Buying Time with Climate Engineering?

An analysis of the buying time framing in favor of climate engineering

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Foreword

This work is the outcome of three and a half years of research in the DFG priority program SPP 1689 “Climate Engineering – Risks, Challenges, Opportunities?” as part of the project C-E-thics. The main objectives of C-E-thics was to sort, scrutinize and evaluate the main moral arguments about climate engineering. While my colleagues worked, among others, on the trade-off argument, the lesser evil argument, and the argument from political economy, I myself was concerned with the buying time argument – an argument in favor of potential climate engineering deployment. It was a challenging argument in many ways: Firstly, it was challenging to reconstruct a reasonable version of this argument, that adds to and clarifies the current discussion about a potential buying time deployment of climate engineering. Secondly, it challenged my own point of view about climate engineering. While intuitively, I would headlong reject any use of climate engineering, analyzing the buying time argument made me concede that there might be forms of deployment that actually could be beneficial and morally sound, albeit in very strict boundary-conditions. However, those very clear-cut and limited deployment schemes are only morally acceptable when embedded in a comprehensive climate portfolio including fast and far reaching emission cuts. In the end, the need for immediate and drastic mitigation cannot be reduced by the possibility of future climate engineering deployment, nor be postponed.

This thesis has been made possible by numerous people that supported and encouraged me in numerous ways. I would like to thank them, though I cannot possibly mention all of them here.

I thank my doctoral advisor, Gregor Betz, for giving me the opportunity to work in this fascinating project and to deepen research in my main areas of interests: climate, ethics and argumentation theory. He gave this thesis the main direction and the right ‘drive’. I also thank him for being very supportive and understanding of my family situation, always knowing the importance of putting first things first.

I wish to thank my research group, the members of the shared research group LOBSTER and the members of the SPP, especially Christian Baatz for supporting me in all respects from discussing my ideas to conference organization to online paper research.

I wish to thank my family for their amazing support. Foremost, I thank my husband, Gregor Neuber. He is a wonderful husband and father, a loving man and an insightful partner in discussing my work. This thesis would not have been possible without his constant encouragement, his constant belief in me and his constant and selfless help in letting me work long hours on the weekends.

I thank my father, Konrad Ott. He gave valuable insights to my thesis, greatly widening my viewpoints, and was always available for late-night near-breakdown phone calls. I thank my mother, Veronika Surau-Ott. Not only did she always show a keen interest in my research and discussed the thesis with me from a fresh and neutral standpoint, she also supported me and my family at home, allowing me to continue writing. I thank my brother, Immanuel Ott, for being a fierce critic and for teaching me to be an even fiercer advocate. I thank my mother in law, Irina Neuber, for being there in the last week of my writing, essentially enabling me to finish my thesis.

Last, but never least, I wish to thank my children, for being understanding, for always cheering me up when I come home, just for being the cutest and most awesome kids in the world, and for constantly reminding me of what is really important in life. I would dedicate this work to them. But… One result of my thesis is the rather bleak prospect, that future generations might have no choice but to engage in climate engineering strategies. We may find ourselves in a situation, in which the policy options we propose violate our own normative standards. This prospect is nothing I would wish to dedicate to anyone.

This thesis is written with a deep love for nature; a love for every single being and for everything there is. It is written with the hope and faith that the current and future generations will be able, against all difficulties, to stabilize temperature rise, to turn the wheel around and to stop polluting and exploiting our planet. I hope to teach my children to be conscious about nature, to be aware of the limits we live within and to be content – virtues that are so dearly needed in the anthropocene. I hope to show them the beauty of nature, the wondrous creatures and the mesmerizing places, from the smallest ant to the highest heights of the mountains – this is what I dedicate to my children.

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Abbreviations and Metrics

BECCS	Bioenergy with Carbon Capture and Storage
BT-argument	Buying Time argument
CDR	Carbon Dioxide Removal
CE	Climate Engineering
EJ	Exajoule, measuring unit to indicate energy consumption
GHG	Greenhouse Gases
Gt CO_2/yr	Annual emission of gigatonnes of Carbon Dioxide
Mt SO_2/yr	Annual emission of megatonnes of Sulfur Dioxide
NET	Negative Emission Technology
ppm	parts per million
RCP	Representative Concentration Pathway
SRM	Solar Radiation Management
SAI	Sulfate Aerosol Injection
W/m^2	Watt per square meter

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Summary of the argument and main results

Can climate engineering help provide more time for an ambitious mitigation program? And if so, is a buying time deployment of climate engineering morally acceptable? The work at hand means to thoroughly scrutinize this specific argument of the climate engineering discourse – the buying time argument (BT-argument). The point of departure of this research is the notion that climate engineering (CE) is not inherently morally wrong. The guiding question is: Is there a possible buying time deployment of a climate engineering technology absent any general moral constraints?

The discussion enfolds in three parts: The first part (Chapter 1 and Chapter 2) is of introductory character and sets the stage for the debate. The second part (Chapter 3 to Chapter 5) constitutes the focus of the investigation. Here, the buying time argument is translated into a deductively valid premise-conclusion-structure and a strong buying time principle is developed. In particular, this principle implies that deployment of CE is to be finite and should not interfere with mitigation efforts. The BT-argument is discussed in light of four specific climate engineering deployment scenarios, two including sulfate aerosol injection (SAI) and two including bioenergy with carbon capture and storage (BECCS). In one of the scenario pairs it is assumed that CO_2 emissions to remain within the two-degree budget; in the other an overshoot is assumed. The third part (Chapter 6 and Chapter 7) stresses the moral dimension of the depicted deployment scenarios and gives an outlook for further research into policy choices.

A close reading of the current literature encompassing the buying time idea enables the distillation of the underlying implicit assumptions. Those assumptions of the BT-argument shape the formulation of an elaborated argument principle:

Buying Time Principle (BT-Principle)

If: i. Climate goal G is desirable, ii. option O leads to climate goal G and is beneficial in so doing, iii. option O only reckons with finite CE deployment, iv. CE in O does not lead to less mitigation compared to mitigation in O without CE, v. there is no option O’ which is maximally finite and which leads to G and which is better than O, vi. there are no general moral constraints on option O;
then: option O should be adopted.

From this an argument[1] can be formulated.

Buying Time Argument (BT-Argument)

1. If: i. Climate goal G is desirable, ii. option O leads to climate goal G and is beneficial in so doing so, iii. option O only reckons with finite CE deployment, iv. CE in O does not lead to less mitigation compared to mitigation in O without CE, v. there is no option O' which is maximally finite and which leads to G and which is better than O, vi. there are no general moral constraints on option O;
   then: option O should be adopted.
2. Climate goal G is desirable (desirability thesis).
3. Option O leads to the desirable climate goal G (effectiveness thesis).
4. Option O only allows for finite CE deployment (finitude thesis).
5. CE in O does not lead to less mitigation compared to mitigation in O without CE (no-impediment thesis).
6. There is no option O' which is finite and which leads to G and which is better than O (no-better-option thesis).
7. There are no general moral constraints on option O (morality thesis).
8. THUS: Option O should be adopted.

I introduce two placeholders for the buying time argument: Climate goal G and policy option O. The discourse on CE as a means to buy time incorporates at least four different climate goals G: Two that aim at preventing dangerous climate impacts and two that relate to minimizing the social and economic costs of the inevitable transition towards a carbon-free economy. Those four goals are discussed in light of four policy options O, two for SAI and two for BECCS.

Climate Goal G

Climate Goal 1	Avoiding temperature-dependent tipping points.
Climate Goal 2	Avoiding rate-dependent tipping points.
Climate Goal 3	Reducing adaptation pressure.
Climate Goal 4	Reducing mitigation pressure.

Climate Policy Option O

Climate Policy Option a	SAI + CO_2 emissions remaining within the two-degree budget (CO_2 < 2° budget).

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[1] An argument with placeholders is called an argument scheme, since its premises are not truth-apt. For the sake of brevity, I will use the term 'argument' instead of 'argument scheme'.

Climate Policy Option A	SAI + CO_2 emissions exceeding the two-degree budget (CO_2 > 2° budget).
Climate Policy Option b	BECCS+ CO_2 emissions remaining within the two-degree budget (CO_2 < 2° budget).
Climate Policy Option B	BECCS + CO_2 emissions exceeding the two-degree budget (CO_2 > 2° budget).

The lower case letters *a* and *b* indicate that emissions remain within the two-degree budget; the upper case letters *A* and *B* signify an overshoot scenario. Climate goal G and policy option O are then plotted against each other, which yields a matrix of sixteen instantiations of the BT-argument.

Climate Goal G Policy Option O			Preventing climate tipping points		Reducing pressure	
			Avoiding temperature - dependent tipping points	Avoiding rate-dependent tipping points	Reducing adaptation pressure	Reducing mitigation pressure
			1	**2**	**3**	**4**
SAI	CO_2 < 2° budget	**a**	a1	a2	a3	a4
	CO_2 > 2° budget	**A**	A1	A2	A3	A4
BECCS	CO_2 < 2° budget	**b**	b1	b2	b3	b4
	CO_2 > 2° budget	**B**	B1	B2	B3	B4

Table 1. Argument matrix. The rows depict climate goals G; the columns depict portfolio options O. Each entry represents a version of the BT-argument.

Of those sixteen versions, only two generate plausible premises (arguments a2 and a3). A further six instances can be shown to be implausible. Most notably, the sub-cases assuming an overshoot of CO_2 emissions yield either implausible or at least indecisive arguments. I believe I can demonstrate that the BT-argument has plausible premises only if emissions are assumed to remain within the two-degree budget. The remaining eight versions of the BT-argument are undecided in that I cannot pronounce on their plausibility. Scientific findings to validate the respective premises are inaccessible to me. There are two special cases, however, that pose quite a challenge for the BT-argument: Arguments B1 and B4. Those cases assume BECCS deployment in an overshoot scenario, in which BECCS is used to realize the two-degree target and to reduce mitigation pressure. However, those instantiations violate at least two requirements of the BT-argument. If one still wants to hold on to this scenario as being a buying time instantiation, the respective BT-requirements may need to be attenuated. In particular, the request not to interfere with CO_2 emission cuts may turn out to be absurd for BECCS. If some premises of the initial BT-argument are weakened, the argument instantiations involving BECCS in an overshoot scenario may make for a plausible BT-deployment.

			Preventing climate tipping points		Reducing pressure	
			Avoiding temperature dependent tipping points	Avoiding rate-dependent tipping points.	Reducing adaptation pressure	Reducing mitigation pressure.
			1	**2**	**3**	**4**
SAI	CO_2 < 2° budget	**a**	*No-better-option thesis.* This climate goal amounts to the two-degree target. If CO_2 emissions remain within the two-degree budget, SAI deployment is superfluous in reaching the two-degree target.	SAI might be able to prevent rate depended tipping points, while mitigation efforts serve to realize the two-degree target.	SAI might be able to reduce the pressure of adaptation, if it lessens the rate of temperature change which could generate more time for ecosystems and human systems to adapt.	Since mitigation is assumed to be ambitious in this case, it is unclear, in how far a lessening of the rate of temperature change might influence mitigation costs.
	CO_2 > 2° budget	**A**	*No-impediment thesis* If carbon emissions exceed the two-degree budget, SAI would be used in order to stabilize temperature. It would then be used as a substitute for mitigation, impeding mitigation efforts. *Finitude thesis*. Because SAI would function as a substitute for mitigation efforts, it would have to be used continuously in order to stabilize temperature. Under the assumption of exceeding carbon emissions, SAI would not be finite.			
BECCS	CO_2 < 2° budget	**b**	*No-better-option thesis.* This climate goal amounts to the two-degree target. If CO_2 emissions remain within the two-degree budget, BECCS deployment is superfluous in reaching the two-degree target.	Whether BECCCS can influence the rate of temperature change, cannot be decided within the scope of this work.	If additional BECCS can influence the rate of change, it might also reduce adaptation pressure.	While emission would remain within the two-degree budget, BECCS could be used to further reduce the time pressure for mitigation. Research for BECCS together with sufficient mitigation has not been reviewed for this research thesis.
	CO_2 > 2° budget	**B**	*The special case of BECCS.* BECCS in light of insufficient mitigation might be used to stabilize temperature change. It might however violate several BT-requirements. A weak version of the BT-argument could incorporate this case.	Especially in light of insufficient mitigation, it cannot be decided here, whether BECCCS can influence the rate of temperature change.	Especially in light of insufficient mitigation, it is unclear, whether BECCS can reduce adaptation pressure.	*The special case of BECCS.* BECCS in light of insufficient mitigation might be used to reduce mitigation pressure as it enhances the emission budget. It might however violate several BT-requirements. A weak version of the BT-argument could incorporate this case.

Table 2. Full table of instantiation of the BT-argument. The colors indicate the status of the argument (plausible, implausible, undecided and the special case of BECCS). In each field, the discussion of the argument is shortly summarized and the implausible premises, if any, are indicated.

Plausible Versions (green)

Two plausible versions of the BT-argument are been identified: Arguments a2 and a3. In those cases, SAI is deemed to be finite, beneficial and effective, reducing pressure for adaptation while not interfering with mitigation efforts. This form of moderate and strictly purpose-bound SAI may realize the BT-requirements.

This result is somewhat surprising, because SAI especially has been criticized frequently on moral grounds. Nevertheless, a beneficial buying time deployment of SAI might be conceivable within the given boundaries. It is to be noted that the plausibility of this version prominently depends on the effectiveness of mitigation efforts. Only if emissions remain within the two-degree budget, a plausible SAI deployment is possible. Thus, in addition to the moral obligation to mitigate, it can be shown that CE deployment in a BT-framing is only *plausible* with sufficient mitigation.

Implausible Versions (red)

Five additional SAI-instantiations and one BECCS-instantiation can be shown to be implausible. When relating to goal 1, both SAI and BECCS turn out to be superfluous in the respective policy option *a* and *b* (argument a1 and b1). All other SAI-scenarios which assume emissions to exceed the two-degree budget, become implausible (arguments A1, A2, A3 and A4) – they violate both the finitude- and as the no-impediment requirement. If this result holds true, it may influence the decision making-process as to warn against a supposed ‘buying time deployment’ of SAI in light of insufficient mitigation.

Undecided Versions (light blue)

For several scenarios, I cannot provide further scientific back-up. Those BT-versions must remain undecided in the current discussion. Out of six undecided scenarios, five belong to BECCS scenarios (arguments b2, B2, b3, B3 and b4). This might indicate that there is much more uncertainty regarding BECCS than there is regarding SAI, and highlights the need for comprehensive research on BECCS, before it is mutually assumed as a potential future negative emission technology.

The special case of BECCS (dark blue)

A BECCS deployment to artificially enhance the emission budget (argument B1 and B4) turns out to violate at least two requirements of the BT-argument: The finitude- and the no-impediment requirement, and it may very well also violate the morality requirement. Exactly this case, though, is the *raison d'être* for the contemplation and research of BECCS deployment scenarios. Discussion in Chapter 5 adheres to the strong BT-requirements, which lead to a rejection of BECCS in light of insufficient mitigation efforts. Chapter 6 traces another route by asking whether the BT-requirements might be too strong for the special case of BECCS.

Nevertheless, I argue for a strong version of the BT-argument. I do so by stressing one of the initial assumptions of the BT-framing – the inevitable decarbonization of society. I mean to show that while there might be morally acceptable and even necessary BECCS deployment scenarios, those are no instantiations of the BT-argument. Finally, I wish to discuss general moral concerns that address the plausible BT-instantiations and give an outlook for further research.

To summarize, the main objectives and the main results of my research are given in bullet points:

Main objectives

- Introduction of the moral controversy about climate engineering;
- Introduction of two central CE technologies: SAI and BECCS;
- Close analysis of the buying time framing;
- Reconstruction of the buying time argument and discussion of its premises;
- Discussion of SAI and BECCS instantiations of the BT-argument;
- Critique of the BT-argument with two general moral arguments;
- Demonstration of how argument reconstruction helps to structure and evolve a complex debate.

Main results

- **Ambitious mitigation is necessary for the BT-argument to be plausible.** SAI can only serve as means to buy time, if CO_2 emissions remain within the two-degree budget. Not only is drastic mitigation morally obligatory, but also necessary in order to render the SAI-instantiation of the BT-argument plausible.

- **BT-deployment needs to be finite**. If any CE technology is anticipated to be deployed for a potentially infinite or uncontrollably long period of time, it cannot be called to be in line with the BT-framing.
- **The plausible BT-instantiations are not rebutted by general moral arguments.** Cases that meet the strong BT-requirements do not fall prey to at least two general moral constraints: The hubris-argument and the techno-fix-argument.
- **Case-specific arguments are imperative in evaluating the moral scope of CE deployment.** Each technology should be evaluated as part of a comprehensive climate portfolio, where both the extent of its planned deployment as well as the additional climatic options are taken into account.

Chapter 1 Introduction

This chapter gives the framework for the research thesis at hand. First, the significance of climate engineering (CE) will be illustrated in the context of urgent climate policies. Climate engineering is a risky technology that comes with an array of problems - technical, political and moral. The way CE deployment is framed influences the judgment of those problems. Especially if CE is seen only as a temporary stopgap measure that serves to 'buy time' until efficient mitigation politics take hold, CE deployment is likely to be positively assessed (Section 1.1).

The critical examination of the buying time framing in favor of CE deployment constitutes the core of this research thesis. The buying time framing is embedded in a complex political, socio-economic and moral discourse, with many interdependencies to other fields of research. Additionally, research on CE deals with great uncertainties. In particular research on climate engineering has been conducted to a large extend with argumentative analysis contributing to the so-called 'argumentative turn' in policy analysis (Hansson and Hirsch Hadorn 2016a). Argument reconstruction proofs to be a viable tool for certain kinds of political debates that are faced with deep uncertainty. It allows for the assessment of complex decisions absent any clear probabilities or results (Section 1.2). By means of argument reconstruction, the buying time argument (BT-argument) will be formulated and assessed for validity. The set-up and main results of the research thesis at hand will be outlined in Section 1.3.

1.1 The debate on climate engineering in context of climate change

In November 2015, the most recent major climate conference took place in Paris. It was the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change. All 197 participating states mutually agreed on the danger and urgency of climate change being the foremost threat to human society. The final *Paris Agreement* (UNFCCC 2016) aims at reducing global warming to "well below 2°C above pre-industrial levels" (UNFCCC 2016, p. 3). In order to reach this goal, global GHG emissions should reach net zero by the end of the twenty-first century, asking for drastic emission cuts in the next decades for both developed and developing countries. The *nationally determined contribution* (NDC), which each country formulates individually, is a nation's share to realizing the climate goal. The NDCs are expected to amplify every five years and the nations are expected eventually to abandon the use of fossil fuels (UNFCCC 2016, p. 3). At the time of writing (July 2017), 153 out of 197 parties have ratified the commitment – with the astounding exception of the U.S.A, which withdrew from the Paris Agreement in June 2017.

The Paris Agreement marks the preliminary end of the long discussion on anthropogenic climate change. For decades now, but at the latest with the ratification of the Kyoto Protocol in 1997, the need to cut emissions in order to stabilize temperature at 2°C above pre-industrial level has been present to policy makers and the public alike.

However, existing pledges are not sufficient to reach the two-degree target, but rather would allow for a 2.8°C warming (CAT 2017). The progression of the pledges is intended, but meeting the climate goals keeps getting harder if the pledges continue to range at the lowest possible formulation. Moreover, the mechanism to implement the NDCs is argued to be feeble, and the power of the treaty is supposed to rely mainly on a country's good reputation (Jacquet and Jamieson 2016).

A grand, large-scale and global effort to reduce CO_2 emission[2] is needed in order to meet the commonly agreed climate targets. The first signs of climate change are already visible (IPCC 2014b), some of which are irreversible (Solomon 2009) and both human and natural systems suffer from the impacts. The threat of a 'climate emergency' looms behind current climate predictions, while scientists repeatedly correct their predictions to ever more dire scenarios (e.g. Hansen et al. 2016).

It is in this situation that the idea of climate engineering (also known as geo-engineering, climate manipulation or climate intervention[3], hereafter referred to as CE) has gained interest. Paul Crutzen has opened up the discussion with his 2006 editorial remark, urging for "active scientific research" (Crutzen 2006, p. 217) on stratospheric aerosol injection (SAI) – a technology that could possibly reduce radiative forcing by injecting sulfur particles into the stratosphere. Climate engineering has since been defined as the "deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change" (Royal Society 2009, p. 77). Deployment of climate engineering technologies might avert dangerous

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[2] There are several other Greenhouse Gases (GHGs) that contribute to global warming. Because the main driver of global warming is CO_2 I will focus on CO_2 solely.

[3] Even the wording of the technology is subject of discussion, see also Section 2.5.

climate change in face of insufficient mitigation. And with the latest Intergovernmental Panel on Climate Change's (IPCC) report having included CE as an (admittedly theoretical) option to lessen climate change impacts, CE has been hoisted into the realm of acceptable climate policy options (IPCC 2013).

Climate policy options (or portfolios) contain different strategies on how to cope with climate change. They include options to reduce emission (mitigation), adjust to climate impacts (adaptation) and, as of late, technically averting climate effects (CE).

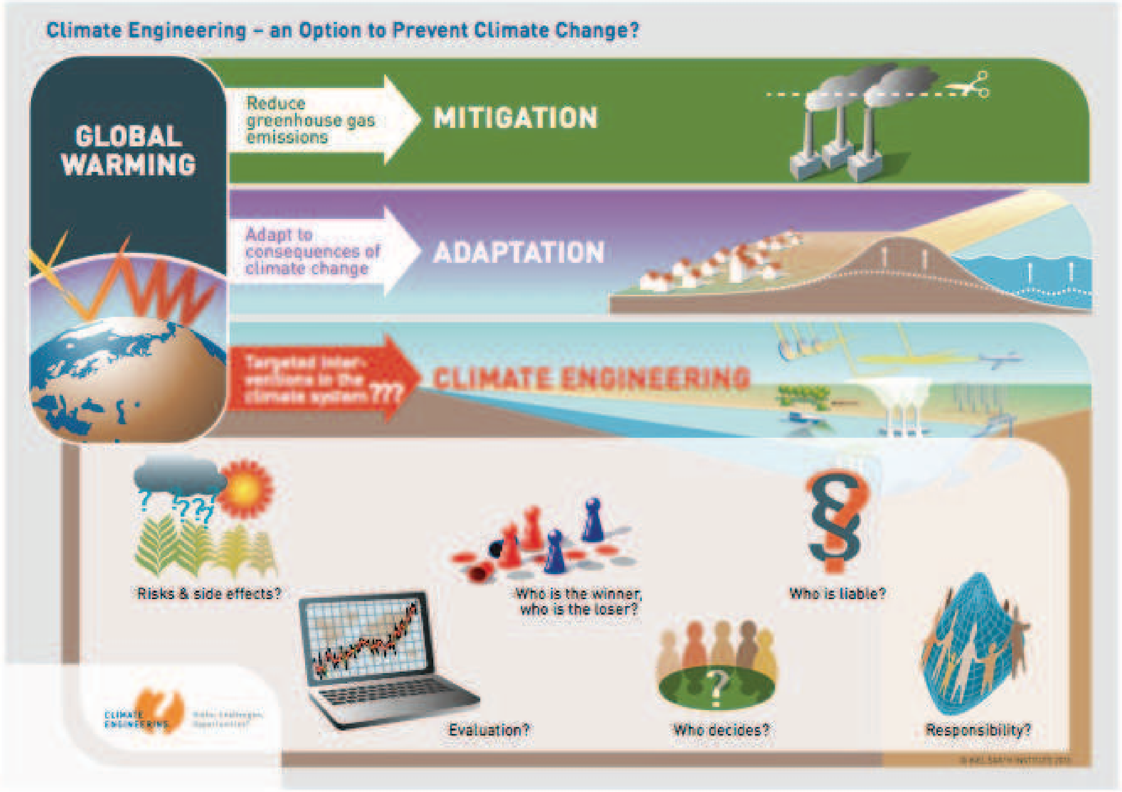

Figure 1. Three possible strategies in a climate policy portfolio: mitigation, adaptation and climate engineering. For the latter some areas of research are indicated (Source: Kiel Earth Institute 2015).

However, the endeavor of climate engineering comes with an array of problems – technologically, politically and morally. With research on CE still being in its infancy, the scope and effectiveness of CE is but a possibility. There are grave, maybe even insurmountable uncertainties about side effects of CE deployment, since both the technologies as well as the climate system are still not sufficiently understood. Social impacts of developing and advertising CE technologies are unclear and there is no viable political framework that could enable a global governance of CE technologies with respect to liability or compensation. The debate about CE is faced with incomplete and uncertain information impeding robust decision-making.

On a more general note, many philosophers have argued that the enterprise of technically counteracting climate change is *as such* morally wrong (Robock 2008, Gardiner 2010, Gardiner 2013). Those authors argue, for instance, that pursuing drastic emission cuts is the foremost priority of developed nations, and CE might divert from this obligation. CE then appears to show a hubristic stance towards nature and our place in it, as it offers a cheap techno-fix for our failed emission cuts.

Between the support of large-scale CE as a strategy to realize climate goals in the face of insufficient mitigation on the one hand, and the devaluation of CE from a moral point of view on the other hand, an apparent middle ground has been sought. In this view, CE deployment should not amount to an alternative to mitigation efforts. Rather, CE presents itself as a stopgap measure that allows for more time, while in the interim period an ambitious mitigation program will be underway in order to push the decarbonization of society. The deployment of CE could help developed nations *to buy time* for initiating a successful climate policy. This way, CE might act as a bridge-technology that could be ramped down as soon as mitigation efforts show sufficient effect. This line of thinking amounts to the buying time framing of climate engineering.

The research question of the thesis at hand is this: Are there possible time buying deployments absent any general moral constraints? This question assumes that CE is not inherently morally wrong – if that were the case, CE deployment would have to be rejected no matter the mode of deployment. In contrast, the BT-argument is consequentialist; hence, it assesses the deployment of CE on grounds of its results.[4]

The BT-framing now advocates a limited CE deployment in both its intensity as well as its duration. If the relevant requirements are met, a decent CE deployment seems imaginable. This shows that the framing of CE as a means to buy time makes a positive evaluation more likely. I will follow that thought, while critically examining the underlying assumptions. I will translate the vague buying time framing into an argument – the buying time argument (BT-argument) – and discuss the possibility of

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[4] The evaluation of the BT-argument has significant intersections to the field of technology assessment. Grunwald (2008, 2009) gives a comprehensive introduction to the method and scope of technology assessment (TA). The thesis at hand, however, uses the method of argument reconstruction and evaluates the premises of the BT-argument thusly.

morally acceptable CE deployment in light of this argument. In doing so, I adhere to what has been called the ‘argumentative turn’ in policymaking: Debates that are faced with incomplete and uncertain information can be substantiated with the help of argument analysis.

Evaluation of the moral status of a certain technology, however, remains incomplete, if it is not embedded within a comprehensive policy mix that also accounts for a mitigation pathway. Therefor, the thesis at hand uses climate portfolios as instantiations for the BT-argument.

1.2 Method

In both our daily life and politics, many decision problems are characterized by great (or deep) uncertainty: The lack of probabilistic foresight, the lack of information about relevant consequences and the lack of a clear ranking of our values[5]. Climate change and climate engineering are paradigmatic cases for decisions under great uncertainty.

> “(…) climate change is associated with conditions of deep uncertainty, where decision-makers do not know or cannot agree on: (i) the system models, (ii) the prior probability distributions for inputs to the system model(s) and their interdependencies, and/or (iii) the value system(s) used to rank alternatives.”
> (Lempert et al. 2004, p. 2)

Traditional decision theories (like cost-benefit-analysis) cannot deal very well with great, or deep, uncertainty, because they rely on a concrete value of their input variables. But in political context, there may be ‘hard choices’ that cannot be resolved unambiguously, having to be made nevertheless.

A way of addressing issues inflicted with great uncertainty lies in argument analysis. Argument analysis is a diverse field of philosophical research that can help clarifying a complex and uncertain situation by making the arguments pro and contra a certain decision explicit. Especially normative principles that underlie certain assumptions are made visible by argument reconstruction. This is obtained by analytical thinking in the best sense: Creating transparency, avoiding ambiguity, and highlighting

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[5] This is not intended to be a definition of ‘deep uncertainty’, rather a colloquial understanding of what it amounts to.

inferential relations. While there is no final result to be gained from this approach, decision makers might see more clearly what the arguments are about, how to evaluate them in light of their own values and what would follow from them. The argumentative turn has been characterized by Hansson:

> “This is a ‘widened rationality approach’ that scrutinizes inferences from what is known and what is unknown for the decision at hand. It recognizes and includes the normative components and makes them explicit. This is what we mean by the argumentative turn in decision support and uncertainty analysis.“
> (Hansson and Hirsch Hadorn 2016b, p. 29)

Betz has exemplified this methodological approach to the problem of CE in his 2012 paper on the arming-the-future argument (AF-argument) (Betz 2012a). Betz analyses this prominent argument in favor of CE research and discusses its the premises as well as the objections to it, thereby pinpointing the critical issues at stake. Furthermore, Betz indicates what a proponent of the AF-argument needs to ensure if her argument is to remain plausible (e.g. installing mechanisms that prevent automatic CE deployment).

Elliott has described climate engineering as the „poster child“ of argumentative research (Elliot 2016, p. 305), not least because Betz and Cacean (2012) have brought forward a comprehensive argument map on the moral controversy about CE. Their study is a textbook example for how valuable the method of argument analysis can be for the discourse on climate engineering. The many different uncertainties surrounding the research and deployment of CE may be taken hold of by means of presenting them as arguments which themselves assume certain normative principles. That way, the discussion may shift from the empirical question of how to reduce uncertainty to the normative question of how to rationally deal with this uncertainty. Elliot stresses that especially in the case of CE, the ethical discussion precedes the natural scientific one.

> „Since there are such pervasive uncertainties associated with climate geoengineering, it is a fool’s errand to try to quantify the likely costs and benefits associated with various climate geoengineering schemes with precision in an effort to determine a rational choice. (…) Many of the foundational documents discussing climate geoengineering highlight the necessity of thinking through its ethical ramifications”. (Elliot 2016, p. 313)

For the BT-argument, argument analysis proves to offer a tool for evaluating different deployment scenarios under an ethical perspective. Certain implicit assumptions, like the inevitable decarbonization by the end of the century (Section 3.1), can thus be problematized and discussed.

An essential part of argument analysis is argument reconstruction. Argument reconstruction aims at translating different claims of a debate into deductively valid arguments and picturing their dialectical inferences. While a debate consists of two features – the dynamic process of giving and taking arguments on the one side, and the static 'freeze frame' of the arguments and their interrelations – argument reconstruction focuses on the latter aspect of the debate (Betz 2010).

Argument reconstruction can either focus on the reconstruction of single arguments, or on the reconstruction of the whole debate. Single argument reconstruction takes the semantic-syntactical inferences of sentences as theses into account and translates them into premise-conclusion-structures (i.e. arguments); debate reconstruction highlights dialectical relations like support and attack between single arguments and theses. Those two tasks are intertwined when considering argumentative texts.

The practice of argument reconstruction is a hermeneutic process of analyzing scientific texts, whose results are deductively valid[6], semi-formal premise-conclusion-structures, which make their dialectical interrelation visible. Argument reconstruction is also an interpretative task, since the text under investigation usually does not present arguments in a formal manner. Mostly, arguments in texts are found in the form of 'enthymemes' – arguments that are incomplete in that "(…) a premise or the conclusion has been 'left implicit' " (Betz and Brun 2016, p. 50). Additionally, many arguments found in scientific texts cannot be assessed directly, for they contain vague or ambiguous wording. It is the chore of argument reconstruction to transform those incomplete arguments into structures with clear and truth-apt premises.

Betz and Brun summarize the practice of argument reconstruction as follows:

> "A reconstruction of an individual argument takes an argumentative text as its input and aims at delivering an inference as its output. The guiding principles are the hermeneutic

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[6] Every inductive argument can be transformed into a deductive argument via premise inclusion (Betz 2010).

> maxims of accuracy and charity as well as the ideal of clarity with its aspects of explicitness, precision, and transparency."
> (Betz and Brun 2016, p. 47)

An argument resulting from argument reconstruction should be explicit, precise and transparent: All relevant premises should be made explicit and they should consist in complete, truth-apt sentences. The argument should also be precise, i.e. it should not contain any ambiguous wording or ill-defined concepts, whereby the decision on what concepts need further explication is given by the scope of interpretation and the current context of the debate. On the other hand, certain concepts may be left undefined as to serve as a placeholder. In the reconstruction of the BT-argument, two placeholders are used: Climate goal G and policy option O.

Some concepts are essential to the argument itself, so that one does not understand the argument without understanding those concepts. In such cases, vague or ambiguous wording needs to be as concrete as possible in order to make the argument as strong as possible. In the work at hand, the vague notion of 'buying time' is replaced by the presumably more tangible concept of 'reducing mitigation pressure'.

Finally, the internal structure of the argument needs to be made transparent. The benefit of argument analysis arguably lies in the presentation of a comprehensive and transparent structure of the argument, facilitating a well-founded evaluation and judgment. If the argument itself was opaque in that one could not understand its meaning or its logical structure, the goal of clarity of argument reconstruction might not be achieved.

Arguments relate to other arguments in a debate – they support or attack each other. Those interdependencies can be called 'dialectical relations' and can be defined accordingly[7]:

Support: Argument A supports argument B, if the conclusion of argument A is equivalent to one premise in argument B.

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[7] A normal-language definition of the following concepts is given which have been laid out in detail in Betz 2009, Betz 2010 and Betz 2012b.

Attack: Argument A attacks argument B, if the conclusion of argument A is in contradiction to one premise in argument B.

Independence: If argument A and B neither attack nor support each other, argument A and argument B are independent.

Argument reconstruction gives a preliminary viewpoint of a given debate. A debate is defined as a structure, consisting of theses and arguments with the respective dialectical relations between them. It can be denoted by the Greek letter τ.

In the work at hand, the method of argument reconstruction and analysis serves the following purposes:

- Structuring the debate surrounding the BT-argument and ultimately structuring the work itself;
- Formulation of a comprehensive BT-argument and the discussion of its premises;
- Elucidating the thought process behind the formulation of the BT-argument and accounting for some premise variation;
- Evaluation of the BT-argument by means of exemplary deployment scenarios;
- Discussion of possible objections to the BT-argument.

The result of this work will not consist in a definite decision about which deployment scenario of a given CE technology is morally acceptable – this is not what can be gained through argument reconstruction. Rather, I wish to shed some light on *what kind of* considerations are at stake (economic, social, etc.) and *what kind of* assumptions are to be made (substitution, fairness, etc.), if CE deployment is accepted as being a morally acceptable option. Finally, argument analysis allows for formulating two versions of the BT-argument, a weak and a strong one which might be the basis for further political decision making.

1.3 Outline and set-up of this work

This thesis means to thoroughly discuss one specific argument of the climate engineering discourse – the buying time argument. But of course, no argument stands for itself, each argument belongs to a universe of discourse and relates to and draws from other arguments. Taking this into account, Chapter 2 serves to introduce the debate on climate engineering. First, establishing the canonical distinction of solar radiation management (SRM) and carbon dioxide removal (CDR) further deepens the concept of CE. If CE is to be deployed, it will be embedded in a complex policy mix consisting in mitigation, adaptation and (possibly) CE. Thus, CE is discussed as a possible part of a comprehensive climate policy portfolio (Section 2.1).

Having introduced a broad definition of CE, the next section sets the basic corner stones for the moral controversy on CE. In climate ethics, the pivotal moral obligation of the current generation is the obligation to pursue drastic emission cuts (mitigation obligation) (Section 2.2). This obligation is the moral epicenter around which the further debate revolves. In light of this obligation, the moral controversy on CE is further portrayed (Section 2.3). Following Betz and Cacean (2012), the main theses and arguments pro and contra research and deployment of CE are given. The BT-argument, however, does not figure prominently in this early exposition, indicating that the BT-argument has only recently played a major role.

The argument reconstruction of Betz and Cacean (2012) uses the placeholder T for a specific CE technology. The authors reason that some arguments only apply to a certain technology or a group of technologies. Arguments about *CE in general* usually fall short, since the diverse features of individual technologies might not be addressed by a generalizing argument. Hence, the placeholder T ought to be specified when evaluating the arguments. This resonates with the objection that not even the broad categories of CDR and SRM do justice to the technology assessment. In discussing arguments that clearly do not apply to certain (groups of) technologies, I will make a case for a technology- and even portfolio-specific evaluation of the BT-argument (Section 2.4). Consequently, the following investigation will focus on two specific technologies. The subsequent sections will introduce sulfate aerosol injection (SAI) (Section 2.5) and bioenergy with carbon capture and storage (BECCS) (Section 2.6).

Chapter 3 to 5 form the centerpiece of the thesis. First, the current discourse is recapitulated on the basis of a selected corpus of literature representing the buying time idea (Section 3.1). From those quotes, several implicit assumptions of the buying time argument are derived. Two kinds of implicit assumption can be distinguished: Assumptions that relate to a desirable climate goal, and assumptions that refer to future political and social development. Those assumptions shape the formulation of the BT-argument.

The buying time argument is then translated into a deductively valid premise-conclusion-structure (Section 3.2). The central principle (buying time principle) is designed so as to capture the different implicit assumptions identified in the previous section.

The BT-principle works with two placeholders – climate goal G and policy option O. I identify two overarching climate goals that are associated with the buying time idea: Avoiding dangerous climate impacts and reducing pressure. Those goals are further specified with two respective sub-cases, resulting in four instantiations for climate goal G, the desirability of which is also established in Section 3.3.

In order to evaluate any version of the BT-argument, both placeholders need to be replaced. In Chapter 4, four specific climate engineering scenarios are introduced as instances of policy option O: Two for sulfate aerosol injection (SAI) and two for bioenergy with carbon capture and storage (BECCS), with one scenario of each assuming CO_2 emissions to remain within the two-degree budget, and one assuming an overshoot. The scenarios have been chosen so as to resonate with the buying time idea, and to discuss whether the different climate goals associated with the BT-argument might be realized through option O. The first scenarios depict a moderate SAI deployment in order to lessen the rate of temperature change (Section 4.1). The latter scenarios are BECCS scenarios that technically increase the two-degree emission budget (Section 4.2). The results from Chapter 3 and 4 are connected, and an argument matrix of sixteen fields is established by plotting the four instantiations each of placeholders O and G against each other (Section 4.3). Those constitute the sixteen versions of the BT-argument that are checked for plausibility in Chapter 5.

Chapter 5 then evaluates the different versions of the BT-argument. Surprisingly, only two arguments can instantly be called plausible (Section 5.1): Moderate SAI plus sufficient mitigation could help avoid rate-dependent tipping points as well as help reduce adaptation pressure (argument a2 and a3[8]).

Other combinations of G and O yield at least one implausible premise, which quite easily can be detected (Section 5.2). The remaining versions are neither obviously plausible nor obviously implausible (Section 5.3). On the one hand, the evaluation of

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[8] For the numbering of the arguments see Summary or Section 4.3.

at least six arguments is impossible in the scope of this work, since they rely on scientific findings that are inaccessible to me.

On the other hand, I identify two versions of the BT-argument (B1 and B4, of which only B4 is discussed), whose status is unclear, because the design of the BT-argument itself may be questionable. Both argument versions adopt the prominently discussed case of BECCS as a means to buy time in face of less than sufficient mitigation which turns out to be at odds with at least two buying time requirements: The finitude requirement and the no-impediment requirement. This scenario, however, may be necessary from a practical point of view. The BT-requirements might turn out to be too rigid for this case, hinting at a possible revision of the BT-argument.

The next chapter will try to reformulate the BT-argument so as to capture the BECCS scenario in question (Section 6.1). Especially the possibility of acceptable substitution will be further examined. But, as the discussion will show, a weak version of the BT-argument which does not include a finitude requirement and reckons with acceptable substitution is no buying time argument at all. That is not to say, however that the respective deployment scenario is morally wrong – only that it is no buying time deployment.

Finally and lastly, the research thesis at hand scrutinizes general moral constraints on CE deployment. This will be discussed by means of the two plausible SAI-instantiations (argument a2 and a3). The question is: If each of the strong BT-requirements is plausibly met, could CE deployment still be morally wrong? I will focus on two general moral objections to CE deployment – the hubris- and the techno-fix argument.

In the last chapter (Chapter 7), the numerous questions that still remain unresolved are resumed and an outlook on possible areas of further research is given. Those include argumentation theory, virtue ethics and degrowth.

Chapter 2 The Climate Engineering Controversy

This chapter serves to set the scene for the following research. First, establishing the canonical distinction of solar radiation management (SRM) and carbon dioxide removal (CDR) further deepens the concept of CE. If CE is to be deployed, it will be embedded in a complex policy mix consisting in mitigation, adaptation and (possibly) CE. Thus, CE is discussed as a possible part of a comprehensive climate policy portfolio (Section 2.1).

Having introduced a broad definition of CE, the next section sets the basic corner stones for the moral controversy on CE. In climate ethics, the pivotal moral obligation of the current generation is the obligation to pursue drastic emission cuts (mitigation obligation) (Section 2.2). In light of this obligation, the moral controversy on CE is further portrayed (Section 2.3). Following Betz and Cacean (2012), the main theses and arguments pro and contra research and deployment of CE are given.

The argument reconstruction of Betz and Cacean (2012) uses the placeholder T for a CE technology. The authors reason that some arguments only apply to a certain technology or a group of technologies. Arguments about *CE in general* usually fall short, since the diverse features of individual technologies might not even be touched by the argument at stake. Hence, the placeholder T ought to be specified when evaluating the arguments. This resonates with the objection that not even the broad categories of CDR and SRM do the technology assessment justice. In discussing arguments that clearly do not apply to certain (groups of) technologies, I will make a case for a technology- and even portfolio-specific evaluation of the BT-argument (Section 2.4).

Consequently, only two technologies will be of focus in the following investigation. The subsequent sections will introduce sulfate aerosol injection (SAI) (Section 2.5) and bioenergy with carbon capture and storage (BECCS) (Section 2.6).

2.1 Climate engineering and policy responses to climate change

Ever since climate change was recognized a global problem, responses to this problem were categorized as being either part of a mitigation or of an adaptation strategy. The 2007 Assessment Report of the International Panel on Climate Change (IPCC) knows only those climate strategies, as well, and states that "societies can respond to climate change by adapting to its impacts and by reducing GHG emissions (mitigation)" (IPCC 2007, p. 56). Mitigation efforts can be determined in resemblance to the four Representative Emission Pathways (RCPs) that have been modeled to illustrate emission trajectories and corresponding effects (van Vuuren 2011). RCP2.6, for example, is deemed to be coherent with limiting global temperature rise to two degree Celsius above preindustrial level. But both recent political development as well as natural inertia (many effects of past emissions cannot be reversed (Solomon 2009)) give rise to the belief that limiting global warming by political and social means only is out of reach.

> "Even if an aggressive global mitigation program is undertaken, substantial reductions in greenhouse gas levels would not be realized for several decades, and the halting or reversing of some of the detrimental effects already built into the climate system (e.g., ocean warming, ocean acidification, polar ice melting, sea level rise) would not follow for many decades or even centuries beyond that."
> (McNutt et al. 2015a, p. 18)

Consequently, the need for other, additional solutions is voiced. One set of technologies to battle global warming is known as climate engineering (CE). Paul Crutzen has openly discussed CE as a third option besides mitigation and adaptation (Crutzen 2006). It has since been advocated as part of a reasonable climate policy portfolio (e.g. Keith 2013, Long 2016).

Climate engineering itself is defined as the "deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change" (Royal Society 2009, p. 77). It aims at delaying or even offsetting climate change impacts technically by either manipulating the global mean temperature directly or by removing CO_2 from the atmosphere. According to those two approaches, one can distinguish two kinds of CE-technologies: 1. solar radiation management (SRM) and 2. carbon dioxide removal (CDR).

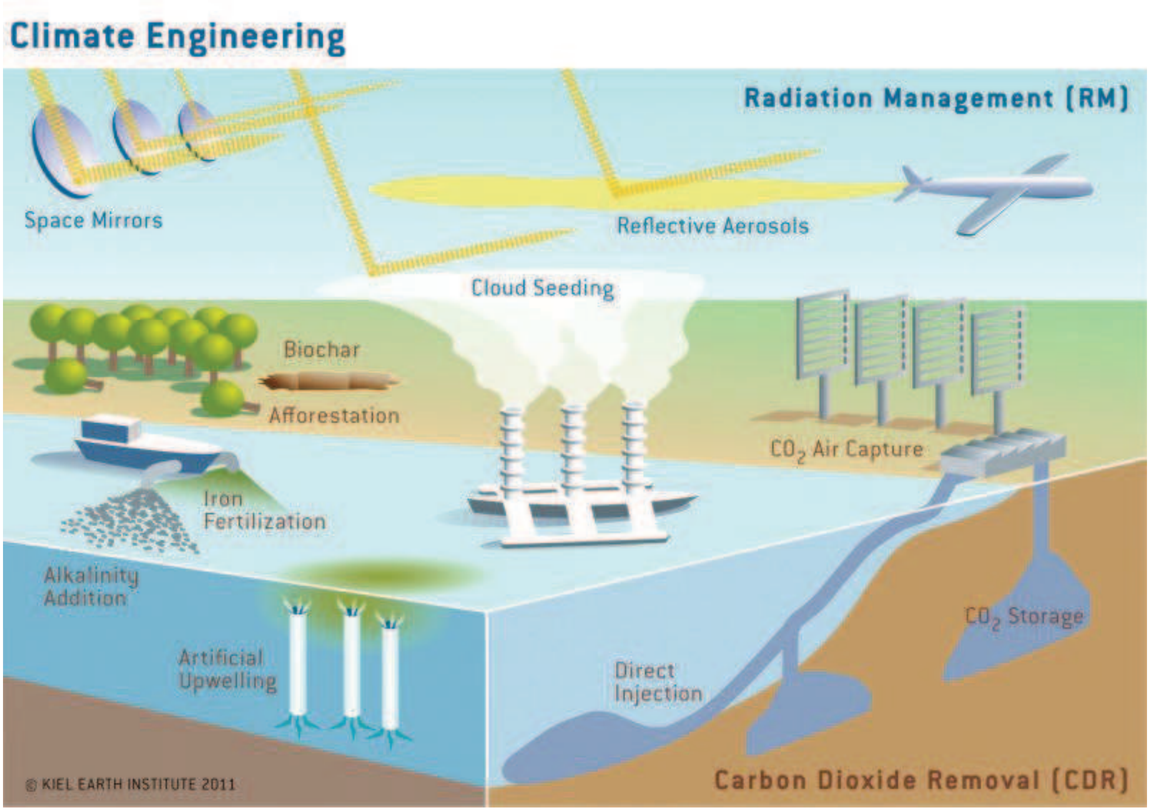

Figure 2. Different climate engineering technologies, sorted by SRM and CDR approaches (source: Kiel Earth Insitute 2011).

1. SRM. In order to control and stabilize the global mean temperature, Solar Radiation Management (SRM)-technologies influence the energy balance of the earth by reflecting the incoming sunlight and thus influence the radiative forcing. Reflecting SRM schemes might be situated in the atmosphere (*reflective aerosols*) or even in outer space (*space mirrors*). While the idea of space mirrors would actually amount to reflective particles orbiting earth, this idea is not very prominently discussed due to technical and financial difficulties. Some more promising strategies include the enhancement of cloud formation (*cloud seeding*), which shield a significant amount of sunlight. However, the physics behind cloud formation is still very little understood which may lead to great uncertainty regarding the side effects of this set of technologies (Royal Society 2009).

Injection of reflective aerosols, mostly sulfate aerosol (*sulfate aerosol injection,* SAI), has been researched into at large. There is quite a corpus of literature that focuses on different aspects of this technology, ranging from the technical and physical aspects to moral issues and governmental challenges. The latest comprehensive overview on the different aspects of this technology can be found in the National Academy of Science's 2016 study (McNutt et al. 2015a and McNutt et al. 2015b). It summarizes the state of the art on SAI research and is used as the main resource for the thesis at hand.

The common aspect of Solar Radiation Management strategies is their ability to influence the global mean temperature directly. SRM technologies are deemed to be quick and effective (see Section 2.3), but they don't address the root cause of climate change – the concentration of CO_2 in the atmosphere. This is also reason for a mostly negative stance towards SRM technologies, since a symptomatic approach towards climate change is associated with the reprehensive attitude of 'techno-fixing' climate change (see also Section 2.3 and Section 6.2).

2. CDR. The second group of climate engineering strategies aims at directly removing carbon dioxide from the atmosphere (Carbon Dioxide Removal, CDR). This may happen through mechanical or technical *carbon air capture*, for example via *artificial trees* or *biochar*, or by enhancing natural CO_2 sinks, such as *ocean fertilization*, enhancement of *oceans alkalinity*, and *afforestation*. A combination of those approaches is the technology bioenergy with carbon capture and storage (BECCS). Biomass is harvested and combusted for energy production, while the resulting CO_2 emission is captured and stored underground. BECCS is seen as a very promising approach in climate policies, and is the second technology that this thesis focuses on.

Even though CDR-technologies treat the root cause of climate change, i.e. the concentration of carbon dioxide in the atmosphere, they too have great influence on natural cycles. It is not clear, for example, how the enhancement of the ocean's alkalinity affects the ecosystem. Afforestation struggles with problems like land use conflicts, influences on wildlife habitat or a trade-off with the earth's albedo (Rickels et al. 2011, Royal Society 2009). Besides these problems, CDR technologies are generally more expensive than SRM schemes, and take much longer to show effect. As such they might not be able to prevent a sudden and catastrophic change in climate.

The best way to manage climate change is arguably a portfolio of different strategies. CE could be part of a climate policy portfolio, adding to mitigation and adaptation (Wagner and Zeckhauser 2012, Rayner et al. 2013, Morrow 2014). However, the portfolio approach to climate politics might oversimplify the problems at stake. Since

CE and mitigation might have interdependencies, and CE might inflict a reduction in mitigation efforts, a purely additive concept of a portfolio might be myopic (Gardiner 2013, Morrow 2014). The difficulties with the portfolio approach will be further addressed in context of allowed substitution (Section 2.2, 3.2, 5.4 and 6.1). For now, it suffices to take CE as another option in a potential climate policy mix.

2.2 Mitigation obligation

The fundamental believe in climate ethics is that future generations have the same moral rights as the current generation. In particular, future generations have the right to have access to an array of lifestyle options equal to (or at least comparable to) our current choices.

One influential model, which argues for equal options for future generations, is the 'equity model' of Edith Weiss (Weiss 1989, Weiss 1992). She coined this model as opposed to the opulence model, in which the current generation raises its standard of living and accumulates maximum wealth by consuming as much natural capital as possible. According to Weiss, the opulence model has serious shortcomings, since it overlooks the long-term effect of nature degradation. The equity model, on the other hand, states that future generations should have at least the choice to pursue the same standard of living as the current one by the same means. For the current generation, this implies a moral obligation to preserve such choices, especially with respect to natural capital.

Regarding climate change, irreversible climate impacts, occurring at so-called climate tipping points, would limit the options of future generations inadmissibly. Tipping points are climatic situations that tilt the sensitive balance of the climate system beyond recovery, with possibly disastrous consequences. Tipping points are characterized by the fact that the initial state cannot be restored, even if the initial parameters were to re-emerge. There is a number of climate tipping points, such as the Amazon rainforest dieback, the loss of the Polar ice packs and melting of the Antarctic ice sheets (Lenton et al. 2008).

Since tipping points may limit the options of future generations and possibly impair their standard of living, they ought to be avoided. If, on the other hand, the two-degree target is realized, there is the chance of avoiding most (if not all) of those tipping points. In this sense, the two-degree target is the quantitative measure to realize the equity model of climate ethics. It also is the commonly agreed upon climate goal in global climate politics. The Paris Agreement (see Section 1.1) even speaks about stabilizing global warming at "well below 2°C". As of July 2017, 153 out of 197 Parties have ratified the commitment.[9]

At the same time, mitigation – the drastic reduction in GHG emissions – has been the preferred option for realizing the two-degree target. Since its emergence, the IPCC report has highlighted the importance of emission reduction. The Kyoto Protocol, which was launched in 1992, has committed its parties to the reduction of GHG emissions (UNFCCC 1998). National declarations such as the WBGU Guidelines (WBGU 2014) declare mitigation to be the priority in climate protection.[10]

The central position of mitigation to achieve the two-degree goal, however, is wavering when other options reach the same goal. While in the 1980s and 1990s discussion on CE was an academic niche, the 2006 article by Paul Crutzen (Crutzen 2006) introduced CE and in particular SAI to the discussion about the best climate policy.

The moral obligation to mitigate is therefore no longer absolute, but must be assessed relative to all other options that achieve the same goal. The obligation to reduce emissions must be defended against SAI and other CE options. This shall be done at this point, thus establishing a *prima facie* obligation for mitigation as opposed to CE.

Whether the mitigation obligation still holds in face of other measures, which also reach the two-degree target, depends on whether these measures can replace mitigation. Can SRM and CDR be regarded a substitute for mitigation?

Baatz and Ott (Baatz and Ott 2016) define a substitute as follows:

> „Y is a substitute for X if Y achieves the same aim as X. (...) Strategy Y is a perfect substitute for mitigation if it avoids all negative climatic effects resulting from GHG emissions, without thereby creating other harms or risks."
>
> (Baatz and Ott 2016, p. 99f)

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[9] In June 2017, President Trump has declined to ratify the Paris Agreement. The consequences of his choice may prove devastating for global climate protection. On the other hand, in July 2017 at the G20 summit in Hamburg (Germany), all other 19 states have agreed to further pursue the Paris Agreement, isolating the US climate policy. What effect this development has for potential CE deployment is unclear.

[10] Other obligations constituted by climate ethics transgress the mitigation obligation, like the obligation to help developing countries to adapt, or to obligation to compensate for current climate damages. Those obligations are connected with the mitigation obligation, but cannot be further addressed in the scope of this work.

The authors argue that SRM and CDR are no substitutes for mitigation, since they either do not eliminate all negative effects of climate change (e.g. ocean acidification), or generate additional risks. In the case of CDR measures, this conclusion may be weakened and the authors admit that some small-scale, moderate CDR may very well be a perfect substitute for mitigation. However, due to the cost intensity and the land use restrictions for these measures (see Section 2.6), large-scale CDRs cannot be considered a perfect substitute. Since CE measures, if they were to be applied, would not substitute mitigation efforts, the moral obligation to mitigate still holds.

Even an optimal portfolio mix cannot relieve the current generation from the basic obligation to drastically mitigate. From this the authors conclude that mitigation is the *primary* obligation. Adaptation, SRM and CDR are *secondary* obligations that result from the inadequate realization of the primary commitment. They follow from the primary obligation; they do not make it obsolete.

Baatz (2016) provides another strong argument as to why mitigation is preferable to CE. He further advances the dilemma-argument (Ott 2012) and argues that, in particular, SAI can lead to a dilemma for future generations, if it is carried out without parallel aggressive mitigation measures. According to Baatz, future generations could find themselves between scylla and charyptis: They would either have to continue to operate SAI and would have to bear the possible negative consequences of its deployment, or they would have to end SAI abruptly and thus would have to experience accelerated climate change. Baatz argues that, the more mitigation is pushed, the lower is the probability for future generations to face this dilemma will be. If the dilemma-argument holds, mitigation is not only a *prima facie* obligation, but is compulsory especially in face of SAI deployment.

Gardiner (2013) has argued in a more fundamental fashion against deploying CE headlong. He has elaborated on the moral ‘schizophrenia’ which is present in demanding CE to be a moral obligation, promoting it as a viable or single alternative to mitigation, while ignoring the primary obligation to mitigate first. In his view, this moral schizophrenia is reason not to pursue CE development and deployment, but rather focus strongly on the mitigation obligation.

All in all, the mitigation obligation is can be established as an *all things considered* obligation, that holds even in face of possible CE. The reasons for this strong obligation are the imperfect substitutability between CE and mitigation, the possible unmanageable side effects of CE and the dilemma generated by certain forms of CE, like SAI. From an existential moral point of view, the suspension of the mitigation obligation shows signs of moral corruption, and even schizophrenia (Gardiner 2013). However, this does not define the extent of mitigation. In an ideal world, the two-degree target should be achieved with mitigation alone (if this is still possible[11]). The mitigation obligation could then be defined quantitatively, e.g. as a certain emission trajectory like the RCP 2.6 (van Vuuren 2011), or as a carbon emission budget (Schellnhuber 2009). In a non-ideal world there are manifold trade-offs to other legitimate political objectives (e.g. economic security, infrastructure development, social order, etc.). So, at this point, only a qualitative determination of the mitigation obligation is adopted. Some qualifiers are used synonymously in the work at hand: fast and far reaching (Baatz and Ott 2016), aggressive, ambitious, drastic, sufficient mitigation, decarbonization, change in modes of production and consumption, and so on.

A determination regarding the timespan of mitigation can be incorporated nevertheless: Mitigation and decarbonization respectively, is a task of the near future and cannot be postponed (passed down) indefinitely. However drastic mitigation may look like, it ought to be realized within the next few decades.

For the continuation of this work, the mitigation obligation is defined as follows:

> **(Mitigation Obligation)** The current generation has the moral obligation to drastically reduce their CO_2 emissions within the coming decades.

This broad definition is the moral starting point of the following investigation. The moral obligation to mitigate is an independent obligation that ought to be met regardless of possible CE deployment.

2.3 Main theses and arguments in the moral debate

The first comprehensive argument-analysis on the moral controversy about CE has been conducted by Betz and Cacean (Betz and Cacean 2012, also Rickels et al.

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[11] Baatz seems to think that the two-degree target can still be realized with mitigation efforts alone (Baatz 2016).

2011)[12]. In their landmark report they map the normative issues surrounding CE. They distinguish arguments regarding the deployment and those regarding the research of CE technologies. Moreover, they use the placeholder T for any specific CE technology. They reason that some arguments only apply to a certain technology or a group of technologies. Arguments about *CE in general* usually fall short, since the diverse features of individual technologies might not be addressed by overarching arguments that necessarily homogenize different technologies. Hence, placeholder T ought to be specified when evaluating the arguments.

The central thesis of the argument map is the claim that CE should be researched into immediately. This claim is backed by three theses: Readiness for deployment is desirable; side effects of research and development are negligible; and there is no alternative to immediate research.

First of all, one major driver behind researching into a new technology is the prospect to deploy it. The desirability of deployment of any CE technology is the necessary condition for its research. In other words: If the deployment was morally wrong or not wanted for other reasons, then why research at all? Consequently, the majority of the moral arguments about CE address the desirability of CE deployment.

Secondly, research on CE should only be carried out, if the side effects of this research are deemed to be negligible. Lastly, it is assumed that in order to have a certain technology ready 'in time' research ought to be carried out immediately.

On CE deployment

A number of arguments support the possibility of deploying CE[13]. One of them is the lesser evil argument, also known as the arm-the-future argument (Betz 2012a). The lesser evil argument assumes that there might be a future point in time where we would have to choose between dangerous, unabated climate change on the one hand, and the deployment of CE on the other. In this case, CE would clearly be the lesser evil. The deployment of CE then would indeed be desirable (if not unavoidable). Because of this prospect, one should start researching into CE technologies now, in

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[12] Unless indicated otherwise, the following chapter is a direct synopsis of Betz and Cacean 2012 and all quotes are from there.

[13] Note, that there is no literature arguing in for immediate CE deployment. The possible need for deployment and the possible benefits of CE are highlighted in current literature. Still, scientists argue very carefully, only suggesting that CE might eventually be part of a policy mix, if certain criteria are met.

order to have them ready in time and grant future decision makers an additional option to their climate portfolio (arm the future).

This line of reasoning, which is among the most prominent in favor of CE, can be attacked in various ways: For one, it is not obvious that CE will really be the lesser evil. Taking into account the many unclear side effects, it is debatable what is seen as 'less' or 'evil' (Betz 2012a). Additionally, as Gardiner (2010) argues, there are choices that may be tarnished in each case. Intentional climate manipulation might be one of those choices.

The lesser evil argument is akin to the emergency argument. In a climate emergency, where global climate impacts happen fast and intense, CE might serve as a back-up plan, an insurance that serves as a shield against this kind of catastrophe (Betz 2012a, Hamilton 2013, Keith 2013, Uther 2013). Lately, the emergency framing of climate change has been challenged. Invoking an emergency situation in order to justify the deployment of a risk technology might lead to problematic political and social implications (Horton 2015, Sillmann et al. 2015). First of all, it is not clear what would count as an emergency situation and who has the power to define it. If an emergency state was to be declared, power might concentrate in the hands of a few, with the associated risk of abuse (Horton 2015). The legal status and political background of an emergency situation might threaten deliberative, democratic structures. Additionally, as Gardiner (2010) has prominently pointed out, there is no moral obligation to prepare for an emergency situation that we still have the capacity to avoid (or at least reduce).

The rebuttal of the emergency framing also gives rise to the argument central for the thesis at hand: the buying time argument. Instead of preparing for an emergency scenario that we could arguably still avoid, CE could be used as a stopgap measure to buy time until climate politics show effect. This argument will be developed in detail in the following chapters.

Another argument in favor of CE deployment relates to the two-degree target. As said before, political and social efforts may not be enough to stabilize temperature at this level. Hence, the deployment of CE seems necessary. This argument relies on assumptions about the future development of international climate politics, which might be pessimistic. Assuming the necessity of CE because of insufficient mitigation efforts could also turn out to be a self-fulfilling prophecy and enhance a trade-off with mitigation.

A third line of reasoning pro potential CE deployment calls to the monetary benefits of CE in comparison to fast and far reaching mitigation. CE is deemed to be quicker and easier than drastic mitigation; hence deploying it would be economically rational Those kinds of arguments are easily rebutted, for ease and effectiveness are by no means the only issues when considering CE deployment. Negative side effects of CE might seriously outweigh the benefits of quick and easy deployment.

The largest group of arguments against CE deployment consequently relates to potential side effects of deployment. Critics of CE fear unseen and uncontrollable effects on the environment (Robock 2008). Hence, they oppose the deployment and consequently the research of CE technologies. For advocates of research precisely this uncertainty is reason to deepen the research.

Additionally, the deployment of CE might lead to great injustice. Especially with SAI, studies indicate that the ecological impacts will be distributed unequally, potentially harming the world's vulnerable more than the already benefitted. Especially native peoples that contribute the least to global warming might be affected substantially by artificial climate modification. The question of consent becomes essential in such cases (Whyte 2012).

There is also a discrepancy between local and global effect of CE. While globally, a CE technology might turn out to be beneficial, local side effects such as dangers associated with underground storage of CO_2, or the change in regional precipitation patterns might prove to be harmful for the affected areas. This inequality is morally relevant, if it cannot be compensated for. This again might give reason not to deploy CE.

Taking the numerous side effects into account, CE has been criticized on a general note. CE is seen as a new form of human hubris that aims at controlling nature regardless the consequences. Such arguments claim that CE shows the failure of a people that cannot live on a given environment without destroying it ("fouling the nest") (Fleming 2010, Gardiner 2012). Lastly, religious considerations speak against the deployment of CE, for it is seen as a violation of a God-given order.

On CE research and development

The most prominent argument against research is the so-called moral hazard argument (which can also applies to the possible deployment of CE). In short, it states that the prospect of CE deployment will diminish the efforts to mitigate. From the moment that CE deployment becomes a real option, mitigation will seem unattractive. In comparison to 'easy and effective' CE, mitigation seems expensive, time consuming and tedious. But since mitigation efforts are arguably the priority in tackling climate change, CE should not be offered as a cheap solution (Corner and Pidgeon 2010, Hale 2012, Lin 2013, Morrow 2014).

Advocates of CE meet this concern by pointing out that CE and mitigation are no alternatives, but rather equal parts of a comprehensive climate policy portfolio. Many arguments in favor of CE assume that any CE deployment will be accompanied by serious mitigation efforts[14]. Under this perspective, the assessment of CE depends on the supporting climate strategies like mitigation and adaptation. This is also the reason, why the investigation at hand evaluates the BT-argument in light of comprehensive deployment scenarios, and not with respect to CE alone.

However, as stated before, there are many uncertainties tied to CE deployment. Advocates of CE research argue that those uncertainties can only be resolved through further research. In order to enable a robust political decision about future climate actions, decision makers must be provided with all relevant information. In researching different options for tackling climate change, current and future decision makers would then have more choices of action (arm-the-future argument, see above). A global 'moratorium' on climate engineering research could help enable an informed, consensual decision. On the other hand, there might be irreducible uncertainties associated with CE deployment, which even further research cannot eliminate (Section 6.2.1).

2.4 Challenging the canonical distinction

So far, CE has been discussed as an umbrella concept, with only distinguishing between the two broad categories of CDR and SRM (Section 2.1). But as stated in the previous section, arguments about *CE in general* are usually shortsighted, and may not be applied to individual technologies. Instead, I propose that arguments about the deployment of CE need to be technology-specific and must account for an at least broadly sketched climate portfolio. This is due to two reasons:

1. The terminology about CE might be insufficient and biased.

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[14] For an overview on this literature see Baatz (2016).

2. Some arguments do not apply to some (groups of) technologies.

1. Terminology insufficient. CE technologies have been introduced as another strategy to tackle climate change as opposed to mitigation or adaptation. But, as mentioned in Section 1.1, at least CDR technologies are related to mitigation strategies, as they too aim at reducing the CO_2 concentration in the atmosphere.

Over-simplifying the group of CE and CDR technologies in particular, might hinder progress in ethical as well as legal discussion. The definition of a technology influences the legal framework, under which its deployment might be regulated. While mitigation technologies might be regulated domestically, CDR technologies might fall under strict international agreements about nature conservation (Reynolds 2014, Reynolds 2015, Armeni and Redgwell 2015). Hence, it is crucial to define what mitigation strategies amount to as opposed to CDR technologies.

The objective of mitigation is to reduce, limit and stabilize climate change at a certain level. The IPCC defines Mitigation:

> “Mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases.”
> (IPCC 2014a, p. 4)

The above quote mentions two aspects of mitigation: *reduce the sources* and *enhance the sinks* of GHGs. Both parts do not rule out that CDR measures can be seen as part of mitigation. Especially BECCS aims at capturing CO_2 before it enters the atmosphere, and hence can be said to reduce the source of emission. Additionally, biomass acts as a natural sink for CO_2.

So, it seems crude to frame mitigation and CE (including CDR) as two clearly distinct strategies. They overlap – moreover, depending on the definition, are equal. Another, more promising categorization comes from Clare Heyward (Heyward 2013). She urges to abandon the dichotomy between Mitigation and CE strategies, since the attributes for this distinction are insufficient, too broad and too vague. Heyward especially finds the often-cited Royal Society’s definition of CE as “deliberate, large-scale manipulation of the planetary environment in order to counteract anthropogenic climate change” (Royal Society 2009, p. 77) unhelpful when discussing the special ethical issues associated with climate responses.

Her proposal is to distinguish the strategies according to the *point* at which they occur in the “process between emitting GHGs and the loss of human wellbeing” (Heyward 2013, p. 25).

Aim	**Avoiding climate change**			**Avoiding “dangerous” climate change**	**Responding to dangerous climate change**
	Avoiding a given level of atmospheric GHG concentration.		Avoiding global average temperature increases.	Ensuring that rising temperatures do not impact upon core interests.	Providing redress for injuries to core interests.
Strategy	**Mitigation** Reducing GHG emissions.	**CDR** Drawing GHGs out of the atmosphere.	**SRM** Increasing Albedo.	**Adaptation** Improved irrigation, flood defences, protection against disease.	**Rectification** Financial compensation, symbolic reparation.

Table 3. Categorization of CE technologies according to Heyward 2013.

In this categorization, mitigation and CDR are distinctly separated, as the former aims at reducing CO_2 output *in the first place*, and the latter at minimizing the present CO_2 concentration *ex post.*

Another set of CE definitions has been developed independently, but in close resemblance to Heyward’s proposal. The authors (Boucher et al. 2014) argue that an unclear definition of CE technologies might obscure and even prevent political decision-making. They propose a different terminology, in which CDR measures no longer count as mitigation measures, but rather constitute a separate form of climate interventions, and SRM technologies might even fall under adaptation measures. Most notably, they present a separate category of domestic CO_2 removal, which enables the distinction between local and global CDR.

Proposed Name and Acronym	**Short definition**	**Examples**
Anthropogenic emissions reductions (AER)	Initiatives and measures to reduce or prevent anthropogenic emissions of warming agents into the atmosphere.	Improved energy efficiency, reduction in production and/or consumption of goods and services, introduction of renewable energies, nuclear energy, fossil fuel energy with CCS, reducing emissions from deforestation and forest degradation, emission reductions of BC and ozone precursors.
Territorial or domestic removal of atmospheric CO_2 and other long-lived greenhouse gases (D-GGR)	Removal of CO_2 and long-lived greenhouse gases from the atmosphere operating within national jurisdictions and little consequences outside.	Reforestation, biochar and other means of increasing storage of C in soils, small-scale afforestation, BECCS, CO_2 air capture and storage in territorial (geological) reservoirs, enhanced weathering (without input of by-products into rivers or the oceans).
Trans-territorial or trans-boundary removal of atmospheric CO_2 and other long-lived greenhouse gases (T-GGR)	Removal of atmospheric CO_2 and long-lived greenhouse gases from the atmosphere operating or having consequences partly or fully across or beyond national jurisdictions.	Large-scale afforestation, ocean alkalinity, enhanced weathering (with input of by-products into rivers or the oceans), iron fertilization, injection of CO_2 into the ocean.
Regional to planetary targeted climate or environmental modification (TCM)	Intentional modification of the Earth's energy fluxes in order to offset climate change at the regional to global scale.	Injection of stratospheric aerosols, marine cloud brightening, cirrus suppression, desert brightening on a large scale, ocean heat mixing, modification to Arctic sea ice.
Climate change adaptation measures including local targeted climate or environmental modification (CCAM).	Initiatives and measures to reduce the vulnerability of natural and human systems to the effects of climate change. Local risk management.	Relocating urban or rural settlements, building dykes, air conditioning, agricultural crop choices, reflective crops, whitening of human settlements on a small scale, irrigation.

Table 4. Incomplete Table according to Boucher et al. 2014. Only the definition and examples are reprinted, while the original table of Boucher at al. also includes: Mapping onto existing terminology, Scale of Action, Scale of Impact, Impact on the global Commons, Trans-Boundary or Trans-National Side Effect and Permanence of the Effect.

Following this terminology, there is a clear distinction between measures that remove CO_2 from the atmosphere and measures that reduce its initial output. This allows to frame negative emission technologies like BECCS as CDR measures (D-GGR in terms of Boucher et al. 2014) as opposed to mitigation strategies (AER). While I will not exactly share the nomenclature of the presented terminology, for my purpose it is important to note that BECCS is not a mitigation approach, but generally counts as a CE technology.

The results so far suggest that a general discussion of CE technologies falls short, since it is not at all clear, what 'CE' technologies are. While there are evaluation patterns that apply to CE in general or to some technology groups, there might be nevertheless single features that are obscured by a generalization. This finding correlates with the decision to use the placeholder T in the argument map introduced above. Betz and Cacean (2012) suggest that the moral arguments about CE can only be fully evaluated, when the placeholder T is substituted with a concrete technology. This goes even beyond a redefined terminology, but instead asks for a technology-specific evaluation of the arguments.

2. Technology-specific arguments. General arguments about CE might obscure certain aspects of a technology or of its envisaged deployment. This is true not only of the technologies themselves, but also of the portfolios in which they are embedded. Each technology should be evaluated in a comprehensive climate portfolio, where both the extent of its planned deployment as well as the additional climate options like mitigation is taken into account. To illustrate this, I will briefly discuss some arguments which are not applicable to certain technologies, or, even if they are technology-specific, do not apply to all possible deployment scenarios.

Emergency-Argument

Some authors see CE as a kind of emergency insurance, in case climate change is faster and more severe than expected (Section 2.3). CE could then help to stabilize temperature and to avert the worst effects. The insurance metaphor is therefore closely linked to the emergency-argument. While we should put all our efforts into preventing a climate catastrophe, the damage could be so immense that we should be prepared for its occurrence.

An insurance measure should quickly and effectively balance out the catastrophe against which it is made, and compensate for its damage. Hence, the focus of authors adopting this emergency-metaphor lies on the controllability and economic rationality of CE measures (Luokkanen et al. 2013). This might be the case especially for SAI, since it is deemed to be easy to apply, cheap in its maintenance costs and rather effective in cooling the earth.

The emergency framing loses its impact when used for CDR measures. Due to the physical inertia of the atmosphere, effectiveness of CDRs is only visible after years or even decades. While during an abrupt temperature rise with potentially irreversible effects, SAI could be used quickly and effectively to stabilize temperature artificially, CDR can only stabilize temperature in the long term. Emergency considerations do not apply to CDR technologies.

Termination problem

If SAI is used as a substitute for fast and far reaching mitigation, CO_2 concentration will continue to rise. Only the effect of high CO_2 concentration, namely the temperature rise, will be artificially influenced and stabilized. An abrupt termination of SAI (for example, due to social and political upheavals) would lead to an accelerated heating enforced by the large volume of atmospheric CO_2 (Royal Society 2009, Robock 2008). This might be disastrous for the climate and the biosphere. Additionally, this situation could put future generations in a dilemmatic situation: Either they would have to decide to continue to operate SAI, with possibly fatal side effects, or they would have to accept accelerated climate change (Ott 2012, see Section 2.2).

The termination problem is obviously coined for a specific case: SAI deployment without adequate mitigation. It is easy to see that SAI does not lead to a termination problem when it is accompanied with drastic mitigation cuts – for example in a buying time scenario.

Furthermore, the termination problem does not apply to any types of CDR measures – for they do address the root cause of climate change by reducing the CO_2 content in the atmosphere. Even if CDR measures were used as an alternative to and a substitute for CO_2 emission reduction, and were to be discontinued, there would be no rapid temperature rise as in the illustrated SAI case.

Dual use

A very special problem is connected to SRM technologies. Due to their influencing the radiative balance, they can manipulate local weather patterns with potential negative side effects. For example, local floods or droughts can be triggered by SAI. This makes SAI and other SRM technologies potential weapons of warfare (Corner and Pidgeon 2010, Goodell 2010). In fact, the idea of weather manipulation as an instrument of warfare goes back a least to the middle of the last century and much of the research on SAI and other SRM technologies is based on military research of similar schemes (Fleming 2010). Weather modification for the purpose of warfare is prohibited by international convention, and the 'rearmament' of these technologies could already be read as a violation of the convention (Corner and Pidgeon 2010). Obviously, however, this specific risk is only present for SRM or SAI. It is difficult to conceive a weapon of mass destruction being derived from long-term CDR measures. That being said, some specific forms of CDR, like ocean fertilization, might very well be used as a form of large-scale pollution with hostile intentions.

Some arguments, on the other hand, apply to all CE technologies, albeit specified to the technology at hand. Consideration of procedural and distributional justice, for example, should be addressed for all CE technologies. But the examination of those issues too is case-different. And while for one technology a fair distribution of its side effects might be found, other technologies might not allow for an equitable solution. Here, too, technology- and portfolio-specific arguments ought to be made.

Taking all this into consideration, I will focus on two specific climate engineering technologies: sulfate aerosol injection (SAI) and bioenergy with carbon capture and storage (BECCS). Also, according to the results of the previous sections, in evaluating the BT-argument, I will concentrate on two different deployment scenarios – or policy mixes – for each technology. Accompanying climate options like mitigation influence the intensity and time frame of the technology-deployment and hence shape its evaluation. Especially, I will make a case-discrimination with respect to mitigation efforts. Before those deployment scenarios will be discussed, the physical background of the technologies is delineated. Sections 2.5 and 2.6 draw substantially from McNutt et al. (2015a) and Rickels et al. (2011). If not indicated otherwise, the depiction of the technologies is a direct synopsis of McNutt et al. (2015a); this also goes for the indication of further literature.

2.5 Sulfate aerosol injection

Scientists have pursued the idea to intentionally manipulate the weather at least since the middle of the 19th century (Fleming 2010). The ‘promethean dream’ to control the climate has a long history that is partially connected to the military use of ‘weather control’ (Hamilton 2013). It was the observation of temperature declining after the Mount Pinatubo eruption in 1991 that gave the idea of climate intervention as a way to tackle climate change broader support and eventually led to further research on sulfate aerosol injection (SAI) (Crutzen 2006). Small particles of sulfur in the stratosphere are thought to reflect some amount of incoming sunlight, thereby reducing the radiative forcing and thus stabilizing the ambient air temperature at a certain degree. SAI currently is the most prominently discussed SRM-technology, for it is deemed to be cheap and effective. Many scientists think of it as a ‘Plan B’; an insurance if all other efforts to combat climate change fail (see Section 2.3)

Many studies attest SAI the ability to stabilize temperature (McNutt et al. 2015a, Rickels et al. 2011, Royal Society 2009, Wigley 2006, Robock et al. 2009). However, temperature is by no means the only problem of climate change. First of all, since SAI does not change the carbon dioxide concentration in the atmosphere, it cannot address problems caused by it, e.g. the acidification of the oceans (Robock 2008). It will most likely affect global precipitation patterns, thus potentially enhancing droughts or floods in countries already affected by climate change. It is also not clear who will regulate the development, let alone the deployment. Last but not least, precisely because of its ability to serve as a Plan B and a last resort for catastrophic climate change, the danger of lessening mitigation efforts might turn out to be a problem (Section 2.3). For a better understanding of the issues surrounding SAI, the scientific background will now be sketched.

Atmospheric-chemical background[15]

Sulfate aerosol injection (SAI) relies on the role that aerosols play in atmospheric chemistry. Aerosoles are particles with tiny diameter that reside in the atmosphere. Depending on the height, they remain in the atmosphere for days or up to years. They

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[15] The following depiction is a summary of McNutt et al. 2015a, p 66ff, if not indicated otherwise.

interact with the earth's energy balance by either reflecting sunlight or by absorbing it. Both reflecting and absorbing particles have a cooling effect on the earth's climate. Aerosols may occur naturally (dust, soil, bacteria) or may be of anthropogenic origin. Despite their suggested benefit on the earth's energy balance, artificial sulfur aerosols also have health and environmental impacts.

Sulfur aerosols are formed when (natural or anthropogenic) gases containing sulfur are transported into the higher altitudes, namely the stratosphere. They may also be injected directly, e.g. by volcanic eruption or artificially by means of balloon or aircraft. There, sulfur atoms react with oxygen (e.g. from water vapor) to form larger particles (so-called nucleation). Those newly formed aerosols either proceed to ascend and evaporate or they are being transported to the polar regions.

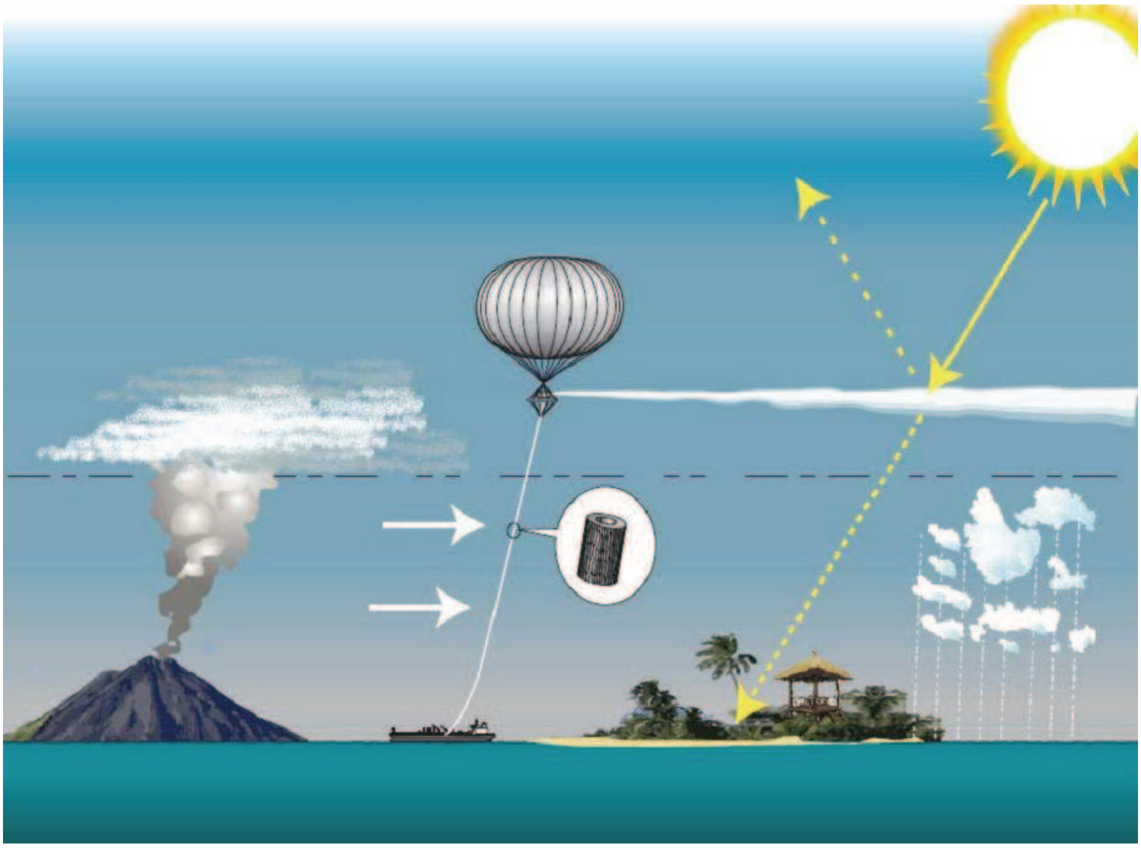

Figure 3. SAI scheme injected by balloons (source: wikicommons).

Benefits and idealized deployment scenarios

Sulfate aerosols can reduce the radiative forcing due to their ability to reflect insolation. Assuming a doubling of the current CO_2 concentration over the next decades, the resulting radiative forcing induced by CO_2 would be about 4 W/m^2.

Some models assume this amount as the baseline scenario for their setup (Kravitz et al. 2012, Rasch et al. 2008, Robock et al. 2008). Here, a large research gap is evident and models diverge quite greatly depending on their setup. Some models have found, that under the assumption of a doubling of atmospheric CO_2, an injection of 5 $MtSO_2$/yr would reduce temperature about 0.3°C to 0.4°C (Robock et al. 2008). Another study that used more advanced microphysical assumptions calculated a decline in temperature that is twice as big for similar injection rates (Jones et al. 2010). Yet other authors who include a more nuanced view on the chemical processes, suggest that in order to reach a 'sulfur burden' reaching a radiative forcing of 4 W/m^2, sulfur injection of 10 Mt/yr is needed (Kravitz et al. 2012, Rasch et al. 2008). The differences in the result indicate that the effectiveness of the technology depends on several as of yet unclear factors, including the means of injection, diffusion and declining of the particles, atmospheric physical and chemical reactions of the aerosols.

The envisioned medium of SAI is either a gas-mix of water vapor and sulfate or crude SO_2 particles, which influence the lifespan of the aerosols. The most cost-efficient way to inject SAI into the stratosphere is presumably by means of aircraft, but the technical details of emitting those particles at 25 km height are not to be ignored (Rickels et al. 2011). Generally, injection into the stratosphere (20-25km above sea level) is assumed; the site of injection changes for different model studies. While injection at the tropical stratosphere is proposed by some authors, others suggest a broad global injection at an even higher latitude. Stratospheric sulfate aerosols have different local and global effects. Since they both scatter and absorb sunlight, they are responsible for net global cooling, but may result in local heating. The system of aerosol formation is characterized by small changes having a large effect. Thus, recent research suggests that adequate models are not yet in reach. The same holds for the technical methods of sulfur injection.

It is important to note the status of the scenario assumptions, such as those given above. Some studies assume full-blown SAI as an alternative to mitigation efforts (e.g. Tjiputra et al. 2016), others design their studies against varying RCPs (e.g. Kravitz et al. 2015) with varying deployment rates, others adapt a doubling of the CO_2 concentration (see above). Such assumptions are naught but baselines, against which the effectiveness of certain SAI approaches is measured. It does not mean that the authors of the studies necessarily believe their assumptions to happen or to be the most realistic prognoses about future development in climate politics. Especially do those authors by no means propose using solely SAI to counteract global anthropogenic CO_2 emissions. While one could presuppose certain self-enhancing processes in technology development, which could make the deployment of a newly researched technology inevitable (see Section 2.3), the status of the scenario assumptions does not suggest as much. Another type of SAI scenario employs the idea of using SAI in order to reduce the warming rate, rather than stabilizing temperature. This scenario is discussed in Chapter 4 and serves as a case study for the further investigtion, because, unlike the temperature-stabilizing scenarios, the moderate SAI scenario resonates best with the buying time idea.

Effects on the environment

SAI is associated with many environmental effects. I will briefly discuss some of them exemplarily:

Ozone Depletion. SAI deployment offsetting a doubling in CO_2 concentration is estimated to delay the recovery of the ozone layer. However, this effect is thought to be fairly small, significantly smaller than the ozone depletion measured between 1980 and 2000 (McNutt et al. 2015, p. 86f).

Photosynthesis. Since the atmospheric CO_2 concentration would not be reduced by SAI, but in fact would continue to rise due to anthropogenic emissions (in the aforementioned scenarios), certain plants might profit. Excess CO_2 might serve as a 'fertilizer' to plants, increasing their productivity. Moreover, the light diffusing quality of sulfate aerosols would result in a light spectrum more beneficial to most land plants (Rickels et al. 2011).

Precipitation. A decline in global precipitation is seen as one essential side effect of SAI deployment. Due to a higher saturation of the upper atmosphere with water vapor, less water might reach the earth's surface. As a result, rainfall as well as soil moisture might decline in some regions. However, these impacts might be smaller than the impacts experienced under unabated climate change. (McNutt et al. 2015, p. 95f).

Acid Rain. Since sulfur will eventually be removed from the atmosphere via rainfall, the acidity of the soil and the ocean might be affected ('acid rain'). The contribution of SAI to acid rain, however, as compared to current man-made pollution is thought to be negligible (Kravitz 2009).

Ocean Acidification. The ocean's ability to store CO_2 is largely responsible for its acidification. Acidification means that the pH level of the ocean decreases, thereby influencing the ecosystem and its inhabitants (Raven et al. 2005). While ocean acidification is a result of continued anthropogenic carbon emission, and not of the use of SAI itself, it is still associated with this technology. Since ocean acidification might pose a serious ecologic problem, a technology that does not address this problem, might not represent a viable option.

Public Health. When the aerosols are washed out of the atmosphere, e.g. by rainfall, humans and animals alike might be exposed to them. In how far those particles inflict the respiratory system is still unclear. While some authors suggest that a certain impact is to be expected (Effiong and Neitzel 2016), others deem those impacts to be way below the recommended maximum exposure (Jones et al. 2016).

2.6 Bioenergy with carbon capture and storage

Carbon capture and storage (CCS) is a technology that aims at minimizing CO_2 emissions from large emitters, such as fossil fuel power plants, by preventing CO_2 exhaust to reach the atmosphere. If carbon capture and storage is coupled with biomass production and power generation, this technology is referred to as bioenergy with carbon capture and storage (BECCS). BECCS is dealt with as a promising clean ('green') energy technology which would supply energy demands as well as realize net negative CO_2 emission (McNutt et al. 2015b).

The classification of this technology is not clear-cut. While BECCS has been considered a mitigation technology (Keith 2000, Lin 2009, Royal Society 2009), other authors include BECCS into the climate engineering canon, being a CDR technology (Harrison and Hester 2014, Zhanga et al. 2015). BECCS can be seen as a hybrid between mitigation and climate engineering technologies: Biomass on the one hand can serve as a renewable energy, encouraging the detachment from fossil fuels. CCS, on the other hand, is a potential risk technology that, applied at large scale, can be framed as a CE technology. Especially under the impression of the Paris

Agreement, BECCS – seen as a technical solution to the 'emission gap' (see Section 4.2) – has been framed as a CE approach:

> "BECCS which stands for bioenergy with carbon capture and storage, is one example of a carbon dioxide removal (CDR) technology. (…) Like all geoengineering techniques, BECCS is controversial, and its feasibility and potential scale are still uncertain."
> (Shepherd 2016)

I discuss BECCS as a climate engineering technology for two reasons: Firstly, according to the definition of Heyward (2013) and Boucher (2014) (Section 2.4), any measure to technically remove CO_2 from the atmosphere may count as (a version of) a CDR approach. And secondly, the scale, the aim and the technical uncertainties associated with BECCS raise similar moral issues and concerns as is the case with other CE technologies.

In essence, the actual nomenclature is secondary. What strikes me as important, though, is the acknowledgment of large-scale BECCS as a risky technology with potential planetary impacts and side effects. A deepened discussion of the potential scale of deployment will follow in Sections 4.2, 5.4 and 6.1. The framing of BECCS as a CE technology can highlight other issues and moral problems than would be present when the 'lens' of mitigation is applied. The following paragraphs sketch the scientific background of BECCS and draw substantially from McNutt et al. (2015b).

Scientific background, benefits and idealized deployment scenarios

Bioenergy with carbon capture and storage (BECCS) is an approach that combines renewable energy from biomass with technical (i.e. chemical) CO_2 removal. While During its maturation, biomass assimilates (stores) CO_2 from the ambient air via photosynthesis. During the conversion of biomass for energy use (such as heat, electricity, or fuel), CO_2 is released. The resulting CO_2 exhaust, present as a stream of highly dense CO_2, can be captured at point source (via chemical or technical absorption) and then be stored in underground caverns. So, in theory, BECCS is a carbon negative energy source.

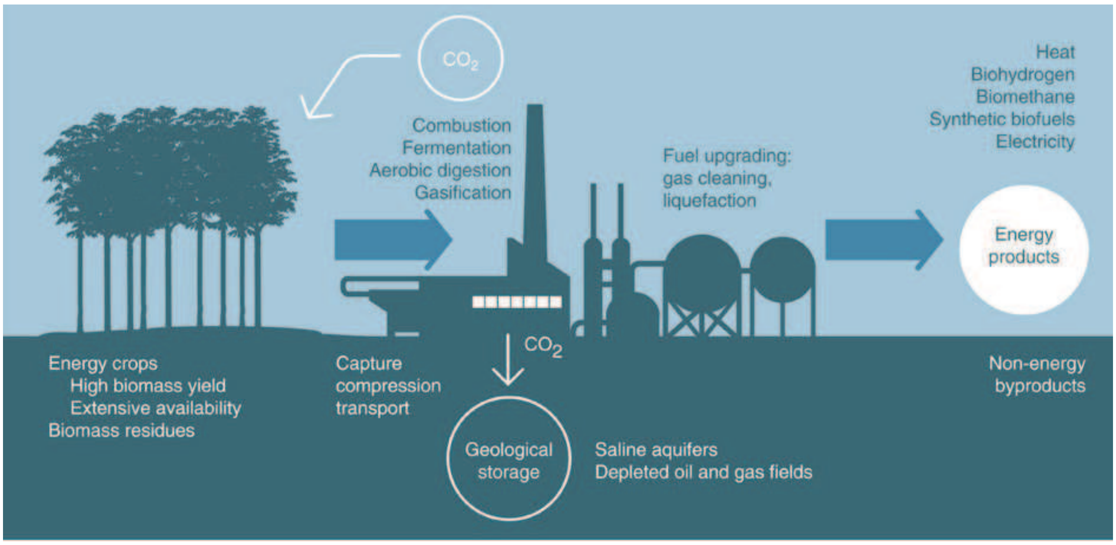

Figure 4. Schematic BECCS cycle (source: Canadell and Schulze 2014).

Energy Potential BECCS could contribute substantially to the worlds energy supply. Theoretically, the estimated maximum energy potential lies between 50 to 675 EJ/yr. To put this number into perspective, the energy demand of Germany in 2016 was at 13.4 EJ (BMWE 2017). By end of the 21st century, the theoretical maximum contribution of BECCS could reach up to 400 EJ/yr, but is highly limited by the availability of arable land. This makes biomass plantations and food production direct competitors for land. Studies reporting high numbers of BECCS energy potential assume a radical shift in dietary choices away from meat which would free up arable land for energy production (Edmonds et al. 2013). However, there is little indication that changes in food choices will occur in the near term future. On the contrary, global consumption of meat and diary products is continuously rising (Henchion 2014). Given these limits, BECCS might only play an auxiliary role in global energy security.

Mitigation Potential Since the practical effectiveness of BECCS is severely restricted, the cost-optimal level would reside at a level of 12 to 14 Gt CO_2/yr. Beyond this amount, the cost of each Gt CO_2 captured by BECCS would rise steeply due to land limitations. This is but a fraction of the estimated future global fossil fuel emission of 31Gt CO_2/yr. If BECCS were to be used as the single factor to ensure RCP2.6 in light of currently projected emission trajectories, the estimated land-use of food-production and biomass-production combined would rise to up to 2.1 billion hectares in 2100. To put this number into perspective, today's global cropland amounts to 1.6 billion hectare.

The effectiveness of BECCS is also limited by the potential to process biomass as well as the readiness of effective storing mechanisms. One study suggests a carbon loss of about 50% during the BECCS carbon flow (Smith and Torn 2013). Moreover, the energy input required for capturing, transporting and storing might counterbalance the negative emission potential of BECCS.

The mitigation potential is limited by other factors as well. As has been noted recently, BECCS might create a feedback on the carbon cycle. When carbon dioxide is removed form the atmosphere, the ocean might release CO_2 in order to balance the artificial carbon loss (Chen and Tavoni 2013). Also, soil carbon emissions during and after the plantation of biomass may also reduce the net negative emissions of BECCS (Pourhashem et al. 2016).

Effects on the environment

Transport and storage safety. The gravest side effects of BECCS arguably occur during transport and storage (McNutt et al. 2015b). There are two kinds of harms associated with BECCS: Infliction on the local population near CCS sites due to exposure to CO_2 during the injection, or long-term CO_2 pollution by storage leakage (Medvecky, Lacey and Ashworth 2013). Leak pipelines might cause highly concentrated carbon dioxide pollution. On the other hand, if storage sites are not safe, for example due to seismic activity, leakage may contribute to severe CO_2 pollution of land and sea habitats. A devastating, though natural example of what a CO_2 pollution looks like, gives the 1986 Lake Nyon disaster. Lake Nyon, located in the Northwest region of Cameroon, houses a magma chamber filled with carbon dioxide. In August 1986, the lake released a huge cloud of about 300 000 tons of CO_2 which caused at least 1700 people and 3500 animals to suffocate. The eruption was probably caused by underground seismic activity (e.g. Kling 1987).

Having said that, recent studies suggest that the probability of leakage is fairly low (Wennersten et al. 2015). If so, future decision makers could still decide upon carbon storage.

Land competition and food security. Since BECCS relies on the availability of arable land, the transformation of woodland or grassland into biomass plantations might be considered a side effect of BECCS. Primary forests or native grasslands have a high biodiversity and contribute to natural carbon sequestration. It is morally relevant which land is used for bioenergy production (Section 5.4). The ethical aspect of land-use is especially important if biomass were to be produced in the global South, where arable land is scarce and the available cropland is essential for self-sufficient, small-scale agriculture. Moreover, if animal rights and species conservation are considered, the conservation of wildlife habitat would influence the acceptability of biofuel plantations.

Moreover, food prices may rise due to the increased demand of cropland. A recent study suggests, however that this effect is reversed, as soon as BECCS influences the carbon price. Subsequently, BECCS might even temper the rise in food prices (Muratori et al. 2016). Additionally, as stated above, if food choices were to change, some pressure on cropland could be reduced. Whether BECCS could be deployed beneficially, is influenced by land availability, food security and other choices regarding mitigation.

2.7 Results

This chapter has served to introduce the moral controversy on climate engineering and to depict two specific technologies that are of focus in the following investigation. Most notably, the moral obligation to engage in fast and far reaching mitigation has been established.

> **(Mitigation Obligation)** The current generation has the moral obligation to drastically reduce their CO_2 emissions within the next few decades.

The mitigation obligation influences the reconstruction of the BT-argument, as will be shown in the course of Chapter 3. Nevertheless, it is an independent obligation that ought to be met regardless of the possibility of CE deployment.

The terminology as well as assessment patterns for CE *in toto* is debatable. The terminology under which a technology is framed has consequences down to its legal status. Regarding the moral controversy, some arguments of the ongoing debate do not necessarily apply to individual technologies or mask their singular features. Especially important seems the distinction between mitigation and CDR techniques which is not always easy to draw. Taking those difficulties about classification into account, this thesis will argue technology-specific with the focus on two technologies: SAI and BECCS. Building onto the general physical background of those technologies, which has been given above, two specific deployment scenarios will be depicted in Chapter 4, enabling the scenario-specific evaluation of the BT-argument in Chapter 5.

Chapter 3 The Buying Time Argument

Are we running out of time? The effects of global climate change are palpable, yet CO_2 emissions continue to rise globally. In order to launch an adequate mitigation program and to cope with further climatic changes, we arguably need more time. CE technologies are framed as an option to buy time, since they might be able to postpone some climate effects or to artificially remove excess CO_2 from the atmosphere. This possibility gives rise to both approval and critique of CE. Advocates of future CE deployment believe it to be an adequate (if not plain necessary[16]) option to avoid harmful climatic effects. For critics, on the other hand, the vision of buying time via CE is just a way of delaying a real solution by means of a quick technical fix.

This chapter is dedicated to the construction and the discussion of the BT-argument. First, the current discourse on the buying time idea is recapitulated by presenting a selected corpus of literature (Section 3.1). From those quotes, several implicit assumptions of the buying time argument are distilled and discussed. The metaphor of ‘buying time’ is translated into the more tangible terms of pressure and reduction of pressure. That way, the pretentious use of time variables is avoided and the idea of the argument can be captured more directly.[17]

The buying time argument is translated into a deductively valid premise-conclusion-structure (Section 3.2). The central principle (buying time principle, BT-principle) is designed so as to capture the different implicit assumptions identified in the before section. The BT-principle works with two placeholders – climate goal G and policy option O. In section 3.3 I identify four climate goals that are associated with the buying time idea and discuss their desirability as secondary climate goals.

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[16] Informal discussion in the geoengineering google-group demonstrates that some researchers believe CE to be the only option to avoid dangerous climate impacts, such as the melting of the polar ice caps. Latest call for actively deploying CE: Veli Albert Kallio, 6. Juni 2017 15:58 (https://groups.google.com/forum/#!topic/geoengineering/vcNIf7EgIC4)

[17] I continue to call this specific argument the buying time argument, even though the wording no longer appears in the premises themselves. Resemblance and connection to the current discourse on the buying time argument seems important to me in order to enable further discussion.

3.1 Current state of research

The idea to use CE deployment in order to ‘buy time’ in face of hesitant mitigation efforts seems rather intuitive. If, however, the exact meaning is to be evaluated, ‘buying time’ turns out to be a metaphor; a buzzword that promises a prudent, minimally invasive use of CE technologies. But what does it mean to ‘buy time’? From whom? How much? And at what price?

It seems that those questions beg the definition of certain time concepts, like time span, or earlier-than relations. But trying to formulate such concepts, ironically, does not quite grasp the original idea of the buying time argument. It might be misleading for the understanding of the buying time framing to try pinpointing the exact amount and definition of time related concepts in the use of CE.[18]

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[18] An earlier version of my BT-argument reconstruction was this:

1. There will be a point in time t_1, when the CO_2 level in the atmosphere (CO_2^+) will lead to a climate situation Sit^+.
2. Policy mix P might stabilize the atmospheric CO_2 concentration below CO_2^+ by t_2.
3. t_1 might lie before t_2.
4. Policy mix P might not be able to prevent climate situation sit^+ before t_1
5. It is mandatory to prevent a climate situation sit^+ and policy mix P is the preferred way to do so.
6. If Policy mix P might not be able to prevent climate situation sit^+ at t_1, but it is mandatory to prevent a climate situation sit^+ and policy mix P is the preferred way to do so, then it might be necessary to engage in different policy mix Q to prevent climate situation sit+ before $t_{1,}$ given that option is morally allowed.
7. Policy mix Q is morally allowed only if: a. there are no moral restrains against it, b. the side-effects of this option do not overweight the benefit, c. there is no better alternative and d. Policy mix Q will end and be replaced by Policy mix P eventually.
8. Between t_1 and t_2, the side effects of CE technology T are acceptable compared to the benefit.
9. There are no moral constraints against CE technology T.
10. Between t_1 and t_2, there is no better alternative to CE technology T.
11. Policy mix Q will end and be replaced with Policy mix P eventually.
12. (CL) It might be necessary to deploy CE technology T between t_1 and t_2.

The problem with those time related premises lies in the evaluation of the placeholders t_1 and t_2 and the subsequent determination of the time span of CE deployment. Should CE be deployed in t_1 or before t_1? If so, how much before t_1? Also, what does it mean to assess the side effects of a CE technology only between t_1 and t_2 (premise 8, 10)? The argument is not deductively valid, because, among other things, the conclusion asks for temporally limited CE deployment between t_1 and t_2, but the principle in premise 6 does not include a time limit, but rather asks for deployment before t_1.

While it would certainly be possible to create a deductively valid reconstruction of the BT-argument in a similar vein as the argument above, I felt that further pursuing the reconstruction actually did not further specify the buying time idea, but instead led to side stages about what time concepts are needed to define a ‘prevent-relation’ (premise 4), essentially creating a different argument. At this point, I refrained from further pursuing the idea of defining time-specific premises for the BT-argument. Rather, I focused on the goals that are thought to be realized with the help of temporal CE deployment. This then led me to the formulation of the pressure terminology, which I deem to better represent the idea behind the BT-argument. The fuzzy notion of time-concepts is captured via the finitude thesis, that asks for limited, rather short and controllable CE deployment (Section 3.2, Section 5.).

Rather, since ‘buying time’ is a metaphor, it makes sense to decipher it into more tangible terms. In order to achieve this, I will analyze a selected corpus of articles using the buying time metaphor. It will turn out that the buying time framing can be translated into a ‘reducing pressure’ framing.

While I wish to substantiate the BT-argument for two specific technologies, the quoted literature refers to different (groups of) CE technologies. So, in advancing the premises of the BT argument, I continue to refer to CE in general, and will cut the BT-argument for the specific technologies in Chapter 5.

Averting dangerous climate impacts

The most prominent benefit of a future CE deployment is the prospect of avoiding dangerous climate impacts. In a climate emergency situation, CE might be able to help avert catastrophic climate effects, such as the reaching of tipping points (see Section 1.1). Having said this, the emergency framing of CE deployment has been criticized as of late (see Section 2.3). Recent literature argues to abandon the emergency framing altogether (Sillmann et al. 2015, Horton 2015). Instead, a peak shaving deployment to buy more time is outlined.

> „The most common alternative [to the emergency framing], known as ‘peak shaving’, would entail application of SAI or some other type of solar geoengineering to reduce the worst effects of peak GHG emissions while implementing an ambitious program of mitigation and adaptation. One variant of peak shaving would involve a gradual ramp-up of solar geoengineering until a modest plateau is reached; as emissions declined, so too would injections of stratospheric aerosols (…). Another potential approach would utilize SRM on a regional scale, for example in the Arctic, in order to address specific, localized damages from climate change.“
> (Horton 2015, p. 4f)

With the help of a CE technology, the worst impacts of temperature rise could arguably be averted. CE technologies might

> “…be used as a stop-gap measure to buy time for a societal transformation to a carbon-free economy, shaving off the worst effects of climate change along the way”
> (Schäfer et al. 2014, p. 5).

The peak-shaving framing assumes that the worst effects of the GHG-peak would indeed be catastrophic. Especially climate tipping points might have grave impacts on natural and human systems and ought to be avoided (see Section 2.2) – if need be with climate engineering:

> „A popular framing is that sunlight reflection could "buy time" for decarbonizing the economy and allowing greenhouse gas concentrations to stabilize and then come down."
> (Lenton and Vaugham 2013, p. 2)

> "Some geoengineering measures appear to offer humanity the ability to shave the peaks off CO_2 driven emissions and avoid tipping points. Wigley (2006) argues that sulphate particle injection might be used to "buy time" in reducing CO_2 emissions. This potential to shave peaks would go some way to addressing the concern voiced by some that temperature rises over the next century may exceed irreversible "tipping elements" in the climate system leading to drastic changes with potentially catastrophic impacts on human and natural systems."
> (Rayner et al. 2013, p. 8)

> „An optimal outcome would seem to be that mitigation can be accomplished relatively rapidly and relatively easily, such that geoengineering might need to be implemented for only several decades in order to shave off the peak change in climate and increase the likelihood that the most adverse and irreversible environmental and societal consequences will not be triggered."
> (MacCracken 2009, p. 11)

This 'peak-shaving quality' is found in many CE technologies, especially SAI; they are thought to be used temporarily in order to avert some serious effects. Those technologies then might represent a quick, easy-to-control tool that could be ramped up and down relatively simple.

While the emergency framing assumes deployment only in case of devastating climate impacts, the buying time framing advocates a *preventive* deployment, as to avoid those impacts in the first place. Huttunen and Hildén (2013), who have also collected and analyzed publications about CE, have identified several frames for CE deployment. They especially distinguish the 'technological fix' and the 'last resort' frames for CE, and indicate that a buying time deployment would be an alternative to a possible emergency deployment:

> "In the 'Technological fix' subframe, represented by 27 articles, geoengineering is presented as a possible third option beside mitigation and adaptation. It could be used to buy time for mitigation or used side by side with mitigation. None of the analyzed papers suggests that geoengineering should completely replace emission reductions. The key difference to the 'Last resort' subframe is the argument that geoengineering could be used before any emergency situation arises, if justified by costs estimates."
> (Huttunen and Hildén 2013, p. 13)

Those quotes are paradigmatic for the discourse on CE as a means to buy time. The idea of a peak shaving deployment that those authors present, can be illustrated like this:

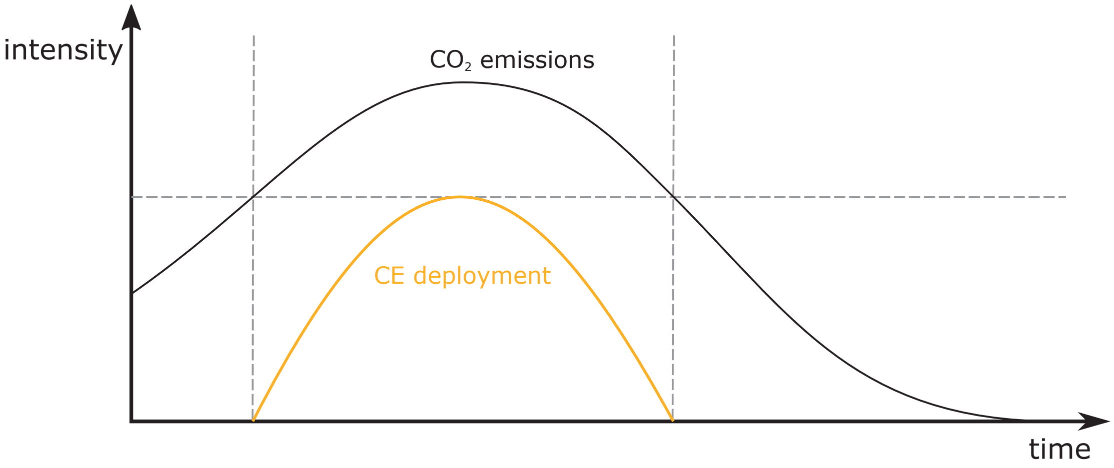

Figure 5. Simplified peak shaving/ buying time deployment. The orange line indicates a temporary, modest deployment of CE that declines parallel to CO_2 emissions.

This simple idea and *a fortiori* the above figure are, however, spurious[19]. They assume that the worst climate impacts coincide with the peak of GHG emission: "reduce the worst *effects of peak GHG emissions*" (Horton 201, p. 5, emphasis added [FN]). But climate impacts result from the CO_2 concentration in the atmosphere, not the act of emitting. Since the concentration of CO_2 will not necessarily go down as soon as we stop emitting, dangerous climate impacts may occur even after we have stopped emitting CO_2 (see Figure 6 below).

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[19] I mean not to devalue the work of the cited authors in general, but rather wish to highlight the potential misconception underlying an advocacy of the BT-argument.

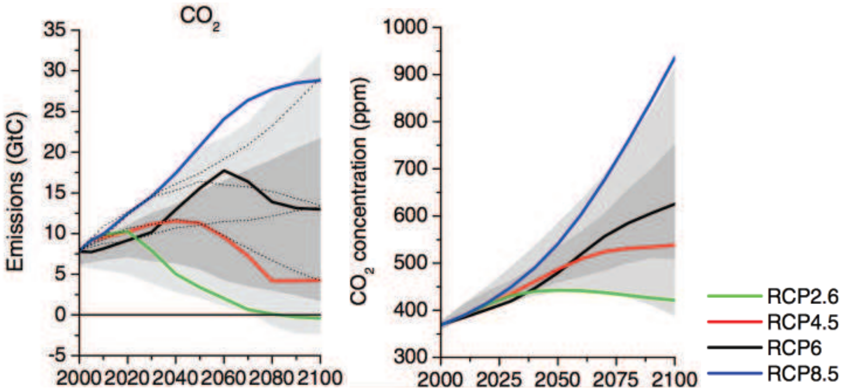

Figure 6. CO_2 concentration in the atmosphere will remain near stable or even continue to grow, even if CO2 emissions are cut drastically within this century (source: Van Vuuren 2011).

The notion to use CE until our CO_2 emissions goes down is misleading – CE as a peak-shaving measure would have to be used until CO_2 *concentration* goes down, which, as indicated, might considerably lag behind our mitigation efforts.

It could be argued that this is a harmless misunderstanding and that one similarly could advance a peak-shaving argument that relates to peak concentration. However, I think that this is the first misconception about the BT-argument, which makes it so appealing. If the stopgap quality is associated with CO_2 emissions, the time-span of CE deployment would arguably not surpass a few decades for all RCPs except RCP8.5. But if the argument was transparently related to the CO_2 concentration, the anticipated duration of CE deployment would rise significantly. In order to balance out high CO_2 concentration, CE would have to be used well beyond of the end of the century for all RCPs except RCP2.6 – a fact that highly influences the moral, political and technical evaluation of the technology.

But of course, the act of emitting carbon dioxide does influence the atmospheric concentration. Insufficient cuts in CO_2 emission would inflate the time span even for a moderate buying time deployment (MacCracken 2009). In order to make the BT-argument as strong as possible (which is the aim of this investigation), the relation between CO_2 emissions, CO_2 concentration, mitigation efforts and temperature rise must be made as transparent as possible. I will attempt to do so by specifying the deployment scenarios with regard to different emission pathways (Chapter 4).

But even this first plunge into the topic indicates that framing CE deployment as a means to buy time or to shave the peak, would still amount to a deployment for several decades, possibly even beyond the end of the century – nothing that can be controlled or implemented easily.

Managing transition, Transition anyway

When searching for buying time strategies in face of climate change, Nico Bauer (2005) has presented carbon capture and storage (CCS) as a possibility to buy time. His work is related to the thesis at hand, as it has a similar research question ("*Is CCS an option to buy time?*") and deals with a similar technology. In the introductory section of his work, Bauer defines his research question.

> "Is CCS an option to buy time in order to shift the climate induced transition to a renewable based energy system? The question assumes that the shift towards renewables is inevitable in the long run, if fossil fuel scarcity induces this transition. The pressure from the climate system leads to a premature transition and CCS could defer this prematurity towards its *natural* timing.”
> (Bauer 2005, p. 4, emphasis in original)

Bauer enfolds the metaphor of buying time by highlighting the discrepancy in time between a "premature [20] and a "natural transition of society. Nevertheless, Bauer assumes that there will be a transition of society away from fossil fuel – latest when fossil fuel reservoirs are exhausted. There is no alternative to transitioning towards a low-, and eventually no-carbon society. But how will this transition happen? Will it take place in a manner that is manageable and bearable for our society or will it happen abruptly and at high cost? CCS and *mutatis mutandis* some CE technologies like BECCS might help to manage this transition.

From an early stage on, several authors have stressed that a gradual mitigation program has many advantages (Wigley et al. 1996, Wigley 2006, Nordhaus 2008), and CE might be able to help phase in ambitious mitigation. The Royal Society formulates the buying time argument similarly:

> "The length of time required to phase out fossil fuels, and to modify the various global human systems contributing to climate change, may be longer than the time available to

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[20] The word 'premature' suggests some sort of oblivion. Climate change seems to have stricken quite without warning, and society is now faced with the impossibility to change at short notice. This, however, is not the case. The danger of a rise in temperature has long been known, and transition now is by no means premature, but rather overdue.

> avoid serious adverse impacts. In this case, SRM might have the potential to temporarily stabilize the global temperature and its associated effects, while providing time to reduce GHG emissions.”
> (Royal Society 2011, p. 19)

CE technologies (or SRM specifically) might help to phase in efficient mitigation by reducing the pressure of immediate action. In this sense, CE technologies are a way of managing the transition of society towards decarbonization; CE is an auxiliary tool in climate politics. The BT-framing presupposes that decarbonization is indeed a political goal, moreover, a globally shared political goal

Reducing pressure of mitigation and/or adaptation

The inevitable transition towards carbon-free production and consumption should arguably come at the lowest possible social and economic costs. This is part of the rationale that David Keith gives in his 2013 book (Keith 2013). Keith argues prominently for a prudent SRM deployment, partially because of its cost-effectiveness. In a similar vein, Wigley (2006) has offered a calculation of a policy mix consisting of mitigation and CE that proves to be less costly than rapid mitigation alone:

> “A combined mitigation/ geoengineering approach to climate stabilization has a number of advantages over either alternative used separately. A relatively modest geoengineering investment (…) could reduce the economic and technological burden on mitigation substantially, by deferring the need for immediate or near-future cuts in CO_2 emissions. More ambitious geoengineering, when combined with mitigation, could even lead to the stabilization of global mean temperature at near present levels and reduce future sea-level rise to a rate much less than that observed over the 20th century (…)”
> (Wigley 2006, p. 454)[21]

As important as mitigation might be, an additional CE deployment could “provide additional time to address the economic and technological challenges faced by a mitigation-only approach” (Wigley 2006, p. 452). Since some CE technologies could arguably be launched slowly and as easily be tapered off again, so the

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[21] Note that Wigley assumes permanent low SRM. His results can still be used to illustrate how economic pressure of mitigation can be reduced via additional CE deployment.

argument goes, it could be a form of adjustment to correct and support the progress of Mitigation.

> "Even absent any climate emergency, CE can be used as part of a low-cost inter-temporal climate response by deploying it incrementally to shave the near-term peak of global heating that would occur this century even with aggressive emission cuts. Such an incremental deployment, phased in then out over a century or so, could reduce near-term climate disruption and associated risks, thereby buying time and allowing emission cuts and adaptation measures to be made in an orderly program of technology deployment and capital turnover, at much lower cost and disruption than under more rapid deployment."
> (Parson and Ernst 2013, p. 318)

It is the core assumption of the BT-argument that transition will happen anyway. How this transformation will come about, is left tacit. But it is mutually seen as a costly process, and CE deployment could help to minimizing the costs of transition.

> „Due to the high costs arising from the necessary transition to a carbon neutral economy, all options that could contribute to reducing the costs of this transition should be explored."
> (Zürn and Schäfer 2013, p. 6)

The buying time metaphor is used to describe a management of an inevitable decarbonization of society while reducing its costs.

> "Catastrophic climate change would likely unfold over a number of centuries, but avoiding it will require a technological revolution, and geoengineering might help to "buy time" to develop and diffuse these new technologies"
> (Barrett 2008, p. 50)

In summary, this is what I deem to lie at the heart of the buying time idea: Shifting away from fossil fuels and towards a net-zero emission economy is challenging. CE technologies might render this transition easier, less costly or less abrupt, thereby taking some pressure off immediate choices of action.

Temporal deployment only

One central assumption of the BT-argument is the prospect of society developing towards a low- or even no-carbon economy (see above). If production and consumption start being carbon neutral, CO_2 emissions will eventually decline also. Then, the argument goes, CE deployment might no longer be needed. So, the assumption of the inevitable transition of society implies that CE deployment be only temporal. The whole idea of the BT-argument is that deployment of CE will be finite and purpose-bound:

> "… geoengineering might need to be implemented for only several decades …"
> (MacCracken 2009, p. 11)

> "… at least among policy makers, nobody believes that geoengineering offers anything but a relatively short stopgap to buy time for other action."
> (Bunzl 2009, p. 2)

These quotes state explicitly that a BT deployment of CE would have to be limited in time. The authors seem to be quite optimistic about the "relatively short" deployment period, which, as indicated, might inflate when drastic emissions cuts are further delayed (see above). It is nevertheless salient to the BT-argument to assume that, at some point, CE deployment will no longer be needed. This is indeed the very meaning of a stopgap: being limited in time.

Summary

Four key elements of the buying time framing have been derived from the selected quotes of the ongoing discourse:

Averting dangerous climate impacts
Managing transition, Transition anyway
Reducing pressure of mitigation and/or adaptation
Temporal deployment only

From those assumptions, two relate to potential climate goals that are to be realized with the help of CE: *Averting dangerous climate impacts, Reducing pressure of mitigation and/or adaptation.* One defines the envisaged mode of CE deployment:

Temporal deployment only, which is backed by assumptions about future political and social development: *Transition anyway*.

The idea of the BT argument can be captured, when the desired outcome of CE deployment and its relation to other climate policy goals is at the center of the argument reconstruction. Two possible climate goals associated with a stopgap deployment of CE will be adopted for the further investigation:

1. Avoiding dangerous climate impacts
2. Reducing pressure

Having those goals established, a comprehensive argument can now be formulated which includes prudent requirements for a goal-orientated buying time deployment.

3.2 Establishing the buying time argument

In essence, the BT argument is a consequentialist argument: A certain means should realize a certain end. For the BT argument, this consequentialist principle reads: A certain climate policy mix should be adopted in order to reach a pre-defined climate goal. However, there are some restrictions to the use of CE that originate from the buying time framing, as has been illustrated in the section above. The special *buying time requirements* shape the *buying time principle,* which underlies the *buying time argument.* If a climate policy mix incorporates the BT-requirements, it can be said to be a *buying time deployment*.

For a comprehensive climate portfolio, placeholder O is introduced, while placeholder G denotes the desired climate goal. Both the placeholders and the requirements shape the form of the buying time principle. It can be formulated as follows:

Buying Time Principle (BT-Principle)

If: i. climate goal G is desirable, ii. option O leads to climate goal G and is beneficial in so doing so, iii. option O only reckons with finite CE deployment, iv. CE in O does not lead to less mitigation compared to mitigation in O without CE, v. there is no option O’ which is maximally finite and which leads to G and which is better than O, vi. there are no general moral constraints on option O;
then: option O should be adopted.

The BT-argument, which incorporates the BT-principle, can be established:

Buying Time Argument (BT-Argument)

BT1. If: i. climate goal G is desirable, ii. option O leads to climate goal G and is beneficial in so doing so, iii. option O only reckons with finite CE deployment, iv. CE in O does not lead to less mitigation compared to mitigation in O without CE, v. there is no option O' which is maximally finite and which leads to G and which is better than O, vi. there are no general moral constraints on option O;
then: option O should be adopted.

BT2. Climate goal G is desirable (desirability thesis).

BT3. Option O leads to desirable climate goal G (effectiveness thesis).

BT4. Option O only allows for finite CE deployment (finitude thesis).

BT5. CE in O does not lead to less mitigation compared to mitigation in O without CE (no-impediment thesis).

BT6. There is no option O' which is finite and which leads to G and which is better than O (no-better-option thesis).

BT7. There are no general moral constraints on option O (morality thesis).

BT8. THUS: Option O should be adopted.

The BT-principle consists in six requirements (i. – vi.), which seem essential to me when reconstructing the buying time idea. I will refer to them as *theses*, since they can be stated as complete, truth-apt sentences. Each thesis states a necessary condition; together they are sufficient for the BT-principle to be true. The characteristics of the buying time argument are captured quite adequately in this formulation of the argument, as will become clear in the following discussion of the BT-requirements.

i. Climate goal G is desirable (desirability thesis).

The desirability thesis states that climate goal G ought to be politically desirable. If the climate goal is not desirable, there is no point in implementing a process that realizes this goal. Instead, a different goal and hence a different policy mix would then be the better choice. Section 3.3 will further discuss this thesis along with the respective climate goals.

ii. Option O leads to climate goal G and is beneficial in so doing so (effectiveness thesis).

Once the desirability of climate goal G has been established, the effectiveness of climate option O must be guaranteed. Whether option O really leads to climate goal

G can only be decided via scientific research. CE research currently consists in computer-based model simulations, which aim at validating claims about efficiency and effectiveness, as well as taking some side effects into account. The kind of premises that one would expect in support of the effectiveness thesis are predictions about the future, obtained by computer-generated simulations.

The validity and scope of those predictions are limited, though. For one, model simulations are only as good as their scenario assumptions. If implausible or incomplete assumptions enter the scenario, the results might also be dubitable (Dieckhoff and Leuschner 2016). Additionally, scenarios generated by simulations are only *possible* states of the world. The probability of those scenarios can only be estimated (Betz 2015). The question is, what degree of probability would suffice for a CE deployment to be called effective? Would we want a 99% probability or would we settle for 75%? And how could those numbers possibly be obtained?

Here it is important to highlight the status such scenario assumptions have in the current discussion. Scientists engaging in CE research do not necessarily believe their assumptions to be the most realistic prognosis about future development in climate politics. In particular, those authors by no means propose SAI or BECCS as an alternative to mitigation efforts, even if they might calculate the effectiveness of those technologies for a business-as-usual scenario.

Lastly, there might still be insurmountable uncertainties associated with CE deployment (Betz and Cacean 2012). There might be side effects that we simply cannot anticipate through model studies, and which might turn out to be disastrous. Those insurmountable uncertainties could be a reason not to engage in CE at all (see also discussion of the irreducible uncertainties argument in Section 6.2.1).

The effectiveness thesis asks for option O to be beneficial as well. Option O is beneficial if the benefits of this option should outweigh its negative side effects. This simple request might prove to be the hardest as well as the most important to evaluate. The problem evidently lies in the formulation and evaluation of a cost-benefit relation in case of CE, accompanied with the immediate critique as to whether such a narrow economic concept is the best measure to decide upon the desired outcome. Associated with it are many uncertainties: What parameters should be included in the research? What weighing should be attributed to the parameters? How to deal with uncertainties? How to deal with issues of justice?

In the course of this work, an evaluation of this requirement can only be touched upon. I do not attempt to come to a final conclusion. Rather, I wish to discuss the *conditions for the possibility* for a beneficial deployment (see also Section 5.1 and 5.4).

iii. Option O only reckons with finite CE deployment (finitude thesis).

The finitude thesis, which only allows for temporally limited CE deployment, is especially important to the BT-argument. Of course, this makes the BT-principle rather strong. Incorporating the finitude requirement into the BT-principle can be justified through the following considerations:

Many authors of the buying time discourse adhere to the temporal deployment only assumption (Section 3.1). Words like 'postponing' and 'stopgap measure' are used frequently when relating to the buying time framing. The sheer meaning of the words implies some form of finitude – a stopgap is by definition only a bridge; the second best choice until a real solution is obtained. The meaning of the word 'postponing' also implies some form of temporal finitude. While it is in theory possible to infinitely postpone something, postponing, in practice, usually refers to some reasonable timeframe.

Secondly, I would argue that any CE deployment which is not finite in concept is no buying time deployment, but instead amounts to a *substitute* for mitigation efforts. Successful decarbonization of society implies, that mitigation efforts show an effect. Under this assumption, BT-deployment would be used as an auxiliary measure to reduce pressure and buy time. Conversely, if the process of decarbonization is assumed to fail, CE deployment would have to be used continuously as a substitute for insufficient emission cuts. So, the finitude requirement only then is superfluous, if CE is anticipated to be a substitute for emission cuts.

This leads to the third reason as to why the finitude requirement has been included in the BT-principle. The idea of CE being only a temporary stopgap measure is backed by the idea that the transition of society will happen anyway. Eventually, a low- or no-carbon society is thought to be inevitable, making artificial counter-balances to the carbon circle (like BECCS) or the radiative forcing (like SAI) redundant. In this picture, CE is not structurally needed for the transition *per se*. It is only needed to manage the manner of transition. Once the necessary change towards a low- or no-carbon economy has been achieved, CE is deemed to be superfluous. The transition anyway hypothesis that many authors silently adopt (see Section 3.1) is the main reason as to why CE can and should be finite. This line of thought will be deepened in Chapter 6 where the danger of CE undermining a transition of society is discussed (Section 6.2.2).

So, I argue that only finite deployment schemes count as buying time scenarios. However, the concept of finitude must be specified somewhat. While a deployment of 800 years (MacMartin 2014) is in theory finite, this would in practice surpass any reasonable policy making. Finitude as I wish to understand it not only refers to a pre-determined period of time, but also implicitly makes assumptions about controllability. If the time span in which any CE measure is deployed makes unrealistic assumptions about centuries to come, I will argue that this timespan is not finite in a practical sense.

Specifying the concept of finitude might also capture the ambiguity that arises when the terms ‘short’ and ‘finite’ are used synonymously: I understand finitude as a practically controllably timeframe that does not critically surpass the end of this century – a timeframe that correlates to the RCP’s prognostic realm (van Vuuren 2011, IPCC 2013), and in this sense is relatively short.[22]

iv. CE in O does not lead to less mitigation compared to mitigation in O without CE (no-impediment thesis).

The next requirement essentially demands that there is no or at least a controllable relation between mitigation and CE deployment. It requests that mitigation efforts remain constant, whether CE will be deployed or not. Underlying the no-impediment requirement is the demand for CE deployment not to be used as a substitute for mitigation efforts. This requirement can be backed by the following considerations:

In Section 2.2, I argued that there is a strong moral obligation to pursue mitigation efforts even in face of possible CE deployment. I have established this obligation as superior to CE deployment, because CE and mitigation essentially do not address

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[22] Of course, this limitation can be criticized. Even potential infinite deployment of global technology has proven to be sustained by man: Global telephone and internet technologies are examples of technologies that are both global and potentially infinite. However, those technologies are not necessarily risk technologies. For CE technologies, the deployment span should be finite, short, and controllable due to of the potential hazardous side effects of those technologies.

the same issues. Particularly if mitigation is understood in a broader sense as part of a sustainable transformation of society away from a fossil fuel-based economy, CE measures cannot substitute for that. In light of the mitigation obligation, CE and mitigation cannot serve as substitutes. Additionally, there are enhanced risks in CE deployment, and CE deployment might eventually lead to a dilemma for future generations.

The no-impediment thesis serves two purposes: On the one hand, it stresses the importance of mitigation efforts; on the other hand, it connects the discussion to a broader context of transitioning society. Especially in connection with the transition anyway assumption, which has been identified in section 3.1 and which also serves to back the finitude thesis, the no-impediment thesis gains force for the social and political debate. This will be further discussed in Chapter 6.

v. There is no option O' which is maximally finite and which leads to G and which is better than O (no-better-option thesis)

A full evaluation of this thesis goes far beyond the scope of this work, as potential harms and benefits would have to be compared comprehensively between different climate portfolios including CE. Defining a better-than relation may be equally challenging as finding a reasonable cost-benefit relation. Rather, for the purpose of this work, the no-better-option thesis has the function of a 'safeguard' that helps to identify an inadmissible narrowing of options by presenting CE-deployment as the only or best option. In particular, this means that, if ambitious mitigation were to be seen as a realistic and viable approach, which did not inappropriately burden social and economic structures, this option should be preferred to a portfolio including CE. If two portfolios equally realize a desired climate goal G, the portfolio without CE should be adopted. If there is no immediate benefit gained from CE, it should not be part of a climate policy mix, due to its inherent uncertainty being a risk technology.

While this may seem obvious, it might be hard to achieve. Framing CE as a viable option might diminish the willingness to engage in equally viable, but potentially more difficult options (this is a version of the moral hazard argument, see Section 2.3). The no-better-option thesis urges us to be very careful in ruling out other options, and not to project a CE-portfolio prematurely.

vi. There are no general moral constraints on option O (morality thesis).

Finally, the morality thesis asks for option O to be generally morally acceptable. There are at least two drawbacks to putting the morality thesis separately at the end of the argument: Defining a beneficial deployment (effectiveness thesis) rests on normative assumptions (e.g. about fairness) and thus could also be dealt with in the context of the morality thesis. Secondly, if there is indication that a CE deployment scheme might be in general morally unacceptable, this might rule out the scenario to start with. After all, if CE deployment is inherently morally wrong, why bother exploring any other requirements like the effectiveness- or the finitude thesis?

Meanwhile, the work at hand has a different research question: Are there possible BT-deployments absent any general moral constraints? So, for now, it is assumed that CE is not inherently morally wrong. Of course, the general moral status of CE *is* of importance, but will be discussed only after the compliance with the other central BT-requirements is assessed.

The order of the BT-requirements determines the order in which the requirements are evaluated in the remainder of this thesis: At first, the ‘hard facts’ about the deployment scenario are given and the stage for any policy option O is set: Is the goal desirable, and does the portfolio realize it in a (theoretically) beneficial manner? After this, the central BT-requirements are evaluated: Is option O finite? Does it impair mitigation efforts? And could there be an alternative? Finally, the general moral status of climate option O is assessed.

3.3 Instantiations and desirability of climate goal G

Only if placeholders G and O are instantiated do the premises become truth-apt and can the argument be evaluated for its validity. In this section, climate goal G is further subdivided into four climate goals and the desirability of each goal is established.

Two broad climate goals at which CE deployment is aimed have already been introduced in Section 3.1: 1) avoiding dangerous climate impacts, and 2) reducing pressure. Those two goals can now be further specified:

Ad 1. Avoiding dangerous climate impacts

In Section 2.2, the general obligation to avoid irreversible and dire climate impacts has been established in the context of the mitigation obligation. In particular, climate tipping points ought to be avoided. Reducing global warming to 2°C above pre-industrial level generates a 66% chance of realizing this goal and avoiding temperature-dependent tipping points (IPCC 2013).

Additionally, there are some tipping points that are affected by the rate of climate change, i.e. that are rate-dependent. A policy option that would aim at reducing the rate of temperature change would also address rate-dependent climate tipping points. So, the broad goal to avoid dangerous climate impacts can be divided into two sub-goals:

Climate Goal 1	Avoiding temperature-dependent tipping points.
Climate Goal 2	Avoiding rate-dependent tipping points.

Ad 2. Reducing pressure

The notion of ‘reducing pressure’ is what I deem to lie at the heart of the buying time framing. According to the authors using this framing, the time gained via a buying time deployment would be put to use as to manage mitigation and adaptation in an orderly fashion: More clear-headedly, less cost-intensively – in short, with less pressure.[23]

The goal of reducing pressure is actually a compound goal. It focuses on stabilizing the global mean temperature at a certain degree, while at the same time asking for reduction in its social and economic costs. In the following, costs for mitigation are separated from costs for adaptation. This generates two additional climate goals:

Climate Goal 3	Reducing adaptation costs and stabilizing temperature at 2°C above pre-industrial level, compared to adaptation costs without CE.
Climate Goal 4	Reducing mitigation costs and stabilizing temperature at 2°C above pre-industrial level, compared to mitigation costs without CE.

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[23] Economic considerations may especially shape the understanding of the pressure terminology, e.g. when phasing out economic branches is compared to phasing in new ones.

For the sake of readability, I will use the short version 'reducing mitigation pressure' and 'reducing adaptation pressure' for the remainder of this work, while having in mind that those goals are actually compound[24].

The starting point of each argument is the stipulation that those goals are desirable. The first requirement of the BT-argument asks for any climate policy goal to be desirable (desirability thesis). Is this the case for each of the four goals?

Climate Goal 1: Avoiding temperature-dependent tipping points.

Mitigation efforts essentially aim at realizing climate goal 1. Hence, the desirability of climate goal 1 has been established in Section 2.2 in the context of the mitigation obligation. A version of the BT-argument, which assumes any option O in order to achieve climate goal 1, amounts to the so-called two-degree argument that has already been introduced into the debate (Betz and Cacean 2012). It assumes that the two-degree target can be realized only with the aid of CE (see also Section 5.2.2). Regardless of whether this argument turns out to be true, the anticipated climate goal is indeed desirable.

Climate Goal 2: Avoiding rate-dependent tipping points.

Given that tipping points might have irreversible and potentially negative consequences for both current and future generations, it is morally imperative to avoid them. The same holds consequently for rate-dependent tipping points. Hence, both 'avoiding tipping point' goals are *prima facie* morally desirable. Therefore, if at all possible, the current generation should aim at avoiding each sort of tipping points and the two respective climate goals can be said to be indeed desirable.

Climate Goal 3: Reducing adaptation pressure

The (moral) obligation to minimize or reduce costs, respectively, lies at the heart of the buying time argument. This obligation can be backed in two different ways:

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[24] The goal of reducing pressure is not only compound, but also comparative: State of the world 1 should be transformed (reduced) into state of the world 2 by means of policy option O. What 'reduction' would translate to in terms of policy pathways and what amount of reduction would be acceptable *all things considered* cannot be decided in the scope of this work. In this sense, some fuzziness of the BT-argument remains. Still, I believe the reducing-pressure terminology to be more accessible in terms of research and further policy choices.

Either with reference to economic rationality or via considerations about appropriateness when dealing with moral obligations.

Economic rationality in a broad sense is a strategy that aims at reducing costs while maximizing utility, e.g. achieving a desired goal (e.g. Anand 1995). At first sight, this is by no means a problematic approach. In fact, this kind of thinking is involved in most of our day-to-day actions. If there are two ways in which a result can be obtained, it seems rational to choose the less cost-intensive way[25]. Problems only arise when minimizing costs leads to negative or even immoral behavior: If, for example, a third person or the environment is negatively affected. Other people's rights (and moral obligation towards the environment and animals) constitute the boundary at which cost-minimization should end. For the deployment of CE this means, if the negative side effects of the deployment impose risks on other people or the environment, this strategy is not morally acceptable, even if it might minimize mitigation or adaptation costs.

Appropriateness on the other hand refers to the amount or degree of 'burden' or 'sacrifice' that can be expected from moral agents when carrying out their moral obligation. Minimizing adaptation costs (and mitigation cost, respectively) can be justified by appropriateness-consideration, if it is assumed that the envisaged adaptation pathway is 'too hard' on the moral agents.

Regarding adaptation, it might very well be the case that the pace of climate change generates severe problems for societies and citizens seeking to adapt. Some adaptation measures might take considerable time to be realized (IPCC 2014c). If it were possible to lessen the rate of climate change, adaptation measures could be installed in a timely manner and possibly at lower cost.

That being said, there is a discrepancy between local burdens and global impacts of climate change. While adaptation costs are borne by single countries, climate change and CE technologies act on a global level with possible global side effects. While for some countries it would be desirable to reduce adaptation costs via SAI, other countries might be harmed by the side effects of such deployment. Thus, climate goals must be agreed upon internationally and in accordance with a mutually beneficial weighting of side effects. If those challenges are met, reduction of adaptation costs could be a desirable climate goal.

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[25] Cost is a broad concept that also may include time, material, and also opportunity costs.

Climate Goal 4: Reducing mitigation pressure

The same line of reasoning applies with respect to the reduction of mitigation cost. By both economic rationality as well as appropriateness considerations, reduction of mitigation costs can be justified (e.g. Hampicke 2000).

Mitigation costs can be defined as the costs that result from engaging in carbon-neutral behavior at both an economic as well as individual level. The simple assumption here is that an extended time frame in which those measures ought to be realized leads to less pressure and hence less costs. Riahi et al. (2015) suggest that this assumption might really turn out to be overly simplistic. They show that, on the contrary, postponed mitigation efforts even increase overall mitigation costs. If a certain emission budget is to be satisfied, diverting from the optimal emission curve – in the sense of there being a temporal emission overshoot – asks for future emissions to decrease rapidly, which is even more costly. Only if BECCS or other negative emission technologies are anticipated in such an overshoot scenario can mitigation costs be reduced – but, as Riahi et al. urgently argue (Riahi et al. 2015), this 'bet' on future negative emissions is highly speculative and comes at the cost of possibly not complying with the two-degree target. Whether under these circumstances the reduction of mitigation costs is still desirable depends on a careful weighting of the different options and the consequences associated with realizing or not realizing certain political objectives.

With regard to appropriateness, Baatz and Ott (2016) have argued recently that certain mitigation strategies are inappropriate if they push citizens beyond a sufficiency threshold. This will probably not be the case in certain energy-shift scenarios for Germany in the next couple of decades. There are, for example, energy-shift scenarios for Germany that would come at reasonable costs and would resonate with the mitigation goals of the German Government. So, at least for Germany, reduction of mitigation costs might turn out to be superfluous in light of appropriateness considerations.

Another thing worth highlighting is that the obligation to mitigate is untouched by the desirability to minimize the costs of mitigation strategies. Minimizing mitigation costs should not be confused with minimizing mitigation efforts. Specifically, the reduction of mitigation costs ought not to be achieved by reducing mitigation altogether. This is why the mitigation obligation holds independently of the BT-argument. The no-impediment thesis in turn is influenced by the mitigation obligation, forbidding inadmissible substitution between mitigation and CE. The evaluation of the no-impediment thesis turns out to be quite complex, though, especially in case of reducing mitigation pressure via BECCS (see Section 4.5.3 and 4.5.4.)

The discussion in the previous paragraphs suggest that the desirability of the two 'reducing pressure' goals is highly dependent on the way they are brought about. They are susceptible to weighting with other goals or ethical obligations. In that sense, they might be called *secondary* climate goals (see 2.2). In particular, the reduction of mitigation costs can only be justified if it does not impede other, primary climate goals, such as the two-degree target.

Nonetheless, ultimately decisive for those weighting issues is the actual, non-ideal situation decision makers are confronted with. So, while in theory those secondary climate goals should be renounced as soon as they are found to interfere with far-reaching mitigation efforts, in reality, some sort of CE might turn out to be the only option for a 2°, or even a 1.5° world.[26]

3.4 Results

In the above chapter, the central assumptions of the buying time framing have been sifted out so as to formulate the buying time principle underlying the BT-argument:

Buying Time Principle (BT-Principle)

If: i. Climate goal G is desirable, ii. option O leads to climate goal G and is beneficial in so doing so, iii. option O only reckons with finite CE deployment, iv. CE in O does not lead to less mitigation compared to mitigation in O without CE, v. there is no option O' which is maximally finite and which leads to G and which is better than O, vi. there are no general moral constraints on option O;
then: option O should be adopted.

According to this principle, a buying time deployment of CE needs to be *desirable, effective, beneficial, finite, not in conflict with mitigation, the best available option* and *morally allowed.*

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[26] This limitation, however, is no drawback to my claim. My aim in this thesis is the thorough analysis of one specific argument in favor of CE in light of certain, to date plausible, assumptions. This is not diminished by the fact that some assumptions might turn out to no longer hold true.

The outstanding feature, which sets this argument apart from other consequentialist arguments about effective and beneficial CE-deployment, is arguably the incorporation of the finitude thesis and the no-impediment thesis. The assumptions backing the finitude thesis are:

- (*Transition Anyway*) Successful decarbonization of society is anticipated. Eventually, a low- or no-carbon society is thought to be reality, making artificial counter-balances to the CO_2 circle superfluous.
- (*No Substitute*) If decarbonization is successful in the end, CE deployment will cease, since it will no longer be needed to counteract insufficient emission cuts. This means that CE of any kind would only be deployed additionally to a comprehensive mitigation pathway, not instead of one. A non-finite CE deployment would amount to a *substitute* for mitigation efforts which is not acceptable within the BT-framing.
- (*Controllability*) Finitude can only be justified as a concept, if it incorporates some form of practical controllability. Deployment scenarios that point to well beyond the end of this century, may be finite in theory, but are not controllable in a practical sense.

The assumptions that shape the formulation of the no-impediment thesis are:

- (*Mitigation Obligation*) The current generation has the moral obligation to drastically reduce their CO_2 emissions within the next few decades. This obligation holds even in face of possible CE deployment.
- (*No Substitute*) If decarbonization is successful in the end, CE deployment will cease, since it will no longer be needed to counteract insufficient emission cuts. This means that CE of any kind would only be deployed additionally to a comprehensive mitigation pathway, not instead of one. A non-finite CE deployment would amount to a *substitute* for mitigation efforts, which is not acceptable within the BT-framing.

The BT-principle and -argument respectively, include two placeholders: climate goal G and policy option O. Four climate goals have been identified:

Climate Goal G

Climate Goal 1	Avoiding temperature-dependent tipping points.
Climate Goal 2	Avoiding rate-dependent tipping points.
Climate Goal 3	Reducing adaptation pressure.
Climate Goal 4	Reducing mitigation pressure.

In Chapter 4, I will introduce four different deployment scenarios that serve as instantiations for policy option O, enabling in-depth evaluation of the BT-argument in Chapter 5.

Chapter 4 Deployment Scenarios

The buying time argument scheme is characterized by the use of two placeholders O and G. Only if the placeholders are replaced with a concrete option and goal the argument's plausibility can be evaluated. Instantiations for climate goal G have been discussed in the previous chapter. The guiding question of the following two chapters is, whether there are climate policy options O that make the argument plausible. In other words: Is the proposed buying time idea compatible with concrete deployment scenarios?

To answer this question, two deployment scenarios will be depicted in this chapter. There are deployment scenarios that resonate with the buying time idea, and may have, in fact, been created specifically for that purpose. Two such scenarios have come to my attention: 1. Reduced Warming Rate – buying time for adaptation, and 2. Flexible Emission Budget – reducing mitigation pressure.

The first scenario is a SAI deployment that has been proposed by Keith and MacMartin (2015) (Section 4.1). The authors introduce a SAI scenario set-up designed to reduce the pace of the global warming rate for different emission trajectories (RCPs). The extraordinary feature of this scenario-bundle is the finitude of SAI deployment, which is present in at least two sub-cases. The authors do not argue that this deployment scenario should be adopted or that it is the best scenario conceivable. Rather, they demonstrate how a well-defined scenario can be shaped on base of guiding principles, and present a case study for the sake of advancing the discussion.

The second scenario incorporates BECCS deployment in light of current mitigation trends (van Vuuren et al. 2013). The authors demonstrate, how BECCS might be used to artificially extend the remaining emission budget in order to realize the two-degree target. Again, the authors of this scenario do not argue for its actual deployment, but rather use it to illustrate what a certain climate policy assuming BECCS would amount to.

4.1 Reduced warming rate – buying time for adaptation

One scenario for a sulfate aerosol injection scheme (SAI, see also section 2.5) has been introduced by David Keith and MacMartin and their colleagues (MacMartin et al. 2014, Keith and MacMartin 2015). In their proposal, SAI is used in order to reduce the rate of global temperature change for a given emission trajectory, rather than stop the temperature increase all together. This scenario is an excellent example for the BT-argument, for it is designed specifically in accordance with the buying time approach:

> "At a minimum, introducing [the proposed SAI scenario] would increase the *amount of time* to both learn and adapt; by reducing the needed rate for adaptation, it could *reduce costs of adaptation* […]."
> (MacMartin at al. 2014, p. 2, emphasis added [FN])

Additionally, the authors incorporate the idea to argue case-specific: "One cannot meaningfully evaluate solar geoengineering without a scenario for its implementation." (Keith and MacMartin 2015, p. 201). This resonates perfectly with the assumption of the work at hand, which asks for a case specific analysis of the empirical premises of the BT argument.

Lastly, the authors assume (at least for some RCPs) the finitude of the SAI deployment. This scenario is, taken all things into consideration, the best candidate for a plausible instantiation of the BT argument that has come to my attention so far. Consequently, the SAI scenario of Keith and his colleagues will function as one case study for the further evaluation of the BT argument.[27]

Temperature increase in the next century, even under optimistic mitigation assumptions, will have severe influence on life on earth. It is not only the absolute change in global mean temperature, which catalyzes dangerous climate events, but also the *rate* of warming. The frequency and strength of some climate events are determined by the warming rate and a quick temperature rise will make adaptation to those climate threats even more difficult (MacMartin et al. 2014).

SAI could limit the rate of global temperature rise. MacMartin, Keith and their colleagues have proposed a modest, temporal deployment of SAI (the authors use the

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[27] Keith and MacMartin 2015 is a revised version of MacMartin et al. 2014.

acronym SRM synonymously). This way, the authors argue that SAI could buy time for adaptation measures.

> „In particular, using SRM to limit the rate of temperature change would provide more time for both ecosystems and human systems to adapt to climate changes.“
> (MacMartin et al. 2014, p. 11)

The scenario is designed to meet specific criteria: It has to be temporal, moderate and responsive. These are the normative principles that guide the scenario setup.
The technology that the authors envisage is a sulfate aerosol solar radiation management (SAI). The physics behind this technology has been discussed in Section 2.5, and the authors specify the physical set-up only in certain details.
They assume the radiative forcing of one million ton of sulfur (MtS) to be 0.6 – 0.8 Wm^{-2}. For a given RCP, the scenario targets at cutting the rate of change of the respective radiative forcing in half. This suggests that the choice of a certain RCP is decisive for the scenario.

> „The choice of emissions trajectory has a profound influence over the magnitude and duration of geoengineering required to limit the rate of change of global mean temperature.“
> (MacMartin et al. 2014, p. 5)

For the main part of their investigation and for illustrative purpose, the authors assume RCP4.5 and calculate the amount of injected sulfur accordingly. In the RCP4.5 pathway, injection would start with 0.035 MtS per year and would increase steadily in the first decade by the same amount. After 10 years, the yearly injection would amount to 0.35MtS. The rate of injection would be adjusted in order to steady the rate of temperature change (picture below, second panel).

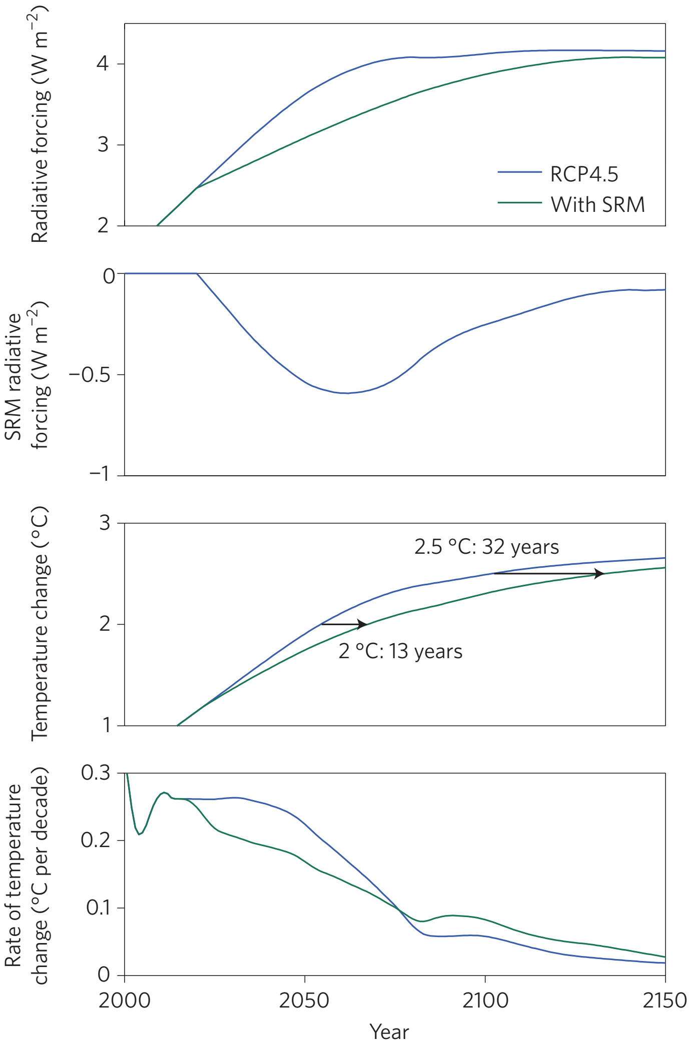

Figure 7. The top panel shows the total radiative forcing for RCP4.5, and a radiative forcing profile in which the rate of change is halved. The second panel indicates the suggested SAI (SRM) profile. Effect on global mean temperature is shown in the third panel, indicating the time benefit, and the corresponding injection rates per decade are shown in the last panel (source: Keith and MacMartin 2015).

As the figure above shows, the point in time, at which temperature reaches a certain degree above pre-industrial level, is delayed for several years, if SAI is used to limit the rate of temperature change.

Using a different approach, the authors determine the amount of SAI in accordance with a steady warming rate of 0.1°C per decade (instead of cutting warming rate in half, as in Keith and MacMartin (2015)). For RCP4.5, the length of required SAI deployment would have to be 160 years, if SAI is used to limit temperature change to 0.1°C per decade.

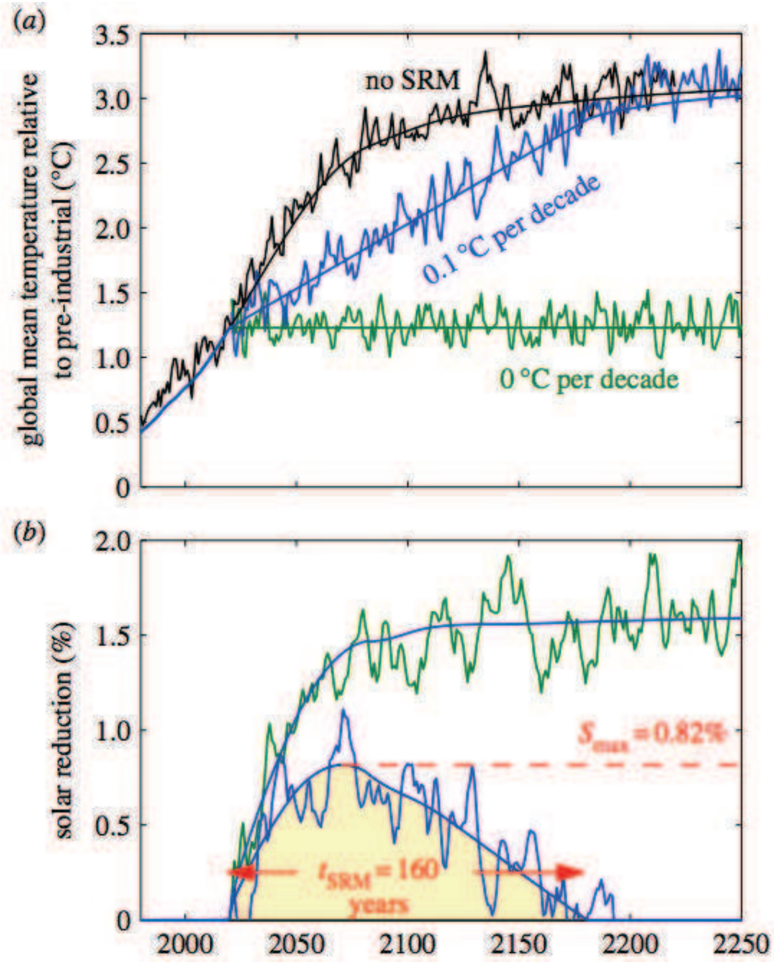

Figure 8. The top panel (a) shows SAI (SRM) being used for either maintaining constant global mean temperature (‘0°C per decade) starting in 2020 or limiting the rate of change to 0.1°C per decade for an RCP4.5 pathway. Panel (b) shows the corresponding solar reduction potential of SRM as well as the length of time over which SAI (SRM) would have to be deployed (source: MacMartin et al. 2014, online version in color).

For other RCPs, the below picture indicates the required timeframe and intensity of SAI schemes for varying temperature goals. If SAI is used to constrain temperature rise to 0.0 °C, that is to maintain current temperature, for all RCPs but RCP2.6, the finitude of the CE scheme is not given.

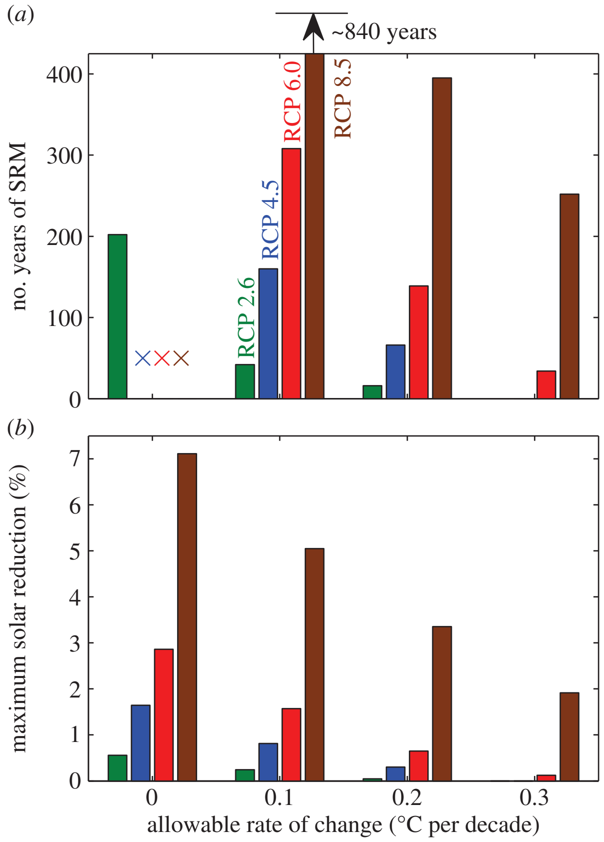

Figure 9. The panels show the duration (a) and amount (b) of SAI that would be required to constrain the rate of temperature change for different RCP pathways. For RCP8.5, the amount and duration of SAI is significantly larger than for other pathways. If SAI (SRM) is used to maintain a constant temperature (zero rate of change), the maximum solar reduction is finite for each RCP, but duration is only finite for RCP2.6 (indicated by 'x' for the other RCPs). (MacMartin et al. 2014, online version in color.)

Whether this scenario is optimal or even possible, is still not decided (as the authors state themselves). Instead, it presents itself as one first step towards a comprehensive analysis of purpose-bound and technology specific deployment scenarios. The authors use this case not to argue for its implementation, but rather to make discussion of the matter more transparent.

It is important to repeat that SAI in this scenario would not be used to tackle absolute temperature change: „(...) it [temporary SRM deployment] would not address problems such as temperature-dependent tipping point thresholds *(...)"* (MacMartin et al. 2014, p. 2). SAI would only account for reducing the *rate of change* for a given temperature rise, not its magnitude. In this setup, the main driver to limit global temperature rise would remain to be mitigation. Accordingly, it is still and only mitigation which could possibly lead to the stabilization of global mean temperature at 2°C above pre-industrial level (given the assumptions of the respective RCP).

This scenario does not frame SAI as a substitute for mitigation efforts, since both SAI and mitigation are concerned with different aspects of global climate change. While the former addresses the rate of change, the latter influences its quantity. The absolute temperature change is still determined by mitigation efforts, and SAI would be used supplementary to reduce the rate at which this change is to come about. SAI in this scenario does not reduce the dire need for drastic emission cuts – it rather points out what additional help SAI could generate. This is a great advantage of the scenario, since it does not initially run afoul of being a "cheap techno-fix" which supposedly makes mitigation obsolete. Moreover, the no-impediment thesis becomes at least plausible in this scenario, as shall be discussed in Chapter 5.

4.2 Flexible Emission Budget – minimizing pressure for mitigation

Another way in which CE could buy time relates to the emission budget. The budget approach to the two-degree target is a common method when evaluating necessary emission strategies (e.g. IPCC 2013, Kriegler et al. 2015). This approach rests on the observation that net cumulative emissions of anthropogenic GHG are near linear to the change of global mean temperature. Even if the specific emission trajectory alters – CO_2 emission reaches its peak early and decreases slowly or it peaks late and falls steeply – if the net cumulative emissions are roughly the same at the end of the century, absolute temperature change will be similar for those trajectories. The budget approach usually embraces the period until the end of the century, at which time a net-zero economy is assumed. CO_2 concentration of about 450ppm is assumed to realize the two-degree target with a probability of more than 66% (Rogelj 2016).

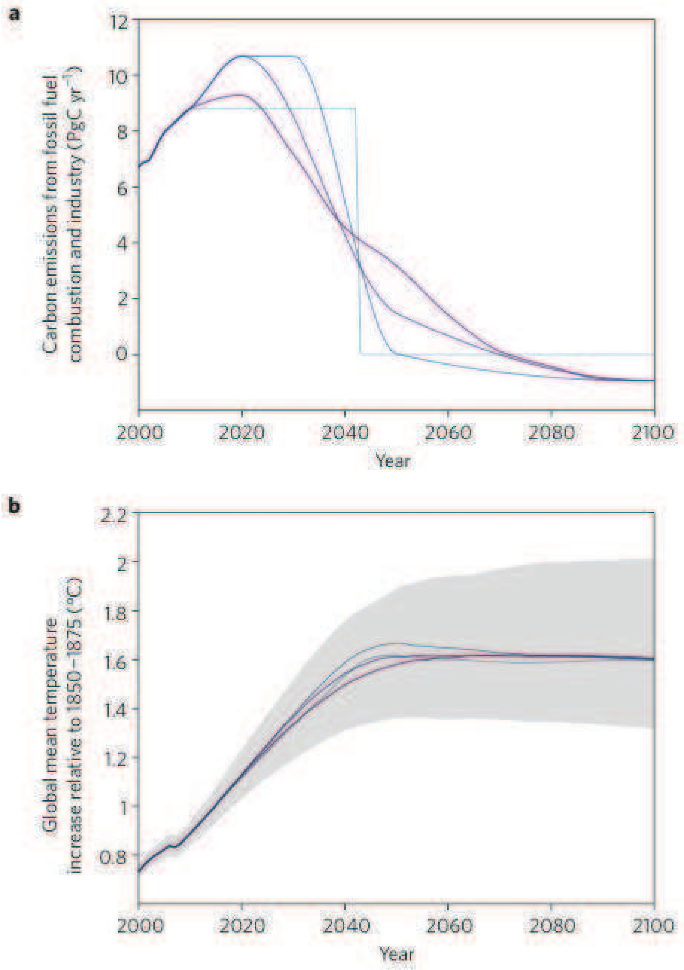

Figure 10. Four CO_2 emission pathways with identical cumulative carbon emissions over the twenty-first century (a) and their corresponding temperature projections (b). The grey area indicates the uncertainty range (source: Rogelj et al. 2016).

Rogelj et al. (2016) have analyzed the varying methods, by which different carbon budgets were obtained. They conclude that if differentiated climate feedbacks are taken into account, the remaining carbon budget would be no more than 590–1,240 $GtCO_2$ between 2015 and 2100. The question is, of course, how the remaining emissions are to be allocated and whether an overshoot can be balanced out via future negative emissions.

Van Vuuren et al. (2013) show how drastically emissions would have to be reduced in order to realize near-zero emissions in 2100. For example, assuming a 2% reduction rate per year, emissions in 2020 must be similar to those in 2000 and must lie 10% under the anticipated baseline scenario (Fig. 1, Panel a) which assumes a business-as-usual economy. If a limited mitigation potential is assumed, reduction must happen even more quickly (Fig. 1, Panel b).

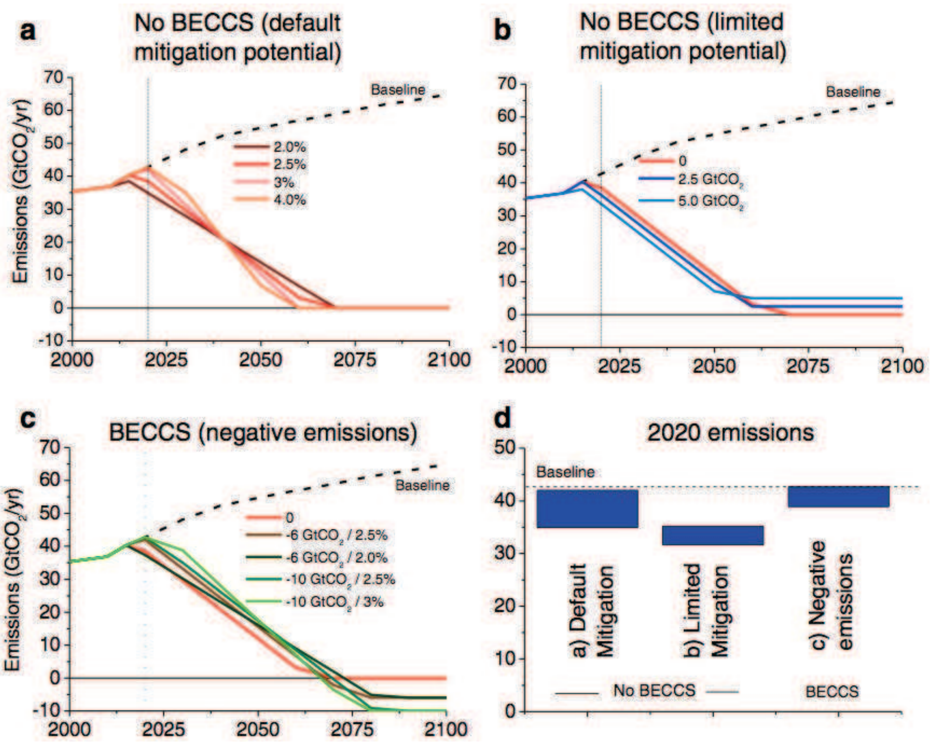

Figure 11. Illustrative emission pathways based on carbon budget of 1600 GtCO$_2$ and constant emission reduction rate. Panel (a) shows emission pathways going to zero emission with the respective reduction rate, panel (b) shows results if the emission reduction potential is limited, panel (c) shows the results if negative emissions via BECCS are assumed. Panel (d) summarizes the emission window for 2020, if emissions in 2100 are zero with a maximum reduction rate of 2-3% per year (source: Van Vuuren et al. 2013).

The authors now demonstrate how the pressure of immediate mitigation could be lessened when assuming future negative emissions obtained with bioenergy with carbon capture and storage (BECCS).

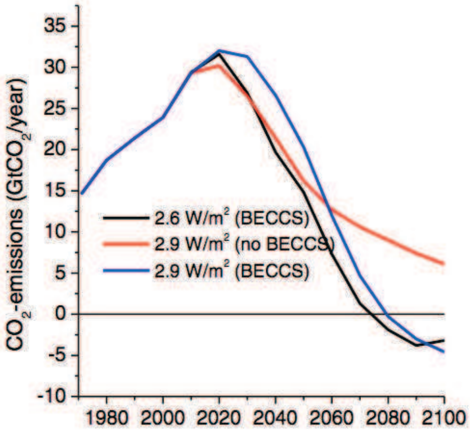

Figure 12. Emission trajectory of scenarios with and without BECCS leading to stabilization at 450 and 480ppm CO$_2$-eq (source: Van Vuuren et al. 2013).

It is obvious from the above figure, how BECCS can postpone the point of installing drastic emission reduction, thereby allowing an emission overshoot. The red graph, which indicates stabilization at 450 ppm by 2100 under the assumption of RCP2.6, demands a sharp decrease in carbon emission by 2020 latest. The blue graph, however which assumes BECCS and negative emissions in the future, delays this point by about 10 years. Also, the curve decreases much steeper than the red one, hence implicating a more powerful CO_2 -reduction-potential of BECCS as compared to mitigation alone. This indeed could lessen the pressure of immediate mitigation and hence might be a means to buy time.

On the other hand, if a more ambitious climate target is aimed at, BECCS might still be able to allow a temporary overshoot, but would demand emission reduction to be as immediate as the RCP2.6 suggests (black graph).

It is worthwhile in this context to evaluate the intended national determined contribution (INDC), as have Riahi et al. (2015) done[28]. The authors distinguish two mitigation scenarios that have short-term targets for 2030: HST and LST. While LST (low short-term target) aims at emitting only 53 Gt of CO_2-eq. by 2030, HST (high short-term target) settles at a mitigation effort of reaching 61 Gt of CO_2-eq. In the HST pathway, already 70% of the two-degree emission budget is spent by 2030, creating an "emission gap" as compared to an optimal two-degree pathway.

This of course puts a lot of pressure on the remaining decades to reduce emissions substantially. By 2050, the identified emission gap would have to be closed in order to reach stabilization at 450ppm or 550ppm resp. This "leaves only 20 years (2030 to 2050) for a fundamental transformation of the global energy-economic system." (Riahi et al. 2015, p. 13).

Depending on the assumptions about energy demand, energy transformation, technical feasibility and social and political behavior, this 20-year transformation is seen as either impossible or feasible. Notably the availability of negative emission technologies (NETs) influences the judgment.

The authors now reach the important conclusion that

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[28] More recently, the Paris pledges have been analyzed. At the time of writing, the latest INDCs also would not be compatible with a stabilization of temperature at below 2°, and relying on negative emissions seems insufficient (Kartha and Dooley 2016).

> „… in particular the HST pathway, narrows policy choices and increases the risks that some of the currently optional technologies, such as the large-scale deployment of biomass or CCS, will become "a must" by 2030 in order to achieve low stabilization targets."
>
> (Riahi et al. 2015, p. 20)

In other words: The way short-term emission pathways are designed today highly influences the options available to the future.[29] This highlights the interdependency of CE technologies and current emission strategies. If, for example, negative emission technologies like BECCS are anticipated, an emission overshoot is still consistent with the two-degree target. On the other hand, when high short-term emissions are agreed upon, BECCS seems to become inevitable. This self-enhancing process is morally relevant, and will be discussed in Section 5.4.

4.3 Results and complete argument matrix

This chapter has introduced two different scenarios that serve as the blue print against which the BT argument is evaluated. The first one is a well-defined SAI deployment scenario, which has been sketched out for different RCPs. The second scenario evaluates, how BECCS can be used to close the emission gap of current emission pledges. Both scenarios serve the same purpose for the upcoming chapters: Replacing placeholder O in the BT argument, thus enabling the evaluation of the premises.

The SAI scenarios show how time span and intensity of the designed deployments would differ for each RCP. I will adopt a case-discrimination accordingly, with one case adopting a mitigation pathway related to RCP2.6, in which remaining within the two-degree emission budget is assumed to be more likely, and one case assuming an emission overshoot that exceeds the two-degree budget. The same case-discrimination will be applied to the BECCS cases.

However, even in an RCP2.6 scenario, there might be an emission overshoot, which could possibly be leveled out by future negative emissions (Section 4.2). That being

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[29] From a policy perspective initial low pledges might be prudent: Because reduction targets under the Paris Agreement will increase over time, states will only pledge low INDC in the first period even if their energy policies are already more advanced.

said, the two-degree budget serves as the quantitative threshold defining emission efforts, while the RCPs indicate the likelihood of remaining within this budget.
This generates four climate policy options O:

Climate Policy Option O

Climate Policy Option a	SAI + CO_2 emissions remaining within the two-degree budget ($CO_2 < 2°$ budget).
Climate Policy Option A	SAI + CO_2 emissions exceeding the two-degree budget ($CO_2 > 2°$ budget).
Climate Policy Option b	BECCS+ CO_2 emissions remaining within the two-degree budget ($CO_2 < 2°$ budget).
Climate Policy Option B	BECCS + CO_2 emissions exceeding the two-degree budget ($CO_2 > 2°$ budget).

The lower case letters a and b indicate emissions remaining within the two-degree budget; the upper case letters A and B signify an overshoot scenario.
An argument matrix, which plots O and G against each other, yields sixteen version of the BT-argument:

Climate Goal G / Policy Option O			Preventing climate tipping points		Reducing pressure	
			Avoiding temperature - dependent tipping points	Avoiding rate-dependent tipping points.	Reducing adaptation pressure	Reducing mitigation pressure.
			1	**2**	**3**	**4**
SAI	$CO_2 < 2°$ budget	**a**	a1	a2	a3	a4
	$CO_2 > 2°$ budget	**A**	A1	A2	A3	A4
BECCS	$CO_2 < 2°$ budget	**b**	b1	b2	b3	b4
	$CO_2 > 2°$ budget	**B**	B1	B2	B3	B4

Table 5. Argument matrix. The rows depict climate goals G, the columns depict portfolio options O. Each entry represents a version of the BT-argument

As introduced in Chapter 2, a climate policy portfolio consists of at least three options: mitigation, adaptation and CE. For now, I will assume that there is no relation between these options[30]. Instead, I will incorporate two CE technologies, SAI and BECCS, and differentiate two sub-cases regarding mitigation efforts, as the above table illustrates. Those sub-cases are not determined by the compliance with the mitigation obligation. Rather, they are purely quantitative: Are emission cuts anticipated that would remain within the two-degree budget of CO_2 emissions?

By including the amount of mitigation as a background assumption of climate policy option O, the moral status of mitigation efforts is not decisive when evaluating the premises of the BT-argument. There is a clear strategic benefit in doing so: The premises of the buying time argument can be evaluated in light of the 'empirical' assumption about the climate portfolio, without having to decide about normative premises including a moral principle that asks for CE to be accompanied by fast and far reaching mitigation. This enables a rather analytical evaluation of the BT-argument.

This analysis, however, generates far-reaching results. Most notably, the sub-cases assuming an overshoot render at least one premises of the BT-argument implausible or at least undecided. I believe to be able to demonstrate that the BT argument only then has *plausible* premises, if emissions are assumed to remain within the two-degree budget. This is indeed a great result, and a clear benefit as opposed to continuously emphasizing the moral obligation to engage in drastic mitigation efforts in face of CE – which already is obvious and still does not lead to more ambitious mitigation.

The mitigation obligation is of course the moral epicenter of this work. It enters the BT-argument in two ways: As the no-impediment thesis, and later, as a general evaluation pattern in Chapter 6. Especially does the mitigation obligation hold independently of any assumed CE deployment. I deem this result to be a benefit of the argument reconstruction at hand.

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[30] This assumption will be further scrutinized in Chapter 6.

Chapter 5 Evaluation of the Arguments

In Chapter 4, I have introduced two technology deployment scenarios, which I believe to resonate best with the buying time idea, thereby introducing four instantiations of placeholder O. In Chapter 3, different instantiations for climate goal G have been introduced, which combined result in a sixteen-field matrix for the BT-argument. The aim of this chapter is now to evaluate for each combination of G and O, whether the respective argument generates plausible[31] premises. Not all versions must or can be discussed in detail, however. If only one premise turns out to be implausible, the whole argument can be rejected (Section 5.2). Surprisingly, only two arguments can be said to be plausible (Section 5.1). Moderate SAI plus sufficient mitigation could help avoid rate-dependent tipping points as well as help reduce adaptation pressure (argument a2 and a3).

The remaining versions are neither obviously plausible nor obviously implausible. In most cases, I cannot decide upon the plausibility of a given scenario due to a lack of knowledge. Especially when scientific facts are at stake, which surpass the information of the two exemplary deployment scenarios introduced in Chapter 4, evaluation of the arguments must remain incomplete. I will label those arguments accordingly as being beyond the scope of this work, while at the same time urging for further research (Section 5.3).

On the other hand, there are deployment-scenarios that seem in itself rational, but are at odds with the BT argument in its present form. Most notably, the prominently discussed case of BECCS as a means to buy time in face of less than sufficient mitigation turns out to obscure the dubitable status of at least two buying time requirements – the finitude of the deployment and the impact on mitigation efforts. In this situation, there are two possibilities: Holding onto the strong version of the BT-argument and rejecting the scenario, or reformulation the BT-requirements so that they incorporate the desired scenario. In this chapter, the first path is traced (Section 5.4), while a reformulation of the BT-argument is sought in Chapter 6.

The discussion here serves two purposes: 1. on the methodological level, it shows how the buying time argument can be evaluated and 2. on the practical level, it might

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[31] Plausibility, as well as likelihood is understood in a broad, every-day meaning. Plausibility in a argumentation-theoretical discourse is an elaborate concept (e.g. Walton 2001), referring to which is not necessary for the current purpose.

give some insight on how to assess different deployment scenarios. This kind of argument-evaluation is a first step towards a comprehensive case study, which is necessary for assessing the moral status of any CE deployment. While I am aware that this can only be a first tentative judgment, this work serves as an example of how argument analysis can indeed be politically relevant.

5.1 Plausible instantiations

There are two combinations of G and O that yield arguments with plausible premises. The green areas signify those arguments.

Climate Goal G			Preventing climate tipping points		Reducing pressure	
			Avoiding temperature - dependent tipping points	Avoiding rate-dependent tipping points.	Reducing adaptation pressure	Reducing mitigation pressure.
Policy Option O			**1**	**2**	**3**	**4**
SAI	CO_2 < 2° budget	**a**	a1	a2	a3	a4
	CO_2 > 2° budget	**A**	A1	A2	A3	A4
BECCS	CO_2 < 2° budget	**b**	b1	b2	b3	b4
	CO_2 > 2° budget	**B**	B1	B2	B3	B4

Table 6. Plausible Instantiations of the BT-argument.

The two arguments a2 and a3 will be discussed in turn, starting with the strongest and most interesting case of SAI-deployment in order to reduce pressure for adaptation (argument a3, Section 5.1.2). The second argument a2 is very similar to a3, and will be discussed briefly. Both argument a2 and a3 assume mitigation efforts to remain within the two-degree budget, while the use of SAI addresses the rate of temperature change.

In order to evaluate the plausibility of the arguments, each premise needs to be scrutinized and its plausibility needs to be shown. This will be done for those two arguments a2 and a3, with the exception of the morality thesis. As said before, the research question of the thesis at hand is, whether a BT-deployment is possible absent any general moral constraints about CE. This means that for the time being, it is assumed that neither SAI nor BECCS are inherently morally wrong. Whether this is true, will be subject of Chapter 6, when general moral constraints on plausible BT-instantiations are discussed.

5.1.2 Argument a3

G	Climate Goal 3	Reducing adaptation pressure.
O	Climate Policy Option a	SAI + CO_2 emissions remaining within the two-degree budget (CO_2 < 2° budget)

The first deployment scenario introduced in this chapter has clearly been designed to meet the climate goal identified as the Reducing Adaptation Costs Goal (Climate Goal 3). The climate portfolio in this scenario aims at stabilizing temperature at 2 °C, while on the other hand, lessening the rate of change in order to buy more time for adaptation.

The envisage CE technique is a special version of SAI. The calculations are made – among others – for an RCP2.6 pathway, hence, for this version, mitigation in option O will be assumed to enable emissions to meet the two-degree target.

It is essential to this scenario that SAI is not used to stabilize temperature, but only to lower the *rate* of temperature change. The stabilization of temperature in accordance with the specific RCP is achieved solely through cuts in CO_2 emissions.

Of the six BT-requirements, only the following theses need to be evaluated in the upcoming section: effectiveness thesis, finitude thesis, no-impediment thesis, and no-better-option thesis. The desirability thesis has already been established for each climate goal G (Section 3.3), and the morality thesis will be focus of Chapter 6. As said before, the question of the work at hand is, whether a BT-deployment is possible absent any general moral constraints about CE. This means that, for the time being, SAI and BECCS are framed as not being inherently morally wrong.

(Effectiveness Thesis) Option a *leads to desirable climate goal* G3 *and is beneficial in so doing so.*

According to the scenario set-up, SAI will be successful in reducing the warming rate (MacMartin et al. 2014). The authors argue that SAI will thus be able to reduce adaptation pressure, by generation more time for learning and installing different adaptation measures. Furthermore, if the RCP2.6 mitigation pathway is assumed, the stabilization of temperature at 2°C above pre-industrial level is likely to be guaranteed. Therefore, indeed, SAI deployment can be called effective.

The second part of the effectiveness premise asks for a beneficial deployment. The weighting of the benefits and the negative side effects in order to guarantess some form of beneficial deployment, is a matter of great dispute. It would be beyond the scope of this work to fully decide for the deployment scenarios at hand, if the benefits outweigh the costs. So, rather, some central and most discussed side effects of SAI deployment are isolated and presented here.

Whether the scenario at hand eventually is beneficial or not, depends on model results I cannot provide. The question here is, if MacMartin's and Keith's deployment scenario has the theoretical *conditions for the possibility* of being beneficial. I will focus on three possible negative side effects associated with SAI: precipitation, methods of injection and affiliation to the fossil fuel sector and procedural justice. The guiding question is: Are there circumstances that would render this scenario beneficial?

Precipitation. Keith and MacMartin have specified some climate damages resulting from SAI, including the deviation of precipitation from pre-industrial level (Keith and MacMartin 2015). The authors suggest that the level of SAI, which maximizes climate benefits (namely the temperature stabilization), is much higher than the level that maximizes the sum of harms and benefits. In consequence, the level of beneficial SAI would always be less than the level of most effective SAI. Given that, is it possible that the moderate SAI approach could count as beneficial? What percentage of change in precipitation could still be 'acceptable'?

Acceptable climate impacts generated by SAI deployment[32] could, for example, be defined in accordance with basic human rights, such as access to food and clear water, and not infringing the sufficiency threshold of the affected (Shue 2010).

If deviation from natural precipitation patterns violates human rights or makes self-sufficient life in certain areas of the world difficult if not impossible, it surely would not be beneficial. Questions in this regard are, among others: What groups of people are affected by SAI impacts? In what climate and precipitation range can their lifestyles exist? Are there forms of compensation conceivable?

This very short discussion means to illustrate the theoretical possibility to shape a beneficial SAI deployment, if those questions can be answered satisfactorily.

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[32] This supposes, that there are acceptable impacts of SAI, and that not simply all effects of SAI would count as inacceptable. This correlates with the notion of SAI not being inherently morally wrong.

Methods of Injection. The authors propose the use of aircraft to inject the sulfate (Keith and MacMartin 2015). Obviously, airplanes must be fueled. Hence, the use of SAI would, at least to some extend, require the use of fossil fuels and thus add to continued CO_2 emission. This could only be acceptable, if the other benefits (such as prevention of climate tipping points) outweigh this challenge.

However, it could be argued that the use of fossil fuel for aircraft is a contingent factor, and sustainable aviation fuel is underway. If this was a real possibility, not only would SAI injection cease to add to carbon emission, but would also lose its connection to the fossil fuel sector.

Procedural justice. While it is long and by argued that the use of SAI would be simple and cost-effective, even allowing for single states to undergo the deployment, it is still a technique that requires central control. Since it is a large-scale manipulation of a common good – the atmosphere – its deployment has to be subdued to common decision making. A global moratorium on SAI use might be hard to achieve, but at least it could be argued that common global agreements are possible and are in fact, presently installed in many different areas. Hence, global agreement on SAI deployment can be possible and is necessary for beneficial deployment.

So, in conclusion there could be situations in which a BT-deployment of SAI could be more beneficial than harmful. However, this might be only the case for low-scale SAI deployment, or far less or far shorter deployment than might be desirable from a purely temperature-based assessment. As the authors of this scenario have stated: “Whatever the weighting of these benefits and cost functions, the ratio of benefits to costs will be largest for very small amounts of SRM.” (Keith and MacMartin 2015, p. 204). They continue to observe: “(One) must conclude that the optimal amount of SRM will always be less than the amount of SRM that maximizes benefits.” (Keith and MacMartin 2015, p. 204). This very important conclusion should be present for any possible framing of SAI deployment. It implies that beneficial SAI deployment might be possible, but only within clear-cut boundaries. Those boundaries might arguably be given in a RCP2.6 world, where emission are cut to remain within the two-degree budget and SAI would have to be deployed for a short period of time only.

(Finitude Thesis) Option a *only allows for finite SAI deployment.*

In their 2014 paper, MacMartin at al. determine the deployment time of SAI for different RCPs. In an RCP2.6 world, for example, SAI deployment would only be necessary for 40 years. However, the time frame increases sharply: For the RCP4.5, the duration of deployment would be 160 years, culmination to roughly 800 years for RCP8.5.

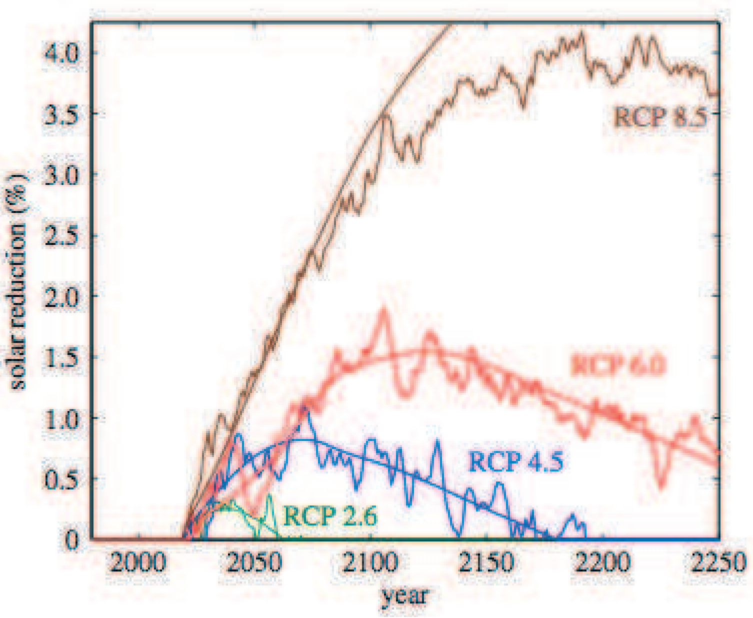

Figure 13. Comparison of the solar reductions required to maintain a 0.1°C per decade rate of temperature change for different emission pathways (source: MacMartin et al. 2014). See also Figure 9, Section 4.1.

In Section 3.2 I have argued that finitude is a practical concept, which makes assumptions about controllability. Any time frame that clearly surpasses the end of the century, may in theory be finite, but cannot be handled practically. Additionally, it presents a huge risk transfer into the future.

The authors also calculate the termination time for the RCPs, depending on the allowed rate of temperature change (see Section 4.1, Figure 9). Only if 0°C change is allowed (i.e. if SAI is used to stabilize temperature at pre-industrial level indefinitely), the use of SAI in all RCPs but RCP2.6 is infinite. Under all other circumstances, both the intensity and the duration of the deployment is projected to be finite. But again, it must be stressed that some expected durations of SAI surpass any realistic timeframe on which policy decisions could rely on.

Assuming CO_2 emissions to remain within the two-degree budget, and assuming that this might most likely be the case in RCP2.6, a duration of about 40 years is indeed a manageable, finite timeframe.

(No-impediment Thesis) SAI in option a *does not lead to less mitigation compared to mitigation in option* a *without SAI.*

As illustrated before, MacMartin and his colleagues contrast the SAI deployment with different RCPs. The RCPs and with them, mitigation efforts, are the background assumptions that enter their model set-up. In this sense, they assume mitigation efforts staying constant for each RCP. Thus, the scenario design aligns with the requirement that SAI deployment should not compromise mitigation efforts. Since the envisaged SAI deployment would only address the *rate* of temperature change and not the temperature change itself, it would not act as a substitute for mitigation. If, moreover, a mitigation pathway like the RCP2.6 is assumed, the two-degree target might be reached with mitigation efforts alone, while SAI would address the secondary climate goal of reducing adaptation pressure.

However, there are some drawbacks to the evaluation of the no-impediment thesis. It might be difficult to attribute the increase in temperature and the change in the warming rate to SAI and mitigation separately. Since the effectiveness of a SAI scheme and of mitigation partly overlap, there might be no clear role-attribution to either of them. This problem is even more manifest in the BECCS-cases.

Additionally, the likelihood of the scenario can be challenged. Even if the design of the scenario makes the no-impediment thesis true, there is no guarantee that this will be the case if implemented in "real life" climate policy. This "reality gap" will be focus of discussion in Chapter 6. Here, it needs to be stressed, that at least the assumptions of this deployment scenario presuppose constant, sufficient and eventually successful mitigation efforts.

(No-better-option Thesis) There is no option O' which is finite and which leads to climate goal G3 *and which is better than option* a.

As introduced above, the no-better-option thesis in my BT-argument reconstruction works as a 'safeguard' to make sure that no option not including SAI deployment, is ruled out prematurely. If two portfolios equally realize a desired climate goal G, the portfolio without CE should be adopted. So, in context of this version of the BT-argument (Argument a3), it needs to be asked if there is a conceivable portfolio without SAI that is equally powerful in reducing the rate of temperature change and thus in reducing pressure for adaptation.

The temperature change can be influenced by ambitious mitigation strategies. But SAI is specifically designed to influence the rate of change *on basis* of those mitigation strategies. It is an additional climate strategy that serves a secondary purpose. Hence, a portfolio without SAI might be able to determine the temperature change, but would have no possibility to influence the rate of temperature change in this given setup[33].

So, regarding the specific climate goal to reduce adaptation pressure and assuming that even drastic mitigation primarily influence the absolute temperature change, SAI presents itself indeed as the best option for this purpose.

5.1.2 Argument a2

G	Climate Goal 2	Avoiding rate-dependent tipping points.
O	Climate Policy Option a	SAI + CO_2 emissions remaining within the two-degree budget (CO_2 < 2° budget)

In this version of the buying time argument, the same deployment scenario is taken into consideration as above: It is climate option *a,* (MacMartin et al. 2014, Keith and MacMartin 2015) that introduces time limited and purpose bound SAI in order to reduce the warming rate. They calculate their deployment scheme in light of different RCPs, and as in the previous chapter, I will assume a scenario which ensures the two-degree target via mitigation efforts. For argument a2, the climate goal is to avoid rate-dependent tipping point, such as the shutdown of the thermohaline circulation (Stocker and Schmittner 1997). Since the in-depth discussion of this specific policy mix has been given above, I will not discuss each premise individually, but rather discuss them together.

At first glance, all BT-requirements can be said to be met – the scenario was designed exactly for this purpose. SAI is effective, in that it would reduce the warming rate and hence prevent rate-dependent tipping points, it might also be beneficial in so doing so. Mitigation efforts would ensure the realization of the two-

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[33] Of course, if temperature would rise less sharply, the rate of change would also be influenced. But for a given projected temperature rise, only SAI could arguably influence the rate of change. There might be other CE strategies to also serve the purpose of influencing the changing rate. However, the question here is, whether there is a portfolio without any CE measure that realizes the same goal.

degree target. Also is SAI finite and the no-impediment thesis is true for the same reason as it was true in the previous argument: Since mitigation efforts are assumed to stay constantly high in the respective RCP, they will not be affected by SAI. Lastly, the no-better-option thesis must be said to be plausible, too, since no climate strategy without SAI might address the rate of global temperature change.

To conclude, this version of the BT-argument which aims at avoiding rate-dependent tipping points via SAI and which assumes a high level of mitigation in order to realize the two-degree target, is plausible. However, the discussion indicates quite clearly that the underlying emission pathway is the decisive element for the evaluation. Even when assuming SAI, emissions must be reduced massively, in order to reach the two-degree goal.

5.2 Implausible instantiations

The above section (Section 5.1) has introduced two instantiations of the BT-argument with respect to one specific SAI deployment scenario. The premises resulting from this instantiations are *prima facie* plausible. In this section, I will discuss six versions of the BT-argument that I deem to be implausible, represented by the red areas (see table below).

Climate Goal G Policy Option O			Preventing climate tipping points		Reducing pressure	
			Avoiding temperature - dependent tipping points	Avoiding rate-dependent tipping points.	Reducing adaptation pressure	Reducing mitigation pressure.
			1	**2**	**3**	**4**
SAI	$CO_2 < 2°$ budget	**a**	a1	a2	a3	a4
	$CO_2 > 2°$ budget	**A**	A1	A2	A3	A4
BECCS	$CO_2 < 2°$ budget	**b**	b1	b2	b3	b4
	$CO_2 > 2°$ budget	**B**	B1	B2	B3	B4

Table 7. Plausible and implausible instantiations of the BT-argument.

In case of identifying implausible arguments, it suffices to point out only one implausible premise. I will discuss the implausible argument instantiations in groups of what climate goal they are supposed to reach (arguments a1 and b1) and what policy option they assume (arguments A1 – A4), respectively. One tentative conclusion of the table above is that an SAI-portfolio assuming CO_2 emissions exceeding the two-degree budget results in an implausible instantiation of the BTA (arguments A1 – A4). If this is true, this result might influence the decision making-process in case a buying time deployment via SAI is advocated in light of possible insufficient mitigation.

5.2.1 Arguments a1 and b1

Policy option *a* has already been discussed as a plausible instantiation of two BT-versions (arguments a2 and a3, see Section 5.1). If the goal differs, however, the SAI deployment scenario leads to implausible premises of the respective argument.

If climate goal 1 is stipulated, the BT-argument essentially amounts to the two-degree target: It aims at preventing temperature-dependent tipping points. This is to be achieved via stabilization of global temperature rise to maximally 2°C above pre-industrial level (see Section 1.1, Section 2.1, Section 2.2, Section 3.3 and Section 4.1).

Climate portfolio *a* might be able to realize the two-degree target, since it assumes emissions to remain within the two-degree budget. This way, mitigation in option O guarantees the realization of climate goal 1. As said before, the SAI deployment in this set-up does not address the amount of temperature change, but the rate at which it happens. In argument a1, SAI deployment is superfluous for reaching the respective climate goal

If the two-degree target would be reached with mitigation alone (which is the background assumption of this argument), then there is indeed a better option than mitigation plus SAI, and that is: mitigation alone. If mitigation alone would be effective in realizing the two-degree target, then SAI would be redundant. Hence a portfolio without SAI is a better option; the no-better option thesis would become implausible.

The same reasoning applies to argument b1 and policy mix b, respectively, where BECCS is assumed additionally to already sufficient mitigation. That way, BECCS would also be superflous, and the better option as compared to BECCS combined with mitigation would be: mitigation alone. In both arguments a2 and b1, the two-degree target can be reached with mitigation alone and CE deployment is not needed. The no-better-option thesis becomes implausible in both cases.

5.2.2 Arguments A1, A2, A3 and A4

As indicated in Section 3.3, each of the four climate goals includes the stabilization of temperature rise at 2°C above pre-industrial level. A mitigation trajectory which leads to a global temperature rise of more than 2°C does not realize the two-degree target. Hence, climate option A which assumes CO_2 emissions to exceed the two-degree budget and which assumes SAI deployment not to address absolute temperature change, is not effective in reaching any of the relevant climate goals.

Having said this, SAI deployment could still be used to achieve the two-degree target under insufficient mitigation efforts, if it is used to address temperature change directly. A lack of mitigation efforts could possibly be balanced by more SAI, if SAI is used as a substitute. The respective argument to support such SAI deployment is the so-called two-degree target argument that has been already been introduced by Betz and Cacean (2012) (see also Section 3.3). Such a deployment scheme, however, would deeply differ from the scenario introduced above in Section 4.1. In a temperature-stabilizing scenario, SAI would act as a substitute to mitigation. The no-impediment thesis becomes at least questionable in such a set-up.

Additionally, if mitigation efforts will not be able to stabilize temperature medium-term, SAI deployment might have to be continued infinitely, or at least for a very long timespan (Section 4.1, also MacMartin et al. 2014). This violates one essential buying time requirement: the finitude thesis. In summary, a scenario that assumes SAI deployment in light of insufficient mitigation makes at least two premises of the corresponding argument implausible: the finitude thesis and the no-impediment thesis.

The below table shows the implausible versions of the BT-argument and indicates the premises, that become implausible or at least questionable in the specific set-up.

Climate Goal G			Preventing climate tipping points		Reducing pressure	
			Avoiding temperature - dependent tipping points	Avoiding rate-dependent tipping points.	Reducing adaptation pressure	Reducing mitigation pressure.
Policy Option O			**1**	**2**	**3**	**4**
SAI	$CO_2 < 2°$ budget	**a**	No-better-option thesis			
	$CO_2 > 2°$ budget	**A**	No-impediment thesis, finitude thesis	No-impediment thesis, finitude thesis	No-impediment thesis, finitude thesis	No-impediment thesis, finitude thesis
BECCS	$CO_2 < 2°$ budget	**b**	b1			
	$CO_2 > 2°$ budget	**B**				

Table 8. Implausible instantiations of the BT-argument. The implausible premises of the respective argument are shown in the fields.

5.3 Lack of knowledge

In most cases, I simply do not have the expertise to judge the plausibility of a given scenario, especially when scientific facts are at stake that surpass the information of the two exemplary deployment scenarios introduced in Chapter 4.

Climate Goal G			Preventing climate tipping points		Reducing pressure	
			Avoiding temperature - dependent tipping points	Avoiding rate-dependent tipping points.	Reducing adaptation pressure	Reducing mitigation pressure.
Policy Option O			**1**	**2**	**3**	**4**
SAI	$CO_2 < 2°$ budget	**a**	a1	a2	a3	a4
	$CO_2 > 2°$ budget	**A**	A1	A2	A3	A4
BECCS	$CO_2 < 2°$ budget	**b**	b1	b2	b3	b4
	$CO_2 > 2°$ budget	**B**	B1	B2	B3	B4

Table 9. Plausible, implausible and undecided arguments. Light blue indicates a lack of knowledge about the scenario, dark blue indicates two cases that are unclear with regard to the underlying BT-principle.

There are six arguments that I cannot fully evaluate in this work due to a lack of knowledge. Four of them are arguments assuming a BECCS-scenario (b2, B2, b3 and B3). Those arguments mean to realize the related climate goals 2 and 3: Reducing adaptation pressure and avoiding rate-dependent tipping points. Those arguments share the same uncertainty: It is unclear whether BECCS – a technology which primarily deals with the concentration of CO_2 in the atmosphere and only secondarily with the pace this concentration comes about – can address any rate-dependent climate goals. It is beyond the scope of this thesis to judge the many ongoing model-runs for BECCS.

Two other arguments containing uncertain premises are a4 and b4. They each assume a mitigation pathway, which realizes the two-degree target independently of additional CE deployment. The respective climate goal is a reduction in mitigation pressure (climate goal 4). While argument B4, which assumes BECCS in face of insufficient mitigation as a means to reduce further mitigation pressure, will be the focus of discussion in the next section (Section 5.4), the notion of reducing mitigation pressure for already successful mitigation might make no sense. Hence, arguments a4 and b4 are included in the group of indeterminable arguments.

The first two arguments I will deal with are arguments b2 and B2:

Argument b2:

G	Climate Goal 2	Avoiding rate-dependent tipping points.
O	Climate Policy Option b	BECCS + CO_2 emissions remaining within the two-degree budget (CO_2 < 2° budget).

Argument B3

G	Climate Goal 2	Avoiding rate-dependent tipping points.
O	Climate Policy Option B	BECCS + CO_2 emissions exceeding the two-degree budget (CO_2 > 2° budget)

Whether BECCS is able to tackle the rate of temperature change is unclear. It might have some effect on the warming rate by manipulation the amount of CO_2 in the atmosphere. This is not a direct adjustment of the warming rate as exemplified by the SAI scenario. It cannot be ruled out, however that BECCS might be able to realize climate goal 2. If, in addition, an emission overshoot is anticipated (argument B2), BECCS would arguably be used to both stabilize the absolute temperature change and influence the pace of warming. The interdependency of those two aspects and the role BECS can play here, is opaque to me. The effectiveness thesis cannot be evaluated for both arguments in the given context.

Argument b3:

G	Climate Goal 3	Reducing Adaptation pressure
O	Climate Policy Option b	BECCS + CO_2 emissions remaining within the two-degree budget (CO_2 < 2° budget).

Argument B3

G	Climate Goal 3	Reducing Adaptation pressure
O	Climate Policy Option B	BECCS + CO_2 emissions exceeding the two-degree budget (CO_2 > 2° budget)

For similar reasons, arguments b3 and B3 cannot be further evaluated. Since climate goal 3 is related to climate goal 2 – a reduction in the rate of climate change may allow for a reduction of adaptation pressure – the same uncertainties arise. The scenarios introduced in Chapter 4 do not give any insights on whether BECCS might be able to buy time for adaptation.[34]

It is, again, not impossible to conceive a BECCS scenario, in which the point in time, at which adaptation measures would have to be installed, is postponed by the use of BECCS. Especially in addition to ambitious mitigation efforts (argument b3), deployment of BECCS could enhance an already effective mitigation pathway to give adaptation measures more time to be implemented. Justifying those arguments, however, is not possible in the scope of this work.

The next two arguments both relate to climate goal 4: Reduction of mitigation costs.

Argument a4:

G	Climate Goal 4	Reducing Mitigation pressure
O	Climate Policy Option a	SAI + CO_2 emissions remaining within the two-degree budget (CO_2 < 2° budget)

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[34] One may argue that time for adaptation *follows* from more time for mitigation (BECCS as a means to buy time for mitigation will be discussed in Section 5.2). At the same time that mitigation pressure is lessened, time for adaptation measures is also generated. However, this claim also cannot be backed in the current investigation and is left for further research.

Argument b4

G	Climate Goal 4	Reducing Mitigation pressure
O	Climate Policy Option b	BECCS + CO_2 emissions remaining within the two-degree budget (CO_2 < 2° budget).

In case of argument a4, it needs to be pointed out that SAI deployment as introduced by MacMartin and Keith (MacMartin et al. 2014, Keith and MacMartin 2015) and his colleagues is calculated against the backdrop of a certain RCP trajectory. SAI in those scenarios works additionally to mitigation efforts and, at least theoretically, does not affect them (see Section 5.1). Since SAI is used only to reduce the rate of change, it does not relate primarily to mitigation costs. Whether there is a connection between mitigation costs and the lessening of the rate of temperature change, must be validated by further research. A preliminary assessment indicates that the effectiveness thesis is at least dubitable in case of argument a4.

Of course, this result is obtained within the limitation to the SAI-scenario introduced above. Other SAI scenarios are imaginable that very well could aim at reducing mitigation costs. A very common perception of SAI deployment is as a limited substitute for mitigation in order to stabilize temperature, when mitigation alone would not be successful in doing so. In such a set up, however, the no-impediment thesis would be in jeopardy.

Whether SAI as part of a policy mix, as introduced in section 4.1, will have any effect on mitigation costs, is at least debatable. Further research is needed for each of the unclear arguments, if they are to be established as plausible instances of the buying time argument.

5.4 A special case: Argument B4

There are deployment-scenarios that seem in itself rational, but are at odds with the BT-argument in its present form. Especially the prominently discussed case of BECCS as a means to buy time in face of less than sufficient mitigation (Section 4.2), turns out to obscure the dubitable status of at least two buying time requirements: The finitude of the deployment and the impact on mitigation efforts. In this situation, there are two possibilities: Relying on the strong version of the BT-argument and rejecting the BECCS scenario, or reformulation the BT-requirements in a way that they incorporate the scenario. In this section, I will trace the first option and discuss climate policy option B as an implausible instance of the BT-argument.

Argument B4 might be the most important one when discussing the buying time framing. Argument B1 is closely related to B4 and will be discussed simultaneously. Both arguments assume that mitigation efforts will not be able to stabilize temperature at 2°C above pre-industrial level. The underlying idea of those argument versions then is that in light of insufficient mitigation, BECCS could close the emission gap and thus help reaching the two-degree target, even if emissions temporarily exceed the two-degree budget. It is this the scenario that has been introduced in Section 4.2. Additionally, if future negative emissions are anticipated, the timeframe for drastic emission cuts would broaden, thus buying time for further mitigation approaches.

Argument B1:

G	Climate Goal 1	Avoiding temperature-dependent tipping points
O	Climate Policy Option B	BECCS + CO_2 emissions exceeding the two-degree budget (CO_2 > 2° budget)

Argument B4:

G	Climate Goal 4	Reducing Mitigation pressure
O	Climate Policy Option B	BECCS + CO_2 emissions exceeding the two-degree budget (CO_2 > 2° budget)

Since both arguments assume insufficient mitigation, they will be discussed together. The BT-theses will be specified for argument B4, the validity of the according thesis in B1 follows from them[35].

As the discussion will reveal, a BECCS deployment to artificially enhance the emission budget violates at least two BT-requirements, the finitude- and the no-impediment requirement, and it may very well also violate the morality requirement. That being said, this scenario may turn out to be actually necessary when tackling climate change. We may find ourselves in a situation, in which the scenario we propose violates our own normative standards. This quite sobering thought will be further strengthened in Chapter 6. On the other hand, this fact might suggest that the

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[35] Since climate goal 4 includes climate goal 1, if a premise including goal 4 is valid, the same holds *mutatis mutandis* for a premise including goal 1.

BT-argument in its current form is too strong. A possible weak version of the BT-argument will also be discussed in Chapter 6.

I will discuss all BT-theses for argument B4 in detail. The main focus lies on the effectiveness thesis (including the beneficial requirement); the finitude- and the no-better-option thesis will be discussed together. Especially the no-impediment thesis will pave the way for discussion in Chapter 6.[36]

(Effectiveness Thesis) Option B leads to desirable climate goal 4 and is beneficial in so doing so.

The idea of the emission budget is that temperature can be stabilized at a certain degree regardless of the concrete emission trajectory. The two-degree budget has been advised to be around at 950 $GtCO_2$ highest, if CO_2 concentration is to be stabilized at 480ppm (IPCC 2014). This means, an emission pathway assuming a short-term overshoot can still be consistent with the two-degree target, if it is balanced out with net negative emissions by the end of the century.

While a substantial transformation in society would have to take place within the next decades or even years (see Section 4.2), with the assumption of future BECCS, the need for immediate and drastic emission cuts might be delayed. So, BECCS, as envisaged by the scenario introduced in 4.2, might indeed be effective in reducing mitigation pressure, because it might postpone the point in time, at which emissions have to go down, while at the same time minimizing the necessary amount of reduction.

However, this assessment of BECCS is influenced by possibly utopic assumptions about the effectiveness and readiness of the technology. As has been suggested recently by Kartha and Dooley (2016), it might be risky to rely on future negative emissions with BECCS, because this option might turn out to involve unacceptable risks, or prove to be either not feasible or ineffective. The effectiveness of BECCS is severely limited by land availability and the readiness of capturing schemes. Betting on negative emission may turn out to be a dangerous self-fulfilling prophecy (Fuss et al. 2014).

The effectiveness thesis asks for BECCS to be beneficial as well. The point to be made here, again, cannot be to definitely decide whether the buying time deployment

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[36] The following discussion is partially adopted form Muraca and Neuber (2017).

of BECCS is beneficial or not. This would require more in-depth research than can be provided here. Rather, the question is, whether the proposed BECCS deployment may provide the *conditions for the possibility* of beneficial deployment.

As with the SAI scenario, I will focus here on three exemplary side effects of BECCS: Land-use conflicts, transport and storage safety and procedural justice. The guiding question is: Are there circumstances that could render a BECCS scenario beneficial?

Land-use conflicts. The potential of BECCS is restrained by many factors, such as land availability, freshwater for irrigation, food demand, and future climatic and social developments. Near-term, this potential is massively limited by the availability of arable land. The conversion of agricultural land into biomass plantations is determined by food demands, dietary choices and might include heavy fertilization (Schäfer et al. 2015; McNutt et al. 2015b).

If BECCS were to be used in a way consistent with RCP2.6, i.e. in order to reach the 2-degree-target, the estimated land-use of food-production and biomass-production combined would amount to 2.1 billion hectares in 2100. To put this number into perspective, today's cropland amount to 1.6 billion hectare (McNutt et al. 2015).

The conversion of land into biomass plantations ought to suffice certain ethical criteria. One set of ethical principles is proposed by the Nuffield principles on Biofuel (Weale et al. 2011):

> i. Biofuel development should not be at the expense of people's essential rights (including access to sufficient food and water, health rights, work rights and land entitlements).
>
> ii. Biofuels should be environmentally sustainable.
>
> iii. Biofuels should contribute to a net reduction of total greenhouse gas emissions and not exacerbate global climate change.
>
> iv. Biofuels should develop in accordance with trade principles that are fair and recognize the rights of people to just reward (including labor rights and intellectual property rights).
>
> v. Costs and benefits of biofuels should be distributed in an equitable way.

The first two principles refer to land-use problems. This is especially important if biomass were to be produced in the global South, where arable land is scarce and the available cropland is essential for self-sufficient, small-scale agriculture. Moreover, if animal rights and species conservation are considered, the conversion of wildlife habitat would not be an option either.

Land-use conflicts may be prevented partially, if food-production where to use less land. This might either happen via increased productivity or via a change in food choices. Increasing the productivity of food-production might be possible in some regions of the world, but mostly via drastic measures (such as the employment of chemical fertilizers).

Highly specialized and fertilized monocultures of biomass might arguably not be compatible with the Nuffield principles on Biofuel. Moreover, the agricultural infrastructure needs to be augmented and needs constant care. The stream of maintenance might outweigh the benefit of BECCS, regarding both the increased cost and the energy needs.

Transport and storage safety. The gravest side effects of BECCS arguably occur during transport and storage (McNutt et al. 2015b). There are two kinds of harms associated with BECCS: Infliction of local population near CCS sites due to exposure to CO_2 during the injection, or long-term CO_2 pollution by storage leakage (Medvecky, Lacey and Ashworth 2013). Leak pipelines might cause highly concentrated carbon dioxide pollution. On the other hand, if storage sites are not safe, for example due to seismic activity, leakage may contribute to severe CO_2 pollution of land and sea habitats. The safety of those storing sites depends on further technological observation, like monitoring and early warning systems that would enable to evacuate the affected in time. But since both seismic and volcanic activity is still not sufficiently predictable, storage of CO_2 can never be fully safe. This is true for both geological caverns as well as deep-sea storage. While the leakage of the former might affect land-animals and humans, the latter might affect sea-animals and even the ecosystem ocean as a whole. Having said that, recent studies suggest that the probability of leakage is fairly low (Wennersten, Sun and Li 2015). If so, future decision makers could still decide upon carbon storage.

Procedural justice: Finally, BECCS power plants require a huge amount of upfront investments. Controlling BECCS should suffice criteria of procedural justice, which maximizes the right of co-determination of locals. Decisions about CO_2 storing sites may prove to face similar difficulties as the search for nuclear repositories. At least, decisions about the site of growing, processing and storing should aim at being consensual, taking the special threat to locals into account.

In summary, BECCS is prone to issues of both procedural and distributional justice. Benefits and side effects of BECCS should be distributed fairly, and the governance of BECCS needs to be democratic and transparent. This does not suggest that beneficial BECCS deployment is impossible. Rather, the discussion above might indicate further research questions for beneficial BECCS deployment.

Recent examples of scholars exploring the possibility of beneficial (an morally sound) CCS deployment are Boucher and Gough (2012) and Medveky et al. (2014). Boucher and Gough (2012) introduce guidelines, by which the deployment of CCS technologies, and *mutatis mutandis* BECCS, can be assessed. Those guidelines rest, among others, on central ethical principles about procedural and distribution justice as well as human rights. Medveky et al. (2014) highlight central moral issues with BECCS, and categorize them, especially with regard to transport and storage safety. Research in this direction could help to further strengthen the case for beneficial BECCS deployment.

(Finitude Thesis) Option B only allows for finite BECCS deployment;
(*No-better-option Thesis) There is no option O' which is finite and which leads to climate goal 4 and which is better than option B.*

In light of insufficient mitigation, there might be no other way than to deploy BECCS (or other negative emission technologies) in order to reach the two-degree target. This complies with the results of a recent meta-study by Fuss et al. (2014). Fuss et al. shows, how many models consistent with the two-degree target assume future use of BECC. The authors think this to be an alarming result, since both the effectiveness or even the readiness of the technology is not determined yet, hence relying on BECCS as a potential way to reduce immediate mitigation pressure might be risky (also Kartha and Dooley 2016). The no-better-option thesis might turn out to be true, but only because BECCS may present itself as a self-fulfilling prophecy.

With regard to finitude, there is no indication in the scenario introduced above (Section 4.2) (van Vuuren 2013 and 2016) that BECCS will end before 2100. In accordance with my understanding of finitude, which also implies practical controllability, BECCS in policy option B is not finite. This alone should be reason to reject the possibility of BECCS as being a BT-deployment, since it violates at least one premise of the argument: the finitude thesis.

(No-Impediment Thesis) BECCS in option B does not lead to less mitigation compared to mitigation in option B without BECCS.

The evaluation of this thesis is more difficult than the evaluation of the corresponding thesis in an SAI scenario. Because the design of the SAI scenarios was especially framed as to not interfere with mitigation efforts, the BECCS scenario at hand enables a lessening in mitigation efforts, or rather: It alleviates the negative side effects of insufficient mitigation efforts. It is only intuitive to assume BECCS and mitigation to be at least partially substitutes.

The use of BECCS is designed to *delay* drastic mitigation strategies, hence it can be said to it indeed compromise mitigation efforts. To put it differently: The BECCS scenario at hand is designed to work under compromised mitigation efforts. On the other hand, once these studies are published, there might be a feedback loop that even diminishes existing pledges and seduce policy makers to rely even more heavily on future BECCS. Already most RCP2.6 projections assume future negative emission technologies, mostly BECCS (Fuss et al. 2014). So, by the same token, by which the no-better-option thesis becomes plausible, the no-impediment thesis becomes implausible.

The difficulties in assessing the no-impediment thesis are connected to the ability of BECCS to serve as a *substitute* for mitigation. As stated initially (Section 2.2), small-scale BECCS might be count as a perfect substitute for mitigation. What this could mean for the evaluation of the arguments at hand (B1 and B4) shall be further discussed in Chapter 6.

5.5 Results

In this chapter, four categories of instantiation of the BT-argument have been identified.

Plausible Versions (green)

I have identified two plausible versions of the BT-argument, arguments a2 and a3. In those cases, SAI is deemed to be finite, short, beneficial and effective, while not interfering with mitigation efforts. This form of moderate and strictly purpose-bound SAI may realize the BT-requirements.

This result is somewhat surprising, because SAI especially has been criticized frequently on moral grounds. Nevertheless, a beneficial buying time deployment of

SAI might be conceivable, within the given boundaries. It is to be noted that the plausibility of this version prominently depends on the effectiveness of mitigation efforts. Only if emissions remain within the two-degree budget, a plausible SAI deployment is possible. Thus, in addition to the moral obligation to mitigate, it can be shown that CE deployment in a BT-framing is only *plausible* with sufficient mitigation.

Implausible Versions (red)

Five additional SAI-instantiations and one BECCS-instantiation have been identified as being implausible. When relating to Goal 1, both SAI and BECCS turn out to be superfluous in the respective policy option *a* and *b* (argument a1 and b1). All other SAI-scenarios, which assume emissions to exceed the two-degree budget, become implausible (arguments A1, A2, A3 and A4) – they violate both the finitude- as well as the no impediment-requirement. If that is true, this result might influence the decision making-process, as soon as a ‘buying time deployment’ of SAI in light of insufficient mitigation is advocated.

Undecided Versions (light blue)

For several scenarios, I cannot provide further scientific back up. Those BT-versions must remain undecided in the work at hand. Out of six undecided scenarios, five belong to BECCS scenarios (arguments b2, B2, b3, B3 and b4). This might indicate that there is much more uncertainty regarding BECCS than there is regarding SAI[37], and highlights the need for comprehensive research on BECCS, before it is mutually assumed as a potential future negative emission technology. Model-runs could be performed under further constraints, such as food security, property rights over land, and nature conservation targets (biodiversity). Without such morally relevant constraints BECCS modeling might remain abstract.

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[37] Of course, it might be an argumentative bypass to follow from my lack of knowledge that there is greater uncertainty with BECCS than with SAI. In this sense, all research is only possible in the personal boundaries of knowledge and might be biased. However, a comprehensive scenario analysis for BECCS, like the SAI-scenario by MacMartin et al. (2014) and Keith and MacMartin (2015), has of yet not come to my attention.

The special case of BECCS (dark blue)

A BECCS deployment to artificially enhance the emission budget turns out to violate at least two BT-requirements: the finitude- and the no-impediment requirement, and it may very well also violate the morality requirement. Exactly this case, though, is the *raison d'être* for the contemplation and research of BECCS deployment scenarios. The above discussion has adhered to the strong BT-requirements, leading to a rejection of BECCS in light of insufficient mitigation efforts. Chapter 6 will trace another route by asking whether the BT-requirements might be too strong for the special case of BECCS.

To sum up, there are possible deployment scenarios that resonate with the buying time framing. Especially the two SAI cases (argument a2 and a3) might count as reasonable instantiations of the BT-argument. However, those scenarios only work if (and only if) parallel mitigation efforts take place that themselves will be able to reach the two-degree target. As a result, beneficial CE deployment will have to be quite limited, purpose bound and finite. Climate option *a* seems to fulfill those criteria. In this portfolio, SAI deployment is an additional strategy to take some pressure off or to delay the point in time by which certain goals have to be achieved. And – going back to the quotes from the ongoing discourse (section 3.1) – this is all there is to the buying time idea.

BECCS deployment, on the other hand, poses quite a riddle for the BT-argument, even if it seems to be a perfect instantiation at first sight. Especially the no-impediment thesis might turn out to be too strict for a BECCS.

			Preventing climate tipping points		Reducing pressure	
			Avoiding temperature dependent tipping points	Avoiding rate-dependent tipping points.	Reducing adaptation pressure	Reducing mitigation pressure.
			1	**2**	**3**	**4**
SAI	CO_2 < 2° budget	**a**	*No-better-option thesis.* This climate goal amounts to the two-degree target. If CO_2 emissions remain within the two-degree budget, SAI deployment is superfluous in reaching the two-degree target.	SAI might be able to prevent rate depended tipping points, while mitigation efforts serve to realize the two-degree target.	SAI might be able to reduce the pressure of adaptation, if it lessens the rate of temperature change, which could generate more time for ecosystems and human systems to adapt.	Since mitigation is assumed to be ambitious in this case, it is unclear, in how far a lessening of the rate of temperature change might influence mitigation costs.
	CO_2 > 2° budget	**A**	*No-impediment thesis.* If carbon emissions exceed the two-degree budget, SAI would be used in order to stabilize temperature. It would then be used as a substitute for mitigation, impeding mitigation efforts. *Finitude thesis.* Because SAI would function as a substitute for mitigation efforts, it would have to be used continuously in order to stabilize temperature. Under the assumption of exceeding carbon emissions, SAI would not be finite.			
BECCS	CO_2 < 2° budget	**b**	*No-better-option thesis.* This climate goal amounts to the two-degree target. If CO_2 emissions remain within the two-degree budget, BECCS deployment is superfluous in reaching the two-degree target.	Whether BECCCS can influence the rate of temperature change, cannot be decided within the scope of this work.	If additional BECCS can influence the rate of change, it might also reduce adaptation pressure.	While emission would remain within the two-degree budget, BECCS could be used to further reduce the time pressure for mitigation. Research for BECCS together with sufficient mitigation has not been reviewed for this research thesis.
	CO_2 > 2° budget	**B**	*The special case of BECCS.* BECCS in light of insufficient mitigation might be used to stabilize temperature change. It might however violate several BT-requirements. A weak version of the BT-argument could incorporate this case.	Especially in light of insufficient mitigation, it cannot be decided here, whether BECCCS can influence the rate of temperature change.	Especially in light of insufficient mitigation, it is unclear, whether BECCS can reduce adaptation pressure.	*The special case of BECCS.* BECCS in light of insufficient mitigation might be used to reduce mitigation pressure as it enhances the emission budget. It might however violate several BT-requirements. A weak version of the BT-argument could incorporate this case.

Table 10 (same as Table 2). Full table of instantiation of the BT-argument.

Chapter 6 Deepened Analysis of the Buying Time Argument

According to the analysis in Chapter 5, there are two possible deployment scenarios that resonate with the buying time framing: A moderate, time limited SAI deployment in order to either reduce adaptation pressure (argument a3) or to reduce rate-induced climate impacts (argument a2). However, those scenarios are plausible only if parallel mitigation efforts take place that themselves will be able to reach the two-degree target. As a result, beneficial SAI deployment will have to be quite limited, purpose-bound and finite, as the authors of the scenario acknowledge (MacMartin et al. 2014). In this scenario, SAI deployment is viewed as an additional strategy to take some pressure off or to delay the point in time, by which certain climate goals, like adaptation measures, have to be realized. And – going back to the quotes from the ongoing discourse (Section 3.2) – this is all there is to the buying time idea.

BECCS deployment, on the other hand, poses quite a challenge for the BT-argument. The hope that BECCS may be used to reach the two-degree target even in face of poor mitigation efforts (arguments B1 and B4), is essentially the *raison d'être* for the contemplation and research of BECCS deployment scenarios. However, at least two BT-requirements are not plausible in those instantiations: the no-impediment thesis and the finitude thesis. As argued in Section 3.2, it is exactly those requirements that constitute the core of the BT-argument. This imposes a dilemmatic choice: Either the strong BT-requirements are maintained, leading to a rejection of the desired BECCS scenario(s), or the BT-requirements are watered down, establishing a ‘weak’ buying time argument, with the danger of allowing undesired scenarios to count as BT-scenarios as well.

The first horn of the dilemma – the rejection of the BECCS scenario(s) on grounds of the strong BT-requirements – has been traced in the previous section (Section 5.4). The next section will try to reformulate the BT-argument so as to capture the BECCS scenario (Section 6.1). Especially the possibility of acceptable substitution between BECCS and mitigation will be further examined.

Finally and lastly, the research thesis at hand scrutinizes general moral constraints on CE deployment. This will be discussed by means of the two plausible SAI-instantiations (argument a2 and a3). The question is: If every of the strong BT-requirement is plausibly met, could CE deployment still be morally wrong? I will focus on two general moral objections to CE deployment: the hubris- and the techno-fix argument (Section 6.2) and show how a moderate, finite SAI deployment might not be susceptible to those general moral concerns.

6.1 Weak buying time argument

The hope that BECCS may be used to realize the two-degree target even in face of poor mitigation efforts is eventually the *raison d'être* for the contemplation and research of BECCS deployment scenarios. As discussion in Section 5.4 has shown, however, if the strong BT-requirements are applied, such scenarios must be rejected. It might be argued, then, that in such cases the BT-argument is too strong and that the BT-argument should be reformulated in order to capture the BECCS scenarios. This would yield two respective versions: a strong BT-argument and a weak BT-argument. In what follows, a weak version is established. Especially two BT-theses become implausible in arguments B1 and B4: the finitude thesis and the no-impediment thesis. In order to establish a different version of those theses it is worthwhile to reconsider the assumptions, which shaped their formulation in the first place (Section 3.2). They can be called supporting theses, as they support the BT-argument directly.

The assumptions backing the finitude thesis are:

- (*Transition Anyway*) Successful decarbonization of society is anticipated. Eventually, a low- or no-carbon society is thought to be reality, making artificial counter-balances to the CO_2 circle superfluous.
- (*No Substitute*) If decarbonization is successful in the end, CE deployment will cease, since it will no longer be needed to counteract insufficient emission cuts. This means that CE of any kind would only be deployed additionally to a comprehensive mitigation pathway, not instead of one. A non-finite CE deployment would amount to a *substitute* for mitigation efforts, which is not acceptable within the BT-framing.

- (*Controllability*) Finitude implies some form of practical controllability. Deployment scenarios that point to well beyond the end of this century, may be finite in theory, but are not controllable in a practical sense.

The assumptions that led to the formulation of the no-impediment thesis are:

- (*Mitigation Obligation*) The current generation has the moral obligation to drastically reduce their CO_2 emissions within the next few decades. This obligation holds even in face of possible CE deployment.
- (*No Substitute*) If decarbonization is successful in the end, CE deployment will cease, since it will no longer be needed to counteract insufficient emission cuts. This means that CE of any kind would only be deployed additionally to a comprehensive mitigation pathway, not instead of one. A non-finite CE deployment would amount to a *substitute* for mitigation efforts, which is not acceptable within the BT-framing.

Rejecting the strong version of the BT-argument and instead adopting a weak version would imply that at least one of the supporting theses is implausible. It seems to me that especially the no-substitute thesis may not hold in case of BECCS: BECCS might quite well function as an acceptable substitute for mitigation, as will be discussed below.
A weak BT-principle could read like this:

Buying Time*-Principle (BT*-Principle)
If: i. Climate goal G is desirable, ii. option O leads to climate goal G and is beneficial in so doing so, iii. CE in O is a perfect substitute for mitigation in O, iv. there are no general moral constraints on option O;
then: option O should be adopted.

Most notably, the no-impediment thesis was replaced by the requirement to function as a perfect substitute (requirement iii):

iii. CE in O is a perfect substitute for mitigation in O (substitute thesis).

Also, the finitude thesis and the no-better-option thesis have been removed. Both theses seem to be at odds with the notion of CE serving as a perfect substitute for mitigation. The no-better-option thesis implies that any option reaching goal G without CE should be preferred to an option including CE (Section 3.2). But if CE in portfolio O is used as a perfect substitute for some amount of mitigation, option O is as desirable as the possible option O' without CE. Similarly, the finitude thesis can be removed, if BECCS is a perfect substitute that can be carried out indefinitely. So, both theses have been declined for the sake of the substitute thesis.

For the specification of what 'perfect substitute' amounts to, I will recall the definition given in Section 2.2, by Baatz and Ott (2016):

> "Strategy Y is a perfect substitute for mitigation if it avoids all negative climatic effects resulting from GHG emissions, without thereby creating other harms or risks."
> (Baatz and Ott 2016, p. 99f.)

Does the BECCS overshoot-scenario (climate option B) resonate with the weak BT-argument? Is the substitute thesis plausible?

The BECCS scenario introduced in Section 4.2 (van Vuuren et al. 2013) was designed to close the emission gap current mitigation efforts seem to generate. It assumes the reduction potential of BECCS to be -6 Gt CO_2/yr and -10 Gt CO_2/yr, respectively (van Vuuren et al. 2013, p. 18). This is well below the maximum reduction potential, which other authors assume to be as high as 18 Gt CO_2/yr (McNutt et al. 2015b). As mentioned before, the potential of BECCS is limited by the availability of arable land and by infrastructure including fresh water access and fertilization. In a recent study, Smith and Torn (2013) calculated a BECCS scenario with a specific type of plant (switchgrass) with focus on water and fertilizer-requirement. In order to remove 3.7 Gt CO_2/yr from the atmosphere (which is much less than the necessary 6Gt CO_2/yr in the emission-gap scenario!), the magnitude of all three factors would be exorbitant: 200 million hectare of land which is 20 times the area currently used in the US for bioethanol production, 20% of the global production of fertilizer (20 Tg/yr of nitrogen) and 4% of global renewable water resources (4,000 km3/yr) (Smith and Torn 2013, McNutt et al. 2015b).

Even a fraction of the assumed mitigation potential in van Vuuren's scenario might turn out to be strenuous on the environment as well as competitive regarding land-availability and infrastructure. The side effects of such a scenario make it questionable, whether BECCS is effective and beneficial and could possibly count as a perfect substitute for mitigation.

This does not rule out other, less strenuous BECCS scenarios. Those might be considerably downsized, and might have a significantly lower mitigation potential. So, in theory, beneficial BECCS is conceivable, that could also serve as a perfect substitute for mitigation. Yet, the mitigation potential of such deployment scheme might not be enough to close the emission gap, hence, it might not prove to be effective in a very basic sense. The BECCS-deployment in question, which is assumed to close the emission gap (option B, arguments B1 and B4), is due to its magnitude no perfect substitute. Even a weak version of the buying time argument does not render arguments B1 and B4 plausible.

Additionally, I wish to argue that the rejection of the finitude thesis poses a serious problem for any anticipated deployment of CE as a means to buy time. As said before, the transition anyway thesis lies at the heart of the buying time argument: Only if the prospect of a decarbonized society is taken seriously, CE-deployment can be framed as being an auxiliary measure, a temporary stopgap to buy time. Climate goal 4 (reducing mitigation pressure) itself can only be formulated, if mitigation as part of decarbonizing the economy is seen as the primary political goal, of which the reduction of pressure is the secondary goal. If the finitude thesis is not taken into consideration, this supposed weak BT-framing might jeopardize a fundamental transition of society (see also Muraca and Neuber 2017).

The weak version of the BT-argument allows for (some amount of) substitution between CE and mitigation. A rampant substitution, though, might negatively influence the pursuit of decarbonization. A trade-off between mitigation efforts and CE measures is at least a possibility (Baatz 2016, see also chapter 2.3). As soon as CE measures are framed as viable substitute for emission cuts, mitigation efforts might decline (Corner and Pidgeon 2010, Betz and Cacean 2012, Hale 2012, Baatz 2016). If furthermore, CE measures are not required to be temporally limited, a fundamental transition of society might not be undertaken – indefinite and acceptable substitution via CE could enable current modes of production and consumption to persist. How true is the buying time framing under those assumptions?

> „Would [CE technologies] be used as a stop-gap measure to buy time for a societal

> transformation to a carbon-free economy, shaving off the worst effects of climate change along the way? Or as a substitute for this transformation, allowing for business as usual to continue?“
> (Schäfer et al. 2014, p. 243)

How these questions are answered, seems to be a question of faith. Bunzl (2009) for example argues very strongly against a moral hazard, i.e. the danger of diminishing mitigation efforts in light of CE.

> “Moral hazard only arises for geoengineering if you think that research or, if it came to it, implementation would undermine other actions and lead to more, not less greenhouse gas output. That seems far-fetched since, at least among policy makers, nobody believes that geoengineering offers anything but a relatively short stopgap to buy time for other action.”
> (Bunzl 2009, p. 2)

The above quotes show, again, how dearly connected the idea of decarbonizing society is to the idea of a finite CE-deployment. It is the finitude of CE deployment that correlates to the transition of society – a transition that is deemed to be both necessary as well as inevitable by most authors. CE deployment beyond any practically controllable time frame (like the BECCS-scenario in option B) might equally push a decarbonization of society into a distant future.

> “The transition to a low-carbon society must not be delayed any longer. The climate crisis is already here and considerable CO_2 emission reductions must be made immediately. Developing and evaluating geoengineering will waste valuable time: this will not mean buying time, but rather spending or losing it. This is why the countries of the world cannot afford geoengineering. The discourse critical of geoengineering claims that geoengineering opportunities could result in the avoidance of CO_2 emission reductions and delay the necessary mitigation of climate change. Geoengineering is a way of postponing the unavoidable structural change of contemporary society.”
> (Anshelm and Hansson 2014, p. 142)

The moral relevance of not imposing a dilemma on future generations has been established in light of the mitigation obligation (Section 2.2). Postponing the needed decarbonization of our society might constitute an equally inadmissible risk transfer to future generations.

Another problem related to intergenerational justice is connected to carbon storage in the BECCS scenario. Confronted with deep uncertainty, current decision-makers cannot oversee all possible incidents and side effects related to carbon storage. In this sense, BECCS passes down the buck to future generations. It defuses the current problem of CO_2 emissions into a future problem of artificial carbon sinks.

In this light, BECCS will only buy time in a very diffuse and speculative sense. In order to be more than a lip service, I urge that the BT-argument should include requirements about both finitude and controllability.

This summarizes the considerations about an alternative, weak version of the BT-argument. A weak BT-argument would not incorporate any finitude requirement and would allow for (some form of) substitution. I have argued that the special case of BECCS as a means to close the emission gap, would not count as permissible substitution, due to its magnitude – it would not be plausible even under a weak BT-argument. Furthermore, I have argued that the finitude thesis is dearly connected to one crucial assumption of the BT-framing: the transition anyway thesis. Refraining from the finitude requirement might influence potential policy choices as to delay a needed decarbonization of society. While a non-finite BECCS deployment might still be morally admissible, if not plain necessary, it is no 'buying time' deployment as of my understanding. The weak version of the buying time argument is not an alternative, but no buying time argument at all.

6.2 General moral constraints

Two plausible instantiations of the (strong) BT-argument have been identified: argument a2 and a3. Both arguments assume drastic mitigation ensuring CO_2 emissions to remain within the two-degree budget with additional SAI deployment to limit the rate of temperature change. The evaluation of the arguments, however, was not completed as to include the last thesis – the morality thesis. This shall be done in the next section. I will discuss two general moral arguments against CE-deployment specified for the SAI scenarios at hand: the hubris argument and the techno-fix argument.

6.2.1 Hubris argument

One general moral argument against the deployment of CE has been brought forward from the viewpoint of virtue ethics. The hubris or playing-god argument states that we should not engage in any CE scheme, for the scope of the endeavor is just beyond our human understanding. Trying to control the climate system, even for a limited period of time, would be a sign of hubris, in that it ignores the role we humans play on this planet. The hubris-argument has been one of the earliest virtue ethical arguments against the deployment of CE (Jamieson 1996, Ott 2010, Gardiner 2010, Owen 2014).

A common perception of the hubris framing is that man should not aim at interfering with a given natural order. Order in nature is more than arbitrary; it is in itself valuable and hence refers to – if not a divine being – a metaphysical system. Such a version of the hubris argument lacks an essential deductive step from any sort of metaphysical order to the fact that we as humans need to respect it (Levine 2014). While the accusation of hubris comes easy, only a handful of philosophers have advanced this argument to the full. A very recent exception is the work of Meyer and Uhle (2014), in which they try to justify the virtue ethical heuristic for the evaluation of CE. Their definition of hubris reads like this:

> „Persons (or groups of persons) show hubris, if they act with a reprehensible overestimation of their abilities.“
> (Meyer and Uhle 2015, p. 5)

The authors suggest that this concept might serve as a *heuristic* for the topic of CE, in that is highlights certain aspects of technology deployment that otherwise would be hidden. Hubris as defined by Meyer and Uhle (2015) does not rely on any metaphysical order. Rather, it is connected to *epistemic virtues* of what we can possibly know. From this perspective, hubris ought to be avoided because it presents a failure and a vice: The failure lies in the misjudgment of the *probability* of CE research results, the vice lies in the recklessness of advocating controllability of CE despite the epistemic failure.

Misjudgment about probabilities is in itself not reprehensible, but rather inevitable and quite common among human beings. Scientists know rather well that the scope of their models is limited, that the climate system is too complex to fully understand

and that there are still numerous unknown factors that may lead to unintended side-effects when pursuing intentional climate manipulation.

But as Levine (2014) has stated recently, those concerns could be best described as a consequentialist argument. Such an argument would not rely on a virtue ethical heuristic, but rather would include precautionary thinking when irreducible uncertainties are at stake.

Thusly understood, the argument reconstruction that has been proposed by Betz and Cacean (2012, p. 120) could serve to capture the hubris-framing in a consequentialist manner:

Irreducible Uncertainties

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[38].
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: 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.

This argument can be used to object the effectiveness thesis of the BT-argument. It shows, that the hubris argument can be re-formulated as a prudent consequentialist argument under uncertainty that asks us to obtain from any consequences that might have harmful consequences and that we cannot decide upon. Many scholars would either endorse this argument or criticize it on grounds of the empirical premises (1) and (2). Evaluation of those two premises then would constitute the main focus of future debate.

Having said this, I wish to highlight a different aspect of the argument, which goes beyond the evaluation of its empirical premises and relates to the hubris heuristic proposed by Meyer and Uhle (2014). While the trouble with uncertainties surrounding CE can be captured via the consequentialist argument above, within the

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[38] R&D stands for research and development.

hubris framing, the misjudgment of the boundaries of our knowledge is not simply an epistemic failure, but a vice – it is reckless!

The recklessness lies in the fact that *against better judgment* the knowledge gap is ignored (Meyer and Uhle 2014, p. 6). The virtue ethical framing of the uncertainty argument urges us to be more moderate, even humble about our knowledge of the natural system and our ability to control it – and the lack thereof. It urges us to weigh our lack of knowledge in those delicate systems higher than the amount of what we actually do know – because it may be dangerous, if we don't. Possible dangerous side effect of CE deployment might arise because of a specific mind-set, which overestimates what we know and underestimates what we don't. So in essence, the hubris framing suggests a certain judgment about our gap of knowledge. This judgment, the internal assessment of the data we have, is determined by (epistemic) virtues. So, the virtue ethical argument of hubris asks us to judge our knowledge in a specific way. It hence is not an alternative to the consequentialist 'irreducible uncertainties' argument above, which is based on a decision principle under uncertainty, but it asks us to *weigh* this uncertainty in a specific way. There is no need to appeal to a metaphysical preorder to make the hubris argument work.

While there are rational decision principles for uncertain settings (like the precautionary principle), the hubris framing as a virtue ethical argument urges us to make those precautionary considerations a priority when weighting the arguments pro and con CE deployment. In this sense, it serves as a meta-argumentative guideline about the status of arguments, in that it weighs the argument about irreducible uncertainty stronger than other arguments, like arguments about effectiveness.

A hubristic SAI deployment could be avoided, if the reckless ignorance of uncertainties is ruled out. MacMartin and Keith (2014), the authors of the SAI-deployment scenario adopted in arguments a2 and a3, seem to think that they have done so. They include a learning curve and ask SAI deployment to be responsive, so that new information can lead to a modification or even the decline of SAI deployment[39]. While the hubris-argument has moral force in evaluating SAI deployment, it might arguably be met by a careful and modest deployment-scheme –

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[39] If SAI deployment was modified, because observation has suggested inacceptable impacts, the responsibility for those impacts of past deployment still remains. If liability is not determined, even a learning curve might not guarantee fair and beneficial SAI deployment.

the hubris argument is not a general moral constraint to plausible BT-deployment scenarios.

6.2.2 Techno-fix argument

An alternative framing of the buying time idea refers to CE as the ‘second-best solution’ for climate change. It states that if there is a problem, but our first choice is not at our disposal (yet), we need to adopt another option, given that second solution has no moral restrictions. In our daily lives, we act on base of such a principle of the second-best choice frequently. In political contexts and collective decision-making, the same principle can and must apply. A special version of this principle arises in cases, where social issues cannot be settled by social means alone and a technical solution to those problems seems apt.

Weinberg (1991) has concerned himself with those ‘technological fixes’ to social problems. His question was: “To what extend can social problems be circumvented by reducing them to technological problems?” (Weinberg 1991, p. 42).

Weinberg deems the reframing or redefining of some social problems as technical ones to be very promising. Social problems tend to be very complex and solving them might require changes at the individual behavioral level of members of society, which is hard to achieve. On the other hand, technological fixes are clear cut, easy and seemingly effective solutions to some social problems. They can be applied independent of individuals. As an example for a beneficial technological fix, Weinberg mentions the introduction of the seat belt against car accident deaths.

He is, however, very clear about the limitation of those technological fixes. Social problems need to be solved by social means eventually, and technological fixes are always a second best choice.

> “Technology will never replace social engineering. But technology has provided and will continue to provide to the social engineer broader options, to make intractable social problems less intractable; perhaps, most of all, technology will buy time – that precious commodity that converts violent social revolution into acceptable social evolution.“
> (Weinberg 1991, p. 48)

For Weinberg one of the most beneficial features of a technological fix is that it *may buy more time for social transition*. The time generating quality of technological fixes lies at the heart of the BT-argument in favor of CE, as has been demonstrated thoroughly. So, the technological fix framing is related to the buying time argument. But it is also clear from the above quote that a technological fix cannot serve as a substitute for a social solution – the same has been shown for CE and mitigation.

Scott has dubbed the fear associated with a misinterpreted technological fix the 'techno-fix'-objection (Scott 2012): The reckless use of CE, without dealing with the underlying social problem, or even worsening it. This is the danger that lies within the technological fix argument and arguably also with the buying time argument, if the BT-requirements are not met or watered down, and CE is used as a substitute for mitigation (Section 6.1).

Some form of SAI deployment might be used as a stopgap measure to buy more time for social transition – this is what the BT-argument shows. But when does the BT-argument support a 'cheap techno-fix'? Techno-fixes are deemed to be a way of delaying the problem, not solving it, since they do not address the root cause of the problem, and advocates of the techno-fix framing would reject CE deployment as inherently flawed.

> "[Solutions] to environmental problems like climate change could never be powerful technologies like SRM. Western societies must challenge their fundamental values and worldview to find solution to climate change."
> (Scott 2012, p. 161)

This 'western worldview' that ought to be changed, arguably amounts to the notion that business as usual can be continued and that our modes of production and consumption can be upheld, though possibly by different means. Concepts like green growth or sustainable consumption are accompanied with the promise that a lifestyle change is not needed, but rather that economic, yet sustainable growth guarantees perpetual, environmental friendly wealth. The notion of 'green growth' has been challenged frequently. Brand calls green growth the "next oxymoron" (Brand 2012), and Grunwald argues that sustainable consumerism is no silver bullet to "save the environment", but instead that the paradigm of consumption and growth has to be changed altogether by political and legal means (Grunwald 2015). A different economic setup like the degrowth framing could enable a comprehensive technology assessment of such technologies, in order to rule out the naïve technophile believe that technological progress can take center stage in solving the ecological crisis at hand (Grunwald 2016).

This line of thought resonates with the idea of Section 6.1, which identified the transition anyway thesis to be essential to the buying time argument, in that a transition of society mustn't be delayed by possible CE deployment. Only if a fundamental transition of society is underway, CE-deployment might not be suspected to be a 'techno-fix'. The finitude requirement in the BT-argument serves to ensure this, as it both assumes and enables a general transition of modes of production and consumption. If it can be plausibly met, BT-deployment of CE might not be object to the general suspicion of 'techno-fixing' our way out of climate change[40].

The techno-fix objection is a general critique of the attitudes supposedly visible in CE deployment. In this view, CE deployment would in each case be an inadmissible delay of real solutions to climate change, namely fast and far reaching mitigation. If, on the other hand, it were possible to reach the two-degree target with mitigation alone, CE might indeed not be needed at all:

> "(The discourse critical of CE) emphasizes that there is no need for geoengineering: existing technologies and renewables would surely be sufficient to considerably decrease CO_2 emissions if they were deployed worldwide. However, this would require radical systemic change, which the governments of the world are unwilling or unable to accept. This is where geoengineering presents itself as a pseudo solution, maintaining the status quo or, in the long run, possibly even worsening the global climate crisis"
>
> (Anshelm 2014, p. 139)

However, especially in light of sufficient mitigation, a buying time deployment can be justified. As I have argued in Chapter 3, the BT-argument also addresses the secondary climate goal of reducing pressure. Arguably, reducing the pressure for mitigation only then makes sense, when mitigation is indeed undertaken.

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[40] While I have frequently used the terms decarbonization, transition of society and the like, decarbonization arguably does not necessarily include a redistribution of wealth, or generate a just form of production. To further substantiate the techno-fix argument, different assessment patterns could be applied. The degrowth framing might be helpful, when evaluating CE in front of different social and economic assumptions (Muraca and Neuber 2017).

Paradoxically, it might not be valid to reject CE deployment in face of sufficient mitigation.

To sum up, the techno-fix argument does not object the plausible SAI-instantiations of the BT-argument (argument a2 and a3), because 1) the design of a plausible BT-deployment incorporates a transformation towards decarbonization and 2) CE in this instantiation aims at realizing the secondary climate goal of reducing pressure.

6.3 Results

The possibility of acceptable substitution between BECCS and mitigation has been examined in Section 6.1. Due to the magnitude of BECCS deployment in order to close the emission gap visible in current mitigation pledges, BECCS would have to be deployed large-scale. The associated side effects, uncertainties and risks rule out that large-scale BECCS can count as a perfect substitute for mitigation. Even a weak version of the BT-argument, which would allow for some form of substitution, does not become plausible for climate option *B* (BECCS and insufficient mitigation).

On the other hand, two general moral constraints, the hubris argument and the techno-fix argument, were shown to not automatically lead to a rejection of the plausible instantiations of the strong BT-argument. Regarding the plausible instantiations of the BT-argument, the 'techno-fix' objection can be met if it is made sure that:

1. No decline in current mitigation efforts takes place;
2. Serious mitigation as part of a shift in society is already underway;
3. The termination of CE at a defined point in time will be guaranteed.

Those are arguably quite ambitious goals. But if the BT-argument is to work, it should not leave room for empty promises. This leads to the tentative conclusion: Beneficial and acceptable BT-deployment of CE technologies might theoretically be possible, but the practical limitations and the imperfect moral nature of our political decisions set the bar fairly high.

Some form of negative emission technologies might be necessary to reach the two-degree target. We might find ourselves in the situation where we might have to use BECCS (and even SAI) in order to manage climate change and avoid catastrophic impacts. This might even be done in a beneficial manner. But we shouldn't fool ourselves by calling it a buying time deployment. In this case, CE would no longer serve as a stopgap measure, as so many authors would like to believe, but as a substitute for our failure to change our ways of production and consumption in time. The euphemism ‘buying time’ might then only serve to make us feel better, but it should not deceive about the fact that we have existentially failed in our mission to live on this planet without ‘fouling our nest’.

Chapter 7 Conclusion and Outlook

In the research thesis at hand, I have evaluated the buying time argument in favor of CE-deployment. I was able to identify two plausible instantiations of the argument with respect to SAI deployment and have discussed the option of beneficial BECCS deployment as a means to buy time. The main results can be briefly summarized as follows:

- Moderate, finite SAI can be a plausible instantiation of the BT-argument.
- Only if mitigation efforts guarantee the realization of the two-degree target does the BT-argument become plausible. The BT-argument becomes implausible if its central assumption about decarbonization is dropped or watered down.
- BECCS in order to reduce mitigation pressure in light of insufficient mitigation is not an instance of the BT-argument, as it violates the finitude requirement as well as the no-impediment requirement.
- Such BECCS deployment could nevertheless be acceptable as well as plain necessary – it just will not be an instantiation of the BT-argument.
- A weak version of the BT-argument is no BT-argument at all. The finitude requirement as well as the no-impediment requirement, which both depend on the assumption of decarbonizing society, are essential to the buying time idea.

This brings us back to the initial research questions: Can climate engineering help provide more time for an ambitious mitigation program? And if so, is a buying time deployment of climate engineering morally acceptable? The answer to the first question must be no. A strong version of the buying time argument becomes plausible only if serious mitigation is already underway. CE cannot buy time for an ambitious *mitigation* program, as exactly this mitigation program must be presupposed for the BT-argument to become plausible. CE (SAI specifically) can merely help buy time for *adaptation*, as it might reduce the rate of global temperature change. This result indicates that the buying time framing of CE is overly optimistic and deceives about its underlying assumptions. While a naïve BT-framing might make the evaluation of CE *in general* more positive (Section 1.1), a scrutinized BT-argument is very clear about the limitations, difficulties and drawbacks of a possible BT-deployment.

The answer to the second question, however, is yes. There are at least two instantiations of the BT-argument that are both plausible and morally acceptable. This result should not be overstrained, though. The two plausible instantiations of the BT-argument (argument a2 and a3) are rather limited in their scope and length of time, and assume drastic emission cuts that remain within the two-degree budget (without an overshoot).

A large number of questions still remain unresolved:

- There is the need for further research into BECCS scenarios that fully resonate with the BT-approach. Under what circumstances can BECCS realize its associated goal to reduce mitigation pressure without turning into a mere substitute for mitigation? Under what circumstances is BECCS only a 'cheap techno-fix', and under what circumstances a helpful stopgap measure?
- Research on moderate and realistic SAI deployment should equally continue. Particular attention should be given to the legal, including mechanisms to ensure compliance with the no impediment-requirement (that is, continued mitigation efforts even in light of SAI).
- Similarly, I have argued that the techno-fix-objection can be met, if mitigation efforts stay constantly high and the termination of CE is ensured. To guarantee this, certain legal and political measures ought to be established. A climate engineering treaty that involves conditions for CE deployment might be conceivable.
- Establishing a strong mitigation obligation continues to be the focus of climate ethics. Particularily in light of the BT-argument, the mitigation obligation can further be strengthened. A connection to the trade-off argument (see section 2.3.) in light of the BT-argument can also be drawn and should be further explored.
- The virtue ethical stance and the weighting of arguments play an important role in assessing the BT-argument. Research here might prove to be of interest for argumentation theory in general as well as practical philosophy.

There are numerous links to current philosophical research areas, which I will selectively highlight below:

Argumentation theory. I have written above that the virtue ethical hubris argument against CE deployment urges us to be moderate, even humble about our knowledge of natural systems, and especially the lack thereof. The virtue ethical framing of the hubris argument gives a special weight to the argument about irreducible uncertainties (Section 6.2.1). In this sense, it might serve as a meta-ethical guideline about the status of arguments. This opens up a new line of thoughts: Which role do attitudes play in weighing reasons?

A meta-theoretical argument-principle to incorporate this idea could be established. It would be applicable to the theory of dialectical structures (Betz 2010). Such a principle could reside on the macro-level of the debate, as it would describe a weighting-relation between (groups of) arguments.

> **(Weighting-principle)** Given attitude H in debate τ, argument a1 in τ is preferred to argument a2 in τ.

Attitude H is in essence a preference relation on a given dialectical structure τ (for the nomenclature see Section 1.2). It might go further than stance attribution (Betz 2009), and might also give a different insight than the concept of degree of justification (Betz 2012b). The degree of justification is an internal assessment mechanism that yields a numerical result for given finite dialectical structure. The preference relation H, on the other hand, might serve as a qualitative measure, taking the semantic structure of the arguments into account. H might then be further specified, determining its attributes like transitivity and completeness.

Such research could be part of the ongoing extension of knowledge in argumentation theory.

Virtue ethics. Naturally, such meta-arguments belong to the realm of virtue ethics. Virtue ethics seem to play an important role in a number of fields of practical ethics, such as environmental ethics (Di Paola 2015).

If what has been demonstrated in terms of the hubris argument is true, virtue ethical arguments might serve as meta-arguments that enable proponents of a debate to weight single arguments in a certain way. If the hubris-argument in its meta-argumentative form is believed to be true, arguments about uncertainty gain *prima facie* more force, than, say, effectiveness considerations.

However, when does a proponent adhere to such virtue ethical meta-considerations? The problem about virtue ethical arguments is the question of how convincing they are to a person who does not share the same virtue ethical intuitions as the person advancing the respective virtue ethical argument (Levine 2014). Which virtue ethical argument a person finds compelling arguably depends on her attitude (*hexis* in Aristotelian terms). This does not mean that attitudes are arbitrary or that they belong to the realm of a kind of moral 'anything goes'. How far one can argue in favor of certain attitudes has been of focus in recent philosophical research (e.g. Kurbacher 2017).

Education. The discussion of attitudes, or of *hexis*, is part of current philosophical research. Attitudes shape our evaluation patterns, they influence our thinking at a very fundamental level, and eventually enable us to formulate a judgment. Certainly, attitudes are not arbitrary, and desirable attitudes ought to be identified. But how does one *obtain* one's attitude? How does one argue in favor of a certain attitude? And lastly, if it is true that attitudes are rather subconscious, and in a way inaccessible to rational thinking, how can attitudes even be addressed through reasoning? Eventually, this might transgress the realm of philosophical research and might fall into the practical sphere of education. Successful education can enable the individual to formulate well-founded judgments developing her powers to decide on which attitudes she adopts. Hence, a virtue-ethical approach might also be concerned with the question of education, both on the theoretical as well as on the practical level.

Degrowth. One central assumption of the buying time argument is the inevitable decarbonization of society. However, in what terms this change in production and consumption is to come about is undetermined in this argument. In particular, further political implications of decarbonization are not addressed, such as the fair distribution of wealth. Shifting current economies towards net zero does not necessarily imply that such economies will be more just, for example regarding the standard of living, or that they will have a higher level of nature conservation or be more environmentally friendly. Pollution and exploitation of the vulnerable (the environment, animals, native people or people of the third world) might still occur in a global carbon-neutral economy. This gives rise to concern. As I have argued elsewhere (Muraca and Neuber 2017), a strong mitigation approach ought to be embedded in a comprehensive scheme of transforming society. Questions about distributional justice in mitigation ought to be addressed as well as environmental issues. This also resonates with the techno-fix objection against CE (Section 6.2.2), which warns against a delayed shift in society, if CE is applied.

A promising framework to address those issues is arguably the degrowth approach. Certain well-defined criteria can be established to assess the deployment of CE-technologies, such as the viability-criteria and the conviviality-criteria (Muraca and Neuber 2017). An assessment of CE in light of an alternative social and economic background might prove to provide new insights. After all, it is conventional economic thinking which provokes a number of fundamental arguments against CE such as the techno-fix argument. The need for a shift in economic paradigms might be due in order to cope with the specific difficulties posed by CE. As the saying goes: Problems cannot be solved by the same level of thinking that created them.

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