY), also arguments A39 EFFICIENCY ARGUMENT and A41 EASINESS ARGUMENT are accepted.

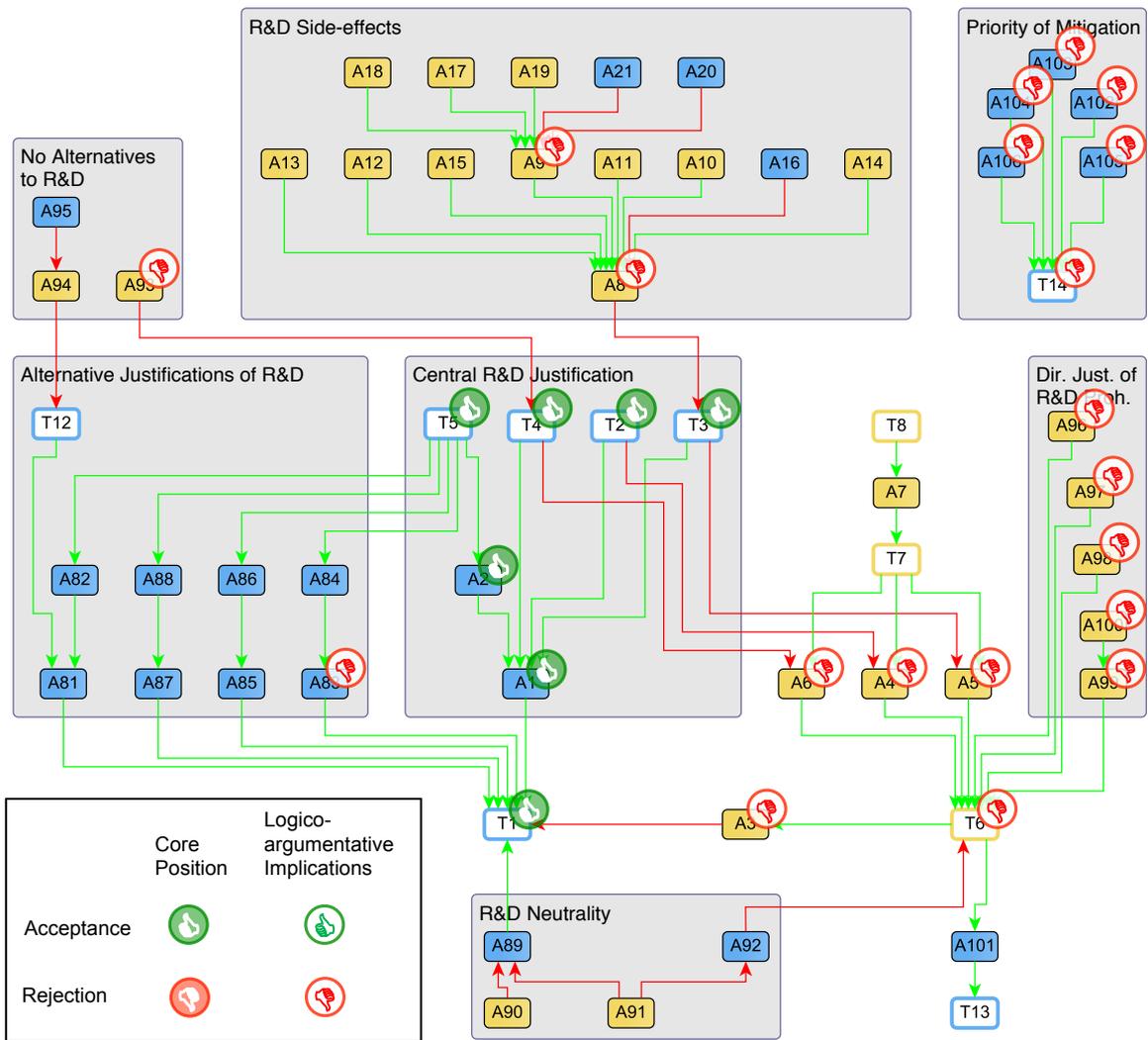
Core Position

- Acceptance: T1-T5, A1, A2, A39, A41
- Rejection: –

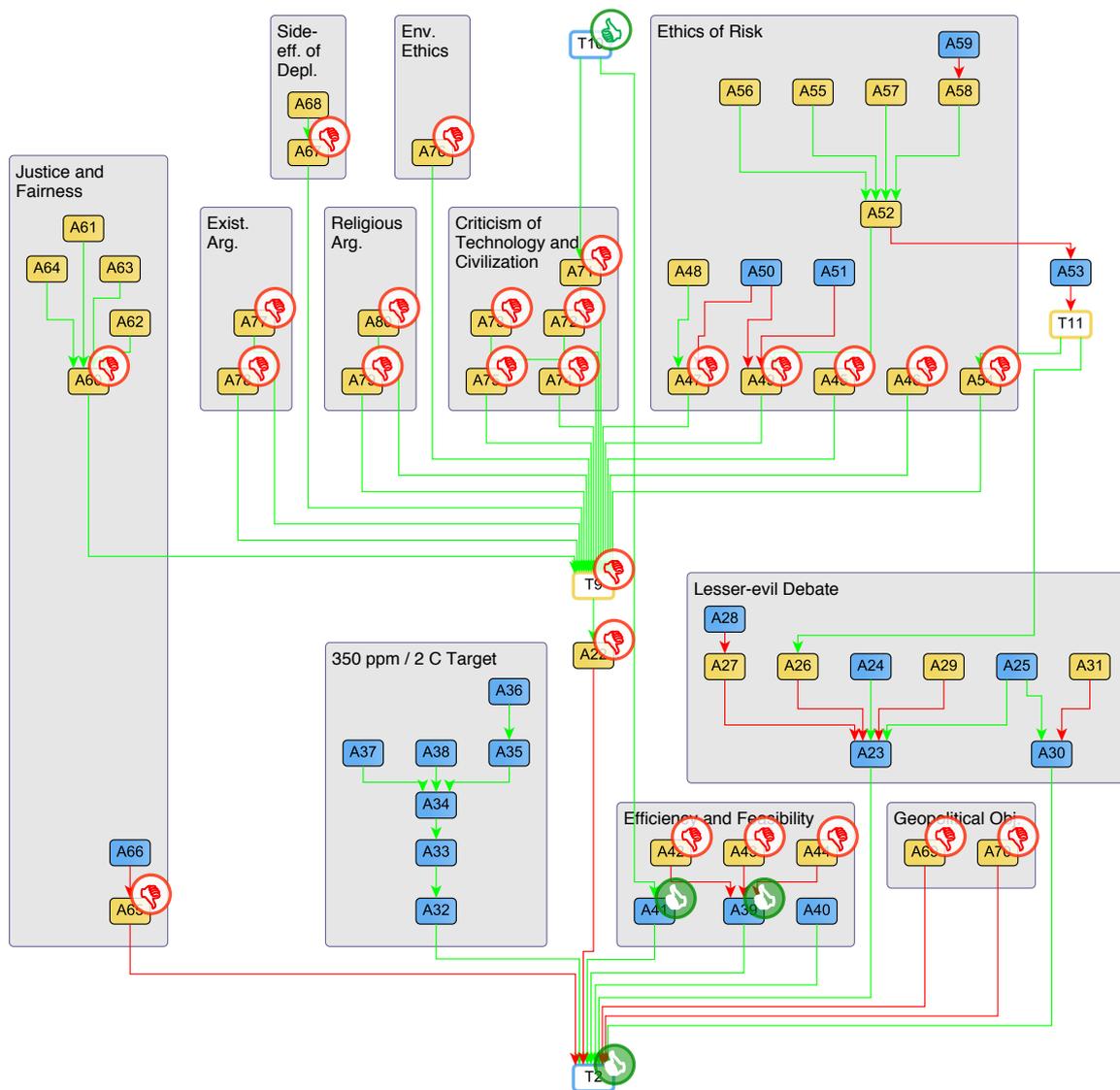
The above core position possesses a number of logico-argumentative implications: Whoever assumes the core position must also accept or reject further arguments and theses for reasons of coherence. Most evidently, the position in question is bound to reject the prohibition of R&D into cloud-albedo enhancement. Hence, any direct justification of such an R&D prohibition must be rejected as well (cf. Section 3.5.2). In addition, the direct objections (A42-A44) to the efficiency argument need to be rejected. Efficiency considerations, moreover, conflict with thesis T14 according to which mitigation ought to be principally preferred to CE deployment (cf. Section 4.3). Accordingly, the above position is bound to reject T14 and all its justifications (A102-A106). Moreover, all arguments that assume the priority of mitigation (see Section 4.3), namely A9, A67, A83, must be discarded. Further consequences arise from accepting T2. Not only does the position have to reject the geopolitical-military objections and argument A65 against T2, but thesis T9 (which holds that deployment of cloud-albedo enhancement is morally wrong) must be denied, too. Consequently, all justifications of T9 are to be rejected. In order to coherently maintain that R&D side-effects are negligible (T3), it is necessary to reject at least argument A8. Either the position under review weights the side-effects of R&D differently (that is negates premiss (8.8)), or it contests that some of the predicted R&D side-effects are actually negative and possible (or probable). The latter has already been accomplished through the rejection of A9. Finally, the core position is required to reject the attack (A93) on T4 (NO ALTERNATIVES TO R&D).

Logico-argumentative Implications

- Acceptance: T10
- Rejection: T6, any direct justification of T6; objections to the efficiency argument A42-A44; T14, each of the arguments A102-A106 as well as A9, A67, and A83; geopolitical-military objections (A69, A70), and A65; T9, any justification of T9; argument A8; objection (A93) to the thesis that there are no alternatives to R&D
- Neutral (selected arguments and theses): Lesser-evil argumentation; R&D neutrality



Argument Map T: First Position



Argument Map U: First Position

5.2 Second Position: Disclosing the Risks of Ocean Fertilization

The second exemplary position favours R&D into ocean fertilization (Royal Society 2009, p. 16) with the objective of disclosing the risks and side-effects of such interventions (cf. argument maps V and W). Ocean fertilization refers to the process of introducing nutrients (mostly iron) into oligotrophic oceans to boost primary production (algae growth, among other things) and to sequester CO₂ from the atmosphere.

Subject Matter of the Position

- T = Ocean fertilization

- R = Risk assessment

In essence, the position justifies R&D by saying that risk research tends to prevent (rather than foster) premature technology deployment (A81 AVOIDING HASTY CE DEPLOYMENT) and supports mitigation efforts (A83 FOSTERING MITIGATION). The deployment of ocean fertilization is considered to be morally wrong.

Core Position

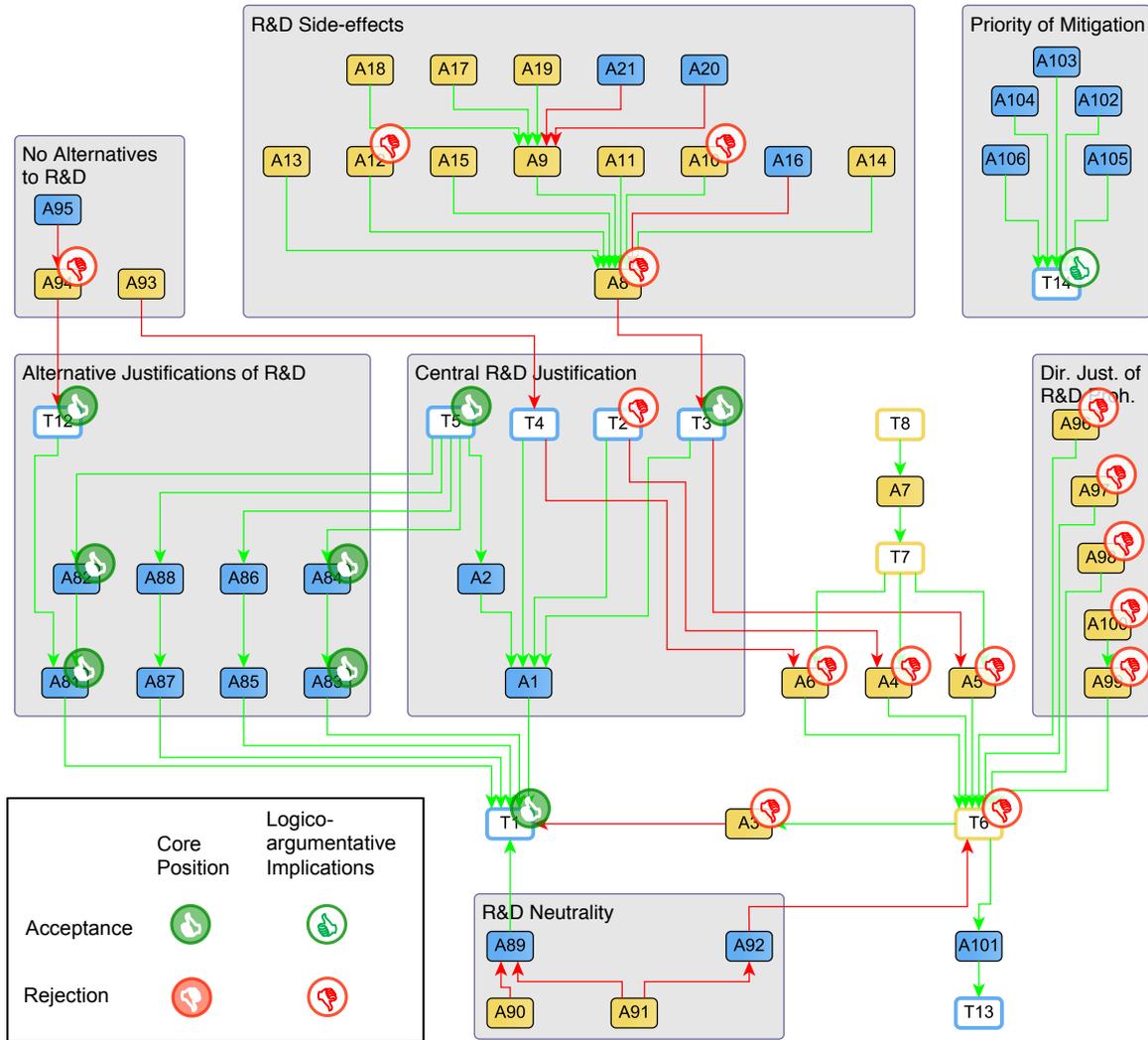
- Acceptance: T1, T5, A81-A84, variants of T3 and T12 (cf. Section 3.4), T9
- Rejection: –

The general prohibition of R&D into the risks of ocean fertilization (T6) must be rejected together with all of its justifications (among other things, thesis T7 and premiss 7.3 of argument A7 can be rejected; the direct justifications of the R&D prohibition, moreover, seem to be aimed at technology development). The acceptance of T9, in addition, implies that T2 must be rejected. Accordingly, all justifications of T2 have to be rejected as well: The lesser-evil argument (A23) could be discarded because, for example, ocean fertilization is not suited as an emergency option anyway (premiss (23.1) is wrong). For the same reason, the sick-patient analogy (A30) appears to be lopsided, too. On top of that, the efficiency and feasibility considerations must be rejected just as the 350 ppm argumentation. Further logico-argumentative implications result from the fact that variants of T3 and T12 are accepted. Thus, the second position, too, is bound to claim that the side-effects of R&D (i.e. the side-effects of R&D into the risks of ocean fertilization) are negligible. Argument A8 could be rejected, for example, by insisting that such specific risk research by no means leads to a reduction of mitigation efforts. In doing so, A9 would be discarded as well. In addition, the position must reject objections to thesis T12: Moratoriums or legally binding agreements, the position is bound to claim, are no suitable alternatives for reaching the respective R&D targets (i.e. enhancement of mitigation, avoidance of hasty deployment).

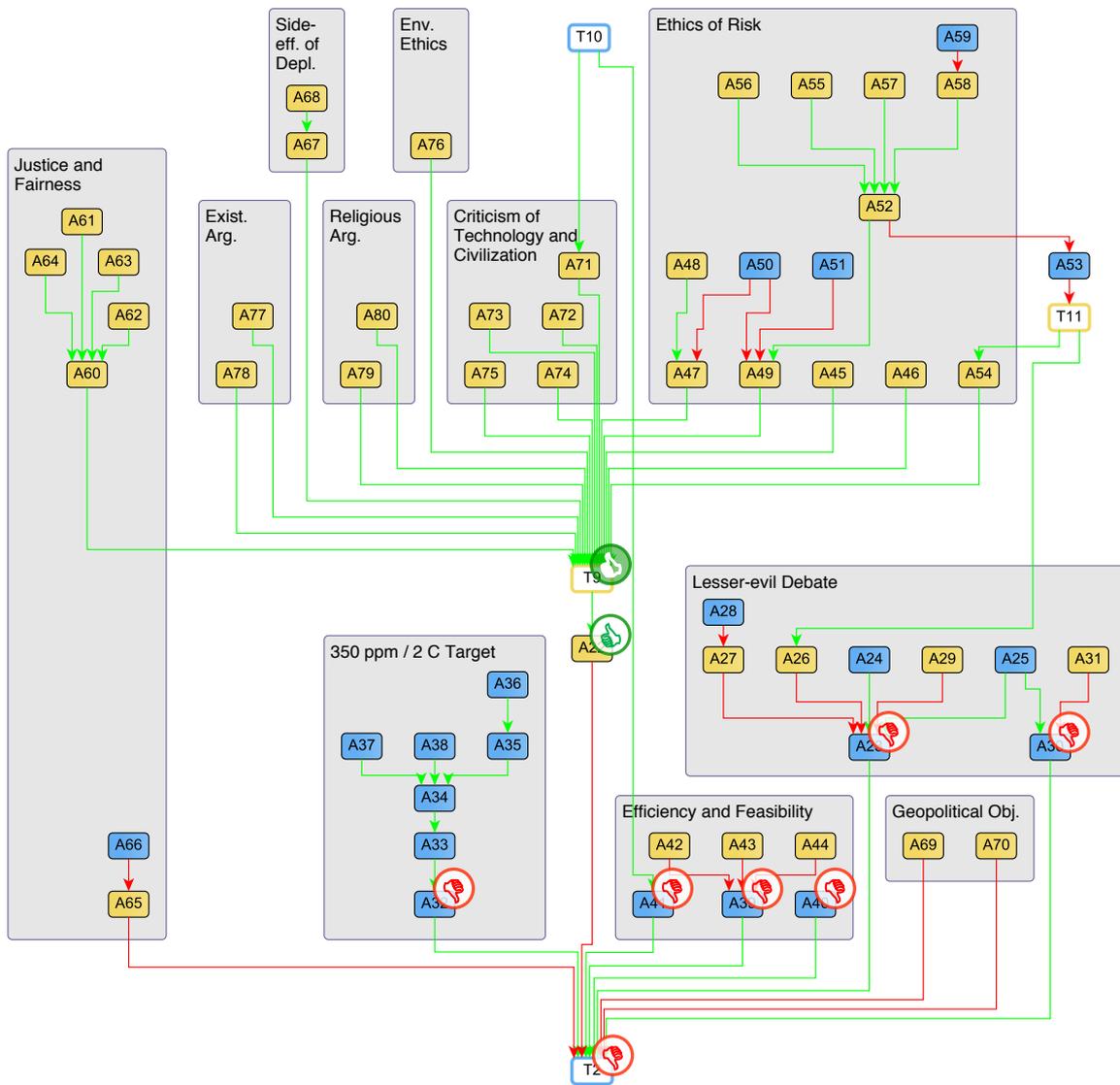
Logico-argumentative Implications

- Acceptance: T14

- Rejection: T6, any justification of T6; T2, any justification of T2; A8, some of the arguments A9-A15 (A10 and A12 in the argument map); objection A94 to variants of T12
- Neutral (selected arguments and theses): Objections to T2, justifications of T9



Argument Map V: Second Position



Argument Map W: Second Position

5.3 Third Position: No SRM Development

The third exemplary position argues against the development of aerosol-based SRM technologies (Royal Society 2009, p. 29) (cf. argument maps X and Y). Such methods are aimed at increasing the share of the reflected and re-emitted solar radiation by stratospheric sulphur aerosol injection.

Subject Matter of the Position

- T = Aerosol-based SRM
- R = Technology development

Essentially, the position subscribes to the prohibition of R&D into SRM technologies (T6) by holding that the respective measures (1.) solely end up transferring risks to future generations (A96 RISK TRANSFER ARGUMENT), and (2.) cannot obtain informed global consent anyway (A97 NO INFORMED CONSENT). The position, moreover, accepts the priority of mitigation policies by agreeing that problems should be solved by those who have caused them (A104 POLLUTER-PAYS PRINCIPLE).

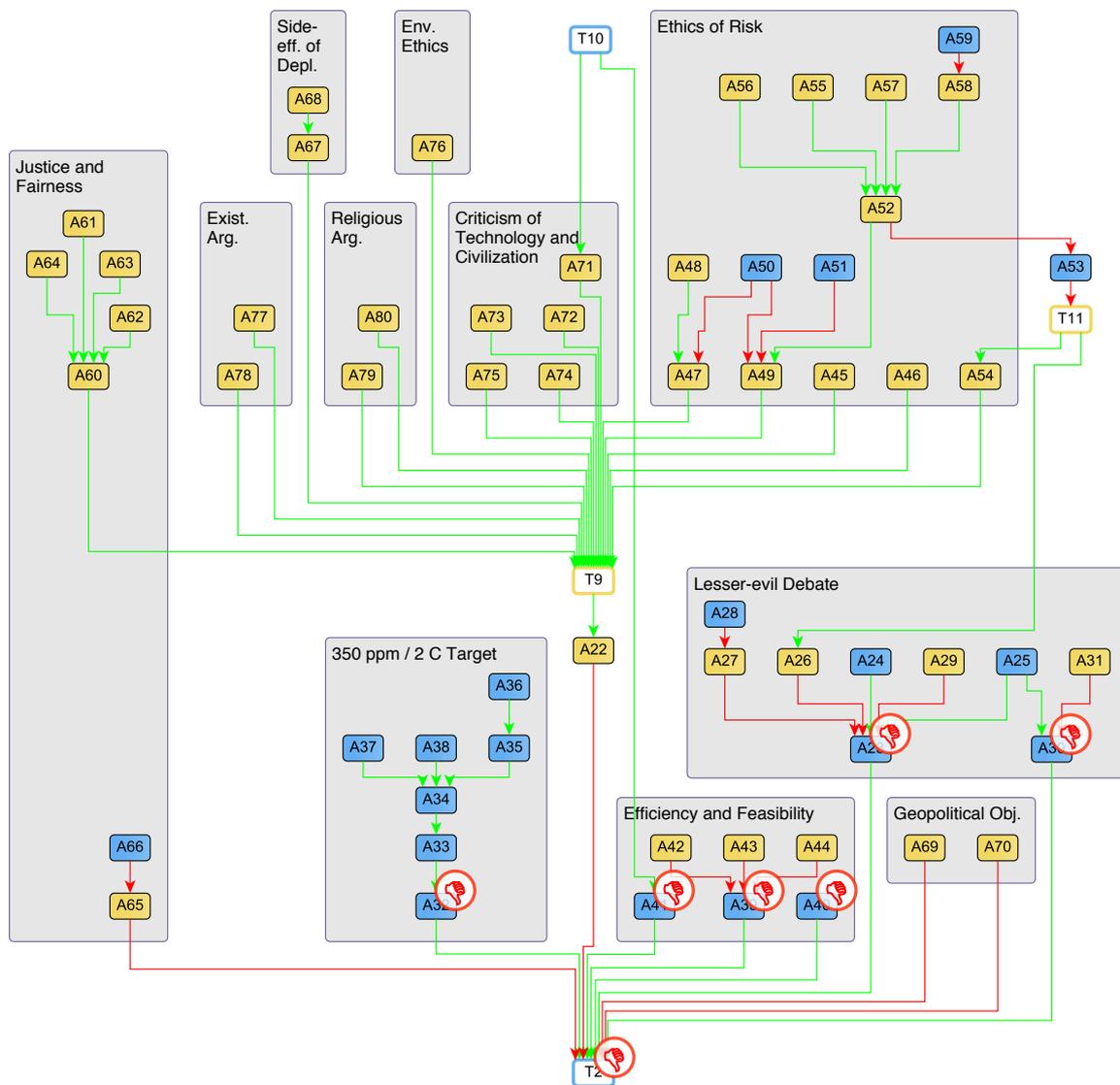
Core Position

- Acceptance: T6, A96, A97, T14, A104
- Rejection: –

For reasons of coherence, anyone who considers the development of aerosol-based SRM technologies wrong is bound to negate the opposite R&D obligation (T1). From this, it evidently follows that all justifications of the R&D obligation must be rejected as well. On the one hand, it is necessary to discard the central consequentialist R&D justification (A1). On the other hand, all of the alternative R&D justifications (A81-A88) must also be rejected. If, as will be assumed below, the position accepts the general principle T5, one of the theses T2-T4 must definitely be discarded. Depending on which of the latter theses is being discarded, one gets confronted with additional logico-argumentative implications: Denial of, for example, T2 implies that each justification of T2 must be rejected (see Section 5.2). The efficiency and feasibility considerations must be refuted at any rate, since they run counter to the priority of mitigation (T14) (see Section 4.3). Concerning the argument cluster “Neutrality of R&D”, arguments A89 and A92 need to be rejected. The third position outlined in this subsection is, however, uncommitted to many of the reconstructed arguments. It is, for instance, *not* bound to accept the objections to theses T2-T4. These objections may be cited to back up the rejection of T2-T4, but they may as well be discarded.

Logico-argumentative Implications

- Acceptance: –
- Rejection: T1, any justification of T1, one of the theses T2-T4, and any justification of the latter (T2 in the argument



Argument Map Y: Third Position

5.4 Fourth Position: Developing Air Capture Technologies

The fourth exemplary position holds that R&D into air capture technologies ought to be carried out (Royal Society 2009, p. 15) in order to attain ambitious climate protection goals such as the 350 ppm target (cf. argument maps Z and AA). Using energy-intensive chemical methods, the technologies referred to capture CO₂ directly from the ambient air, so that it can be stored subsequently.

Subject Matter of the Position

- T = Air capture

- R = Technology development

In essence, the position accepts theses T1-T5, the central, consequentialist justification of the development of air capture methods, and the 350 ppm argumentation (A32-A38).

Core Position

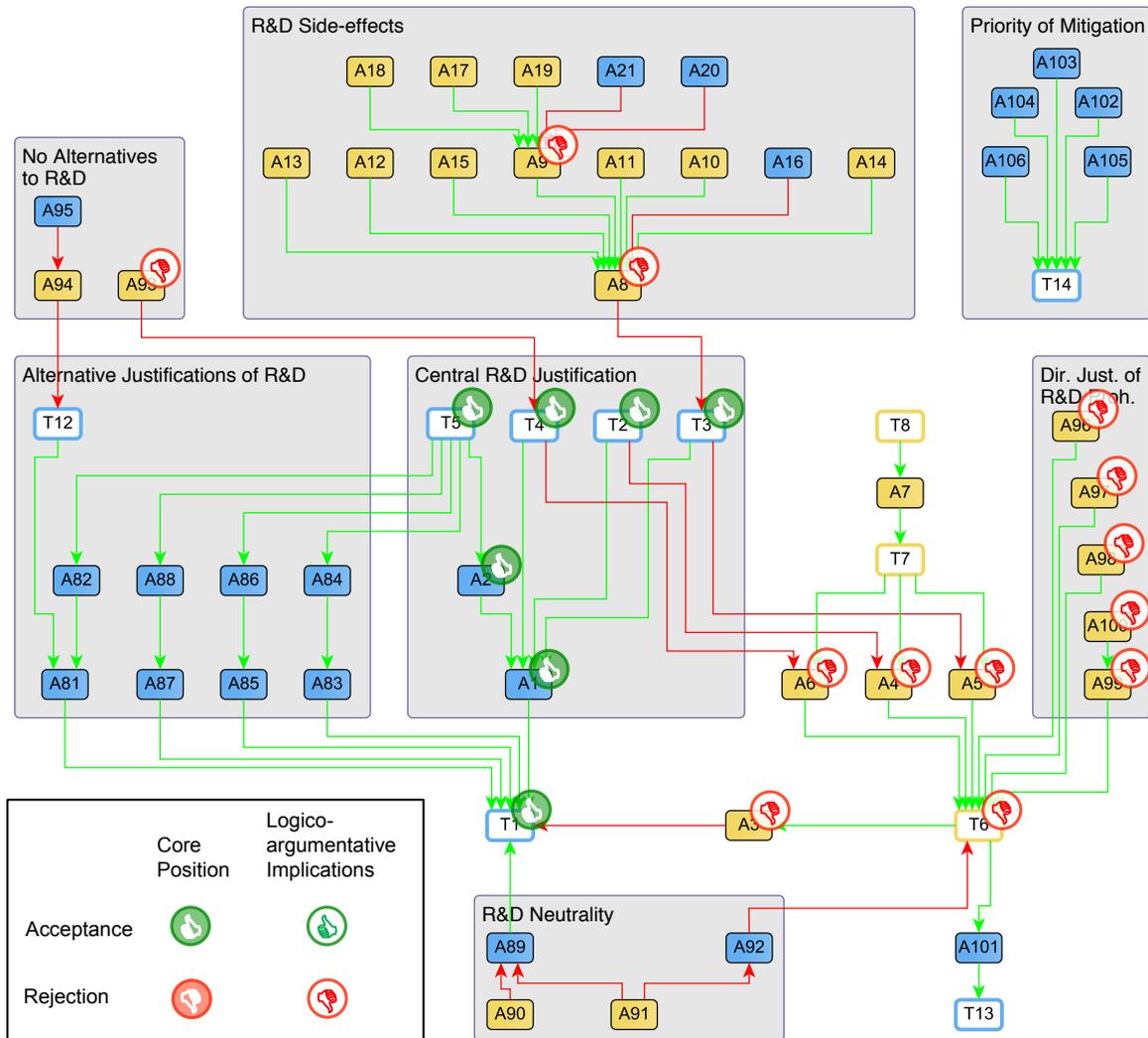
- Acceptance: T1-T5, A1, A2, 350 ppm argumentation
- Rejection: –

Just like the first and second positions, the fourth one, too, is bound to reject the research prohibition thesis (T6) and the direct justifications of a prohibition of air capture development. In this particular case, one might claim that the development of CDR technologies involves much less intergenerational risk transfer than the development of SRM methods (against A96), and that informed consent could be achieved much more easily (against A97). Besides, the position must reject objection A8 to the negligibility of R&D side-effects (T3). It could try to insist, for example, that CDR measures hardly bear any moral-hazard risk and that, hence, argument A9 can be discarded. Next, the direct objections to T2 must be rejected. Some of these objections (A69 and A70) seem to concern SRM only, anyway. The position must also reject thesis T9, according to which it would be morally wrong to deploy air capture methods, and, along with this, any justification of T9. In order to do so, one might claim, once again, that some of the arguments, e.g. the termination problem (A45), solely apply to SRM technologies anyway. But, in addition, several substantial objections (e.g. A67-A68) must be rejected, too. To be able to coherently adhere to T4, the position under review finally needs to reject A93: Since, to be effective in time, air capture technologies have to be deployed as early as possible, postponing R&D, it might be claimed, is no appropriate alternative to starting R&D immediately.

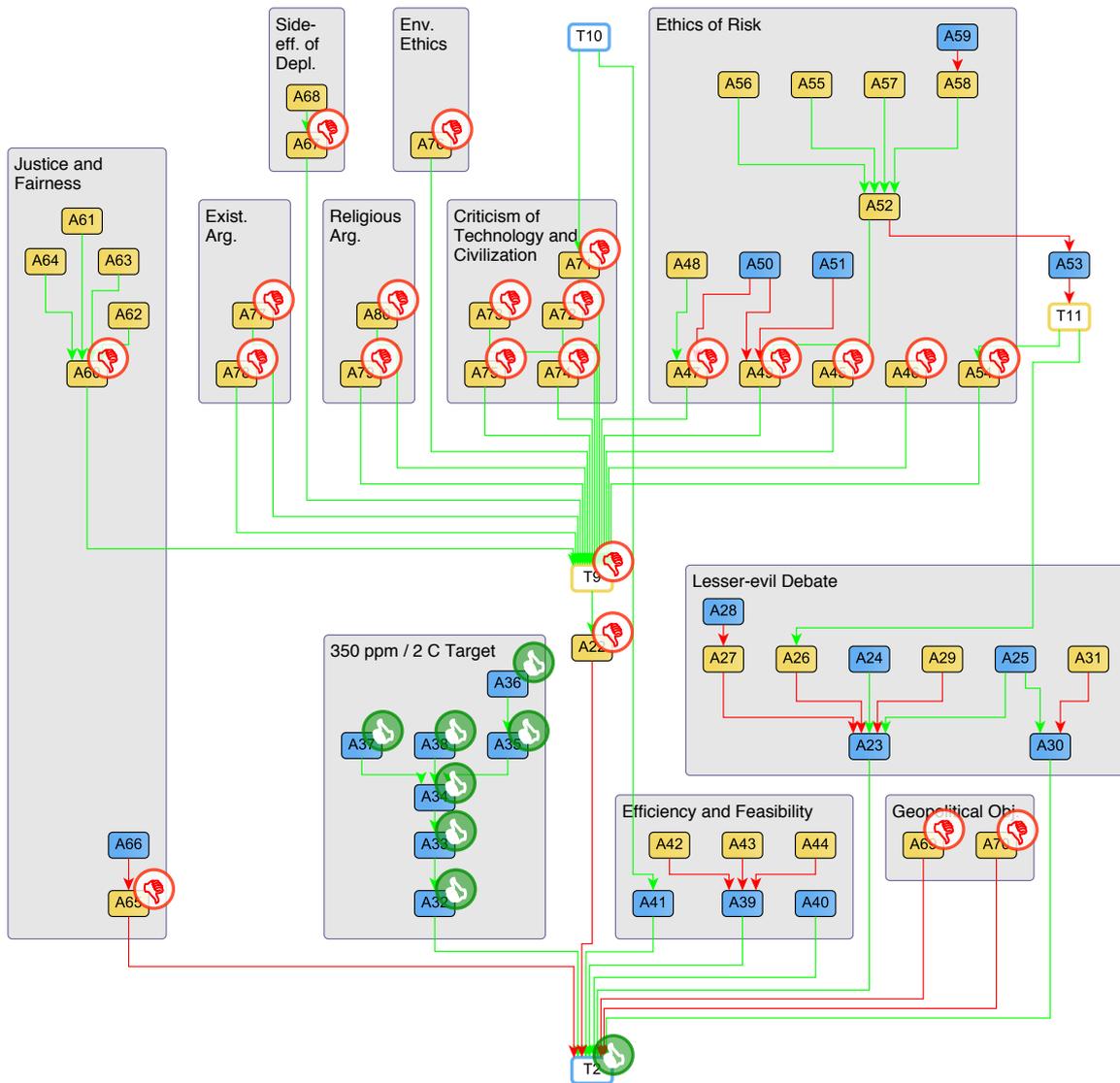
Logico-argumentative Implications

- Acceptance: –
- Rejection: T6, any justification of T6; A8 (e.g. through rejection of A9); direct objections to T2; T9 and any of its justifications; A93

- Neutral (selected arguments and theses): Efficiency and feasibility considerations (A39-A41), lesser-evil argument (A23), alternative justifications of R&D (A81-A88), priority of mitigation (T14)



Argument Map Z: Fourth Position



Argument Map AA: Fourth Position

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Appendix 1

Detailed Reconstructions

List of Theses and Arguments

#	Title		
	<i>Cluster</i>	T13	No National R&D Bans <i>diff.</i>
T1	R&D Obligation <i>diff.</i> ¹	T14	Mitigation First <i>Priority of Mitigation</i>
T2	Readiness for Deployment Desirable <i>Central R&D Justification</i>	A1	Making CE Technologies Ready <i>Central R&D Justification</i>
T3	Side-effects of R&D Neg- ligible <i>Central R&D Justification</i>	A2	Specialisation <i>Central R&D Justification</i>
T4	No Alternatives to R&D (Readiness) <i>Central R&D Justification</i>	A3	Deontic Opposition <i>diff.</i>
T5	Principle of Instrumental Rationality <i>Central R&D Justification</i>	A4	Readiness Not Desirable <i>diff.</i>
T6	R&D Prohibition <i>diff.</i>	A5	Side-effects Unacceptable <i>diff.</i>
T7	Preconditions of Permissi- ble R&D <i>diff.</i>	A6	Better Alternatives <i>diff.</i>
T8	Principle of Instrumental Rationality <i>diff.</i>	A7	Specialisation <i>diff.</i>
T9	CE Deployment Wrong <i>diff.</i>	A8	Overwhelming Negative Side-effects <i>R&D Side-effects</i>
T10	CE Easy <i>diff.</i>	A9	Mitigation Obstruction <i>R&D Side-effects</i>
T11	CE Worsens Climate Im- pacts <i>diff.</i>	A10	Unstoppable Development <i>R&D Side-effects</i>
T12	No Alternatives (Pre- emption) <i>Alternative R&D Justifications</i>	A11	Commercial Control <i>R&D Side-effects</i>
		A12	Field Tests <i>R&D Side-effects</i>
		A13	Techno Escalation <i>R&D Side-effects</i>
		A14	Political Economy <i>R&D Side-effects</i>
		A15	Unilateral Deployment <i>R&D Side-effects</i>

¹ Thesis or argument is related to different argument clusters.

A16	Innovation Argument <i>R&D Side-effects</i>	A35	Catastrophic Sea Level Rise <i>350 ppm / Two-degree Target</i>
A17	Interest Groups <i>R&D Side-effects</i>	A36	Climate History <i>350 ppm / Two-degree Target</i>
A18	CE Hype <i>R&D Side-effects</i>	A37	Mass Extinctions <i>350 ppm / Two-degree Target</i>
A19	Undermining Better Options <i>R&D Side-effects</i>	A38	Worst-case Climate Sensitivity <i>350 ppm / Two-degree Target</i>
A20	Extent Uncertain <i>R&D Side-effects</i>	A39	Efficiency Argument <i>Efficiency and Feasibility Considerations</i>
A21	False Exclusiveness <i>R&D Side-effects</i>	A40	Do-it-alone Argument <i>Efficiency and Feasibility Considerations</i>
A22	No Need <i>diff.</i>	A41	Easiness Argument <i>Efficiency and Feasibility Considerations</i>
A23	Lesser-evil Argument <i>Lesser-evil Debate</i>	A42	Only Partial Offset <i>Efficiency and Feasibility Considerations</i>
A24	CE as Conservation <i>Lesser-evil Debate</i>	A43	Indirect Costs Underestimated <i>Efficiency and Feasibility Considerations</i>
A25	Argument from Survival <i>Lesser-evil Debate</i>	A44	Harming Others <i>Efficiency and Feasibility Considerations</i>
A26	Catastrophic Side-effects <i>Lesser-evil Debate</i>	A45	Termination Problem <i>Ethics of Risk</i>
A27	Intention Makes a Difference <i>Lesser-evil Debate</i>	A46	No Long-term Control <i>Ethics of Risk</i>
A28	Compensation <i>Lesser-evil Debate</i>	A47	No Irreversible Interventions <i>Ethics of Risk</i>
A29	Intentional Harm <i>Lesser-evil Debate</i>	A48	Retaining Options <i>Ethics of Risk</i>
A30	Sick-patient Analogy <i>Lesser-evil Debate</i>	A49	Unseen Side-effects <i>Ethics of Risk</i>
A31	No Absolute Bottom Line <i>Lesser-evil Debate</i>	A50	Mitigation, Too <i>Ethics of Risk</i>
A32	Ready CE Technologies Needed <i>350 ppm / Two-degree Target</i>	A51	Never Perfect Foresight <i>Ethics of Risk</i>
A33	CO ₂ Level Reduction Needed <i>350 ppm / Two-degree Target</i>		
A34	Avoiding Dangerous Climate Change <i>350 ppm / Two-degree Target</i>		

A52	Irreducible Uncertainties <i>Ethics of Risk</i>	A66	Risk of High Climate Sensitivity <i>Arguments from Justice and Fairness</i>
A53	Predictive Progress Possible <i>diff.</i>	A67	Impediment to Mitigation <i>Side-effects of Deployment</i>
A54	It Might Get Worse <i>Ethics of Risk</i>	A68	Amortisation Effect <i>Side-effects of Deployment</i>
A55	Human Error <i>Ethics of Risk</i>	A69	Dual Use <i>Geopolitical Objections</i>
A56	Complexity of Earth System <i>Ethics of Risk</i>	A70	Climate Control Conflicts <i>Geopolitical Objections</i>
A57	Large-scale Field Tests <i>Ethics of Risk</i>	A71	No Rethink <i>Criticism of Technology and Civilization</i>
A58	Socio-political Uncertainties <i>Ethics of Risk</i>	A72	Exploitation <i>Criticism of Technology and Civilization</i>
A59	Short Deployment Conceivable <i>Ethics of Risk</i>	A73	Technical Fix <i>Criticism of Technology and Civilization</i>
A60	Distributional Effects <i>Arguments from Justice and Fairness</i>	A74	Ruling Nature <i>Criticism of Technology and Civilization</i>
A61	Capabilities (Sen/Nussbaum) <i>Arguments from Justice and Fairness</i>	A75	Hubris Argument <i>Criticism of Technology and Civilization</i>
A62	Difference Principle (Rawls) <i>Arguments from Justice and Fairness</i>	A76	Loss of Intangible <i>Environmental Ethics</i>
A63	Egalitarianism <i>Arguments from Justice and Fairness</i>	A77	Elementary Failure <i>Existentialist Arguments</i>
A64	Human Rights (Pogge) <i>Arguments from Justice and Fairness</i>	A78	Conception of Ourselves <i>Existentialist Arguments</i>
A65	Overcoming Global Opposition <i>Arguments from Justice and Fairness</i>	A79	Contempt for the Given <i>Religious Arguments</i>
		A80	Betrayal of the Divine Creation <i>Religious Arguments</i>
		A81	Avoiding Hasty CE Deployment <i>Alternative Justifications of R&D</i>
		A82	Specialisation <i>Alternative Justifications of R&D</i>
		A83	Fostering Mitigation <i>Alternative Justifications of R&D</i>

- A84 Specialisation
Alternative Justifications of R&D
- A85 Planning Long-term R&D Strategy
Alternative Justifications of R&D
- A86 Specialisation
Alternative Justifications of R&D
- A87 Preparing Informed Decision
Alternative Justifications of R&D
- A88 Specialisation
Alternative Justifications of R&D
- A89 R&D First
R&D Neutrality
- A90 R&D No Goal in Itself
R&D Neutrality
- A91 R&D Related to Applications
R&D Neutrality
- A92 Technology Neutral
R&D Neutrality
- A93 Postpone R&D
No Alternatives to R&D
- A94 Moratorium
No Alternatives to R&D
- A95 Clandestine Research
No Alternatives to R&D
- A96 Risk Transfer Argument
Direct Justifications of R&D Prohibition
- A97 No Informed Consent
Direct Justifications of R&D Prohibition
- A98 True Motives
Direct Justifications of R&D Prohibition
- A99 Dilemma Generation
Direct Justifications of R&D Prohibition
- A100 Against Dilemma Generation
Direct Justifications of R&D Prohibition
- A101 Discriminating Prohibitions Unjust
diff.
- A102 Argument from Reversibility
Priority of Mitigation
- A103 Avoiding Dilemmata
Priority of Mitigation
- A104 Polluter-pays Principle
Priority of Mitigation
- A105 No Respect
Priority of Mitigation
- A106 Worst Case
Priority of Mitigation

Theses in Full

T1 R&D OBLIGATION

R&D into the CE technology T under the aspect R ought to be carried out immediately.

T2 READINESS FOR DEPLOYMENT DESIRABLE

The CE technology T should be ready for deployment at a future point in time.

T3 SIDE-EFFECTS OF R&D NEGLIGIBLE

The side-effects of R&D into the CE technology T under the aspect R are negligible as compared to T being [probably] ready for deployment in time.

T4 NO ALTERNATIVES TO R&D (READINESS)

There are no more appropriate alternatives to immediate R&D into the CE technology T under the aspect R which bring about that T is probably ready in time.

T5 PRINCIPLE OF INSTRUMENTAL RATIONALITY

An action A ought to be carried out if the following conditions are met: 1. The objective O ought to be realised; 2. A [probably] brings about realisation of O; 3. There is no alternative action A' that would bring about realisation of O while at the same time being more appropriate than A; 4. The side-effects of A are negligible as compared to O [probably] being realised.

T6 R&D PROHIBITION

R&D into the CE technology T under the aspect R ought not to be carried out (immediately).

T7 PRECONDITIONS OF PERMISSIBLE R&D

R&D into a technology under the aspect R may be carried out only if each of the following conditions is met: 1. There is a chance of achieving readiness for deployment; 2. The direct costs of R&D are reasonable; 3. The readiness for deployment of the technology outweighs, considering the probability that such readiness be actually achieved, the expected certain, probable, and possible side-effects of R&D; 4. It is desirable to have the technology ready for deployment.

T8 PRINCIPLE OF INSTRUMENTAL RATIONALITY

A goal-oriented action A should be carried out only if each of the following conditions is met: 1. There is a chance of achieving the objective targeted by A; 2. The direct effort of action A is reasonable; 3. The objective pursued by the action outweighs, considering the probability that the objective be actually achieved, the expected certain, probable, and possible side-effects; 4. The objective targeted by A is desirable.

T9 CE DEPLOYMENT WRONG

A future deployment of the CE technology T is in any case (morally) wrong.

T10 CE EASY

Implementation of the CE technology is comparatively easy.

T11 CE WORSENS CLIMATE IMPACTS

It is certain that the future deployment of CE technologies might even worsen the most catastrophic anthropogenic climate impacts instead of alleviating them.

T12 NO ALTERNATIVES (PRE-EMPTION)

There are no alternative measures leading to the avoidance of a hasty deployment of the CE technology T while at the same time being more appropriate than immediate R&D into the latter under the aspect R.

T13 NO NATIONAL R&D BANS

The prohibition of R&D into the CE technology T should not be upheld and enforced vis-à-vis, e.g., German or European agents.

T14 MITIGATION FIRST

Mitigation, as a climate policy option, is preferable to CE deployment.

Arguments in Full

A1 MAKING CE TECHNOLOGIES READY

- 1) The CE technology T should be ready for deployment at a future point in time.
 - 2) Immediate R&D into the CE technology T under the aspect R [probably] brings about that T is ready in time.
 - 3) There are no more appropriate alternatives to immediate R&D into the CE technology T under the aspect R which bring about that T is ready in time while at the same time being more appropriate than immediate R&D into the CE technology.
 - 4) The side-effects of R&D into the CE technology T under the aspect R are negligible as compared to T being [probably] ready for deployment in time.
 - 5) R&D into a technology ought to be carried out immediately if the following conditions are met: 1. The technology should be ready for deployment at a future point in time; 2. Immediate R&D [probably] brings about that the technology will be ready for deployment; 3. There are no alternatives which bring about that the technology is ready in time while at the same time being more appropriate than immediate R&D; 4. The side-effects of R&D are negligible as compared to the technology being ready for deployment.
-
- 6) **THUS** (from 1-5): R&D into the CE technology T under the aspect R ought to be carried out.

A2 SPECIALISATION

- 1) An action A ought to be carried out if the following conditions are fulfilled: 1. The objective O ought to be realised; 2. Action A [probably] brings about realisation of O; 3. There is no alternative action A' that would bring about realisation of O and is more appropriate than A at the same time; 4. The side-effects of A are negligible as compared to O [probably] being realised.

- 2) THUS (from 1): R&D into a technology ought to be carried out immediately if the following conditions are met: 1. The technology should be ready for deployment at a future point in time; 2. Immediate R&D [probably] brings about that the technology will be ready for deployment; 3. There are no alternatives which bring about that the technology is ready in time while at the same time being more appropriate than immediate R&D; 4. The side-effects of R&D are negligible as compared to the technology being ready for deployment.

A3 DEONTIC OPPOSITION

- 1) R&D into the CE technology T under the aspect R should not be carried out (immediately).
- 2) A certain measure M ought to be taken only if M is not prohibited.

- 3) THUS (from 1, 2): It is false that R&D into the CE technology T ought to be carried out.

A4 READINESS NOT DESIRABLE

- 1) R&D into a technology under the aspect R may be carried out only if each of the following conditions is met: 1. There is a chance of achieving readiness for deployment; 2. The direct costs of R&D are reasonable; 3. The readiness for deployment of the technology outweighs, considering the probability that such readiness be actually achieved, the expected certain, probable, and possible side-effects of R&D; 4. It is desirable to have available an adequate technology ready for deployment.
- 2) It is not desirable at all to have available at a future point in time a CE technology T that is ready for deployment.

- 3) THUS (from 1, 2): R&D into the CE technology T under the aspect R ought not to be carried out (immediately).

A5 SIDE-EFFECTS UNACCEPTABLE

- 1) R&D into a technology under the aspect R may be carried out only if each of the following conditions is met: 1. There is a chance of achieving readiness for deployment; 2. The direct costs of R&D are reasonable; 3. The readiness for deployment of the technology outweighs, considering the probability that such readiness be actually achieved, the expected certain, probable, and possible side-effects of R&D; 4. It is desirable to have available an adequate technology ready for deployment.
 - 2) The (probable) future readiness for deployment of the CE technology T by no means outweighs the expected certain, probable, and possible side-effects of R&D into T.
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- 3) THUS (from 1, 2): R&D into the CE technology T under the aspect R ought not to be carried out (immediately).

A6 BETTER ALTERNATIVES

- 1) R&D into a technology under the aspect R may be carried out only if each of the following conditions is met: 1. There is a chance of achieving readiness for deployment; 2. The direct costs of R&D are reasonable; 3. The readiness for deployment of the technology outweighs, considering the probability that such readiness be actually achieved, the expected certain, probable, and possible side-effects of R&D; 4. It is desirable to have available an adequate technology ready for deployment.
 - 2) The direct costs of R&D into a CE technology are only reasonable if there are no better alternatives, i.e. if there are no alternatives to R&D into the CE technology T under the aspect R that bring about that T will be ready for deployment in time while being more appropriate than immediate R&D into these technologies at the same time.
 - 3) There are more appropriate alternatives to immediate R&D into the CE technology T under the aspect R which bring about that T is ready in time.
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- 4) THUS (from 1-3): R&D into the CE technology T under the aspect R ought not to be carried out (immediately).

A7 SPECIALISATION

- 1) A goal-oriented action A may be carried out only if each of the following conditions is met: 1. There is a chance of achieving the objective targeted by A; 2. The direct effort of action A is reasonable; 3. The objective pursued by the action outweighs, considering the probability that the objective be actually achieved, the expected certain, probable, and possible side-effects; 4. The objective targeted by A is desirable.
 - 2) R&D into a technology is a goal-oriented action.
 - 3) The goal of R&D into a technology is to establish readiness for its deployment.
-
- 4) THUS (from 1-3): R&D into a technology under the aspect R may be carried out only if each of the following conditions is met: 1. There is a chance of achieving readiness for deployment; 2. The direct costs of R&D are reasonable; 3. The readiness for deployment of the technology outweighs, considering the probability that such readiness be actually achieved, the expected certain, probable, and possible side-effects of R&D; 4. It is desirable to have available an adequate technology ready for deployment.

A8 OVERWHELMING NEGATIVE SIDE-EFFECTS

- 1) One of the possible negative side-effects of R&D into the CE technology T under the aspect R is that any reshaping of and technical intervention into nature may become tolerated.
- 2) One of the possible negative side-effects of R&D into the CE technology T under the aspect R consists in the serious impediment to mitigation.
- 3) One of the possible negative side-effects of R&D into the CE technology T under the aspect R consists in the deployment of T without any central and democratic decision to do so.
- 4) One of the possible negative side-effects of R&D into the CE technology T under the aspect R consists in the development of the CE technology T being controlled by big business instead of by democratic committees.
- 5) One of the possible negative side-effects of R&D into the CE technology T under the aspect R consists in its unilateral deployment.

- 6) One of the probable negative side-effects of R&D into the CE technology T under the aspect R consists in the necessity of carrying out large-scale field tests.
 - 7) One of the probable negative side-effects of R&D into the CE technology T under the aspect R consists in its promoting business branches that are reactionary in terms of climate policies.
 - 8) The possible and probable negative side-effects SE1-SE7 clearly outweigh the sum of all [certain, probable, and possible] useful side-effects and the [probable] intended effect that technology T is ready for deployment.
 - 9) If some of the possible and probable negative effects N outweigh the [probable] intended effect O plus all positive side-effects P, then it is wrong that the side-effects of the relevant measure are, relative to the probable achievement of the objective, negligible.
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- 10) THUS (from 1-9): It is not true that: The side-effects of R&D into the CE technology T under the aspect R are negligible as compared to T being [probably] ready for deployment in time.

A9 MITIGATION OBSTRUCTION

R&D into the CE technology T impairs efforts to avoid climate change. (Keith 2000:276; Gardiner 2010:292; Jamieson 1996:333 et seq.; Robock 2008a,b; ETC 2009:34)

A10 UNSTOPPABLE DEVELOPMENT

Research into CE might create an internal dynamic which inevitably leads to deployment even if deployment is dispensable. Yet, one must be able to halt R&D into risk technologies at any moment. (Jamieson 1996:333 et seq.)

A11 COMMERCIAL CONTROL

CE technologies might ultimately be controlled by big business that acts purely on the basis of commercial interest. This would lead to problems similar to those experienced in the pharmaceutical sector. (Robock 2008a; ETC 2009:29,34)

A12 FIELD TESTS

R&D into the CE technology T under the aspect R inevitably goes along with large-scale field tests which actually lead to deployment of T before T has been thoroughly probed. (Elliott 2010:11; Robock 2010)

A13 TECHNO ESCALATION

R&D into CE may sanction technical interventions into nature on any scale whatsoever. (Keith 2000)

A14 POLITICAL ECONOMY

CE promotes the military-industrial sectors and the business branches that are the most reactionary in terms of climate policy. (Ott 2010a,b,d)

A15 UNILATERAL DEPLOYMENT

R&D into CE might lead to unilateral deployment with catastrophic impacts. (Goodell 2010:195-7)

A16 INNOVATION ARGUMENT

R&D into new technologies such as CE triggers spin-offs and creates jobs.

- 1) As a possible positive side-effect, R&D into the CE technology under the aspect R might lead to the creation of spin-offs and jobs.
- 2) The potential creation of spin-offs and jobs, together with the intended achievement of readiness for deployment, outweighs the possible and probable negative side-effects SE1-SE7.

- 3) THUS (from 1, 2): It is not true that: The possible and probable negative side-effects SE1-SE7 clearly outweigh the sum of all [certain, probable and possible] useful side-effects and the [probable] intended consequence that the technology T is ready for deployment.

A17 INTEREST GROUPS

With larger sums going into CE R&D, lobby groups that tend to be opposed to ambitious mitigation policies will be established and strengthened. (Corner & Pidgeon 2010:30)

A18 CE HYPE

R&D into CE could trigger an outright CE hype. And the discussion of CE alone could undermine the motivation of realising costly mitigation and adaptation policies.

A19 UNDERMINING BETTER OPTIONS

The financial and cognitive resources that are used for R&D into CE are not available for preparing and implementing mitigation policies.

A20 EXTENT UNCERTAIN

The strength and existence of a negative feedback from CE R&D to mitigation are uncertain. (Corner & Pidgeon 2010:31)

A21 FALSE EXCLUSIVENESS

CE and mitigation do not rule each other out. (Keith 2010)

A22 NO NEED

- 1) A future deployment of the CE technology T is in any case (morally) wrong.
- 2) Given that the deployment of a technology is (morally) wrong in any case, it is not desirable to have available any whatsoever ready-for-deployment technology.
- 3) THUS (from 1, 2): It is not desirable at all to have available at a future point in time a CE technology T that is ready for deployment.

A23 LESSER-EVIL ARGUMENT

SRM deployment, as compared to unstoppable climate change, may be the lesser evil.

- 1) At some future point in time t, we may end up in a situation where (a) the worst possible impacts of the deployment of the CE technology T are clearly less severe than the worst possible consequences of not deploying it; where (b) relevant probability forecasts are not at our disposal; and where (c) the worst possible consequences of not deploying CE would in fact be catastrophic.

- 2) If relevant probability forecasts are unavailable and if the worst possible consequences of a decision are actually catastrophic, one should choose the option for action with the comparatively best worst possible consequences. (version of the precautionary principle)

- 3) THUS (from 1, 2): At some future point in time t , we may get into a situation where we should deploy the CE technology T .
- 4) If we may get into a situation where a technology T ought to be deployed, the technology T should be ready for deployment in the future, provided that there are no more significant moral reasons against T being ready for deployment. (precautionary reasoning)
- 5) There are no such more significant moral reasons against the readiness for deployment of the CE technology T .

- 6) THUS (from 3-5): The CE technology T should be ready for deployment at a future point in time.

A24 CE AS CONSERVATION

Deploying CE might be the only remaining possibility of saving certain ecosystems. (Keith in Goodell 2010:39)

A25 ARGUMENT FROM SURVIVAL

Unstoppable climate change might endanger the survival of the entire human species. (Corner & Pidgeon 2010:32)

A26 CATASTROPHIC SIDE-EFFECTS

CE is not the lesser evil. (Gardiner 2010:291)

- 1) It is certain that the future deployment of CE technologies might even worsen the most catastrophic anthropogenic climate impacts instead of alleviating them.
- 2) If an action A might bring about a further aggravation of the worst possible impacts of action B , the worst possible impacts of A cannot possibly be better than those of B .

- 3) THUS (from 1, 2): It is certain that the worst possible impacts of the future deployment of the CE technology T are clearly worse than the worst possible impacts of not deploying CE.

- 4) THUS (from 3): It is NOT possible that at a future point in time t we end up in a situation, where the worst possible impacts of

the deployment of the CE technology T are clearly less severe than the worst possible impacts of not deploying CE.

- 5) THUS (from 4): It is NOT possible that at a future point in time t we end up in a situation, where (a) the worst possible impacts of the deployment of the CE technology T are clearly less severe than the worst possible impacts of not deploying it; where (b) relevant probability forecasts are not at our disposal; and where (c) the worst possible impacts of not deploying CE would in fact be catastrophic.

A27 INTENTION MAKES A DIFFERENCE

Intentional interventions into the climate system are (morally) much worse than unintentional ones. (principle of double effect) (Keith 2000; Elliott 2010:18)

A28 COMPENSATION

In the case of compensation, intentional interventions are not worse.

A29 INTENTIONAL HARM

Deploying CE involves harming some (rather than other) people; this reduces the ethical value of our lives. (Gardiner 2010:304)

A30 SICK-PATIENT ANALOGY

The Earth could become a terminally ill patient whom we prescribe a highly risky, hardly understood therapy for seemingly being doomed to die anyway. (Lovelock in Goodell 2010:106)

- 1) A terminally ill patient ought to be prescribed a highly risky therapy if such therapy is found to be the only treatment option.
- 2) If, in the coming decades, greenhouse gas emissions remain unabated and if the climate sensitivity exceeds 6°C, the Earth, by about 2050, will resemble – in every relevant respect (especially as regards the fact that the situation cannot worsen) – a terminally ill patient for whom the only treatment option consists in a highly risky therapy (i.e., in analogy, in the deployment of a CE technology).
- 3) If two situations are equal in every morally relevant respect, an option for action in one of these situations ought to be taken

whenever the analogous option ought to be taken in the other situation.

- 4) THUS (from 1-3): If, in the coming decades, greenhouse gas emissions should remain unabated and if the climate sensitivity should exceed 6°C, CE technology T ought to be deployed by about 2050.
 - 5) It is possible that, in the coming decades, greenhouse gas emissions will remain unabated and climate sensitivity will exceed 6°C.
 - 6) If it is possible to get into a situation where a technology T ought to be deployed, the technology T should be ready for deployment in the future, provided that there are no more significant moral reasons against T being ready for deployment. (precautionary consideration)
 - 7) There are no such more significant moral reasons against the readiness for deployment of the CE technology T.
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- 8) THUS (from 4-7): The CE technology T should be ready for deployment at a future point in time.

A31 NO ABSOLUTE BOTTOM LINE

In contrast to a terminally ill person, who, at worst, dies, anthropogenic climate impacts, no matter how bad they are, can always become worse.

A32 READY CE TECHNOLOGIES NEEDED

Only with the help of a ready CE technology T can the atmospheric CO₂ level be reduced to 350 ppm. (Hansen 2009; Greene et al. 2010)

A33 CO₂ LEVEL REDUCTION NEEDED

The atmospheric CO₂ level should be reduced to less than 350 ppm within this century.

- 1) CO₂ concentration, which is approximately 380 ppm today (2010), is sure to increase further in the coming decades.
-
- 2) THUS (from 1): CO₂ reduction is required to achieve that concentrations are stabilized at less than 350 ppm.

- 3) During the present century, CO₂ concentration is not expected to decrease unless by means of appropriate technical interventions in the climate system (i.e. the carbon cycle).

- 4) THUS (from 2, 3): CO₂ stabilization at less than 350 ppm requires appropriate technical interventions to reduce concentrations.
- 5) In the course of this century, the atmospheric CO₂ concentration ought to be stabilized at less than 350 ppm.
- 6) If a situation S is to be avoided/achieved and if S can only be avoided/achieved by bringing about M, then M ought to be brought about.

- 7) THUS (from 4-6): It is (imperatively) necessary that the atmospheric CO₂ concentration be reduced through technical interventions in the climate system.

A34 AVOIDING DANGEROUS CLIMATE CHANGE

We ought to avoid dangerous climate change (with a sufficiently high probability).

- 1) We can only avoid dangerous climate change (with a sufficiently high probability) if, in the course of this century, we succeed in stabilizing the atmospheric CO₂ concentration at less than 350 ppm.
- 2) If a situation S is to be avoided/achieved and if S can only be avoided/achieved by bringing about M, then M ought to be brought about.

- 3) THUS (from 1, 2): In the course of this century, the atmospheric CO₂ concentration ought to be stabilized at less than 350 ppm.

A35 CATASTROPHIC SEA LEVEL RISE

- 1) A permanent CO₂ concentration above 350 ppm threatens to cause disintegration of the continental ice sheets.
- 2) Disintegration of the continental ice sheets would cause a continuous sea level rise on the order of several metres per century for the coming centuries.
- 3) A continuous sea level rise of several metres per century would definitely destroy the coastal towns. (It is not possible to adapt to such sea level rises.)

- 4) A change of the climate system that leads to the destruction of coastal towns is a dangerous climate change.

- 5) THUS (from 1-4): A permanent CO₂ concentration above 350 ppm threatens to cause a dangerous climate change.

- 6) THUS (from 5): We can only avoid dangerous climate change (with a sufficiently high probability) if, in the course of this century, we succeed in stabilizing the atmospheric CO₂ concentration at less than 350 ppm.

A36 CLIMATE HISTORY

Palaeo-climatic data testify that continental ice sheets might disintegrate at slightly higher global temperatures than today.

A37 MASS EXTINCTIONS

- 1) Global warming of even 2°C would shift and move the Earth's climate zones.
- 2) A majority of the species would not be able to adapt to a shift and move of the climate zones within this century and would thus lose their natural habitat.
- 3) Species losing their natural habitat will become extinct.
- 4) A change of the climate system that leads to the extinction of a majority of the species is a dangerous climate change.

- 5) THUS (from 1-4): Global warming of 2°C represents a dangerous climate change.
- 6) We can only avoid global warming of 2°C (with a sufficiently high probability) if, in the course of this century, we succeed in stabilizing the atmospheric CO₂ concentration at less than 350ppm.

- 7) THUS (from 5, 6): We can only avoid dangerous climate change (with a sufficiently high probability) if, in the course of this century, we succeed in stabilizing the atmospheric CO₂ concentration at less than 350 ppm.

A38 WORST-CASE CLIMATE SENSITIVITY

- 1) Climate sensitivity may well exceed 4 K, without us being able to reliably estimate the probability thereof.
- 2) If climate sensitivity may well exceed 4 K, without us being able to reliably estimate the probability thereof, global warming

of significantly more than 2°C can only be avoided (with a sufficiently high probability) if the radiation budget of the Earth is being balanced without delay.

3) Global warming of significantly more than 2°C would represent a dangerous climate change.

4) THUS (from 1-3): We can only avoid dangerous climate change (with a sufficiently high probability) if we succeed in balancing the radiation budget of the Earth without delay.

5) To balance the radiation budget of the Earth without delay, the CO₂ concentration needs to be stabilized at less than 350 ppm in the course of this century.

6) THUS (from 4, 5): We can only avoid dangerous climate change (with a sufficiently high probability) if, in the course of this century, we succeed in stabilizing the atmospheric CO₂ concentration at less than 350 ppm.

A39 EFFICIENCY ARGUMENT

The direct and indirect costs of CE deployment are clearly below those of mitigation and adaptation. (Ott 2010a,b,d; Gardiner 2010:287; Elliott 2010:20; Wood in Goodell 2010:129)

A40 DO-IT-ALONE ARGUMENT

If necessary, CE technologies can be deployed by a small group of determined nations to the benefit of the entire world. (Ott 2010a,b,d)

A41 EASINESS ARGUMENT

CE allows avoiding dangerous climate change without changing life styles, habits, and the current mode of our economy. (Ott 2010a,b,d)

A42 ONLY PARTIAL OFFSET

The CE method T often neutralises only a fraction of all anthropogenic climate impacts; e.g. not ocean acidification. In principle, its benefits are obviously smaller than those of mitigation. (Gardiner 2010:288; Robock 2008a,b; ETC 2009:19)

A43 INDIRECT COSTS UNDERESTIMATED

The CE method T is anything but cheap, if one considers all indirect costs that arise due to unintended side-effects (Gardiner 2010:288)

A44 HARMING OTHERS

We do not compensate for harming others by merely providing them with technologies which might be used to moderate the harm we have caused. (Gardiner 2010:293)

A45 TERMINATION PROBLEM

CE measures do not possess viable exit options. If deployment is terminated abruptly, rapid and catastrophic climate change ensues. (Ott 2010a,b,d; Robock 2008a,b)

A46 NO LONG-TERM CONTROL

Our social systems and institutions are possibly not capable of controlling risk technologies on long time scales and of ensuring that they are handled with proper technical care. (Corner & Pidgeon 2010:31)

A47 NO IRREVERSIBLE INTERVENTIONS

CE represents an irreversible intervention.

A48 RETAINING OPTIONS

Irreversible interventions narrow the options of future generations in an unacceptable way. (Jamieson 1996:330 et seq.)

A49 UNSEEN SIDE-EFFECTS

As long as the side-effects of CE technologies cannot be reliably predicted, their deployment is morally wrong. (Jamieson 1996:326 et seq.; ETC 2009:34)

- 1) It is not true that: Further R&D into the CE technology T may (a) ensure its effectiveness and (b) exclude catastrophic side-effects of its deployment.
- 2) If further R&D into the CE technology T cannot exclude catastrophic side-effects of its deployment for sure, then side-effects of deployment cannot be predicted reliably at any future point in time.

- 3) As long as the side-effects of a risk technology cannot be reliably predicted, its deployment is morally wrong.
- 4) The CE technology T is a risk technology.
- 5) THUS (from 1-4): The future deployment of the CE technology T is in any case (morally) wrong.

A50 MITIGATION, TOO

Mitigation, too, is at least to some extent an irreversible intervention with unseen side-effects. (Corner & Pidgeon 2010:28)

A51 NEVER PERFECT FORESIGHT

We do never completely foresee the consequences of our actions. (Goodell 2010:135)

A52 IRREDUCIBLE UNCERTAINTIES

There are major irreducible uncertainties regarding the effectiveness and side-effects of CE deployment. (Keith 2000:277; Robock 2008a; Bunzl 2009)

- 1) There are major irreducible uncertainties regarding the effectiveness and side-effects of CE deployment.
- 2) Irreducible uncertainties cannot be reduced through further R&D.
- 3) If uncertainties regarding the effectiveness and side-effects cannot be reduced, neither can effectiveness be guaranteed nor can catastrophic side-effects be excluded.
- 4) THUS (from 1-3): It is not true that: Further R&D into the CE technology T may (a) ensure its effectiveness and (b) exclude catastrophic side-effects of its deployment.

A53 PREDICTIVE PROGRESS POSSIBLE

Scientific research might advance our understanding so that we will be in a position, when actually deploying CE, to robustly rule out the worst case that CE aggravates climate impacts.

- 1) Further R&D into the CE technology T may (a) ensure its effectiveness and (b) exclude catastrophic side-effects of its deployment.
- 2) If CE effectiveness was ensured and catastrophic side-effects of its deployment could be excluded, the deployment of CE tech-

nologies could not further aggravate the worst possible anthropogenic climate impacts.

3) THUS (from 1, 2): It is possible that the future deployment of the CE technology T cannot further aggravate the worst possible anthropogenic climate impacts.

4) THUS (from 3): It is NOT certain that the future deployment of CE technologies might aggravate the worst possible anthropogenic climate impacts instead of mitigating them.

A54 IT MIGHT GET WORSE

In the worst case (which is the decisive one), CE aggravates catastrophic climate impacts.

1) It is certain that the future deployment of CE technologies might even worsen the most catastrophic anthropogenic climate impacts instead of alleviating them.

2) There are no relevant probability forecasts available regarding the impacts of a future deployment of CE technologies.

3) If relevant probability forecasts are unavailable and if the worst possible consequences of a decision are actually catastrophic, one should choose the option for action with the comparatively best worst possible consequences. (version of the precautionary principle)

4) THUS (from 1-3): The CE technology T should not be deployed in the future.

5) THUS (from 4): A future deployment of the CE technology T is in any case (morally) wrong.

A55 HUMAN ERROR

Complex technical interventions which are sustained on longer time scales are susceptible to human error and are hence unpredictable. (Robock 2008a; ETC 2009:34)

A56 COMPLEXITY OF EARTH SYSTEM

As a consequence of the earth system's complexity, we will never be in a position to grasp, let alone quantify, all side-effects of large-scale interventions. (Grunwald 2010; ETC 2009:34)

A57 LARGE-SCALE FIELD TESTS

Only large-scale field tests, which effectively amount to full-fledged deployment, can robustly demonstrate the effectiveness and reliability of CE methods. Hence, we will know whether CE works only once we have deployed it. (Robock 2010)

A58 SOCIO-POLITICAL UNCERTAINTIES

The effectiveness and reliability of CE presuppose a stable institutional framework over several decades. Such boundary conditions are unpredictable.

A59 SHORT DEPLOYMENT CONCEIVABLE

In case mitigation efforts are carried out and highly effective CDR methods are available, SRM might be deployed for no longer than a decade. (Wigley in Goodell 2010:133)

A60 DISTRIBUTIONAL EFFECTS

The uneven distributions of regional climate offsets (benefit), costs, and negative side-effects that go along with a CE deployment are deeply unjust. (Keith 2000:276; Robock 2008a; ETC 2009:34)

A61 CAPABILITIES (SEN/NUSSBAUM)

CE deployment will bring about that less people possess elementary capabilities to lead a successful, good, flourishing human life. (Sen/Nussbaum 1993)

A62 DIFFERENCE PRINCIPLE (RAWLS)

CE deployment will even aggravate the situation of those who are globally already worst off. (Rawls 1975)

A63 EGALITARIANISM

CE deployment widens the existing global socio-economic inequalities instead of reducing them.

A64 HUMAN RIGHTS (POGGE)

CE deployment alters the global institutional and economic conditions such that human rights will be realised to a lesser degree. (Pogge 2002)

A65 OVERCOMING GLOBAL OPPOSITION

Getting global legitimisation (in terms of factual consent and acceptance) for CE deployment is no less difficult than winning broad support for mitigation; if the former could be achieved, global mitigation efforts would not be blocked anymore and the prime reason for CE would fade away. (Gardiner 2010:294)

A66 RISK OF HIGH CLIMATE SENSITIVITY

Even with ambitious mitigation policies, we might fail to achieve the two-degree target such that CE deployment is the lesser of two evils. (Keith 2010)

A67 IMPEDIMENT TO MITIGATION

The deployment of CE makes it highly unlikely that far-reaching mitigation policies are implemented and sustained.

A68 AMORTIZATION EFFECT

Significant investments, required by capital-intensive CE technologies upfront, will amortize only in case the technology is deployed for a sufficiently long period of time. This requires not reducing CO₂ emissions too much.

A69 DUAL USE

The CE technology T may potentially serve as (the basis for) weapons of mass destruction. (Keith 2000:275; Corner & Pidgeon 2010:30; Goodell 2010:210-2; Robock 2008a; ETC 2009:34)

A70 CLIMATE CONTROL CONFLICTS

CE puts future generations in a position to control the climate. This ability generates new conflicts and might even bring about climate wars. (Hulme 2010:351; Robock 2008a)

A71 NO RETHINK

The deployment of CE prevents and postpones the urgently needed rethinking in our societies and the inevitable reforms of our economies. (Corner & Pidgeon 2010:32)

A72 EXPLOITATION

CE is just a cover for our ongoing exploitation of other people, generations, and species. (Gardiner 2010:304)

A73 TECHNICAL FIX

CE is a “technical fix”, tinkering with symptoms instead of resolving the causes. As such, it is fundamentally flawed. (Keith 2000; Gardiner 2010:303; ETC 2009:5)

A74 RULING NATURE

CE methods are but another means for ruling nature and point into a fundamentally wrong direction. (Gardiner 2010:288)

A75 HUBRIS ARGUMENT

CE belongs to a tradition of large-scale interventions which have ignored the boundaries of technical manipulation. It testifies to arrogance and a form of self-deceit that will heavily backfire. (Ott 2010a,b,c,d; Gardiner 2010:303; Jamieson 1996:332)

A76 LOSS OF INTANGIBLE

The deployment of CE triggers a loss of wilderness, originality, and intangibility on unprecedented scales. (Ott 2010a,b,d; Keith 2000:277 et seq.; Robock 2008a)

A77 ELEMENTARY FAILURE

CE testifies that mankind has failed to meet an elementary challenge: To live and to survive on this planet as we have found it. (Gardiner 2010:304; Jamieson 1996:332)

A78 CONCEPTION OF OURSELVES

CE risks undermining our conception of ourselves as moral beings: What does the decision to implement CE or research into it tell about us? What are the humans like that make such decisions? Which are the virtues that may guide their actions? (Gardiner 2010:303)

A79 CONTEMPT FOR THE GIVEN

By deploying the CE technology T, we would not perceive and respect nature as what is given to humans; rather, nature would become something we create intentionally by way of technical reproduction. (According to Zimmerli et al. 1997, III.1)

A80 BETRAYAL OF THE DEVINE CREATION

By deploying the CE technology T, man subjects the Earth without restraint to his will and betrays its prior God-given purpose. (According to Pope John Paul II, Centesimus annus, IV, 37; WCC 1998)

A81 AVOIDING HASTY CE DEPLOYMENT

- 1) Hasty deployment of the CE technology T should be avoided.
 - 2) Immediate R&D under the aspect R [probably] brings about that hasty deployment of the CE technology T is avoided.
 - 3) There are no alternative measures which bring about that hasty deployment of the CE technology T is avoided while at the same time being more appropriate than immediate R&D into CE under the aspect R.
 - 4) The side-effects of R&D into the CE technology T under the aspect R are negligible as compared to [probably] avoiding its hasty deployment.
 - 5) R&D into a technology ought to be carried out immediately if the following conditions are met: 1. Hasty deployment of the technology should be avoided; 2. Immediate R&D [probably] brings about that hasty deployment of the CE technology T is avoided; 3. There are no alternative measures which bring about that hasty deployment of the technology is avoided while at the same time being more appropriate than immediate R&D; 4. The side-effects of R&D are negligible as compared to [probably] avoiding hasty deployment of the technology.
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- 6) **THUS** (from 1-5): R&D into the CE technology T under the aspect R ought to be carried out.

A82 SPECIALISATION

- 1) An action A ought to be carried out if the following conditions are met: 1. The objective O ought to be realised; 2. A [probably]

brings about realisation of O; 3. There is no alternative action A' that would bring about realisation of O while at the same time being more appropriate than A; 4. The side-effects of A are negligible as compared to O [probably] being realised.

- 2) THUS (from 1): R&D into a technology ought to be carried out immediately if the following conditions are met: 1. Hasty deployment of the technology should be avoided; 2. Immediate R&D [probably] brings about that hasty deployment of the CE technology T is avoided; 3. There are no alternative measures which bring about that hasty deployment of the technology is avoided while at the same time being more appropriate than immediate R&D; 4. The side-effects of R&D are negligible as compared to [probably] avoiding hasty deployment of the technology.

A83 FOSTERING MITIGATION

By highlighting limits of CE, R&D will underline the importance of mitigation and avoid that CE is still implicitly relied on. (Keith 2010; Lovelock in Goodell 2010:107)

- 1) Mitigation should be fostered.
 - 2) Immediate R&D into the CE technology T under the aspect R [probably] brings about fostering of mitigation.
 - 3) There are no alternative measures which bring about fostering of mitigation while at the same time being more appropriate than immediate R&D into CE under the aspect R.
 - 4) The side-effects of R&D into the CE technology T under the aspect R are negligible as compared to [probably] fostering mitigation.
 - 5) R&D into a technology ought to be carried out immediately if the following conditions are met: 1. Mitigation should be fostered; 2. Immediate R&D [probably] brings about fostering of mitigation; 3. There are no alternative measures which bring about fostering of mitigation while at the same time being more appropriate than immediate R&D; 4. The side-effects of R&D are negligible as compared to [probably] fostering mitigation.
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- 6) THUS (from 1-5): R&D into the CE technology T under the aspect R ought to be carried out.

A84 SPECIALISATION

- 1) An action A ought to be carried out if the following conditions are met: 1. The objective O ought to be realised; 2. A [probably] brings about realisation of O; 3. There is no alternative action A' that would bring about realisation of O while at the same time being more appropriate than A; 4. The side-effects of A are negligible as compared to O [probably] being realised.
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- 2) THUS (from 1): R&D into a technology ought to be carried out immediately if the following conditions are met: 1. Mitigation should be fostered; 2. Immediate R&D [probably] brings about fostering of mitigation; 3. There are no alternative measures which bring about fostering of mitigation while at the same time being more appropriate than immediate R&D; 4. The side-effects of R&D are negligible as compared to [probably] fostering mitigation.

A85 PLANNING LONG-TERM R&D STRATEGY

- 1) The long-term strategy for R&D into the CE technology T should be prepared.
- 2) Immediate R&D into the CE technology T under the aspect R [probably] brings about preparation of the long-term strategy for R&D into the CE technology T.
- 3) There are no alternatives to immediate R&D into the CE technology T under the aspect R which bring about preparation of the long-term strategy for research into the CE technology T while at the same time being more appropriate than immediate R&D.
- 4) The side-effects of R&D into the CE technology T under the aspect R are negligible as compared to [probably] preparing the long-term strategy for R&D into the CE technology T.
- 5) R&D into a technology under the aspect R ought to be carried out immediately if the following conditions are met: 1. The decision on the long-term R&D strategy should be prepared; 2. Immediate R&D [probably] brings about preparation of the decision on the long-term R&D strategy; 3. There are no alternative measures which bring about preparation of the decision on the long-term R&D strategy while at the same time being more appropriate than immediate R&D; 4. The side-effects of R&D

are negligible as compared to [probably] preparing the decision on the long-term R&D strategy.

- 6) THUS (from 1-5): R&D into the CE technology T under the aspect R ought to be carried out.

A86 SPECIALISATION

- 1) An action A ought to be carried out if the following conditions are met: 1. The objective O ought to be realised; 2. A [probably] brings about realisation of O; 3. There is no alternative action A' that would bring about realisation of O while at the same time being more appropriate than A; 4. The side-effects of A are negligible as compared to O [probably] being realised.
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- 2) THUS (from 1): R&D into a technology under the aspect R ought to be carried out immediately if the following conditions are met: 1. The long-term R&D strategy should be prepared; 2. Immediate R&D [probably] brings about preparation of the decision on the long-term R&D strategy; 3. There are no alternative measures which bring about preparation of the decision on the long-term R&D strategy while at the same time being more appropriate than immediate R&D; 4. The side-effects of R&D are negligible as compared to [probably] preparing the decision on the long-term R&D strategy.

A87 PREPARING INFORMED DECISION

- 1) At a future point in time, we should be able to make best-informed decisions on the deployment of the CE technology T.
- 2) Immediate R&D into the CE technology T under the aspect R [probably] brings about the ability to make best-informed decisions on the deployment of the CE technology T.
- 3) There are no alternatives to immediate R&D into the CE technology T under the aspect R which bring about the ability to make best-informed decisions on the deployment of the CE technology while at the same time being more appropriate than immediate R&D.
- 4) The side-effects of R&D into the CE technology T under the aspect R are negligible as compared to [probably] being able to make best-informed decisions on the deployment of the CE technology T.

- 5) R&D into a technology under the aspect R ought to be carried out immediately if the following conditions are met: 1. We should be able to make best-informed decisions on the deployment of a technology; 2. Immediate R&D [probably] brings about the ability to make best-informed decisions on the deployment of the CE technology T; 3. There are no alternative measures which bring about the ability to make best-informed decisions on the deployment of the CE technology T while at the same time being more appropriate than immediate R&D; 4. The side-effects of R&D are negligible as compared to [probably] being able to make best-informed decisions on the deployment of the CE technology T.
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- 6) THUS (from 1-5): R&D into the CE technology T under the aspect R ought to be carried out.

A88 SPECIALISATION

- 1) An action A ought to be carried out if the following conditions are met: 1. The objective O ought to be realised; 2. A [probably] brings about realisation of O; 3. There is no alternative action A' that would bring about realisation of O while at the same time being more appropriate than A; 4. The side-effects of A are negligible as compared to O [probably] being realised.
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- 2) THUS (from 1): R&D into a technology under the aspect R ought to be carried out immediately if the following conditions are met: 1. We should be able to make best-informed decisions on the deployment of a technology; 2. Immediate R&D [probably] brings about the ability to make best-informed decisions on the deployment of the CE technology T; 3. There are no alternative measures which bring about the ability to make best-informed decisions on the deployment of the CE technology T while at the same time being more appropriate than immediate R&D; 4. The side-effects of R&D are negligible as compared to [probably] being able to make best-informed decisions on the deployment of the CE technology T.

A89 R&D FIRST

R&D should not be constrained; once technologies have been developed, a decision can be taken as to their deployment. (Gardiner 2010:288 et seq.)

A90 R&D NO GOAL IN ITSELF

R&D is no intrinsic goal and not for free, either: Research projects compete for limited funds, requiring a choice as to which projects to pursue. (Gardiner 2010:288 et seq.; Jamieson 1996:333 et seq.)

A91 R&D RELATED TO APPLICATIONS

R&D cannot be separated neatly from its potential results' applications because of psychological as well as socio-economic mechanisms. Frequently, automatic applications cannot be avoided. (Gardiner 2010:288 et seq.)

A92 TECHNOLOGY NEUTRAL

The CE technology T is, in itself, neutral and may be applied for good or bad purposes. Its mere development cannot reasonably be prohibited. (Goodell 2010)

A93 POSTPONE R&D

Preparing a technical intervention which is to be carried out in 50 years is a waste of resources: The technological means upon which the intervention will ultimately rely are not available today at all. (Gardiner 2010:288 et seq.)

A94 MORATORIUM

Hasty and premature deployment of CE technologies might be avoided (alternatively) by an international moratorium.

A95 CLANDESTINE RESEARCH

A moratorium would merely push research activities "underground". (Goodell 2010:200)

A96 RISK TRANSFER ARGUMENT

Planning for deployment and carrying out R&D today means transferring risks to future generations. (Ott 2010a,b,d; Gardiner 2010:293; Jamieson 1996:331)

A97 NO INFORMED CONSENT

R&D into CE requires a broad and well-informed consent of those potentially affected, which is not given. (Jamieson 1996:329 et seq.; Ott 2010a,b,d; Gardiner 2010:293 et seq.; Elliott 2010:19)

A98 TRUE MOTIVES

R&D into CE is but a rationalization for "passing the buck" on to future generations and for not addressing the CO₂ problem in earnest. (cf. Gardiner 2010:295)

A99 DILEMMA GENERATION

R&D into CE is likely to lead to future dilemmata. (Ott 2010c)

- 1) R&D into the CE technology T under the aspect R might lead to a future situation, where (a) atmospheric CO₂ concentrations are very high, (b) the CE technology T is the only measure deployed to compensate such high CO₂ concentrations, and (c) the deployment of the CE technology T entails unforeseen consequences which imply that continued deployment of the CE technology T would cause global evils.
 - 2) In a situation, where (a) atmospheric CO₂ concentrations are very high, (b) the CE technology T is the only measure deployed to compensate such high CO₂ concentrations, and (c) the deployment of the CE technology T entails unforeseen consequences which imply that continued deployment of the CE technology T would cause global evils, (i) decisions need to be made in favour of or against abandonment of the deployment of the respective technology T, (ii) equally good reasons exist for deciding in favour of or against abandonment, and (iii) any alternative action leads to a global misfortune.
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- 3) THUS (from 1, 2): R&D into the CE technology T under the aspect R might lead to a future situation, where (i) decisions need to be made in favour of or against abandonment of the deployment of the respective technology T, (ii) equally good reasons

- exist for deciding in favour of or against abandonment, and (iii) any alternative action leads to a global misfortune.
- 4) A situation S is globally dilemmatic if (i) in S, one has to decide between one of two alternative actions excluding one another, (ii) equally good reasons exist for each action alternative, and (iii) any alternative action leads to a global misfortune.

 - 5) THUS (from 3, 4): R&D into the CE technology T under the aspect R might lead to a globally dilemmatic situation.
 - 6) An action which might lead to a globally dilemmatic situation is prohibited if there are better alternatives.
 - 7) There are better alternatives than R&D into the CE technology T under the aspect R.

 - 8) THUS (from 5-7): R&D into the CE technology T under the aspect R ought not to be carried out (immediately).

A100 AGAINST DILEMMA GENERATION

- 1) Actions that may curb the rights of (future) persons are prohibited as long as omission of the respective action does not demand too much of the agent involved.
- 2) Humans have a right to autonomy and self-determination.
- 3) Autonomy and self-determination essentially depend on the possibility of persons to choose between basically good alternative actions.

- 4) THUS (from 2-3): Humans have a right to choose between basically good alternative actions.

- 5) THUS (from 1,4): Actions that may bring about that (future) persons can only choose between bad actions are prohibited as long as omission of the respective action does not demand too much of the agent involved.
- 6) The omission of an action does not demand too much of the agent involved if there are better alternative actions.
- 7) A globally dilemmatic situation is a situation where agents can but choose between bad alternative actions.

- 8) THUS (from 5-7): An action which might lead to a globally dilemmatic situation is prohibited if there are better alternative actions.

A101 DISCRIMINATING PROHIBITIONS UNJUST

- 1) R&D into the CE technology T under the aspect R ought not to be carried out (immediately).
 - 2) Some nations and businesses get away with defying R&D prohibition.
 - 3) If an action A is prohibited (or morally forbidden) to all stakeholders but some get away with defying the related rules, it seems unjust to uphold the prohibition for the remaining stakeholders.
 - 4) Any prohibition whatsoever ought not to be unjustly upheld and imposed on any stakeholder.
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- 5) THUS (from 1-4): The prohibition of R&D into the CE technology T ought not to be upheld towards, e.g., German or European stakeholders.

A102 ARGUMENT FROM REVERSIBILITY

Changes in behaviour (induced by mitigation policies), are much more reversible than technical interventions. (Jamieson 1996:331)

A103 AVOIDING DILEMMATA

We should avoid upfront to end up in a situation where we are compelled to choose between two evils. (Gardiner 2010:300 et seq.; Elliott 2010:13)

A104 POLLUTER-PAYS PRINCIPLE

Problems should be solved by those (generations) who have caused them; therefore, mitigation is preferable to CE. (Jamieson 1996:331)

A105 NO RESPECT

An initial act of pollution would even be morally wrong if perfect neutralisation of negative impacts were possible *ex post*, because it is an expression of a lack of respect. (Hale 2009; Hale and Grundy 2009)

A106 WORST CASE

No matter whether CE technologies are carried out or not: The worst case, given mitigation policies are carried out, is comparatively better than the worst case without mitigation.

Appendix 2

Commented Bibliography

- [1] S. Barrett, “The Incredible Economics of Geoengineering,” *Environmental & Resource Economics*, vol. 39, 2008, pp. 45-54.

According to Barrett, climate engineering (and SRM, in particular) is a serious alternative or rather serious additional option for counteracting climate change. Barrett emphasizes that low direct costs make deployment of SRM (and notably of stratospheric aerosol injection) relatively probable and believes the major potential risk to be the ensuing political challenges. It is important to find answers to the following questions:

- Who is supposed to decide on the deployment of CE measures?
- Which temperature target are we supposed to agree upon?
- How is the international community supposed to react to the attempt at a unilateral deployment?
- Should there be compensations for disadvantaged countries? If yes, how are these supposed to be fixed and who will pay?

- [2] L. Bengtsson, “Geo-Engineering to Confine Climate Change: Is it at all Feasible?,” *Climatic Change*, vol. 77, 2006, pp. 229-234.

Considering arguments against the deployment of SRM (and against stratospheric aerosol injection, in particular), Bengtsson arrives at the conclusion that the world’s energy problem would be better solved without deploying CE technologies. Bengtsson notably (i) puts doubt on the reliability of detailed climate forecasts, (ii) points out that SRM measures would have to be continued for centuries, and (iii) outlines the problems that cannot be solved by deploying SRM (e.g. acidification and the hazards involved for ocean ecosystems).

- [3] J.J. Blackstock, D.S. Battisti, K. Caldeira, D.M. Eardley, J.I. Katz, D.W. Keith, A.A.N. Patinos, D.P. Schrag, R.H.

Socolow, and S.E. Koonin, “Climate Engineering Responses to Climate Emergencies,” <http://arxiv.org/pdf/0907.5140>, 2009.

The Novim report roughly introduces a programme for R&D into SRM methods (and into stratospheric aerosol injection, in particular) that would minimise the risks of deploying related measures. The authors neither explicitly argue in favour of nor against the deployment of or R&D into such measures but emphasise that the political, sociological, and ecological dimensions of CE must not be ignored during R&D and must play a significant role in R&D and deployment decision-making.

- [4] J.J. Blackstock and J.C.S. Long, “The Politics of Geoengineering,” *Science*, vol. 327, 2010, p. 527.

The authors spell out that SRM measures ought not to be understood as alternatives to mitigation policies and argue for responsible and internationally coordinated R&D into SRM. They suggest that both R&D and the relevant field tests be controlled by generally accepted, international standards and be transparent for the public. Since R&D field tests may have negative impacts across borders, unilateral research might lead to international tensions.

- [5] D. Bodansky, “May We Engineer the Climate?,” *Climatic Change*, vol. 33, July 1996, pp. 309-321.

This article provides an overview of existing international agreements and general principles (precautionary principle, intergenerational equity) that may be of relevance to CE measures. Bodansky argues that these agreements and principles are absolutely insufficient for controlling CE adequately. International control presents a major challenge because the consequences of CE may differ globally and regionally. Three conceivable scenarios are sketched out by the author:

1. CE deployment is decided unilaterally by the different nations.
2. An international decision-making mechanism will be established to decide on CE deployment.
3. The international community basically prohibits deployment of CE.

According to Bodansky, the great difficulties affiliated with option (2) make it most likely that option (3) will be realised.

- [6] R. Bodle and R.A. Kraemer, “Wer darf am Thermostat drehen? Der rechtliche Rahmen von Geo-Engineering,” *Politische Ökologie*, vol. 120, 2010, pp. 44-47.

Bodle and Kraemer state that CE R&D and deployment cannot be regulated by existing international law. The great potential for conflict of unilateral deployment and field tests makes the authors advocate the creation of novel international agreements for regulating both CE R&D and deployment.

- [7] P.G. Brewer, “Evaluating a Technological Fix for Climate,” *Proceedings of the National Academy of Sciences*, vol. 104, 2007, pp. 9915 -9916.

Brewer points out negative consequences of SRM deployment:

- Severe climate changes in the case of abrupt termination.
- Unknown long-term impacts.
- Widely differing regional consequences.
- Decrease in precipitation.

- [8] M. Bunzl, “An Ethical Assessment of Geoengineering,” *Bulletin of the Atomic Scientists*, vol. 64, 2008, p. 18.

Bunzl asks the reader to consider that the various objections to CE are not *per se* a reason to reject CE options. Decisions on whether or not CE measures should be deployed cannot be

taken before the impacts and related unequal distributions of risks and benefits can be assessed.

- [9] M. Bunzl, “Researching Geoengineering: Should not or Could not?,” *Environmental Research Letters*, vol. 4, 2009, p. 045104.

Bunzl rejects the moral-hazard argument as being an exaggerated fear and says that the risk of CE R&D leading more or less inevitably to the deployment of the respective CE options is more significant. According to him, however, a burden of proof is imposed on proponents of R&D into CE through one crucial argument of methodological nature: Limited field tests and modelling cannot tell us anything about the side-effects that may occur during large-scale deployment. It seems that uncertainties are irreducible. And Bunzl ends up posing the question whether R&D into CE, hence, becomes unacceptable.

- [10] R. Cicerone, “Geoengineering: Encouraging Research and Overseeing Implementation,” *Climatic Change*, vol. 77, 2006, pp. 221-226.

Cicerone argues in favour of R&D into CE while suggesting that research and deployment be treated separately. According to him, immediate research is necessary (but not sufficient) for possible future deployment because only research can reveal the different approaches’ potential risks and weaknesses. Moreover, Cicerone advocates a preliminary moratorium on large-scale field tests until agreements have been obtained as to further conditions for research, development, and deployment.

- [11] A. Corner and N. Pidgeon, “Geoengineering the Climate: The Social and Ethical Implications,” *Environment*, vol. 52, 2010, pp. 24-37.

This article provides an overview of CE measures while expounding their ethical and social aspects. In particular, Corner and Pidgeon argue that issues of social and ethical

relevance ought to be discussed in the general public and on an international level. Different possibilities of engaging the public at an early stage (“upstream public engagement”) are introduced based on experience gained in the debate on nanotechnology.

- [12] P. Crutzen, “Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?,” *Climatic Change*, vol. 77, 2006, pp. 211-220.

Crutzen argues for R&D into SRM measures and for stratospheric aerosol injection, in particular, but points out that ambitious mitigation policies are the more appropriate reaction to climate change.

- [13] P. Crutzen, “Erdabkühlung durch stratosphärische Schwefel-Injektionen,” *Jahrbuch Ökologie 2011*, Stuttgart: S. Hirzel, 2010.

Crutzen emphasizes that the “best strategy for solving the climate problem” would be to reduce greenhouse gas emissions. Since no such efforts are being made, Crutzen recommends R&D into SRM.

- [14] L. David, “Climate Change - A Geoengineering Fix?,” *Aerospace America*, vol. 45, 2007, pp. 32-37.

David introduces CE measures placing emphasis on space-related solutions. Besides, he presents ideas and arguments of different critics and sceptics (such as Al Gore, Brad Edwards, and Dennis Bushell).

- [15] K.C. Elliott, “Geoengineering and the Precautionary Principle.” *International Journal of Applied Philosophy*, vol. 24, 2010, pp. 237-253.

This article points out that there are rather different variants of the precautionary principle and that these variants, in part,

imply contrary normative assessments of R&D into, deployment of, and, what is more, the public discussion of CE measures. Moreover, Elliott explains that the precautionary principle may possibly not lead to clear instructions on how to act, since both carrying out R&D into (deploying) CE as well as not doing so may have unforeseen negative effects. If that should be the case, Elliot suggests to consider further ethical principles, i.e.:

- The asymmetry between active and passive action is morally relevant and might be crucial.
- Acts that may have negative consequences for lots of individuals must be accepted by these very individuals.
- A cost-benefit analysis of all conceivable consequences decides on the moral status of relevant action alternatives.

[16] ETC, “Retooling the Planet: Climate Chaos in a Geoengineering Age,” ETC Group, 2009.

This report outlines several CE approaches, introduces their proponents, points out the risks and side-effects of potential deployment, and quotes general arguments against the use of CE measures (moral-hazard argument, commercialisation, possible unilateral deployment, unforeseeable side-effects, etc.). The authors, in addition, argue for (i) a moratorium on field tests and (ii) an obligation to perform R&D solely under participation of a broad public, under the consideration of human rights, and with the informed consent of all persons concerned. Moreover, the report demands the creation of institutions that can bring about a global balance of interests between CE deployment beneficiaries and losers.

[17] ETC, “Geopiracy: The Case Against Geoengineering,” ETC Group; 2010.

This ETC report is a revised version of [16].

[18] J.R. Fleming, “Fixing the Sky: Checkered History of Weather

and Climate Control,” New York: Columbia University Press, 2010.

In this critical book, Fleming proves that there are numerous historical forerunners to today’s proposals of controlling the climate system through technical options. Given the failure of these previous attempts, which had all been characterised by overestimation and hubris, Fleming advises extreme caution and asks the reader to consider that also currently discussed CE measures might be based on excessive confidence and technical overestimation.

- [19] S.M. Gardiner, “Is ‘Arming the Future’ with Geoengineering Really the Lesser Evil? Some Doubts about the Ethics of Intentionally Manipulating the Climate System,” *Climate Ethics: Essential Readings*, S.M. Gardiner, D. Jamieson, and S. Caney, eds., Oxford: Oxford University Press, 2010.

Gardiner gives a comprehensive overview of the ethical aspects of CE measures. He critically analyses, in particular, the arm-the-future argument which argues for research into CE and, among other things, considers the moral-hazard argument, the unstoppable-development argument, and aspects of intra- and intergenerational justice.

- [20] S.M. Gardiner, “Is Geoengineering the ‘Lesser Evil’?,” <http://environmentalresearchweb.org/cws/article/opinion/27600>, 2007.

Gardiner takes up Crutzen’s lesser-evil argument for CE R&D and hints at some problematic points of the underlying argumentation:

- It is not necessarily clear whether CE is the lesser evil in the case of unsuccessful mitigation.
- Investments in CE R&D may undermine efforts into mitigation.
- Further alternatives ought to be considered.

- CE research alone does not suffice to fulfil our moral obligations. In fact, we rather have to think about our compensation obligations towards future generations.

[21] J. Goodell, “How to Cool the Planet: Geoengineering and the Audacious Quest to Fix Earth's Climate,” New York: Houghton Mifflin, 2010.

In this popular-science book, Goodell not only introduces readers to the main CE technologies but also discusses some ethical aspects of CE R&D and deployment, e.g. the dual-use problem, the moral-hazard argument, the problematic absence of an exit option, the priority of mitigation, and the ethical asymmetry between SRM and CDR. In spite of numerous concerns and doubts, the author ultimately advocates comprehensive R&D into CE. Besides, Goodell draws detailed and revealing portraits of the main actors in the CE controversy, e.g. of David Keith, Ken Caldeira, and James Lovelock, but also of Lowell Wood, Bill Gates, and Russ George (the founder of the Planktos company which offers ocean fertilization services).

[22] C. Greene, B. Monger, and M. Huntley, “Geoengineering: The Inescapable Truth of Getting to 350,” *Solutions*, vol. 1, pp. 57–66, 2010.

The authors argue for reaching the 350 ppm target by the end of the 21st century. They conclude that that target cannot be achieved by classical mitigation measures alone and that, thus, CDR measures are inevitable. Combined with bioenergy technologies, CDR methods removing CO₂ from the atmosphere are supposed to be particularly suited for reaching such a stabilization target at reasonable costs. The authors, moreover, advocate R&D into SRM measures which, although not being long-term solutions, may prevent a possible dangerous or catastrophic climate change.

[23] A. Grunwald, “Der Einsatz steigt - Globale Risiken,” *Politische*

Ökologie, vol. 120, 2010, pp. 37-39.

This article critically appraises CE deployment while considering possible risks and impacts of (i) preparatory experiments, (ii) political decision-making, (iii) deployment, and (iv) sudden termination of CE measures. Besides drawing attention to the moral-hazard argument, Grunwald advises to take CE seriously and says that the potentials, risks, and possible side-effects of CE measures ought to be assessed through thorough and transparent research.

- [24] B. Hale, “You Say ‘Solution,’ I Say ‘Pollution’ Ocean Fertilization is a Fishy Solution to a Whale of a Problem,” *Science Progress*, Aug. 2009. (<http://www.scienceprogress.org/2009/08/ocean-fertilization-ethics/>)

Hale holds the thesis that the positive consequences of an action do not suffice to legitimate that very action ethically. It is important instead to ascertain whether the relevant action is being taken while ensuring that the persons concerned by its consequences are respected and will be giving their consent. Against that background, the deployment of ocean fertilization which, in spite of the technical feasibility of the measures involved, is assumed to be very problematic. Hale advocates increased reduction efforts, the use of non-polluting energy sources, and the reduction of CO₂ in the atmosphere by means of reversible and local methods such as air capture and CCS.

- [25] B. Hale, “Getting the Bad Out: Remediation Technologies and Respect for Others,” *The Environment: Philosophy, Science, and Ethics*, W. P. Kabasenche, M. O'Rourke, and Slater, M., eds., MIT Press, forthcoming, 2012.

Based on considerations introduced in [26] und [27], Hale argues for the use of general criteria for evaluation of the ethical permissibility of the deployment of different CE technologies. In the light of these criteria, neither SRM nor

ocean fertilization are permissible. Only under extraordinary and disastrous circumstances should the permissibility of the related measures be evaluated once again. If anything, only methods which, like air capture, are aimed at establishing a former “unpolluted” state of the world are permissible.

- [26] B. Hale and L. Dilling., “Geoengineering, Ocean Fertilization, and the Problem of Permissible Pollution,” *Science, Technology & Human Values*, vol. 36, 2011, pp. 190-212.

Hale and Dilling hold that measures which are meant to compensate or reverse pollution (of the environment) should not only be assessed regarding their effectiveness. They draw up fundamental ethical principles (in the sense of Jamieson, see [28]) to be considered in ethical assessment:

- The ethical assessment of such measures cannot be detached from the actions that have brought about that measures such as these have been considered.
- The measures concerned are not permissible unless all parties that may be affected by their consequences consent to implementing them. This includes, in particular, consideration of the interests of non-human parties.
- The respective measures, if possible, convert the world into a state that had existed prior to pollution.

- [27] B. Hale and W. Grundy, “Remediation and Respect: Do Remediation Technologies Alter Our Responsibility?,” *Environmental Values*, vol. 18, 2009, pp. 397-415.

According to Hale and Grundy, environmental pollution, even with adequate reversing technologies at hand, forbids itself for ethical reasons. Technological solutions such as CE measures, thus, do not legitimate any further pollution of the environment.

- [28] G.C. Hegerl and S. Solomon, “Risks of Climate Engineering,” *Science*, vol. 325, 2009, pp. 955-956.

Hegerl and Solomon point out that it is lopsided to focus the CE controversy on temperature change or stabilisation and stress that changes in precipitation, which are caused by SRM, are equally significant. The risks and side-effects of precipitation changes (e.g. droughts) may cause water resources conflicts, migration, and political instability. Current models even underestimate precipitation changes. Further research into the related side-effects is necessary.

- [29] M. Hulme, „Why We Disagree About Climate Change: Understanding Controversy, Inaction and Opportunity“, Cambridge: Cambridge University Press, 2009.

In his above book, Hulme militates against CE technology development by holding that if such technologies are available and are being deployed it may, in a global context, indeed become rather difficult to agree on a desired temperature. According to Hulme, it cannot be excluded that even wars may be caused by the conflicts that may be arising from such situation.

- [30] D. Jamieson, “Ethics and Intentional Climate Change,” *Climatic Change*, vol. 33, 1996, pp. 323-336.

Jamieson discusses necessary conditions for CE deployment (technical feasibility, reliable forecasts of the related consequences, socio-economic preference over other alternatives, and non-violation of fundamental ethical principles) and argues that, at present, these are not fulfilled. In addition, he advocates R&D into CE under the condition that such R&D takes into account the relevant associated ethical and social aspects. Jamieson points out that R&D into CE may bring about that

- the money to be invested will not be available anymore for other areas of research,
- the respective measures will be deployed even in spite of massive uncertainties regarding effectiveness and side-

effects.

- [31] D.W. Keith, “Geoengineering the Climate: History and Prospect,” *Annual Review of Energy and the Environment*, vol. 25, 2000, pp. 245-284.

This article gives an overview of the history and terminology of climate engineering, discusses some of its risks and points out the following aspects:

- Potential undesirable side-effects (ozone depletion, ocean acidification),
- undermining mitigation efforts (moral-hazard argument),
- creation of political tensions,
- problems arising from setting a precedent (if CE were justifiably deployed, it would be admissible to reshape nature, using technical means, in virtually unlimited ways),
- the problem of merely fighting symptoms.

- [32] D.W. Keith, E. Parson, and M.G. Morgan, “Research on Global Sun Block Needed now,” *Nature*, vol. 463, 2010, pp. 426-427.

Keith et al. advocate starting SRM R&D (inclusive of field tests) without delay. Moreover, they advise against immediate multilateral agreements and recommend instead cooperating internationally in terms of transparent, loosely coordinated programs that support R&D and risk assessment and are coordinated by independent institutions. The authors emphasise that SRM is to be understood exclusively as a supplement to mitigation policies.

- [33] J. Kiehl, “Geoengineering Climate Change: Treating the Symptom over the Cause?,” *Climatic Change*, vol. 77, 2006, pp. 227-228.

Kiehl criticises CE measures as fighting symptoms only and advocates R&D into these measures while stressing the limited

reach and scope of model calculations.

- [34] E. Kintisch, “Hack the Planet: Science's Best Hope – or Worst Nightmare – for Averting Climate Catastrophe,” Hoboken, New Jersey: John Wiley & Sons, 2010.

In this popular-science publication on the CE controversy, Kintisch also touches upon ethical aspects. He describes the controversy as being extremely polarized. His book sheds light on the motivations of numerous CE proponents. In chapter 10, which is of particular interest regarding the ethical assessment of CE, Kintisch explains how conservatives and climate sceptics politically capitalize on the CE option and backs up a variant of the moral-hazard argument, which is central to the debate.

- [35] M. Lawrence, “The Geoengineering Dilemma: To Speak or not to Speak,” *Climatic Change*, vol. 77, 2006, pp. 245-248.

Lawrence advocates open, cautious, and scientific R&D into CE.

- [36] T. Leisner and S. Müller-Klieser, “Aerosolbasierte Methoden des Climate Engineering. Eine Bewertung,” *Technikfolgenabschätzung - Theorie und Praxis*, vol. 19, 2010, pp. 25-32.

This article gives an overview of aerosol-based CE methods, points out their socio-economic uncertainties and risks, and recommends to research into them in order to be able in the future to make a founded decision in favour of or against their deployment.

- [37] U. Lohmann, “Der Sonne entgegen - Sonneneinstrahlungsmanagement,” *Politische Ökologie*, vol. 120, 2010, pp. 23-26.

Lohmann introduces the reader to different SRM approaches and advises against deploying the respective measures because such interventions in a complex system may have unknown

impacts. According to Lohmann, we rather ought to opt for a rapid and significant reduction of greenhouse gas emissions.

- [38] M. MacCracken, “Geoengineering: Worthy of Cautious Evaluation?,” *Climatic Change*, vol. 77, 2006, pp. 235-243.

MacCracken introduces different CE measures, placing emphasis on difficulties arising from stratospheric aerosol injection. Considering the facts that such a measure must be continued for centuries and entails serious consequences if suddenly terminated, it cannot be but an emergency solution and mitigation efforts ought to be increased. MacCracken, in addition, advocates R&D into SRM to better understand the long-term impacts of aerosol injection into the atmosphere.

- [39] M. MacCracken, “Impact Intervention: Regional Geo-engineering as a Complementary Step to Aggressive Mitigation,” *IOP Conference Series: Earth and Environmental Science*, vol. 6, 2009, p. 452003.

The author advocates immediate R&D into CE. He stresses that he does not understand CE measures as being an alternative to mitigation policies.

- [40] D.R. Morrow, R.E. Kopp, and M. Oppenheimer, “Toward Ethical Norms and Institutions for Climate Engineering Research,” *Environmental Research Letters*, vol. 4, 2009, p. 045106.

The authors argue for a detailed analysis of the ethical and institutional aspects of R&D into SRM. Based on ethical norms that regulate experiments on humans and animals, they discuss three elementary principles and point out the difficulties arising when they are applied to SRM research. These difficulties are particularly relevant to field tests within SRM:

1. Respect towards humans: The autonomy of humans ought to be respected by letting them decide themselves whether and in

what way they would participate in an experiment. Since SRM field tests would involve humans of many nations, one must ask whether it would suffice to have the consent of the representatives of the respective nations.

2. Justice and charity: The risks associated with experiments must not be unreasonable. Moreover, the risks and benefits of the experiments must be fairly balanced.
3. Minimalisation: Experiments must not last longer, nor be extended over a larger area, nor have a greater impact on the global climate than is necessary for achieving the experiment's objectives.

- [41] Nationales Komitee für Global Change Forschung, „The Debate on Geoengineering: Arguments, Risks and Consequences,“ Nationales Komitee für Global Change Forschung, 2010.

After giving an overview of the advantages and disadvantages of CE in general, the report points out the pros and cons of specific SRM and CDR methods.

- [42] NERC, “Experiment Earth? Report on a Public Dialogue on Geoengineering.” Natural Environment Research Council (NERC), Sciencewise Expert Resource Center, 2010.

“Experiment Earth?” is a participative procedure, a “public dialog” that has been carried out on the subject of CE in Great Britain in spring 2010, involving a total of 85 laypersons, plus further experts. The report gives a qualitative summary of the laypersons' assessments of nine different CE technologies. It finds that:

- In principle, CDR technologies are preferred over SRM technologies.
- CE measures have not been rejected or excluded categorically. The participants agreed that (i) mitigation measures alone may not suffice or may take effect too late to avoid a dangerous climate change, (ii) mitigation

measures must not be replaced by CE measures, and (iii) mitigation efforts must not be weakened through CE.

- The question of how strongly CE technologies interfere in and change natural processes has been an essential criterion for CE technology evaluation. The environment has been understood as a self-regulating system whose natural equilibrium should not to be modified, if possible.
- The participants gave the following further key criteria: Controllability, reversibility, effectiveness, governability, and a fair balance between costs and benefits.

The authors of the report conclude that it is essential to keep on considering the public opinion about climate engineering and to inform and actively involve the public.

- [43] K. Ott, “Die letzte Versuchung: Geo-Engineering als Ausweg aus der Klimapolitik?,” *Internationale Politik*, vol. 66, 2010, pp. 58-65.

Ott criticises the lacking or insufficient consideration of the ethical aspects of stratospheric sulphate injection in the corresponding report by the Royal Society, points out diverse arguments against using the sulphate option (e.g. the moral-hazard argument, the exit problem, and the hubris argument), and emphasises that a permanent sulphate solution must be rejected from the point of view of ethics.

- [44] K. Ott, “Die letzte Versuchung – Eine ethische Betrachtung von Geo-Engineering,” *Politische Ökologie*, vol. 120, 2010, pp. 40-43.

Ott introduces the reader to the major pro and con arguments of the CE controversy and discusses their weaknesses and strengths. (cf. also [43].)

- [45] K. Ott, “Kritische Kartierung der Argumente der Klimamanipulation,” *Jahrbuch Ökologie 2011*, Stuttgart: S. Hirzel, 2010.

Ott gives a systematic overview of the major arguments in favour of (the arming-the-future, lesser-evil, efficiency, easiness, innovation, and do-it-alone arguments) and against (the risk transfer, termination problem, informed-consent, moral-hazard, undermining-better-options, political-economy, loss-of-intangible, and hubris arguments) CE measures. He evaluates each of these arguments and draws the tentative conclusion that the cons outweigh the pros.

- [46] K. Ott, “Argumente für und wider „Climate Engineering“. Versuch einer Kartierung,” *Technikfolgenabschätzung - Theorie und Praxis*, vol. 19, 2010, pp. 32-41.

This article is a slightly revised version of [45].

- [47] C.L. Parkinson, “Coming Climate Crisis?: Consider the Past, Beware the Big Fix,” Lanham, Maryland: Rowman & Littlefield, 2010.

In his above book, Parkinson comments on and interprets the climate controversy. Three chapters are dedicated to the subject of climate engineering. Parkinson brings back into mind the precedents set by a number of well-intentioned technical interventions in complex systems whose unforeseen negative side-effects have by far been exceeding the intended consequences. Pointing out several massive and presumably irreducible uncertainties, Parkinson militates against CE deployment but at the same time advocates further R&D into CE technologies.

- [48] Parliamentary Office of Science and Technology, “POSTnote: Geo-Engineering Research,” Parliamentary Office of Science and Technology, 2009.

Based on the judgment that all previous forecasts have been underestimating future greenhouse gas emissions, different CE measures (SRM, CDR) are explained and their respective pros

and cons are discussed. The POSTnote implicitly advocates immediate R&D into CE technologies which, if necessary, should be available as emergency options.

- [49] U. Potzel, “Rechnung mit vielen Unbekannten - Geo-Engineering-Forschung,” *Politische Ökologie*, vol. 120, 2010, pp. 34-36.

According to Potzel, R&D into CE is imperative to be able to prepare for climate crises. Such R&D is to be financed exclusively by the governments and should preferably be carried out through international cooperation. Potzel points out that since CE is associated with possible negative side-effects, it must not be understood as an alternative to mitigation policies.

- [50] S. Rayner, “Geoengineering Governance. Regulierung der Klimamanipulation,” *Jahrbuch Ökologie 2011*, Stuttgart: S. Hirzel, 2010.

Rayner introduces different CE options, argues for research into these options and points out difficulties in reaching international agreement on the regulation of research and potential deployment. In that context, he discusses possible relationships to existing international agreements and points to the Oxford Principles as a conceivable framework for CE technology research, development, and deployment:

- CE ought to be treated like a public good.
- Decision-making ought to involve the broad public.
- Any research ought to be published and be made publicly accessible.
- There should be independent assessments and evaluations of the consequences of CE measures.
- CE regulation and governance ought to be clarified prior to the deployment of the corresponding measures.

- [51] A. Robock, “20 Reasons Why Geoengineering May Be a Bad Idea,” *Bulletin of the Atomic Scientists*, vol. 64, 2008, pp. 14-18.

According to Robock, we do not need any climate engineering options to solve the problem posed by potential climate change. Robock lists several reasons against CE: Regionally different consequences (e.g. droughts), ocean acidification, ozone depletion, negative impacts on vegetation, acid rain, changes in cloud formation, white sky, reduced efficiency of solar plants, environmental impacts due to transport of aerosols into the stratosphere, severe climate change in the case of abrupt termination, risks of human errors, undermining of emission reduction, underestimation of long-term costs, problems of commercial control, possibility of military abuse, conflicts with existing agreements (ENMOD), international conflicts of interests when trying to agree on a target temperature, issues of moral responsibility, and unforeseen side-effects.

- [52] A. Robock, “Atmospheric Science: Whither Geoengineering?” *Science*, vol. 320, 2008, pp. 1166-1167.

Robock critically points out the disadvantages of SRM measures (stratospheric aerosol injection). SRM deployment

- decreases the political pressure to reduce greenhouse gas emissions;
- triggers food-supply-threatening droughts in Asia and Africa;
- does not solve the problem of ocean acidification;
- causes a sudden and severe climate change if terminated prematurely;
- reduces the efficiency of solar energy production;
- depletes the ozone layer or retards its recovery.

- [53] A. Robock, M. Bunzl, B. Kravitz, and G.L. Stenchikov, “A Test for Geoengineering?” *Science*, vol. 327, 2010, pp. 530-531.

Robock et al. postulate that a field test for SRM measures based on stratospheric aerosol injection amounts to a full-scale implementation of such measures. Only through such large-scale field tests (approximately 5 Tg SO₂) can the measured climate effects be distinguished from the climate system's natural variability and be clearly attributed to the experimental intervention. In addition, any field test of that kind creates commercial interests and, hence, cannot be stopped immediately.

- [54] Royal Society, "Geoengineering the Climate: Science, Governance and Uncertainty," London: The Royal Society, 2009.

The report introduces the distinction between SRM (solar radiation management) and CDR (carbon dioxide removal) measures. CDR measures, which bear fewer uncertainties and risks, ought to be preferred over SRM measures although they unfold their effect on the climate system in the long term only and are not cost-effective at present. Since SRM measures, on the other hand, can bring about a rapid temperature decrease or stabilisation and are less costly, in addition, they can be deployed in the case of unexpectedly short temperature increases. SRM, however, must not be used as an alternative to but only together with increased conventional mitigation policies, which can be combined with CDR. Due to the high risks and uncertainties, the report advocates immediate R&D (within an annual budget of approximately ten million pounds in Great Britain) that is to be coordinated internationally.

- [55] G. Sardemann and A. Grunwald, "Einführung in den Schwerpunkt," Technikfolgenabschätzung - Theorie und Praxis, vol. 19, 2010, pp. 4-7.

Sardemann and Grunwald argue for R&D into CE, inclusive of a scientific reflection of ethical, legal, and socio-economic aspects. They give an overview of the main arguments of the

CE controversy and differentiate between the following types of risks:

- Risks of preparatory experiments: SRM field tests may already have undesirable and global consequences.
- Risks within the political process: Heterogeneous CE consequences may bring about conflicts and decision blockades.
- Legal uncertainties: It is not yet clear how CE measures can be implemented under international law.
- Operational risks: Once being deployed, CE may trigger unforeseen interactions with the atmosphere and ecological systems.
- Risks of long-term continuation: CE measures must be upheld over centuries or millennia without the occurrence of political instabilities.
- Risks of CE termination: Premature termination may cause a rapid increase in the mean global temperature.
- Risks due to abuse.
- Climate policy uncertainties: It is not yet clear which effects CE may have on the international climate regime.

- [56] D. Scheer and O. Renn, “Klar ist nur die Unklarheit – Die sozio-ökonomischen Dimensionen des Geo-Engineering,” *Politische Ökologie*, vol. 120, 2010, pp. 27-29.

This article sketches the socio-economic dimensions of climate engineering and points out that the CE controversy so far has neither been held systematically nor been evaluated. The authors demand that technological risks be assessed and that ethical aspects be analysed. They stipulate, moreover, that the development and deployment of CE measures be coordinated internationally and be regulated by governments.

- [57] S. Schneider, “Geoengineering: Could or Should We Do It?,” *Climatic Change*, vol. 33, 1996, pp. 291-302.

Schneider raises strong objections against the deployment of

CE methods and argues for increased mitigation efforts while, under reserve, advocating R&D into CE.

- [58] S. Schneider, “Geoengineering: Could We or Should We Make It Work?,” *Philosophical Transactions of The Royal Society A-Mathematical Physical*, vol. 366, 2008, pp. 3843-3862.

Schneider introduces different CE measures and argues explicitly for increased mitigation efforts. He points out that SRM measures would have to be upheld for more than one to two centuries and doubts that international cooperation would be stable enough to render this possible. Schneider eventually advocates R&D into CE.

- [59] J. Virgoe, “International Governance of a Possible Geoengineering Intervention to Combat Climate Change,” *Climatic Change*, vol. 95, 2009, pp. 103-119.

Virgoe discusses the socio-political characteristics of CE measures (for example the moral-hazard problem, potential unilateral deployment, possible risks and side-effects, and the necessity of continuing SRM measures for a long time). He shows that existing international law only insufficiently captures CE and he introduces readers to three possibilities of future control of research and deployment:

1. control through the United Nations,
2. unilateral control,
3. control through a consortium of nations.

Virgoe argues for early R&D into the technological, political, environmental, and regulatory aspects of CE to enable an informed and, if possible, multilaterally legitimated decision in favour of or against the deployment of CE.

- [60] T.M.L. Wigley, “A Combined Mitigation/Geoengineering Approach to Climate Stabilization,” *Science*, vol. 314, 2006, pp. 452-454.

Wigley advocates a combined mitigation/climate engineering (SRM) strategy with CE making available additional time for solving the economic and technological difficulties of mitigation. Moreover, he presents simulation results of several mitigation/CE scenarios.

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Ethical Aspects of Climate Engineering

This study investigates the ethical aspects of deploying and researching into so-called climate engineering methods, i.e. large-scale technical interventions in the climate system with the objective of offsetting anthropogenic climate change. The moral reasons in favour of and against R&D into and deployment of CE methods are analysed by means of argument maps. These argument maps provide an overview of the CE controversy and help to structure the complex debate.

Arguments covered in this analysis include: The central justification of R&D; side-effects of R&D and of deployment; lesser-evil argumentation; two-degree target argumentation; efficiency and feasibility considerations; arguments from ethics of risk; arguments from fairness; geopolitical objections; critique of technology and civilization; religious, existentialist, and environmental-ethics arguments; alternative justifications of R&D; lack of R&D alternatives; direct justifications of R&D prohibition; priority of mitigation policies.

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