Why First Hand Intuitions Should Not Have the Last Word on Climate Engineering

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WHY FIRST HAND INTUITIONS SHOULD NOT HAVE THE LAST WORD ON CLIMATE ENGINEERING

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Abstract

Climate engineering (CE) research and possible deployment raise many important ethical, societal, and political issues. Intuitions play an important role on how these questions are perceived. They not only inform many of the arguments that are currently dominating the philosophical debate but also link our normative evaluation of CE to certain background assumptions related to the underlying perception of the existing social, political, and economic order. Even though these problems and challenges shape our understanding of CE, they are too broad to inform a more detailed evaluation of specific options. It will be argued that the way forward needs to be more nuanced, based on interdisciplinary research of different CE options and their potential negative as well as positive impacts. After discussing some of the problems and philosophical assumptions of such an approach, the paper will draft an evaluative framework that could guide the normative assessment of specific CE options and place it within the interdisciplinary research landscape. Special emphasis will be given to questions of justice.

Keywords: climate engineering, intuitions, evaluative-framework, climate justice, uncertainty.

1. Introduction

Due to the slow progress of climate change policies and growing global greenhouse gas (GHG) emissions, climate engineering (CE) or
geoengineering – *i.e.* proposals for planetary-scale climate interventions aimed at intentionally counteracting the undesired side effects (global warming) of other human activities (emitting GHG) – is increasingly being considered in scientific and political circles around the world. CE is often equated with the dimming of the sun by increasing the amount of aerosol particles in the lower stratosphere. This should enhance the reflection of sunlight beyond what is reflected by the naturally occurring stratospheric aerosol layer (Schäfer *et al.* 2015). However, stratospheric solar radiation management (S-SRM) is just the poster child of the debate due to its global impact, its relative cheapness and often assumed technological feasibility. Involvement in the current scientific debate reveals the diversity of CE proposals, which vary greatly in terms of their technological characteristics. In accordance with the – by now classical – Report on CE of the Royal Society (Shepherd *et al.* 2009), one can discriminate between solar radiation management (SRM) aiming “to reduce the net incoming short-wave (ultra-violet and visible) solar radiation received, by deflecting sunlight, or by increasing the reflectivity (albedo) of the atmosphere, clouds or the Earth’s surface” (79), and carbon dioxide removal (CDR) directed to “reduce the levels of carbon dioxide (CO₂) in the atmosphere, allowing outgoing long-wave (thermal infrared) heat radiation to escape more easily” (76).³

Since the beginning of the current debate in 2006 there has been widespread acknowledgement in the scientific community that CE research and development (R&D), as well as possible deployment, raise many important ethical, societal, and political issues (Keith 2010). These issues may be even more challenging than the scientific and technical ones (Shepherd *et al.*, 2009). Looking back on the debate on CE, it is interesting to see that at an early stage many ethical issues have been discussed by natural and social scientists, historians as well as legal scholars. With the exception of an early article by Dale Jamieson, published in 1996, we have only just recently seen – more or less since 2010 – an increase in the engagement of ethicists in the debate, probing the complex moral terrain. However, the philosophical debate still rests,
to some degree, on a discomfort with the current state of mitigation measures or the underlying social, political, and economic order. As will be argued in this article, the way forward needs to be more nuanced, based on interdisciplinary research of different CE options and their potential negative as well as positive impacts. The paper begins by highlighting some important philosophical arguments and their underlying intuitions, such as the moral hazard argument, the lock-in argument, the techno-fix argument and the hubris-argument. It will then show that these arguments are not conclusive and cannot provide a final answer towards CE research and deployment. After referring to some basic problems of the assessment of CE techniques, this work will develop the outlines of an evaluative framework. In the last part, the paper will show the importance of justice considerations for the normative assessment of CE.

2. Some Basic Philosophical Arguments and Intuitions on Climate Engineering

Let us begin by looking at some prominent arguments and their underlying intuitions that have long dominated the philosophical debate. The long prevailing taboo on SRM in the climate science community was motivated in part by the concern that discussing the possibility of CE could affect mitigation efforts. If CE is perceived as a kind of insurance against possible high emission scenarios its mere possibility could create a moral hazard (Hale 2012). Such complaints often refer primarily to SRM. They are based on the (contested) perception of these techniques as potentially viable strategies to control global temperatures or as a ‘magic bullet’ in the case of a climate emergency. The fear is that such views could lead to regard SRM as a substitute for mitigation or to support a delay of emission reduction, based on cost-benefit arguments. Also, the possibility of removing CO₂ by CDR techniques at a later time could divert attention, efforts, and incentives from the challenge of decreasing greenhouse gas emissions and encourage political inertia. Moral hazard arguments refer not only to the possible effect of CE on mitigation efforts, but are often based on
the intuition that the engagement in CE, either its research or its deployment, manifests a symptom of our unwillingness to address climate change in a sustainable and responsible way (Gardiner 2010, 2013). The use of only some very limited resources on CE research – especially in methods one will most probably not have to bear the risks of implementing – might create the impression that one’s moral obligations have been satisfied, while at the same time leaving the level of current emissions unaddressed (Smith 2012). This seems to lead to moral corruption, defined as the engagement in manipulative or self-deceptive behavior by applying one’s attention selectively to only some options, that may better suit one’s life-style (Gardiner 2006b, 2010 & 2011b; Preston 2013).

This intuition is also reflected in a second argument – closely related to the moral hazard one –, the potential of CE techniques to help to prolong or to lock us into the social and economic order of today, an order perceived as unsustainable and unjust. The underlying fear is that CE could be misused as a shadow solution on a more general, societal level, which would leave the underlying problem of anthropogenic climate change, the careless overconsumption of natural resources (including GHG sinks), untouched (Gardiner 2011b). Unlike other solutions to climate change, CE focuses on the environmental side of global warming. It leaves unaddressed social goals like changes in consumerist life-style or GHG intensive agriculture, energy or consumer goods production and population trends (Schneider 2008; Virgoe 2009; Corner and Pidgeon 2010). Apart from the unwillingness to change or transform our societies and the global economic order in more profound ways, the most important intuition here is that the engagement in CE is based on our strong attachment to an emission-intensive life-style. Furthermore, CE techniques could be misused by those who would be

Furthermore, the idea of ‘arming the future’ by providing CE techniques for the case of a climate emergency has been criticized by Stephen Gardiner as morally schizophrenic. Not only would this be a strange kind of compensation for a crisis which could have been prevented by other options available to us in the moment, like increased global mitigation efforts. Also, taking seriously the endorsed strong ethical concerns embraced in these (arming the future) arguments would lead to approach climate policy in very different and more sustainable ways (Gardiner 2013).
negatively affected by emission controls and who have an interest in high emission rates (Jamieson 1996; Virgoe 2009; Ott 2012; Gardiner 2010, 2013). Here, intuitions run strongly against the permissibility to keep on burning carbon fuels and the ignorance of possible consequences and cleaner alternatives. Schäfer et al. (2014) regard the CE debate as primarily fueled “by its apparent privileging of the status quo and incremental change over a more immediate and radical change in societal organization” (239). This paper argues that, despite arguments concerning the hubristic and novel character of CE (see below), CE can be interpreted, based on Karl Popper’s distinction between utopian and piecemeal social engineering, as a form of the latter rather than the former.5

These questions of change are linked to a further associated argument, the view on CE as part of the dominant preference of Western cultures for technological fixes. As pointed out by Borgmann (2012), technological fixes are based on a deep-rooted habit of solving problems with technology, by changing the circumstances as a response to the failure of people to behave in an appropriate way. The appeal of such technological solutions is often found in their simplicity and timeliness, as well as in their reduced demands on people’s behavior and socio-economic or political systems. Such technological fixes sometimes help to deal with complex social and political problems that may otherwise be unsolvable. Still, their moral status is ambiguous and the techno-fix framing is often used more negatively in the CE debate by connoting an inadequate and morally problematic solution for the underlying problem (Scott 2012; Corner and Pidgeon 2010). Again, intuitions associated with the techno-fix debate refer to an unwillingness to change and to accept the responsibility for our way of life. This is sometimes accompanied by technological pessimism seeing technology as the “determining and controlling influence on society and culture” (Verbeek 2005, 11), leading to the need of a “deeply self-critical perspective by

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5 Piecemeal social engineering can be described as “an approach that challenges the status quo only in small steps, without an ultimate aim in mind for societal development. ... In contrast to this, utopian engineering aims at revolutionary change with the goal of achieving a predefined ideal state, based on assumptions of the capacity for omniscience and control.” (Schäfer et al. 2014, 241). For a detailed account of Popper’s piecemeal social engineering, see Stelzer 2016.
questioning the intellectual foundations that have led to a seeming addiction to technological fixes” (Scott 2013, 6). A further intuition in this context is the fear that technological solutions could create new problems. The deployment of some CE technique could lead to a chain reaction of fixes, as the fix of one problem may trigger the need to fix problems caused by the first fix, and so on. Things could run out of hand and CE interventions might only create an illusion of controllability (Amelung and Funke 2013). Here, a further intuition often turns against advocates of CE, or of certain CE options, accusing them to ignore these risks and falling prey to ‘appraisers optimism’.

Others have argued that, even on a small scale, some forms of CE could indicate the beginning of a deliberate global planetary management for human ends (Virgoe 2009). This sets CE in strong contrast with global environmentalism, where the dominant attitude is often one of minimizing the human impact on the ‘natural’ environment rather than changing the world in ways that may fit certain interests. From such a perspective, we should strive to understand and respect nature, and not change it just for our convenience (Ralston 2009). Based on their large-scale interference in the climate system and their potential strong impact on ecosystems, CE is viewed by some to be hubristic, arrogant, or reckless (Kiehl 2006; Hamilton 2010). The underlying intuition is that the implementation of CE techniques may not just happen to have adverse effects on nature and trigger the loss of biodiversity and wilderness on an unprecedented scale (Hale and Dilling 2011; Preston 2011), but that they could also alter the relationship between humans and nature more generally or aggravate existing negative trends in this respect (Buck 2012). From this perspective, CE seems to be a ‘failure to appreciate one’s place in nature’. It may also serve as another example of our ‘unwillingness to live with nature’ (Jamieson 1996) or it may be seen as the crossing of a new ‘threshold’ on the ‘spectrum of environmental recklessness’ (Gardiner 2010). In some cases, these intuitions also refer to a hubristic attitude towards human

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6 Preston summarizes these intuitions as criticizing CE as a demonstration of “a culpable attitude of domination” and a “paradigm of disrespect” (Preston 2011, 462).
capabilities, attempting to exert domination or control over natural processes (Jamieson 1996; Ralston 2009; Jornen et al. 2011).

3. Why First Hand Intuitions about Climate Engineering Need to Be Reevaluated

Even though the problems and challenges mentioned above shape our understanding of CE, they are too broad to inform a more detailed evaluation of specific CE options. Of course, these debates need to continue, because they sometimes help to clarify our intuitions and background assumptions with respect to CE. However, it would be poor policy advice if we just stuck to our first hand intuitions. This thought will be exemplified in the following by presenting some criticism of the arguments and underlying intuitions given above.

First, the arguments just mentioned are not very conclusive. Even though moral hazard arguments have gained popularity, they have also been criticized for various reasons: for being too opaque (Hale 2012) or normatively underdetermined (Bunzl 2009); for giving only little guidance even if applicable (Preston 2013); for presenting a completely empirical matter, which is only verifiable when the event actually happens (Lin 2013; Reynolds 2014). It has also been argued that the possibility of some CE techniques could have, in reality, the opposite effect of what was expected. In particular, the possibility of the unilateral deployment of S-SRM could be so threatening that it actually motivates mitigation (Millard-Ball 2012; Moreno-Cruz 2013). Yet, these counter arguments may not dismiss a potentially negative trade-off between a push for S-SRM (research and/or deployment) and mitigation efforts (Morrow 2014a; Baatz 2016). Particularly, if we consider other reasons for political inertia in the field of climate policy, it remains uncertain whether the availability of CE options would have a strong impact on mitigation. Surely, political inertia needs to be discussed much more widely and without addressing the reasons for it, far reaching decisions on the deployment of certain CE techniques would most likely be considered illegitimate due to violations of norms of international justice and national sovereignty (Corner and Pidgeon 2010;
Gardiner 2011b). However, it seems at least debatable to pick out CE as a relevant factor of our failure to deal with climate change in a more responsible way or to view CE as nothing more than the manifestation of moral corruption (Gardiner 2013). Both lines of argument – the moral hazard and the lock-in argument – indicate how strongly the debate on CE depends on far reaching questions concerning the current socio-economic and political order and the strong status quo bias of most political actions. Future research as well as the possible deployment of CE techniques will certainly be influenced by the development of our societies and economies. Nevertheless, engagement in CE (research), at least for the moment, seems to be less the driving force of these processes than their result.

Second, the techno-fix argument also rests on these – as one could call them – ideological background assumptions. Surely, (leaving aside moral uncertainty) a world where people changed their behavior based on well-considered moral judgments promises a bright and sustainable future. And it is, without question, the part of philosophers to provide such arguments. However, if there is something to be learned from the philosophical engagement in the climate change debate, it is not the lack of arguments in favor of imminent and extensive action. It is rather the persistence of the motivational problem, *i.e.* the problem of bridging the gap between accepting a moral principle and acting in accordance with it, that should make us worry (Birnbacher 2009). In the history of moral philosophy this issue has been discussed at length. It is reflected in the debate between internalists and externalists (Rosati 2016). While the internalist view rests on the assumption that having moral reasons for an action is inseparable from being motivated to act in accordance with it (Williams 1981; Smith 1994), for externalists having moral reasons for an action and being motivated to carry it out are distinct issues (Shafer-Landau 2000). Wherever one stands in this debate, in practice moral motives based on conscientiousness or a sense of duty often seem too weak to resist the temptations of more immediate, self-centered objectives. Therefore, we may not want to set all our hopes on a ‘political and moral conversion’ – a term Karl Jaspers uses in his book on the atomic bomb (Stelzer 2017b). Rather, we should also investigate technological solutions to current societal and environmental problems.
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(Moellendorf 2014). This could also be a result of taking the intuitions concerning moral corruption and our unwillingness to change (more) serious. Moreover, mitigation does not reflect technological skepticism, either. On the contrary, many policies are based on developments in the sector of renewable energies and technological transformation. Why CE needs to be treated differently than other technological solutions is not obvious, except if one accepts the moral-hazard or lock-in argument.

Third, complaints against CE from the environmentalist side are not to be taken lightly as most options will come with some side effects on ecosystems and/or biodiversity. Even for a CDR technique like afforestation – based on the needed scale of deployment to have an impact – these effects could be far-reaching and severe. Nevertheless, the underlying intuition of CE as hubristic or the passing of a new threshold of environmental recklessness seems less convincing. Such complaints often depend on certain intuitions towards a single technique: S-SRM. Its direct intervention in the climate system could change precipitation patterns, trigger certain chemical feedback processes in the lower stratosphere or lead to ozone depletion. Furthermore, we may not be able to find out about all the possible side effects and feedback processes before deployment (Robock et al. 2010). Without getting into detail, the worry is that we would start messing around with the only climate systems we have, and based on our record of failed interventions into ecosystems and the complexity of the climate system, this seems to be a bad idea (Matthews and Turner 2009). However, one could argue that we are already in a large-scale experiment with the climate through our emissions. It is important to be clear to what we compare CE deployment. No realistic implementation scenarios should underestimate the consequences of global warming. Nevertheless, in contrast to the alteration of the climate as an unintended consequence of our global energy use, CE would represent an intentional and deliberate intervention into the climate system. Intentionality is not only part of many definitions of CE but it also matters morally, as it often triggers a strong link between moral responsibility and harms resulting from those actions (Bodansky 1996). Then again, the intention of CE deployment may actually speak in favor of it, as it would be undertaken – at least in some cases – to decrease some of the most severe consequences of global
warming, on humans and ecosystems alike (for a discussion of such arguments see Morrow 2014b).

Forth, replying to the hubris argument shows how easily one is drawn into discussing a single option with very specific problems. However, much depends on the particular CE technology under discussion. Placing mirrors in space may display hubris more than afforestation, which is seen as much more ‘natural’ than the former (Preston 2013). Furthermore, as pointed out by Heyward (2013), ‘unnaturalness’ is not a feature of CE alone, but might also apply to some forms of mitigation and adaptation, e.g. nuclear power or the use of genetically modified crops. Strong differences between CE technologies have created a debate about the general use of the term geo- or climate engineering, since the techniques summarized under these terms are extremely diverse. In any case, our intuitions towards one CE option should not make us blind to other options. Surely, CDR techniques are also not without costs, especially when we consider questions of effectiveness (how much CO₂ could be removed), efficiency (is it economic feasible to invest in these techniques, when aggressive mitigation could still keep us below 2°C), scale (what kind of infrastructure and energy demands are we talking about when we really want to make a relevant difference to emission levels), and side effects (e.g. how much land would different land-based CDR techniques need and how would this effect food production). What we need is more information and the evaluation of our options under assumptions of comparable scenarios.

4. Some of the Obstacles in Our Way on the Road Ahead

We could go on discussing the above arguments and the underlying intuitions around which the philosophical debate often

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7 It is by no way clear, if this is the case. The need for negative-emission technologies is indicated by reference to the large-scale use of BECCS (Bioenergy with Carbon Capture and Storage) in RCP2.6, which is the only Representative Concentration Pathway (RCP) aiming to keep the 2°C temperature target.
gravitates. However, it seems that arguments that would rule out all or even any specific CE option in all possible scenarios have yet to be found. The latter holds even for S-SRM when we consider lesser evil arguments and compare its deployment to runaway climate change (Stelzer 2015; Stelzer and Shuppert 2016). If this is the case, then one is inclined to put into question some of our intuitions about CE. Of course, these intuitions (see above) are important starting points for debate and can link CE to deeper questions concerning our current social and economic order as well as our responsibility towards a sustainable future. However, it may be time to move on to a more differentiated view that rests on interdisciplinary research and on more accurate criteria to inform our judgments (Tuana et al. 2012).

This does in no way exclude normative reasoning, on the contrary. Not only are normative arguments in the context of the assessment of technologies in need of empirical backup, but interdisciplinary work on the subject can also help to develop the right questions and to come up with an evaluative framework that allows us to get a clearer picture of the normative permissibility of certain CE options. Without question, any such framework will rely on value commitments based on different normative theories, and the results of our normative evaluation will differ depending on which of these normative theories is applied. As part of a normative framework, these values and moral judgments alongside their underlying intuitions are constantly checked against moral principles and background theories as well as contested from outside by those holding different moral views and intuitions (Rawls 1951; Daniels 1979). The appeal of a more nuanced assessment of CE techniques should, therefore, not be understood as downplaying the role of moral intuitions. Moreover, at the end of our normative assessment we may find some of our first hand intuitions confirmed. E.g., if it turns out that the deployment of a certain CE technique would put cost and risks foremost on those most disadvantaged and least responsible for climate change in the first place, the intuition that CE, or at least a certain CE option, could prolong or increase global injustice may turn

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8 I thank one of the reviewers for pressing me on this point.
out to be well founded. Nevertheless, this would be the result and not the starting point of an open assessment of CE techniques.

Even though, in the following no specific normative theory will be emphasized, leaving intuition-based arguments aside and turning towards interdisciplinary research seems to point towards a consequentialist evaluation of climate engineering⁹. However, the normative assessment of consequences faces difficulties as the results provided by natural sciences and economics are often not readily accessible. Let us therefore look at some of the caveats we may face in this regard.

First, we have to deal with uncertainty. Our current knowledge and understanding of the effects and consequences of the deployment of different CE options is less than perfect. Even though the last years have shown an increase in our understanding of different techniques, it seems unrealistic that any time soon we can come up with exact estimates or provide a full understanding of all possible consequences of deployment. We are therefore limited to talking about the expected effects and risks of certain options or deployment scenarios. For many of them, we will not be able to assign even probabilities for certain outcomes – in cases of non-probabilistic or Knightian uncertainty – or we might lack the knowledge about all of their potential outcomes – in cases of ignorance. Although we can expect to gain a better understanding of the effects as climate science and research on CE options advance and therefore reduce some of the epistemological uncertainties involved, we may also face principle knowledge constraints, e.g. based on the inherent complexity of the climate system and its interaction with the biosphere, the oceans, and the cryosphere (Lovelock 2008). Moreover, as pointed out by Sarewitz (2004), one side effect of new research may be new areas of uncertainty or at least ambiguity. It is very difficult to know when we have reached a point of a sufficient level of understanding to be sure that the climate impacts

⁹ Consequentialism can be understood in a broad sense as a normative theory that would base the normative assessment on the expected consequences. This includes not only straightforward utilitarian positions, but also those taking into account the separateness of persons as the bearers of moral rights-claims, such as a rights-based sufficientarianism.
associated with non-intervention may be either as dangerous, or worse than the combined known and unknown impacts of the deployment of certain CE options (Matthews and Turner, 2009).

Second, economic assessments seem problematic for large scale, highly risky and new techniques in future scenarios that come with considerable uncertainty. Under such circumstances it is extremely difficult to adequately apply forms of cost-benefit analysis (CBA). The reason is that these assume that all possible significant consequences can be enumerated in advance and that probability, cost and benefit values can be attributed to them (Baer and Spash, 2009). At the same time, economic assessments are open to instrumental framing effects, like assumptions on sensitivities and discounting, leading to conflicting conclusions (Goes et al. 2011). It should be also mentioned here that consequentialist approaches in ethics – closest to the path of a more nuanced evaluation of CE options – share some of these problems (Norcross 1990; Lenman 2000; Jamieson and Elliot 2009).\(^\text{10}\)

Third, even if we had sufficient information about the probability of different outcomes, it remains doubtful whether judgments about these impacts and risks can be quantitatively calculated and are therefore reducible to economic calculations (Shue 1999, 47). An economic analysis presupposes one measure able to represent all outcomes and make them comparable. However, it seems not possible to attribute automatically monetary values to all benefits and burdens, including human life, physical security, subsistence and health. Neither the risk of basic human interests nor their actual prospective violation itself can be quantitatively expressed in (monetary) costs. Therefore, we need different scales in order to weigh one risk of the violation of such interest against other interests. Furthermore, combining all damages in a monetary damage function may conceal ethical dilemmas and difficult value judgments (Azar and Lindgren 2003).

\(^{10}\) Nevertheless, in a prior publication together with Fabian Schuppert (2016), we set out to explore the possibility of risk-sensitive multi-dimensional consequentialism, which is able to provide ethical guidance for our decision-making in complex situations such as rapid climate change. In the last section of that paper, we applied our approach to a comparison of different climate policy options, including S-SRM.
5. Some Components of an Evaluative Framework

Based on these and other difficulties it is a great challenge to develop an evaluative framework that is able to provide the information and criteria needed for the normative assessment of CE options. An adequate framework would need to consist of an enumeration and definition of the issues to be investigated, as well as criteria and indicators that show how well or badly certain options meet different standards. These standards are often based on political, economic or social goals. Of course, there are many evaluative frameworks: some guide the assessment of proposed global climate policy regimes more generally (e.g. Aldy et al. 2003), others directly refer to CE (e.g. Shepherd et al. 2009; Cusack et al. 2014). Most post-Royal Society assessments have taken up the challenge of including social, political, and ethical criteria, sometimes in overlapping and sometimes in distinct categories. Following these previous approaches, it seems reasonable not to detach our normative assessment from technological, natural, political, and economic aspects, but to integrate it into an interdisciplinary evaluation process. In the following, a draft of an evaluative framework will be developed starting with the consideration of impacts, proceeding towards questions of control, feasibility and sustainability, and ending with the assessment of the distribution of costs, benefits and risks based on Shared Socioeconomic Pathways (SSPs) and the Sustainable Development Goals (SDGs) (see figure 1). The aim of such an evaluative framework is not to create new knowledge – even though it depends on the interpretation of data by partially new developed indicators –, but rather to summarize, organize, and interpret existing knowledge to support our deliberation about CE, and – as indicated above – also to test our intuitions.
As indicated by the central position in the figure, every evaluation needs to begin with a consideration of impacts understood as the (intended or unintended) effects of the CE option under investigation, which may include not only a single technique but also portfolio approaches. For a basic understanding, we have to rely on an impact analysis based on natural sciences and climate and earth system models. During the last years, much work has been done on basic questions concerning different CE options, creating a better picture of effects and side-effects, of the involved chemical and biological processes, energy resources, and land- and infrastructure demands, just to name a few. As we are dealing with the assessment of technologies, we also need to consider indicators that allow us to say more about these techniques and their deployment. We cannot discuss here all the issues involved (they can be found in the literature on Technology Assessment – TA), but it can be stated that risks and constraints seem most important for CE. Questions of risk, defined in a broad sense as the possibility of
unwanted effects, stand in a close relation with the controllability of a technique. Societies are well aware that many technologies come with risks, but if those risks can be controlled, their members are often more willing to take them. Risks can be reduced by certain characteristics of a technology, e.g. reversibility. Reversibility refers to the ability to ‘switch off’ a technological program and have its effects terminated in a short time. Even though it is possible to abandon most CE options, reversibility applies to more than just the ability to end deployment. First, we may face time lags of effects even after the termination. In addition, the avoidance of rebound effects is of importance. Furthermore, methods like S-SRM come with a termination effect, as a failure to maintain the aerosol counterforcing could result in an abrupt and potentially very damaging warming, depending on the time and scale of deployment (Vaughan and Lenton 2011). Some environmental changes in ecosystems or certain changes to climate patterns may also prove to be irreversible, such as large-scale changes in atmospheric chemistry or losses of biodiversity. Reversibility may not only be a question of environmental consequences. The abandonment of certain techniques could also face strong resistance due to vested interests, based on the investments made in the construction and maintenance of the physical infrastructure or the use made of such techniques to keep up the status quo (Preston 2016). Another important aspect related to the topic of controllability of CE techniques is ‘encapsulation’, understood as the degree of ‘foreign material’ that is released into the environment or the possibility to contain the engineered system (Royal Society 2009; Rayner 2011). Contrary to concerns raised in the debate on genetic manipulated crops or organisms for CE, the importance of encapsulation is connected to the scale and the duration of the manipulation of the natural environment and ecosystems. This is due to the fact that many techniques rely on natural processes, even though some of them may only be incomplete analogies, e.g. volcano eruptions for S-SRM. This is also related to a further interesting aspect within the discussion of CE: scalability. Here an important question is whether a technique allows for sub-scale testing and gradual deployment to full-scale (see the discussion on S-SRM above). There are yet other aspects that need be
included, such as the flexibility of the technique or the novelty of the involved processes.

Turning to the constraints, it is not only natural, but also social, political, and economic aspects that need to be considered. Those constraints are important for questions of feasibility. It may be futile to conduct research on techniques that may fulfill most of our expectations towards issues of justice (see below), sustainability, and controllability but which could still not get off the ground because they are not realizable in a meaningful and technological sound way, at least not in the near future. This seems to be what ended the discussion on space mirrors in its early stages. Also, interest in iron fertilization has vanished as the natural processes involved have proven to be too complex to be handled with ‘just a tanker full of iron’\(^\text{11}\). Furthermore, circumstances under which CDR techniques are economically viable and socially and ecologically sustainable remain to be determined (Shepherd 2012; Welch et al. 2012; Stelzer 2017a). In many cases, their economic feasibility would only be given if the uptake of CO\(_2\) were cheaper and/or more efficient than limiting emissions in the first place (Schellnhuber 2011).

Political feasibility connects well to some aspects that were mentioned earlier in this paper. Here, our evaluation also depends on assumptions about different deployment scenarios, e.g. as regards their conflict potential. Conflicts could result from the unilateral deployment of some CE techniques, the potential diverse distribution of costs and benefits, trans-boundary effects, problems of tracing consequences and assigning responsibilities, or competing interests of regional climate control\(^\text{12}\). Questions of procedural justice and governance issues, which have gained attention in the last years of CE research, also fall under this category.

These aspects (by no way a complete enumeration of all things that need to be considered) can also lead to better estimates of the cost and benefits involved. Different economic approaches have been used and

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\(^{11}\) This refers to the famous quote by John Martin: “Give me a half tanker of iron, and I will give you an ice age”.

\(^{12}\) The possible strategic interest in the ability to modify the climate is constantly emphasized in the literature, often in comparative conjunction with interests in weather modification. The Environmental Modification Convention (ENMOD) banned the use of weather modification for military or hostile purposes in 1977.
developed over the years. Based on the problems of CBA indicated above, economists have turned to alternatives such as cost-effectiveness analysis (CEA) – stipulating a political target such as climate stabilization, which then should be achieved at minimum welfare loss –, or cost-risks analysis (CRA) – a hybrid approach between CBA and CEA (Neubersch et al. 2014). In recent years we have seen an emergence of Integrated Assessment Models (IAMs) to represent the effects of certain human activities on the climate system or earth systems and on human activities by bringing together and summarizing information from diverse fields of study. Of course, all results of economic analyses in the field of CE research come with considerable degrees of uncertainty due to incomplete knowledge, the complexity of the subject at hand, or modeling uncertainties. Even more important, their results depend on assumptions about future developments. To make the results of economic analyses more comparable, different scenarios have found their way into the scientific community, like the Representative Concentration Pathways (RCPs) or the recently developed Shared Socio-economic Pathways (SSPs). This dependency on scenarios is often overlooked outside the field of economics. For our normative assessment we should keep this in mind and refer to the underlying assumptions of these scenarios once we use information based on economic models. This would also require us to improve our understanding of the role and influence of these scenarios on the work and results of IAMs.

Furthermore, in order to evaluate the produced data we need indicators that show how well or badly a certain option or set of options meet(s) certain goals, criteria or standards. Evaluation involves a translation process, starting with certain goals, which will need to be translated into criteria/standards, which then will need to be operationalized by certain indicators that can be used to search the existing database. Which goals we take into account and which criteria/standards we develop cannot be determined by science. This process rests on value judgments that are either formulated by experts or are the result of social/political processes – or a combination of both. E.g., in the CE community – at least in Europe – the 17 Sustainable Development Goals (SDGs) are discussed as a possible starting point for the development of criteria and indicators. There are a couple of benefits of using the SDGs. They have some international legitimacy, because 193 countries adopted them in September 2015 and they came into
force at the beginning of 2016. Even though the SDGs are not legally binding, governments are expected to take ownership and establish national frameworks for their achievement based on the 2030 Agenda for Sustainable Development. Over the next fifteen years, the SDGs are supposed to lead the mobilization efforts to end all forms of poverty, fight inequalities and climate change. Therefore, they can be expected to be well known by policy-makers and to be influential in the discussions on sustainability and climate change in the coming years. Academic involvement has already started, for example in the The World in 2050 (TWI2050) project, a global research initiative to provide fact-based knowledge to support the policy process and implementation of the SDGs. Moreover, the SDGs provide a list of 169 targets that can be used as an approximation to some of the criteria and indicators to be developed in detail for the evaluative framework envisioned. Furthermore, it seems important to undertake profound philosophical investigations before using them and also look for potential conflicts between different SDGs and targets.

6. Considering Justice as Part of the Evaluative Framework

Another aspect that makes the SDGs worth considering is their strong emphasis on questions of global justice. Justice is an area where philosophers can contribute to the assessment of CE techniques by posing questions that are relevant to the subject matter and by providing normative theories to support claims of justice. In relation to this topic, what is of interest from a normative perspective are not only adverse effects and harms of deployment as well as possible benefits as compared to unmitigated climate change, but also the temporal and spatial distribution of benefits, burdens, and risks. The latter poses particular issues for global justice, as burdens and risks could be transferred to the poorest countries. Those geographically and economically most vulnerable to changing climate conditions could also be those most likely to be negatively affected by uneven effects of a technique like S-SRM. In addition, they also have the weakest capacity to adapt to the consequences despite being least responsible for global warming (Preston 2012, Svoboda 2016). While it has been argued that in
the case of deployment it would be unfair to create benefits for oneself in exchange for putting burdens and risks on others (Burns 2011; Goes et al. 2011), the question of whether all or some CE techniques would increase existing inequalities and historical injustice of climate change is open for debate. The main reason for this is not only persisting scientific uncertainty about distributional effects, but also the possibility that deployment could benefit especially some of the most vulnerable and poorest countries by reducing climate change-induced risks through decreasing temperature rise or reducing emission levels (Svoboda et al. 2011). If we want to get better answers to these questions, we philosophers have to ask those who are providing us with information to co-develop with us specific indicators that are able to show distributional effects on regions, social and economic sectors or groups in their data, which may also include modifications of their models. The potential of getting output useable for questions of justice seems high. Climate models allow us already to search for responses of particular weather patterns, which are vital to important agricultural regions of the world or especially to those in poorer nations, or, based on IAMs, to consider the influences of different land-based CDR techniques on food prices.

Questions of justice are also relevant when we consider the long-term consequences of CE. Based on the assumption that currently living people stand under the duty to protect future people’s basic interests or rights, intergenerational justice is an integral part of the assessment of CE techniques. The content of these obligations of contemporary people or generations varies with the overall system of rights that is attributed to future persons. Additionally, the idea of intergenerational equity calls for a just distribution in the utilization of resources between generations (Burns 2011). As it is widely discussed in the literature, some CE techniques

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13 For how to combine the evaluation of climate change policies with question of global justice see Moellendorf (2014). Especially his antipoverty principle seems a valuable starting point also for the discussion of CE and global justice.

14 However, we should not expect that we will be able to deploy CE techniques without any negative side-effects. Therefore, philosophers should also engage in the debate on compensation schemes, not only for CE but for anthropogenic climate change induced harms and burdens more generally (for considerations on CE see Wong et al. 2014, Svoboda and Irvine 2014).
could lead in their consequence to an increase of inequalities between generations as they might allow deferring risks and costs to future generations (Gardiner 2010; Goes et al. 2011; Svoboda et al. 2011; Svoboda 2016). Furthermore, by starting to deploy certain CE options, one generation would be choosing a specific path for future people, which may be irreversible or only changeable with considerably high costs (Jamieson 1996; Ott 2012; Smith 2012). For example, due to the long lifetime of CO2, S-SRM would need to be extended for a long period of time, thus creating a permanent threat of termination (see above). Nevertheless, we should be also cautious here and not easily renounce CE. Some of these techniques could help to alleviate effects of a high-emission world by effectively cooling the planet or by helping to decrease emission levels, which would otherwise burden future generations (Tuana 2013). Of course, making assumptions about intergenerational aspects of CE may be very speculative and therefore harder to include in an evaluative framework. Nevertheless, climate models and IAMs often take medium to long-term perspectives into account and therefore provide at least some insights for questions of intergenerational justice.

These normative considerations can provide the basis for a justice based risk-assessment of different CE options. Such risk-profiles can be regarded as a first step towards a normative evaluation. Nevertheless, they are not sufficient as they only indicate the severity of the risks involved, their distribution between roughly defined actors (income-groups, nations, world regions, generations, species) and fields of justice (distributive, compensatory and procedural justice). To develop criteria for judging different options, one needs to refer to indicators that are able to signal the (expected) transgression of certain thresholds as minimal standards that need to be fulfilled by any given option (Stelzer and Schuppert 2016). Such an approach enables the use of multiple thresholds functioning as guardrails that open up a certain range of options, while also clearly indicating when an option is outside that range. While guardrails allow the use of measurable quantities based on specified indicators, their multidimensionality enables us to take into

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15 Because of limited space, questions raised by ecological justice for CE were left out in this paper (see e.g. Preston 2011).
account socio-ethical issues raised by the justice considerations mentioned above. Such guardrails could also include targets of the SDGs and could be applied in a context sensitive manner towards different scenarios, as put forward in the SSPs. A first step for the further development of the evaluative-framework described above could therefore rest on a better understanding of the SDGs and their use to develop criteria and indicators that can offer insights into philosophical questions based on data from IAMs, including also further technological aspects and feasibility constraints. Future research should be accompanied with a philosophical investigation into the use of scenarios like the SSPs and their underlying assumptions and influence on the results of IAMs.

7. Conclusion

This paper argued for the need of a more nuanced evaluative framework. However, such an approach is currently in development and many problems lie ahead of us. Our intuitions will continue to play an important role, but they should be complemented, and also clarified by such an evaluative framework. Furthermore, the search for a better normative assessment of CE options turns out to be connected to fundamental questions of normative theory itself, such as a better understanding of the imposition of risks of harms (including questions of responsibility) and the possibility of weighing different interests on the intra- as well as intergenerational level. Questions of CE therefore provide an important impulse for disciplinary as well as interdisciplinary research.

REFERENCES


WHY FIRST HAND INTUITIONS SHOULD NOT HAVE THE LAST WORD ON CLIMATE ENGINEERING


