Climate engineering and the future of justice

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DOI
10.11647/OBP.0366.04

Publication date
2023

Document Version
Final published version

Published in
Ethics of Socially Disruptive Technologies

Citation (APA)
Taebi, B., Lenzi, D., Buhr, L., Claassen, K., Gerola, A., Hofbauer, B., Paiusco, E., & Rijssenbeek, J. (2023). Climate engineering and the future of justice. In *Ethics of Socially Disruptive Technologies: An Introduction* (pp. 83-111). Open Book Publishers. https://doi.org/10.11647/OBP.0366.04

Ethics of *Socially Disruptive Technologies*

An Introduction

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https://www.openbookpublishers.com/

ISBN Paperback: 978-1-80511-016-3
ISBN Hardback: 978-1-80511-017-0
ISBN Digital (PDF): 978-1-80511-057-6
ISBN Digital ebook (EPUB): 978-1-78374-789-4
ISBN Digital ebook (XML): 978-1-80511-050-7
ISBN Digital ebook (HTML): 978-1-80064-987-3
DOI: 10.11647/OBP.0366

Cover image: Blue Bright Lights, Pixabay, 6th April 2017, https://www.pexels.com/photo/blue-bright-lights-373543/
Cover design: Jeevanjot Kaur Nagpal

4. Climate Engineering and the Future of Justice

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This chapter discusses the societal and ethical challenges of climate engineering or large-scale intentional intervention in the climate system. Climate engineering is highly controversial, and raises many questions about the values of human societies and the desirability of technological visions of the future. Yet existing ethical theories and concepts may not be equipped to deal with the resulting ethical issues. To understand the potential social and political disruptiveness of climate engineering, we argue it must be placed in the context of global environmental changes caused by human activity. However, climate engineering is also accompanied by a high degree of uncertainty and risk in terms of potential and actual unintended impacts on natural processes and society. An important challenge stems from epistemic and normative uncertainties about the reversibility and variability in

1 All mentioned lead authors and contributors contributed in some way to this chapter and approved the final version. BT and DL are the lead authors. They coordinated the contributions to this chapter and did the final editing. BT and DL conceptualised and co-wrote the Sections 4.1. and 4.4. DL also co-wrote Section 4.3. and contributed throughout. LB and JR co-wrote Section 4.2., and LB contributed to Section 4.1. EP co-wrote Section 4.3. and contributed to Section 4.2. BH co-wrote Section 4.3. and contributed to Sections 4.1. and 4.2. KC contributed to Section 4.3., and AG contributed to the paper conceptualization and edited several sections.

 https://doi.org/10.11647/OBP.0366.04

spatial and temporal scales of deployment. Epistemic uncertainties arise in the methodological framework of climate science, while normative uncertainties arise from the challenge of reconciling a plurality of values. A key question is how forms of climate engineering enforce or hinder disruption in social practices and institutional settings in the direction of a sustainable future. Climate engineering technologies can affect and potentially disrupt existing conceptions of climate and environmental justice, due to the scale and scope of impacts upon people currently living on the planet, future generations, and non-human species and ecosystems. The availability of climate engineering may also require rethinking the responsibility for climate mitigation, as well as applications of the precautionary principle. Climate engineering also raises the question of how the perspectives of affected communities can be adequately represented. While it remains unclear whether climate engineering techniques can genuinely assist in lessening the impacts of climate change, the question is whether and to what extent it should be used as a complementary approach to systemic changes in social, economic, and political practices.

Fig. 4.1 Geoengineering. Credit: Menah Wellen

4.1 Introduction

Technology-driven human activities such as the burning of fossil fuels have propelled the earth into a new geological epoch, the 'Anthropocene', i.e. the era of humankind (Crutzen, 2002). The Anthropocene heralds the prospect of a permanent departure from the benign climate and environmental conditions that were known to our ancestors to a much more dangerous future. Since current activities put us on a pathway towards a 'hothouse Earth' (Steffen et al., 2018), transformative change is necessary. This will doubtless involve highly disruptive interventions directed at the global economy and society.

One set of interventions directed at the climate crisis in particular is known as climate engineering or geoengineering. Climate engineering is defined as 'the deliberate or intentional large-scale intervention in the Earth's climate system, in order to moderate global warming' (Royal Society, 2009: 1). Climate engineering is highly controversial and raises many questions about the values of human societies and the desirability of technological visions of the future. Although human beings have engineered their environment throughout their history (Sandler and Basl, 2013: 1) — think of agriculture, house building, resource extraction — human beings have never previously attempted to engineer the global climate. But this is not due merely to the limits of technology. For earlier civilizations, the very idea that human beings could meaningfully alter 'nature' would have been incomprehensible. Yet since the industrial revolution in the eighteenth century, human activities have unintentionally altered nature on a very large scale. Humans have transformed the earth's soil, water and surface and even the composition of the atmosphere. We can characterize high-modernist interventions into nature as intentional (i.e., deliberate and targeted to human purposes), in contrast to the unintentional but profound impacts of anthropogenic activities upon the global climate and the planet as a whole. Thus, climate engineering may represent the logical end-point to intentional intervention into nature in the Anthropocene. As Corner and Pidgeon noted, 'interference in the global climate is precisely the problem that geoengineering is designed to solve' (Corner and Pidgeon, 2010: 28). Nonetheless, the very idea of large-scale intentional intervention into the global climate seems to run up against the limits of current scientific knowledge and governance capacities. Existing ethical theories and concepts may not be equipped to deal with the resulting ethical issues. The deliberate nature of climate engineering marks these techniques out as ethically distinctive (Jamieson, 1996), and distinguishes them from similar effects produced unintentionally on the Earth's natural systems and processes.[2]

Before discussing these issues, we introduce the two main forms of climate engineering. The climate is regulated by two variables: the incoming energy through solar radiation (i.e., sunlight) and the amount of solar radiation that is retained within the planetary system, mostly through greenhouse gasses (GHG). Climate engineering targets both variables. Solar Radiation Management (SRM) techniques affect the planetary reflection levels, whereas Carbon Dioxide Removal (CDR) techniques remove carbon dioxide from the atmosphere. The forms of climate engineering vary greatly in form, scale, and potential for disruptive impacts (for an assessment of CDR, see IPCC (2022: Chapter 12). For SRM, see IPCC (2018: Chapter 4). Box 1 lists some of the key technologies that are being considered in international climate policy.

2 It is more accurate to refer to forms of climate engineering as 'techniques' rather than 'technologies', since many forms of climate engineering do not currently exist or are untested at necessary scale, thus reserving the term 'technology' for functioning socio-technical systems (Rayner, 2010). Another reason for preferring this terminology is that climate engineering includes practices such as reforestation that have been used for millennia, which would be strange to refer to as 'technologies'.

Carbon Dioxide Removal (CDR)

- Afforestation is the planting of forests where no forests have existed previously, while reforestation is the restoration of deforested land.
- Bioenergy with Carbon Capture and Storage (BECCS) features the growth of biomass which removes CO_2 from the air, which is then burned to generate energy. However, carbon capture technology prevents resulting emissions reaching the atmosphere.
- Direct Air Capture with CCS (DACCS) combines CCS with chemical processes to capture CO_2 from ambient air, which is then stored underground.
- Enhanced Weathering (EW) removes atmospheric CO_2 by spreading small particles of ground silicate and carbonate rock onto soils, coasts or oceans.
- Ocean Fertilization (OF) increases the rate at which the ocean draws down atmospheric CO_2 and sequesters it in the deep oceans through the growth of phytoplankton.

Solar Radiation Management (SRM)

- Solar Aerosol Injection (SAI) injects a gas into the atmosphere which then changes into aerosols that block some incoming solar radiation, slightly lowering global average temperature.
- Marine Cloud Brightening (MCB) sprays sea salt or similar particles into marine clouds, increasing their reflectivity and blocking some incoming solar radiation.
- Ground-based Albedo Modification (GBAM) increases the reflectivity of land surfaces, which deflect incoming solar radiation (IPCC 2022).

Box 4.1: An overview of Climate Engineering approaches

Due to the diversity of forms of CDR and SRM, they are generally regarded as raising distinct ethical and governance concerns (Pamplany et al., 2020). In fact, some scholars have argued that grouping two types of fundamentally different techniques into one category is unhelpful and perhaps even misleading (Heyward, 2013; Lenzi, 2018). While both CDR and SRM are controversial, the Royal Society argued that CDR raised fewer ethical concerns. Indeed, some use of CDR is now considered desirable and even necessary to limit warming to 1.5 °C in line with the Paris Agreement. Recent IPCC reports emphasize the goal of 'net zero emissions', which is unattainable without actively removing carbon dioxide (CO_2) from the atmosphere (IPCC, 2022; 2018). SRM techniques and, more specifically, Stratospheric Aerosol Injections (SAI), have provoked the most controversy. Proponents claim it is a feasible technology at a relatively low cost (Keith et al., 2010; Barrett, 2008). However, such estimates ignore indirect costs and impacts. SAI could give rise to large risks (i.e. droughts, effect on agriculture, etc.) in different places from where it is applied, and such risks may manifest in the future rather than at the moment of implementation. This spatial and temporal dispersal of cause and impact has been the subject of significant ethical analysis, as well as trenchant criticisms of its potential for causing injustice (Gardiner, 2010).

With regard to the ethical evaluation of climate engineering, it is worth emphasizing that the levels of intentional intervention and impacts can range from a local to a regional and a planetary scale and from a short-term to long-term intervention. Climate engineering is also accompanied by a high degree of uncertainty and risk in terms of potential and actual unintended impacts on natural processes and society, both spatially and temporally (Corner and Pidgeon, 2010; Sandler and Basl, 2013). In the next section, we review why climate engineering is socially and ecologically disruptive, before moving on to Section 4.3 in which we discuss potential conceptual disruption. In Section 4.4, we will present some directions for the future of philosophy research with respect to climate engineering.

4.2 Impacts and social disruptions

While climate engineering techniques have been proposed with the intended positive physical impacts in mind, they could also give rise to other undesirable and unanticipated impacts. CDR's most obvious intended impact is the reduction of atmospheric CO_2. Because there is a very limited carbon budget remaining for limiting warming to below 1.5 °C, CDR (or 'Negative Emissions Technologies') is regarded by the IPCC as necessary to stabilize the global climate. Nonetheless, there is no requirement to utilize any particular form of CDR, and there is a wide variety of available forms, including 'nature-based' techniques that enhance existing carbon sinks, and engineered carbon removal methods. Clearly, these options raise distinct physical and societal challenges. One prominent technique is Bioenergy with Carbon Capture and Storage, or BECCS, which features heavily in mitigation modeling and in IPCC assessments. A BECCS facility produces energy by burning biomass, with the resulting emissions captured and stored underground or in chemically stable ways, such as through mineralization. This draws down atmospheric CO_2 through the growth of biomass. Ethical concerns with BECCS arise due to the very large scales of envisaged implementation seen in climate mitigation models, which would be necessary in order to have a meaningful impact on the atmospheric concentration of CO_2. Such upscaling would require vast amounts of organic resources including water and arable land, and would compete with other vital land uses such as growing food crops. Clearing land in order to grow BECCS crops could also negatively impact regional biodiversity (Creutzig et al., 2015). Thus, although a single BECCS facility may not have any noteworthy impacts, large-scale implementation would raise concerns about justice and human well-being, especially with regards to vulnerable communities that are likely to be most affected and which may already be disproportionately harmed by climate impacts.

While SRM techniques would block some incoming sunlight, this is not considered to be as a form of climate mitigation or adaptation. Instead, SRM is usually considered as an additional means to reduce some of the most harmful climate change impacts, including rising sea levels and the frequency and severity of extreme weather events (i.e. droughts, floods, hurricanes, etc.). While SRM can be accomplished in a variety of ways, the most commonly discussed approach is through Stratospheric Aerosol Injection, or SAI. This entails spraying aerosols into the stratosphere (10 to 50 kilometers in the atmosphere), increasing the earth's albedo levels. The direct physical impacts are expected to contribute to an overall cooling of the planet, which should practically lead to a reduced rate of global warming, a central driver of catastrophic weather events (Keith, 2013). While model results featuring SAI appear promising in reducing global average temperatures, climate models are simplifications of expected climate system responses and are known to set aside many uncertainties (Pindyck, 2017). This makes reliance upon model results a question of values as well as of epistemic reliability — a point familiar in the philosophy of science as the problem of 'inductive risk' (Rudner, 1953). Put simply, what level of evidence is deemed to be adequate, when the social and ecological consequences of being wrong are severe? In particular, the regional impacts of SAI in such models are highly uncertain and difficult to anticipate because there is very little actual data. This could include impacts on regional weather patterns and climatological forces such as changes in the monsoon, dry and rainy seasons, with obvious implications for food production and biodiversity. Importantly, much of this uncertainty cannot be resolved until the technology is actually deployed (Robock et al., 2008; Kortetmäki and Oksanen, 2016).

For both types of climate engineering, there are several highly problematic ethical implications. These implications are not limited to deployment, but even result from contemplation of some forms of climate engineering, as well as at the research phase. Below, we focus on the potential for social disruption implied by climate engineering. Section 4.3 will address the potential for climate engineering to disrupt conceptions of justice.

As noted at the outset, to understand the potential social and political disruptiveness of climate engineering we must place such interventions in the context of global environmental changes caused by human activity. In conjunction with other drivers of extinction and global environmental change, global warming increases extinction pressures on many species, as ecosystem changes are often too rapid for species to adapt to. The mass extinction of species and the changes in the climate system are two sides of the same coin, caused by resource-intensive, unsustainable fossil-based economies and industrializations (Pimm, 2009). These changes can be understood as socio-ecological disruptions.

Faced with socio-ecological disruption of this magnitude, rapid large-scale changes to the global economy and society are required. At the UN Convention on Biological Diversity summit in December 2022, Inger Andersen, Executive Director of UN Environment Programme, pointed to this principal challenge for humanity:

> I invite you to just walk down the street that is yours and ponder what it was a hundred years ago. Everything is converted in many places. So we can't sort of 'push the hot button' and go back to 'what it was-button'. So what we need to understand is that we need to [...] change our way.[3]

To 'change our way' requires disrupting the institutional and technological infrastructures of fossil-based societies, along with ethical norms and values and social practices — it is about 'changing whole systems of economic, technological and social practice' (Urry, 2015: 57).

A key question is how forms of climate engineering enforce or hinder disruption in social practices and institutional settings in the direction of a sustainable future. A number of crucial social, ethical, and political concerns have been raised in relation to climate engineering as a technological response to climate change. First, SRM, and particularly SAI, may be insufficiently disruptive, preventing the much-needed sustainability transformation. In this way, SAI may be more of a 'socially sustaining technology' rather than a 'socially disruptive technology' (Hopster, 2021), but one that does not bring about the necessary societal changes for a sustainable future. As SAI would be deployed temporarily, it can be seen as a means to 'buy time' (Neuber and Ott, 2020) and shave off peak warming scenarios, reducing some of the most severe impacts of climate change. A major concern, however, is that the availability of this technique (even in theory) might disincentivize decarbonization of the global energy system and prolong unjust and unsustainable market and geopolitical arrangements (Schneider and Fuhr, 2020). This effect is the 'moral hazard' (Gardiner, 2010) or 'mitigation obstruction' (Betz and Cacean, 2012), i.e. that the availability of climate engineering could decrease the political commitment to ramp up radical mitigation. This

3 This is a quote from an interview with Inger Andersen, Executive Director of UN Environment Programme: https://www.bbc.co.uk/programmes/m001fwh4

straightforwardly applies to forms of SRM such as SAI. Yet it also applies to CDR, because the availability of these techniques affects the stringency of mitigation by shifting some near-term mitigation to the future within scenario research (Lenzi, 2018). A related issue is whether CDR leaves the door open for the continuation of the fossil economy, including its existing power structures and dominant agents. Many of the actors best placed to take advantage of CDR (due to existing infrastructure and ownership of appropriate sites) are also leading historical contributors to climate change, including fossil fuel companies. While these companies continue to actively lobby against climate policy, they appear to be repositioning themselves as 'carbon removal' businesses. Historical track records of these giant fossil companies contribute to these worries. For example, privately funded research by Exxon Mobil in 1970 accurately predicted global temperature rise the world is currently experiencing (Cuff, 2023). Given that such companies have a record of putting private profits ahead of the public good (Oreskes and Conway, 2010), the implementation of CDR by such actors may similarly entrench private interests above the global interest in stringent climate mitigation.

Research on some forms of climate engineering could also be highly politically disruptive, raising the need for appropriate governance frameworks. An individual country or even wealthy individual actor could unilaterally decide to carry out research or even deploy SAI (Preston, 2013). For this reason, some argue that there is an urgent need to establish research governance structures to ensure equitable decision-making (NASEM, 2021; McLaren and Corry, 2021; Wagner, 2021). While CDR also poses institutional and governance challenges, many of these arise in the context of climate mitigation and sustainable development. Governing the implications of CDR requires consideration of potential effects upon the stringency of mitigation itself, along with effects of CDR deployment upon other priorities in the context of the Sustainable Development Goals, notably the alleviation of poverty and the prevention of transboundary environmental harm between sovereign states (Honegger et al., 2022). The sourcing of sustainable biomass will be a particular challenge for BECCS. A pure market approach based upon lowest cost would likely mean biomass being grown primarily in the Global South, leading to acute worries about food security and biodiversity impacts (Anderson and Peters, 2016). This is similar to the introduction of biofuel in the first decade of this century that led to a global food crisis, particularly in the Global South (Taebi, 2021: Chapter 6). A new rush for biofuels could allow for the exploitation of biomass producers in the Global South. The differences between SRM and CDR also imply differences for desirable or appropriate governance. Particularly because SRM would immediately have a global effect on the climate, as well as regional (weather) effects, politically legitimate international governance structures will need to account for the spatial and temporal dispersal of impacts (Szerszynski et al., 2013; Heyward and Rayner, 2013; Gardiner and Fragnière, 2016). For CDR, participatory governance regimes are needed regarding the siting location of carbon removal facilities (Honegger et al., 2022).

4.3 Conceptual disruption

Climate engineering technologies can affect and potentially disrupt existing conceptions of climate and environmental justice. This is due to the scale and scope of impacts, which includes wealthy and poor individuals currently alive on Earth, unborn future generations, non-human species, and ecosystems. Of course, climate change itself, along with climate mitigation and adaptation policies, have or will have such impacts. Thus, attention to distributive justice has long been a feature of climate ethics; in particular the question of what would constitute a fair distribution of the burdens of climate policy (Gardiner et al., 2010). Appeals to justice are also a feature of international climate negotiations. Developing nations and small island states have insisted that wealthy industrialized nations take the lead in cutting their emissions and funding the adaptation of nations least historically responsible, while wealthy nations have resisted such calls.[4]

While justice has long been a feature of climate discourses, the additional impacts of climate engineering — both beneficial and harmful — cast these issues of justice in a new light. The availability of climate engineering, both in terms of CDR and SRM, may require a rethinking of some dimensions of climate justice, such as the contents

4 The UNFCCC principle of 'common but differentiated responsibilities' reflects the place of distributive justice in climate politics but does little to mitigate disagreements, since the principle is vague and does not create binding obligations upon parties.

of a responsibility to mitigate. We are the first humans to understand the essential dynamics of the planet's climate, as well as humanity's combined influence upon it. As Shue (2021) has recently argued, this unique historical context makes the current generation a pivotal generation with unprecedented moral responsibility to mitigate climate change. This responsibility connects with some forms of climate engineering in an obvious way, especially as the IPCC has recently reclassified CDR as 'mitigation' rather than climate 'engineering' (IPCC, 2022: Chapter 12). As noted in Section 4.1, because too little mitigation has happened, it is very likely that limiting warming to 'well below 2 °C' will require the use of CDR. However, it remains unclear exactly what would constitute an intergenerationally fair distribution of the burdens of CDR across existing and future generations. As noted in Section 4.2, the example of BECCS shows this clearly: an ungoverned expansion in the global demand for biomass could undermine basic needs by increasing food prices and water scarcity, harm biodiversity, and incentivize land-grabbing in the name of carbon storage. CDR also introduces a potential trade-off between (spatial) social justice and intergenerational social justice. Authors have noted that CDR would extend the global carbon budget, thereby allowing for a longer period of fossil-fuelled development in the Global South to alleviate extreme poverty (Morrow and Svoboda, 2016; Moellendorf, 2022). Thus, the availability of CDR affects how we might think about the obligations of countries, and global obligations of distributive justice in relation to climate change. The current generation therefore faces two options: more ambitious mitigation now via large emissions cuts coupled with relatively small CDR reliance, or less ambitious mitigation to allow for further economic development coupled with the assumption future people will be able to recover from an overshoot through very large-scale CDR.

Because the availability of CDR affects country mitigation policies, and has the potential to shift some decarbonization to the future, another implication is the risk of policy failure to achieve such emission cuts in the future. Therefore, a prevalent concern in the literature is that plans to massively scale up CDR represent a high-stakes gamble on unproven technologies (Fuss et al., 2014; Anderson and Peters, 2016). The ethical literature has examined the implications of such a gamble for intergenerational ethics (Shue, 2017; 2018; Lenzi, 2021). According to Shue (2017; 2018), such a gamble on CDR would be especially problematic insofar as future people cannot consent to making it, but would be the ones affected should the gamble fail.

It is even more controversial whether a responsibility to urgently mitigate or adapt to climate change includes a responsibility to research and ultimately deploy SRM. The ethical and governance literature is highly polarized on this point. Indeed, an influential group of scientists has recently published a SRM 'non-use agreement' calling for a boycott of research, citing concerns with governance and justice (Biermann et al., 2022). For SRM, justice concerns with SAI in particular highlight the potential for unequally distributed negative impacts. As Preston (2013) notes, a world artificially cooled by SAI raises questions about whose interests ought to be protected, and it is far from clear that the interests of the most vulnerable would be prioritized if SAI were ever implemented, or that fair compensation would be given to those subjected to additional harms. Even if we assume that SAI slightly lowered global average temperatures and thus avoided some of the harmful global impacts of climate change (such as sea level rise), the side-effects of SAI may create additional harmful impacts such as affecting precipitation patterns, including the Indian monsoon (Robock et al., 2008). By potentially exacerbating severe weather impact, SAI has the potential to impose severe injustice upon people who have the least ability to adapt.

The potential for SAI to rapidly reduce some of the impacts of climate change also complicates the question of what countries owe one another or to future generations. As noted earlier, this possibility has been framed as a way of 'buying time' for mitigation (Neuber and Ott, 2020; Betz and Cacean, 2012). Some advocates of SRM research have long claimed that, facing insufficient mitigation, there is a moral responsibility to deploy SRM to protect human rights (Horton and Keith, 2016). But many oppose this kind of argument (Gardiner, 2010; McKinnon, 2020; McLaren, 2016; Flegal and Gupta, 2017). Hourdequin (2018) claims that this overly narrow view of justice that presents SRM at the core of its approach ignores the distribution of epistemic power and power to make decisions about climate policy, and hence questions of procedural and recognition justice bearing upon SRM research. Some advocates similarly point to SAI as a means to avoid the greater injustice of runaway climate change, thus framing it as a 'lesser evil'. However, Gardiner (2010) has forcefully objected to framing SAI in this way, arguing that any plan to utilize SAI would be predicated upon the moral failure of the current generation to mitigate its emissions. It has also been argued that pursuing SRM would actually abdicate the moral responsibilities to resolve the root cause of climate change, in favor of a risky 'technofix' (Hamilton, 2013; Biermann et al., 2022). Nonetheless, the continued growth of global emissions and the very tight timeline for limiting warming to below 1.5 °C implies that the importance of these questions will intensify.

Climate engineering also implies rethinking some ideas of moral, and also potential legal responsibility for side-effects resulting from implementation. While climate change was unintentionally brought about as a side-effect of other activities, at least some climate engineering activities (most obviously SAI) directly aim to alter global warming, and we have some foresight concerning potential side-effects. The moral responsibility attributed to such harms turns upon showing that an actor intentionally sought to manipulate the climate system, and whether they knew or should have known about potential side-effects of their action.[5] However, not all side-effects are knowable in advance. For SAI, some side-effects are unknowable prior to implementation. Even for CDR, while there are already known side-effects of large-scale CDR implementation, particularly for land-based techniques such as BECCS, these effects are jointly produced by millions of actors in complex causal chains that can span the whole globe, such as food production and exports. Very large-scale afforestation and reforestation projects would also affect regional and global precipitation patterns (Scharping, 2022). Such possibilities may leave the moral responsibilities for CDR side-effects underdetermined, similarly with the debate about individual climate responsibilities (Nefsky, 2019). Legal responsibilities may come apart from moral responsibilities if there are existing institutional obligations in place, such as the obligation upon states to avoid causing transboundary environmental harm, which applies independently

5 This is why evidence that fossil fuel companies knew or had reasonably justified beliefs that their actions contributed to climate change, and that this was dangerously absent from their policy responses, is a basis for holding them morally and potentially legally responsible. This is despite the fact that the intention of fossil fuel companies was to make money rather than to cause climate change for its own sake. In this context, the prioritization of profits at the expense of the public interest in climate policy and the deliberate production of climate misinformation adds substantially to such responsibility.

of the attribution of an intention to cause harm. Similarly, there is a link with the *Precautionary Principle*, or the principle that argues that lack of full scientific knowledge about a potential risk is insufficient reason to assume that there is no risk; sometimes we should refrain from action if the nature or the magnitude of the known consequences are unacceptable.[6] The mandated applications of the precautionary principle — to the effect that we might consider refraining from action by states, such as within the European Union, — may imply legal responsibilities for states implementing certain forms of climate engineering to act in accordance with precautionary norms, whether or not harm is intended.

Relatedly, questions of how to compensate for damage caused by climate change internationally will be increasingly difficult after large-scale applications of climate engineering are deployed. In the Conference of Parties gathering in Sharm El Sheikh (COP27) in November 2022, countries for the first time agreed to establish a Loss and Damage fund for the purpose of supporting countries most in need (and historically least responsible for causing the damage) to remediate some climate harms. While it is not clear yet how loss and damage will be determined, causality will likely play an important role. Climate engineering makes the already extremely complex climate systems even more complicated, which will further complicate the attribution of responsibilities to parties.

A further area where climate engineering seems to recast existing notions concerns procedural justice. Many forms of climate engineering also raise difficult challenges regarding procedural justice, given the very wide set of potentially affected parties, which may include the global population, future generations, and even non-human nature. Preston (2013) notes that procedural justice is one of the biggest ethical challenges posed by climate engineering. This conclusion appears most plausible for some forms of SRM. For SAI in particular, procedural justice raises particular challenges even at the research and development stage. Indeed, Preston (2013) concludes that procedural justice is unlikely to be satisfied for SAI, given that any implementation of this technique would immediately affect every person living at the time, and all future generations until SAI ceased. Thus, 'the prospect of controlling the global

6 The Rio Declaration on Environment and Development. See Section 4.4. for discussions on the Precautionary Principle.

thermostat is something that all citizens could reasonably claim to have a legitimate stake in' (Corner and Pidgeon, 2010). Such difficulties have encouraged returning to existing legal frameworks that could be brought to bear upon SAI, such as the ENMOD Convention, which is a Cold War arms control treaty that applies to technologies that modify the environment (McGee et al., 2021). While it has been argued that SAI is not necessarily incompatible with democracy or with robust democratic governance (Horton et al., 2018), there seems to be no compelling reason to expect the governance of SAI to actually be democratic. These procedural concerns are conditioned by the mismatch between vulnerability and responsibility for climate change, exacerbated by the fact that developed countries have more political power and are more capable of representing their interests, whereas the less developed are unfavorably placed to call them to account (Gardiner, 2010: 286). Indeed, a major procedural challenge is the expert-analytic character of the geoengineering debate — both for SRM and CDR — and the limited engagement of stakeholders. This is exacerbated by the lack of awareness of the Southern public, primarily in Afro-Asian countries (Pamplany et al., 2020: 3105). Climate engineering raises the question of how the perspectives of communities, specifically those poised to be disproportionately affected by these interventions, can be adequately represented.

The question becomes all the more vexing when considering the risks of further entrenching the discourse along colonial lines. Incorporating intercultural perspectives would thus have to reach beyond the tendency of non-Indigenous researchers to instrumentalize Indigenous communities for or against a particular argument concerning climate engineering (Whyte, 2012; 2017). The multiplicity of Indigenous ontologies, epistemologies, and ethical systems calls for nuanced stakeholder engagement in local contexts. Such engagement allows for redefining concepts such as agency or justice that suits the contexts in which climate engineering technologies will be researched and deployed. For example, the aforementioned issue of intergenerational justice takes a position of prominence in Ubuntu practicing communities as these communities typically conceive of the social community in much broader terms than traditionally Western conceptualizations. The living generation is understood to have duties and obligations towards previous and coming generations. Wiredu (1994: 46) illustrates this when noting that within African Indigenous communities, no duty is as imperious as the husbanding of resources for posterity and that 'in this moral scheme the rights of the unborn play such a cardinal role that any traditional African would be nonplussed by the debate in Western philosophy as to the existence of such rights'. In climate engineering interventions, the duty towards coming generations would thus be framed more centrally than in some non-African communities. There are an abundance of examples illustrating how Indigenous thought can shape, challenge, and critique the dominant discourse. Intercultural perspectives are needed both to account for the variety of viewpoints at stake in climate engineering and to formulate richer ethical accounts of the impacts of climate engineering on wellbeing, social, and political life, and on human relations with non-humans and with the environment (Lazrus et al., 2022).

4.4 Looking ahead

A fundamental challenge for the ethical and political assessment of climate engineering are the underlying, often irreducible uncertainties about the reversibility and variability in spatial and temporal scales of climate engineering deployment. Knowledge about climate change and biodiversity loss is characterized by epistemic uncertainty in terms of variables and databases, but also by 'deep uncertainty' due to the overall framework of model-based knowledge production (Marchau et al., 2019). These uncertainties challenge our empirical and epistemic grasp of the impacts of climate engineering. But climate engineering also raises normative uncertainties (Taebi et al., 2020). These normative uncertainties can best be understood as uncertainties that arise due to a plurality of values which need to be reconciled on a spatiotemporal scale. This entails accounting for different, often opposing, regional, cultural, and individual values as well as the values of future generations. Normative uncertainties could also arise as a result of evolving technologies or evolving moral norms (and values) in the future, which could pose new and unanticipated ethical challenges; this is referred to as techno-moral change (Swierstra et al., 2009) and it is very relevant for contemplating the future of climate engineering technologies (Hofbauer, 2022). An inherent source of epistemic uncertainty is the methodological framework of climate science. Knowledge about climate change is mostly produced by data-intensive models, which are by definition incomplete representations of the real world, but which may also lack important variables that are (as yet) understudied or lacking adequate data. For example, scientists have limited data on the volume and effects of methane gas which is being emitted from the thawing of the Siberian permafrost. Methane is a greenhouse gas, 25 times more potent than carbon dioxide. One way of dealing with these uncertainties is by ensuring that the implementation of either research or deployment proposals for climate engineering technologies do not lead to lock-in or 'slippery slope' situations. In other words, policy plans exploring climate engineering as part of a climate action portfolio should ensure that any implementation remains reversible or as reversible as realistically possible.

However, now that there is a state of scientific consensus on the magnitude and severity of disruptions due to human-induced global warming, lack of data or epistemic uncertainty should not be used as an excuse for not acting against the potentially irreversible harm caused by climate change. A legal and political tool to deal with the problem of irreversibility and risk is to base international political action and shared decision-making upon formulations of the precautionary principle targeted at irreversible or catastrophic environmental and climate harms (Sunstein, 2010; Hartzell-Nichols, 2012). The 1992 Rio Declaration already contains a version of this principle: 'Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environment degradation' (Principle 15 of the Rio Declaration on Environment and Development). Taking the precautionary principle seriously at local, national and international levels requires a shift in values and an overall assessment of irreversible climate change and biodiversity loss and damage: irreversible loss and damage are difficult to pay for. The emphasis and effort should be on precautionary policies. Thus, it seems challenging to interpret whether climate engineering techniques meet the requirements of acting under the precautionary principle.

A related issue is the feasibility of climate engineering proposals. Although the concept of feasibility is vague and difficult to assess, implicit judgements about whether climate engineering proposals are politically or economically feasible abound in both scientific and ethical literature. Most notably, the IPCC included an assessment of climate policy feasibility (including CDR) in its Special Report, and again in its Sixth Assessment Report (IPCC, 2018; 2022). However, there remain serious epistemic as well as normative problems in attempting to assess feasibility, especially political feasibility. Critics have pointed out that the IPCC ignored the role of equity and justice considerations and the limited expertise of climate scientists in assessing political proposals (Lenzi and Kowarsch, 2021). Extra caution is required since claims about what is economically or politically infeasible can be disguised as statements of willingness, knowledge or even strategic attempts to secure advantage (Schuppert and Seidel, 2017).

More fundamentally, climate engineering raises questions about the values of climate policy and the desirability of purely technological solutions. To Paul Crutzen, who coined the term 'Anthropocene', humanity had to move from unintentional environmental modification to embrace a responsibility to intentionally manage (or 'optimize', as he put it) the global climate in 'our' own interests (Crutzen, 2002: 23). The technocratic perspective implied is problematic for several reasons. First, several commentators have argued that trying to 'fix' the climate through climate engineering techniques is tantamount to Western technological hubris (Jamieson, 1996). SRM in the form of SAI in particular seems to reflect a hubristic vision of humanity controlling the climate, thereby affecting planetary conditions (Hamilton, 2013; Hulme, 2014; 2017). For CDR, a similar concern arises in relation to very large-scale implementation scenarios found in some climate models, which would effectively mean human beings collectively managing the global carbon cycle, despite our lack of understanding of many relevant planetary feedbacks and indirect effects (Lenzi, 2018). It is also unclear whose interests should matter. Many leading climate ethicists have argued that climate change should be responded to in a way that protects the human rights or basic needs of current and future generations (Caney, 2010; Cripps, 2013; Shue, 1993; 2019). However, as we saw in the previous section, in the context of climate engineering research and potential implementation there are serious doubts about whether the human rights or basic needs of all will be protected. For instance, some have worried that any deployment of SRM would serve the interests of a 'geoclique' of the wealthy and powerful (McKinnon, 2020), while others believe this deployment could be both inclusive and fairly shared (Morrow, 2020). A further key issue is whether the interests of non-humans should count in any consideration of climate engineering. The technocratic assumption of managing the global climate in the interests of human beings is silent on whether this would include consideration of non-humans for their own sake in the manner of ecological trusteeship, or would merely involve an instrumental form of natural resource stewardship. A general weakness of ethical literature on climate engineering, as with climate ethics more broadly (McShane, 2016), is its lack of engagement with environmental ethics arguments concerning the moral significance of non-human interests (e.g. Rolston III, 1988). This point raises interesting possibilities for future research. In considering the impact of climate change upon the future of non-human species and ecosystems, it seems essential to reconsider the ethical impacts of climate change in non-anthropocentric terms (Nolt, 2011; McShane, 2016). Nolt (2015) extends this argument to also refer to important technological interventions with potentially significant environmental impact such as nuclear energy production. At present, there is very little research on the implications of climate engineering for non-humans, or what environmental values research generally implies for climate engineering. Similarly, it is important to explore the impacts of different climate engineering techniques in non-anthropocentric terms.

Future research on climate engineering may also engage with analyses of the meaning of 'nature' in the Anthropocene (Latour, 2017). As Preston (2012) explains, although the claim that climate change implied the 'end of nature' often operates with a philosophically oversimplified notion of 'nature', it might nonetheless be insightful in relation to climate engineering. According to Preston, the prospect of climate engineering relates to the 'end of nature', because intentional modification of the global climate would create an artificial rather than natural planet. Preston identified two more precise narratives of 'artificing' the planet: first, that climate engineering could be viewed as a planetary attempt at ecological restoration, where although human intentions are part of the functioning of the climate system, the Earth does not become 'a giant artifact' (Preston, 2012: 194) because much space for wildness and unexpectedness remains in the functioning of natural processes, and second that artificing concerns the implications of a planetary expansion of responsibility for managing the climate, in line with Crutzen's (2002) view. Preston notes that

> SRM thrusts us into the role of designer and caretaker of both people and ecosystems. We must manage the climate to be both maximally restorative and minimally risky. We must do this at a global scale in the face of considerable — and perhaps ineliminable — uncertainty in the sciences. This is clearly a daunting challenge. (2012: 197)

Nonetheless, as Preston also notes, the long-standing critiques of the concept of 'nature' in environmental philosophy would caution against any straightforward inferences concerning the naturalness or artificiality of climate engineering. One of the more notable is Plumwood's (1993) ecofeminist critique against the identification of the natural with the feminine and the unruly, which needed to be subdued or dominated by masculine notions of control. Recent contributors have even called for dispensing with the concept of nature entirely in view of its loss of meaning (Vogel, 2015), or rethinking it fundamentally by purging it of the problematic dualism of nature/culture (Latour, 2017). Further engagement with 'nature' in relation to climate engineering would require exploration of the intercultural dimensions of nature and environmental values. There is a wide diversity of traditions on environmental ethics with various uses for the concept (or none), including Asian traditions (Callicott and McRae, 2014) and Indigenous and local traditions (Callicott, 1994). Further, the recent assessment conducted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2022) found a high diversity of environmental values and worldviews across the world, again including some that do not recognise any concept of 'nature'. Given the existence of multiple and conflicting understandings of nature, there does not seem to be any straightforward way to assess the implications of climate engineering.

It remains unclear whether climate engineering techniques can genuinely assist in lessening the impacts of climate change, or assist societies in moving from the fossil-based technologies and land-degrading practices that have brought the Earth into the Anthropocene. From an ethical and political perspective, the question is whether and to what extent climate engineering can and should be used as a complementary approach to systemic changes in social, economic and political practices. Nonetheless, it is clear that the question of how to appropriately govern climate engineering research and deployment requires establishing effective inter- and transnational institutions that address these issues of global responsibility, inequality, uncertainty, and potential sources of new injustices between deploying actors (e.g. national actors) and the interests of those affected.

Further listening and watching

Readers who would like to learn more about the topics discussed in this chapter might be interested in listening to these episodes of the ESDiT podcast (https://anchor.fm/esdit) and other videos:

Behnam Taebi on 'Climate risks and normative uncertainties': https://podcasters.spotify.com/pod/show/esdit/episodes/Behnam-Taebi-on-Climate-Risk-and-Normative-Uncertainties-e1gc7o8/a-a7lfbdv

Ben Hofbauer on 'Geo-engineering and techno-moral change': https://podcasters.spotify.com/pod/show/esdit/episodes/Ben-Hofbauer-on-Geo-engineering--techno-moral-change-e1k1oae/a-a84c4fd

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