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Geoengineering and Non-Ideal Theory

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Abstract

The strongest arguments for the permissibility of geoengineering (also known as climate engineering) rely implicitly on non-ideal theory—roughly, the theory of justice as applied to situations of partial compliance with principles of ideal justice. In an ideally just world, such arguments acknowledge, humanity should not deploy geoengineering; but in our imperfect world, society may need to complement mitigation and adaptation with geoengineering to reduce injustices associated with anthropogenic climate change. We interpret research proponents' arguments as an application of a particular branch of non-ideal theory known as "clinical theory." Clinical theory aims to identify politically feasible institutions or policies that would address existing (or impending) injustice without violating certain kinds of moral permissibility constraints. We argue for three implications of clinical theory: First, conditional on falling costs and feasibility, clinical theory provides strong support for some geoengineering techniques that aim to remove carbon dioxide from the atmosphere. Second, if some kinds of carbon dioxide removal technologies are supported by clinical theory, then clinical theory further supports using those technologies to enable "overshoot" scenarios in which developing countries exceed the cumulative emissions caps that would apply in ideal circumstances. Third, because of tensions between political feasibility and moral permissibility, clinical theory provides only weak support for geoengineering techniques that aim to manage incoming solar radiation.

Keywords: climate change, geoengineering, climate engineering, justice, non-ideal theory

1. Introduction

Some acts are beyond the pale: They ought never to be done, except perhaps in the most dire emergencies. Other acts are wrong in a less stringent sense: They would never be done in an ideal world, but might be permissible in non-ideal circumstances. Deliberate, large-scale modifications of earth systems to counteract or reduce the effects of climate change, known as geoengineering or climate engineering, arguably belongs to one of these two types—but which one? Philosophers have argued that geoengineering faces diverse ethical challenges.[1] Yet advocates of geoengineering research insist that geoengineering might someday be "necessary."[2] One way to construe the research advocates' argument is as a warning that we might need geoengineering to cope with a climate emergency so momentous that ordinary moral constraints do not apply; even if geoengineering truly is "beyond the pale," this argument goes, we may need it to prevent the heavens from falling, as it were. A second way to construe the argument is as an implicit appeal to what political philosophers call "non-ideal theory," which is that part of the theory of justice that tells us what we ought to do in non-ideal circumstances. On this version of the argument, less-than-dire circumstances might permit or even require society to deploy geoengineering, even if no one would deploy it in an ideal world. These two arguments have very different implications for the ethics of geoengineering and geoengineering research.

This paper examines the second argument for geoengineering research, which construes advocacy of geoengineering research as an implicit appeal to non-ideal theory. (Others have already examined the first argument, which invokes potential "climate emergencies" to justify geoengineering research.[3]) The next section explains the species of non-ideal theory that we use in this paper. Sections 3 and 4 discuss the implications of non-ideal theory for supplementing mitigation and adaptation with carbon dioxide removal (CDR) and solar radiation management (SRM), respectively.

We want to issue two caveats about the interpretation of our claims in this paper: First, we assume that geoengineering would only be deployed as part of a larger portfolio that includes mitigation and adaptation, and so we do not intend anything we say to justify relying solely or primarily on geoengineering. Second, CDR and SRM are each broad categories encompassing technologies that differ in important ways. To say that non-ideal theory provides reasons in favor of CDR is not to say that it provides reasons in favor of *every form* of CDR, but rather that there is *some* form of CDR for which non-ideal theory provides reasons; and likewise for SRM.

2. Ideal theory, non-ideal theory, and geoengineering

A theory of justice, in Rawls' sense, is a theory about how society ought to be structured. Much theorizing about justice takes the form of "ideal theory." That is, it asks whether a certain institution would exist or a certain sort of policy would be implemented in an ideally just society. From this perspective, geoengineering faces two problems. First, it seems unlikely that geoengineering would be necessary in an ideally just world, for in such a world, society would have begun serious mitigation efforts some time ago. This thought seems to motivate critics who insist that we ought to focus on mitigation and adaptation instead, as we would in an ideal world, rather than researching geoengineering. Achieving an ideally just world requires overcoming the (perceived) vices that are driving anthropogenic climate change, rather than manifesting them even more brazenly.[4] Second and less contentiously, some kinds of geoengineering are likely to raise serious problems of distributive, intergenerational, and procedural justice.[5] Thus, it is unlikely that those forms of geoengineering would be deployed in an ideally just world. Traditional theorizing about justice, then, tends to weigh against geoengineering.

Concerned that such traditional theorizing provides little or faulty guidance in our imperfect world, many political philosophers have turned to "non-ideal theory." We interpret some advocates of geoengineering research as doing the same. Non-ideal theory is that part of the theory of justice that tells us how to structure society and what policies to implement in imperfectly just circumstances. Many advocates of geoengineering research cite society's less than ideal response to the threat of climate change as their rationale.[6] It is precisely because our greenhouse gas emissions are beginning to impose unjust harms on others, they argue, that we must consider supplementing mitigation and adaptation with geoengineering. Thus, it should be unsurprising that ideal theory lends no support to geoengineering; geoengineering's critics, some might say, have been considering the issue from the wrong perspective.

In this paper, we interpret research advocates' arguments as relying on a particular strand of non-ideal theory known as "clinical theory."[7] On this approach, non-ideal theory aims to identify politically feasible institutions or policies that would address existing (or looming) injustice. As Wiens and other similarly disposed non-ideal theorists argue, the appropriate method for non-ideal theory is to identify clear injustices and develop institutions or policies to prevent, reduce, or overcome those injustices. This need not involve comparing existing or proposed policies with the those of an ideally just society, as proponents of other kinds of non-ideal theory require.[8] In our case, the injustice in question is the imposition of serious climate-related risk on current and future generations, and especially on the most vulnerable members of those generations, most of whom bear little causal or moral responsibility for climate change. Thus, a large part of determining what clinical theory entails about various geoengineering options consists of determining whether each option is politically feasible and whether it would reduce that risk beyond what would be achievable solely through feasible combinations of emissions abatement and adaptation.[9]

As Rawls points out, even non-ideal theory is not a license to enact just any policy: even non-ideal policies must be morally permissible.[10] But what does this mean in non-ideal circumstances? Rawls is vague about this issue, as is much of the rest of the literature.[11] ‘Permissible’ cannot mean ‘permitted in ideal circumstances’, for that would collapse the distinction between ideal and non-ideal theory. Non-ideal circumstances often seem to require society to do things that it would not do in ideal circumstances. The question is how to identify actions that are forbidden in ideal circumstances but permissible in non-ideal circumstances.

We suggest the following interpretation: It is *conceptually* impossible for an agent to perform certain kinds of acts in circumstances where everyone else acts perfectly morally and everyone (including the agent) knows that everyone acts morally. In particular, it is conceptually impossible for an agent in those circumstances to punish someone, exact retribution from someone, protect themselves or a third party from unjust harm, or compensate others for unjust harm inflicted by a third party. What ties these acts together is that they involve making one party worse off because of a wrong that has been or might be done to another. Since such acts necessarily require that someone has wronged or might wrong a third party, they cannot happen in perfectly ideal circumstances. We suggest that these sorts of actions, which only become possible in less than perfectly ideal circumstances, are the *kinds* of actions that may be permissible in non-ideal circumstances, even if physically identical actions (e.g., confining someone in a jail cell) would never actually be performed in ideal circumstances. Note, however, that protecting others from unjust aggression and punishing wrongdoers are generally regarded as morally permissible actions, even in some cases where they involve making some third party worse off. Thus, this view of non-ideal theory does not license any genuinely new moral principle; it simply prohibits people from objecting to an action on the grounds that it would not be done in ideal circumstances or that it *must* be wrong because it moves society “further away” from the ideal state by introducing an action that would be unnecessary—and indeed, impossible—in a perfectly just world.

Furthermore, we do not wish to imply that anything goes in cases of punishment or protection. We propose two criteria that any action must meet to satisfy this non-ideal moral permissibility constraint: a "proportionality criterion," which compares the *prima facie* wrongs that a non-ideal policy inflicts with the injustice that it alleviates; and a "comparative criterion," which compares a proposed non-ideal policy with other politically feasible alternatives.

The basic idea behind the proportionality criterion is that, even in non-ideal circumstances, a particular act of punishment or protection is wrong if it is disproportionate to the good being achieved. For instance, even in non-ideal circumstances, it would be wrong to imprison an entire group of people on the grounds that some member of that group had been preying on innocent members of another group. Such mass imprisonment would protect people from the unjust harm in question, but it would (presumably) cause an amount of harm that is disproportionate to the good being achieved, and it would force innocent people to bear a disproportionate share of that harm. Disproportionate acts of punishment, protection, etc., then, are "beyond the pale." They are forbidden even in non-ideal circumstances.

While some cases of disproportionate injustice are intuitively clear, settling the hard cases would likely require sophisticated "moral modeling." Moral modeling is a method for incorporating a range of moral concerns, including non-consequentialist concerns, into a decision-theoretic framework in order to balance competing moral concerns.[12] With respect to some concerns, such as distributional fairness, there are well-developed methods for doing this, such as adjusting welfare indices for inequality of distribution. Methods for incorporating other concerns have yet to be developed, and so the most difficult decisions in clinical theory probably remain beyond our present abilities to answer. (This is, perhaps, an instance of what Stephen Gardiner call the "theoretical storm," which is the inadequacy of existing moral theory to deal with the complexities of climate change.[13]) As an alternative to moral modeling, one might attempt to develop a set of qualitative guidelines for specific domains. Just war theory is essentially an attempt to develop guidelines for when and how to respond to injustice with violence, which is clearly a non-ideal policy response. Such an effort for climate policy is far beyond the scope of the present paper. In the meantime, however, we would stress that we are not proposing to identify “disproportionate wrongs” with failure on a crude cost-benefit analysis; determining whether the injustices caused by a non-ideal policy are proportionate to the policy’s benefits requires casting a wider moral net than that. Furthermore, we believe that the claims we make in this paper about the proportionality of various non-ideal policies are not too controversial to assess on a more intuitive basis.

The comparative criterion for non-ideal policies (or institutions) requires that a chosen policy (or institution) be better, from the perspective of justice, than any politically feasible alternative. This raises the question of which options count as politically feasible. Political feasibility depends on, among other things, the amount of financial, social, and political resources that advocates invest in promoting a policy. Furthermore, the amount of resources that an advocate *should* invest in promoting a policy increases as the marginal justice-related social gains from enacting that policy increase. So, for some policy advocate, one option is a politically feasible superior alternative to some second option just in case (1) the first option has a better ratio of injustice alleviated to injustice created; (2) the advocate has a reasonable chance of getting the first option enacted if the advocate invests the morally appropriate amount of its resources in promoting the first option; and (3) the advocate has enough resources to invest the morally appropriate amount in promoting the first option. (Note that the amount of resources appropriate for promoting the first option may exceed those that would be appropriate for promoting the second option.) This means that someone can be blameworthy for enacting a moderately unjust non-ideal policy because they could have enacted a much less unjust (but still non-ideal) policy, if only they had tried hard enough. Political resistance to one policy does not, therefore, provide *carte blanche* to enact unjust alternatives. This is especially true when political feasibility is a matter of some wrongdoers’ own *akrasia* or moral corruption, as opposed to the refusal of some third party to cooperate with otherwise willing actors. Such concerns are especially prominent in climate policy, and in the geoengineering policy in particular.[14]

Judging any given geoengineering policy from the perspective of clinical theory, then, requires answering three questions about it: Would it reduce or prevent some injustice? Is it politically feasible? And would it impose ills (e.g., in terms of overall harm, an unjust distribution of harms, unjust power relationships, etc.) that are disproportionate relative to the good being achieved or greater than those that could be achieved by some politically feasible alternative?

3. Carbon dioxide removal and non-ideal theory

CDR is a category of geoengineering comprised of techniques for removing carbon dioxide (CO_2) from the atmosphere and sequestering it in biological, oceanic, or geological reservoirs. This could be done by various means, including but not limited to afforestation, growing crops for use as biofuels or biochar, artificially accelerated absorption of CO_2 by various minerals ("accelerated weathering"), "direct air capture" methods that chemically leach CO_2 from the atmosphere and sequester it underground, or ocean alkalization. Other techniques, such as ocean iron fertilization, have also been proposed, but are generally thought to have unacceptably large side effects.[15]

If deployed at large scale for many decades, CDR could significantly reduce atmospheric CO_2 levels,[16] reducing the amount of harm that elevated CO_2 levels would cause in the long run. Elevated CO_2 levels cause harm in two ways: they increase radiative forcing, which causes climate change, and they cause ocean acidification, which damages marine ecosystems.[17] Both of these effects persist for hundreds or thousands of years. Given how these harms are likely to be distributed across space and time, greenhouse gas emissions create very long-lasting injustices of various kinds.[18] By reducing atmospheric CO_2 concentrations, large-scale CDR could prevent some fraction of our emissions' long-term effect on the oceans and global climate, even reversing some of the effects that have already happened. Thus, it is in principle possible for society to prevent serious injustice through long-term, large-scale deployment of one or more CDR techniques.

On the other hand, every known form of CDR involves significant downsides when deployed at large scale.[19] These downsides fall into four categories: direct costs (e.g., of running the machinery, in the case of direct air capture), indirect costs (e.g., increased food prices due to increased competition for land, in the case of bioenergy with carbon capture and storage [BECCS]), physical risks (e.g., leaching of heavy metals, in the case of spreading mineral dust for accelerated weathering), and other kinds of potential injustices (e.g., “land grabs” that displace vulnerable populations, in the case of afforestation). These downsides increase with the scale and duration of deployment: Burning more biomass in any given year creates greater competition for arable land, spreading more mineral dust for longer periods of time yields a greater accumulation of heavy metals in the soil, and so on. Except in the case of ocean iron fertilization and very large-scale deployment of technologies that displace crop production, these side effects tend to be geographically localized. This is a significant ethical difference between most forms of CDR and SRM—a difference that, in combination with the capacity of all CDR technologies to reduce atmospheric CO_2 concentrations, justifies thinking of CDR as a distinct category.

From the perspective of clinical theory, then, one question is whether it is technically and politically feasible to deploy CDR in ways that prevent more injustice than they cause. This, in turn, depends on the context in which CDR is deployed (e.g., the emissions trajectory on which society finds itself), the suite of CDR technologies being deployed, and the goal that society seeks to achieve through CDR (e.g., returning to atmospheric CO_2 concentrations of 350 parts per million). For instance, we think it is vanishingly unlikely that clinical theory would support using CDR to keep atmospheric CO_2 concentrations at their current level of roughly 400 parts per million under business-as-usual emissions. Even if it proves technically possible to do so, the downsides would be so great that such a policy could not compete, from an ethical perspective, with various policies that involve moderate or (perhaps) aggressive mitigation; the costs of such large-scale CDR are simply too high to justify substituting it for moderate mitigation.

There are two kinds of scenarios, however, in which we think clinical theory could justify deploying CDR. The first scenario is one in which society supplements aggressive mitigation with a relatively modest CDR program.[20] The best such policy, from a clinical theoretic perspective, involves as much mitigation as is politically feasible. The rationale here is that, as observed before, the costs (broadly construed) of any CDR technology increase with the scale and duration of deployment (after allowing for an initial fall in direct costs due to economies of scale). And since the injustices caused by CO_2 emissions are so long-lasting, the clinical theoretic benefits of reducing atmospheric concentrations outweigh the downsides of these relatively cost-effective projects. Exactly how much CDR would be acceptable is uncertain, given the large uncertainties that still surround each proposed technology.

The second kind of scenario, called an “overshoot” scenario, is more controversial. Such scenarios appear in the IPCC reports and in proposals such as Tom Wigley’s.[21] The basic idea is that global society initially exceeds its target CO_2 concentration and then uses CDR to bring concentrations back to the target level relatively quickly. The clinical theoretic argument for using CDR to overshoot the long-run target concentration rests on the idea that the persistence of global poverty is itself a deep injustice, and that it also contributes to further injustices, such as the exploitation or domination of the poor by the rich. From the perspective of clinical theory, then, policies that reduce global poverty are to be pursued, provided that they do not involve disproportionate injustices. Furthermore, we assume that *ceteris paribus*, the more quickly a policy reduces global poverty, the better. We note that the rich—including both developed countries and the wealthier citizens of other countries—are unwilling to provide enough financial and technical assistance to significantly reduce global poverty, much less eliminate it. (In making this observation, we do not intend to imply that such assistance is either necessary or sufficient for the elimination of global poverty; we are simply noting that even if it is in the power of the rich to significantly reduce global poverty, they seem unwilling to do so.) Thus, we hold that the only feasible means of significantly reducing global poverty is for developing countries to achieve sustained and appropriately distributed economic growth. We further hold that the faster that growth is and the sooner it begins, the better.

Achieving rapid, sustained, and appropriately distributed economic growth in poor and middle-income countries requires expanding energy access in those countries. As of 2010, some 1.2 billion people lived without electricity, and 2.8 billion people rely on solid fuels (e.g., wood or charcoal) for cooking. The majority of these people live in Southern Asia and Sub-Saharan Africa.[22] As those people gain greater energy access, they will greatly increase overall energy consumption. Enabling that consumption in a low-carbon way would require an *additional* investment of tens to hundreds of billions of dollars per year in developing countries, relative to the cost of powering development with fossil fuels.[23] Least developed countries, in particular, rely heavily on external funding for climate finance.[24] Other developing countries may be capable, in some sense, of financing mitigation on their own, but doing so would require them to divert significant resources away from other projects that might promote human development more efficiently or more quickly. Low- and middle-income countries, we conclude, cannot reduce poverty as quickly as possible unless they *either* receive large transfers of wealth and technology *or* consume large amounts of fossil fuels over the next few decades. The rich currently appear unwilling to finance low-carbon development at the necessary pace. Furthermore, we suspect that overcoming that resistance would require so much effort that, even given the conception of political feasibility described in section 2, such a clean development pathway is politically infeasible. Thus, rapidly reducing global poverty requires significant consumption of fossil fuels in poor and middle-income countries for the next several decades.

Developing countries' need for fossil fuels creates a dilemma. If developing countries fuel their economic development with large amounts of coal, oil, and gas, it will be very difficult to keep atmospheric concentrations of carbon dioxide below any reasonably "safe" target concentration. Exceeding a safe concentration, however, would exacerbate the looming injustices of climate change. Given the unwillingness of the rich to finance the low-carbon alleviation of global poverty, it therefore seems that the world must choose between the injustice of failing to reduce global poverty as quickly as we should and the injustice of causing more climate change than we should. The better we do with respect to one goal, the worse we do with respect to the other.[25]

By making it possible to overshoot safe atmospheric concentrations of CO_2, CDR might offer a way out of this dilemma. Let us stipulate that "overshooting wisely" amounts to setting an emissions budget for the next several decades that yields an atmospheric concentration in, say, 2050 that is significantly higher than our desired target concentration for 2100; thereby enabling developing countries to fuel more of their development with coal, oil, and gas; and then using CDR to reduce atmospheric carbon dioxide to the target concentration by 2100 without inflicting disproportionate ills. Is such a policy technically and politically feasibly?

It is currently impossible to say whether it is technically possible for CDR to compensate for significant overshooting without inflicting disproportionate wrongs. This is because drawing atmospheric concentrations down after significant overshooting would require deploying CDR at enormous scale for several decades, at least. The relevant technologies are too underdeveloped to give sufficiently precise estimates of their costs and side effects when deployed at scale. Furthermore, hysteresis in various Earth systems means that many important variables, from ocean acidity to ice volume to precipitation rates, lag behind changes in atmospheric CO_2.[26] So, the additional injustice caused by overshooting will persist for some time after CDR restores atmospheric CO_2 to its target level, making it more difficult to avoid disproportionate wrongs. We can say, however, that the benefits of overshooting wisely could be enormous. If the downsides of CDR prove manageable, overshooting wisely would greatly reduce the tremendous injustices associated with global poverty while avoiding the injustices associated with excessive climate risk. As an added benefit, by empowering people to better withstand and adapt to climate change, the economic development associated with overshooting wisely would reduce the risk from any given level of climate change. Thus, we think it is possible that some forms of CDR *might* make it possible to overshoot wisely, although no one has yet demonstrated that any particular form of CDR could do so.

The political feasibility of overshooting wisely turns on two questions: Can developing countries grab enough of the expanded emissions budget to fuel significant economic development? And would future generations stick to the plan of using CDR to draw down atmospheric concentrations of carbon dioxide? Answering either of these with confidence is beyond our expertise, but we see some reasons to offer affirmative answers to both. With respect to the first question, it would be politically and logistically difficult for developed countries to prevent developing countries from emitting additional greenhouse gases. Thus, even if developed countries consume some of the additional emissions budget, developing countries could consume a great deal, too. With respect to the second question, the feasibility of overshooting wisely depends on the existence of CDR technologies that have relatively modest downsides. Given that overshooting would commit future generations to either deploying CDR or suffering significant climate change, they would have an incentive to stick to the plan.

We should not commit ourselves to overshooting just yet, however. It will take vigorous research into CDR to determine whether it is possible to overshoot wisely. And time is not our side. The more heavily we commit to overshooting, the harder it will be to reverse that decision if we learn that we cannot overshoot wisely, for committing to overshooting amounts to building additional carbon-intensive infrastructure that will accelerate the rise in the atmospheric concentration of CO_2. Reversing the decision to exceed our end-of-century target concentration would then require even more drastic cuts. On the other hand, by investing now in emissions abatement and low-carbon energy sectors in developing countries, we would be slowing the expansion of energy access, relative to what would be feasible if we commit to overshooting. Thus, it behooves us to pursue CDR research quickly; and *if* that research provides strong enough reason to think we can overshoot wisely, then from the perspective of clinical theory, we ought to do so.

4. Solar radiation management and non-ideal theory

SRM encompasses various techniques for reflecting a fraction of incoming solar radiation back into space, altering the amount of energy absorbed by the planet. This could be done via ground-based changes in the reflectiveness of the Earth, sulfate aerosol injections in the stratosphere, or brightening marine clouds.[27] If it worked, SRM would reduce radiative forcing, enabling society to slow or even reverse the climatic changes caused by anthropogenic greenhouse gases. Thus, it seems technically possible for SRM to prevent unjust harms from anthropogenic climate change. [28]

However, even proponents of researching SRM hold that it is “imperfect,”[29] both in the sense that it cannot perfectly restore a preindustrial climate and in that it would carry risks of dangerous side effects. It cannot perfectly restore a preindustrial climate because precipitation patterns would differ between the preindustrial climate and a high–greenhouse-gas world cooled to preindustrial temperatures.[30] An artificially cooled, high–greenhouse-gas world would also suffer from ocean acidification, making SRM an imperfect substitute for mitigation. Salient risks of SRM include potential harmful changes in precipitation patterns in vulnerable regions, such as the Sahel[31] or South Asia[32] and, in the case of sulfate aerosol injections, ozone depletion.[33] Furthermore, abrupt termination in the presence of elevated CO_2 levels would result in very rapid global warming.[34] The size of these risks depends greatly, however, on the particular technology used, on the specific way in which SRM is deployed, and on the way it is (planned to be) “turned off.” For instance, low-leverage techniques, such as increasing the reflectiveness of the built environment, might avoid many of these risks. Because of their low leverage, however, such techniques would provide relatively little relief from climate change. We focus here, then, on higher-leverage, higher-risk approaches.

While some forms of SRM could reduce or prevent climate injustice if used well, clinical theory would only favor effective SRM policies that are both politically feasible and morally permissible. Some SRM policies are probably politically feasible. Some may morally permissible. The question is whether there are any policies that would significantly reduce the harms from climate change while satisfying both constraints.

As for the first constraint, many SRM policies seem politically feasible, especially compared to mitigation. Stratospheric aerosol injection is expected to be relatively cheap,[35] and the technology needed to implement it is thought to be easy to assemble from existing components.[36] Moreover, since unilateral or minilateral deployment of SRM is technically possible,[37] one or more actors can implement SRM without solving as difficult a collective action problem as that facing mitigation.[38] As the history of climate negotiations demonstrates, it is difficult to achieve such cooperation, since some high-emitting state may have an interest in either refusing to cooperate or defecting from a previous agreement to cooperate.[39] Because different levels and patterns of SRM deployment would maximize the benefits to different states,[40] it would be similarly difficult to achieve or approach global consensus on a specific plan for deploying SRM. However, given the modest costs and technological requirements of some SRM techniques, a single state—or, more likely, a small coalition[41]—could deploy SRM without securing the (explicit) agreement of (all) others, thus sidestepping any collective action problem. Of course, this does not necessarily mean that unilateral or minilateral SRM would be politically easy[42] or that it would politically feasible for all states. Economically and militarily powerful states would presumably not permit less powerful ones (e.g., a coalition of small island states) to deploy SRM against the powerful states’ wishes. However, unilateral or minilateral SRM does, for better or worse, seem politically feasible for those (coalitions of) states that are sufficiently powerful to be able to ignore or discount the interests of other states.[43] It is therefore plausible to suppose that some varieties of SRM are politically feasible while others are not, the former set being constrained by geopolitical facts regarding what climate interventions powerful states are willing to accept or tolerate. Admittedly, it is difficult to predict what policies will be politically feasible in the medium- or long-term future. It may be that some SRM technique that is politically infeasible at present will be feasible in (say) fifty years. Nonetheless, geopolitical considerations (whatever they happen to be at the time) will constrain which SRM policies are politically feasible, even in the distant future, given the wide range of (often competing) interests various powerful states may have regarding interventions in the climate.

Similarly, we suspect that certain ways of deploying SRM would satisfy the moral permissibility requirement. As we suggested above, one plausible interpretation of this requirement is that, in non-ideal circumstances, society may institute policies that cause harm or result in unjust distributions of burdens and benefits, provided that those harms and injustices are not disproportionate to the good achieved by the policy. On this interpretation, an SRM policy could be morally permissible even if it carries substantial risks of harm and injustice, as long as the policy delivers—or is likely to deliver—sufficiently large benefits. For example, suppose that SRM could buy time for several billion people to adapt to serious climatic changes, but in the meantime, in would cause periodic droughts in some regions. While causing droughts would be wrong in ideal circumstances, doing so in this case might be permissible if the slower pace of adaptation relieved enough suffering. Alternatively, if deploying SRM in some scenario caused massive harm (e.g., dramatically reducing precipitation in the Sahel) while achieving comparatively minor goods (e.g., moderately reducing adaptation costs in North America and Western Europe), SRM deployment would fail to satisfy the moral permissibility criterion in that scenario.

Satisfying both the political feasibility and the moral permissibility constraints simultaneously, however, is more difficult.[44] As we noted above, SRM seems politically feasible for some states because it does not require the same level of global cooperation that mitigation does. Yet unilateral or minilateral SRM is morally problematic for at least two reasons. First, it could violate requirements of procedural justice, since it would exclude many stakeholders from decision-making on a matter that could affect them in substantial ways.[45] Presumably, procedural justice requires that interested parties (e.g., those who could be at risk of harmful precipitation change) have some opportunity to influence decisions in which they have a substantial stake. Indigenous communities, in particular, many of whom could be significantly affected by decisions about SRM, would presumably be excluded or poorly represented in unilateral or minilateral deployment.[46] Second, unilateral or minilateral deployment is likely to result in distributively unjust outcomes, since individual states or small coalitions are likely to prefer SRM policies that serve their own interests (e.g., in terms of temperature and precipitation) even when those policies are contrary to the interests of other states.[47] Without broader participation in decisions regarding deployment, deploying states may have little incentive to take the interests of non-deploying states into account, and this could result in the harms and benefits of SRM being unjustly distributed. This is especially worrisome given that there is substantial overlap between the countries most vulnerable to climate risks and the countries with the least power to influence SRM deployment. Concerns regarding both procedural and distributive justice raise the question of whether unilateral or minilateral SRM would be morally permissible.

To counter these concerns, one might hold that clinical theory favors deployment of SRM only if that deployment is multilateral, such as by allowing all interested parties to have some say in the matter. But an SRM policy of this variety is less politically feasible than unilateral or minilateral SRM—all else being equal—since the former would require agreement among a large number of parties with competing interests. This could be very difficult to achieve, since there is room for disagreement on when and how SRM should be deployed, how aggressive induced cooling should be, how SRM should be monitored and adjusted, and whether it should be deployed at all. Indeed, one incentive for SRM-deploying coalitions to remain small is that broader participation is likely to make it difficult to reach agreement on the specific policy to be adopted.[48] At least in many cases, then, the moral permissibility and political feasibility criteria seem to be in tension, since satisfying one could make it difficult to satisfy the other.

A further tension between the moral permissibility and political feasibility criteria arises from the need for an "exit strategy" built into any SRM policy. On the one hand, SRM deployment becomes more morally problematic the longer it lasts: If deployment continues indefinitely because the world fails to rein in its greenhouse gas emissions, then the required increase in SRM intensity would increase the physical risks associated with SRM. But if the world does rein in its emissions, then the main justification for continued SRM would evaporate. Assuming a lack of international agreement about the proper level of deployment, continued deployment would then impose risks on certain regions in violation of the demands of procedural justice, which would apply more strictly in the absence of pressing climate risk. With or without emissions abatement, then, indefinite deployment would put pressure on the moral permissibility requirement, either because of procedural injustice or potentially harmful or unjust impacts of perpetually intensifying, long-term SRM. On the other hand, only a gradual termination of SRM could avoid catastrophe. Abrupt termination, such as might be caused by a global disaster, could unleash catastrophic warming in the context of high greenhouse gas concentrations.[49] Gradual termination would allow delayed warming to occur in a controlled fashion. The question, then, is whether such an exit strategy is politically feasible. Some commentators worry that it is not. They fear that society will be unable to reduce emissions, especially once SRM eases the (prospective) pain of climate change. If that is true, to deploy SRM is effectively to commit the world to SRM in perpetuity.[50]

One response is to argue that unmitigated climate change creates such enormous risks that unilateral or minilateral SRM would be morally permissible, even without a clear exit strategy. In keeping with our proportionality interpretation of moral permissibility, perhaps the benefits secured by SRM would be large enough to justify the distributive and procedural injustice SRM could involve—especially if the harms and injustice of anthropogenic climate change continue to mount over the coming decades. This raises the possibility that some variety of SRM might become morally permissible in the future even if it is impermissible at present. It is difficult to predict if and when this would be the case, given uncertainties regarding the impacts of both anthropogenic climate change and deployment of particular SRM techniques. Nonetheless, if climate change continues to worsen, it is plausible to think that meeting the moral permissibility condition will become easier for SRM.

On the other hand, acknowledging the injustice involved in such unilateral or minilateral deployment implies that the moral permissibility constraint applies more stringently to them than to multilateral deployment: The moral permissibility constraint requires that a policy's benefits must be proportionate to both the harms *and* the injustices it causes. In other words, the greater the procedural and distributive injustices that some SRM policy involves, the higher the bar becomes for how much good that specific policy must secure in order to be morally permissible. But this suggests that satisfying the moral permissibility condition is more difficult than we might have supposed.

In short, it is possible that clinical theory could justify some policies involving SRM deployment (again, in conjunction with abatement and adaptation). It would do so in a fairly straightforward way for low-leverage techniques, like increasing the reflectiveness of the built environment. Identifying suitable high-leverage policies—if there are any—requires attention not just to the physical effects of a particular policy, but also and at the same time to the political and ethical dimensions of the policy. This lends further support to the argument that scientific study of SRM proposals must proceed simultaneously with social and ethical assessment of those proposals, rather than prior to such assessment.[51] Such research, of course, must also respect the constraints of (non-ideal) justice with respect to both physical risks associated with certain kinds of experimentation and the so-called "moral hazards" of pursuing SRM research at all.[52]

5. Conclusion

In this paper, we have elaborated a common but previously underdeveloped argument in favor of researching and perhaps deploying geoengineering. The argument attempts to circumvent various ethical objections to geoengineering by appealing to the non-ideal circumstances in which we find ourselves. This places it squarely in the realm of what political philosophers call non-ideal theory, particularly in its "clinical" guise. We argued that clinical theory provides different levels of support for different kinds of geoengineering. Clinical theory provides significant but conditional support for certain uses of CDR. More specifically, it provides relatively strong support for supplementing aggressive mitigation with whichever forms of CDR prove to especially cost-effective, and it provides more cautious support for using CDR to enable "overshoot" scenarios. But clinical theory provides only weak support for SRM: While it is technically possible for SRM to reduce unjust harms from climate change, its side effects and unevenly distributed benefits make it unlikely, in our estimation, that any particular SRM policy would be both morally permissible and politically feasible. Finally, our analysis suggests that, from the perspective of clinical theory, research should continue into both CDR and SRM, within the constraints of research ethics.

[1] Betz and Cacean, *Ethical Aspects of Climate Engineering*; Gardiner, "Is 'Arming the Future' with Geoengineering Really the Lesser Evil? Some Doubts about the Ethics of Intentionally

Manipulating the Climate System"; Gardiner, "Ethics, Geoengineering and Moral Schizophrenia: What's the Question?"; Hamilton, *Earthmasters: The Dawn of the Age of Climate Engineering*; Morrow, Kopp, and Oppenheimer, "Toward Ethical Norms and Institutions for Climate Engineering Research"; Morrow, "Starting a Flood to Stop a Fire: Some Moral Constraints on Solar Radiation Management"; Preston, "Re-Thinking the Unthinkable: Environmental Ethics and the Presumptive Argument against Geoengineering"; Preston, "Ethics and Geoengineering: Reviewing the Moral Issues Raised by Solar Radiation Management and Carbon Dioxide Removal"; Smith, "Domination and the Ethics of Solar Radiation Management"; Svoboda et al., "Sulfate Aerosol Geoengineering: The Question of Justice"; Svoboda, "Is Aerosol Geoengineering Ethically Preferable to Other Climate Change Strategies?"; Svoboda, "Aerosol Geoengineering and Fairness"; Svoboda and Irvine, "Ethical and Technical Challenges in Compensating for Harm Due to Solar Radiation Management Geoengineering."

[2] Keith, Parson, and Morgan, "Research on Global Sun Block Needed Now"; Keith, *A Case for Climate Engineering*; National Research Council, "Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration"; Shepherd et al., "Geoengineering the Climate: Science, Governance and Uncertainty"; Victor et al., "The Geoengineering Option A Last Resort Against Global Warming?"; Wigley, "A Combined Mitigation/geoengineering Approach to Climate Stabilization."

[3] Betz, "The Case for Climate Engineering Research: An Analysis of the 'arm the Future' Argument"; Gardiner, "Is 'Arming the Future' with Geoengineering Really the Lesser Evil? Some Doubts about the Ethics of Intentionally Manipulating the Climate System"; Gardiner, "Ethics, Geoengineering and Moral Schizophrenia: What's the Question?"

[4] Hamilton, *Earthmasters: The Dawn of the Age of Climate Engineering*; ETC Group, "Geopiracy: The Case against Geoengineering."

[5] Svoboda et al., "Sulfate Aerosol Geoengineering: The Question of Justice."

[6] See, e.g., Crutzen, "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?"

[7] Different authors use different labels for different approaches to non-ideal theory. The term 'clinical theory' comes from Wiens, "Prescribing Institutions Without Ideal Theory," 46.

[8] Sen, *The Idea of Justice*; Wiens, "Prescribing Institutions Without Ideal Theory."

[9] If geoengineering deployment would reduce emissions abatement or adaptation, then the question becomes more complicated, requiring comparisons of all feasible climate policy portfolios. The literature demonstrates conflicting views about the significance, size, and even the direction of this so-called "moral hazard" effect. Given the deep uncertainties about which complete portfolios are feasible, we focus chiefly (but not exclusively) on the more tractable scenarios in which geoengineering does not displace other responses to climate change. See Hale, "The World That Would Have Been: Moral Hazard Arguments Against Geoengineering."

[10] Rawls, *A Theory of Justice*.

[11] Ibid.; Simmons, "Ideal and Nonideal Theory"; Valentini, "Ideal vs. Non-Ideal Theory: A Conceptual Map."

[12] Colyvan, Cox, and Steele, "Modelling the Moral Dimension of Decisions."

[13] Gardiner, *A Perfect Moral Storm*, 41–44, 247–265.

[14] Ibid., 301–396.

[15] Strong et al., "Ocean Fertilization: Time to Move on."

[16] Ciais et al., "Carbon and Other Biogeochemical Cycles," 546–51.

[17] Doney et al., "Ocean Acidification: The Other CO2 Problem."

[18] For an overview, see: Moellendorf, "Climate Change Justice."

[19] For an overview of these technologies, including costs and risks, see: National Research Council, "Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration," 86–96.

[20] This is the sort of policy portfolio envisioned in the IPCC's Representative Concentration Pathway 2.6 (RCP2.6), which assumes net negative emissions that are achievable only through CDR.

[21] Clarke et al., "Assessing Transformation Pathways"; Wigley, "A Combined Mitigation/geoengineering Approach to Climate Stabilization."

[22] Gupta et al., "Cross-Cutting Investment and Finance Issues," 1235.

[23] Ibid., 1217–1221.

[24] Ibid., 1235.

[25] The authors owe this basic insight and the broad outlines of the argument for it to Henry Shue, who expresses it obliquely in his *Climate Justice: Vulnerability and Protection*.

[26] Mathesius et al., "Long-Term Response of Oceans to CO2 Removal from the Atmosphere"; Wu et al., "The Reversibility of CO2 Induced Climate Change."

[27] Shepherd et al., "Geoengineering the Climate: Science, Governance and Uncertainty."

[28] Keith, *A Case for Climate Engineering*; MacCracken, "On the Possible Use of Geoengineering to Moderate Specific Climate Change Impacts"; Svoboda, "Is Aerosol Geoengineering Ethically Preferable to Other Climate Change Strategies?"

[29] Keith, Parson, and Morgan, "Research on Global Sun Block Needed Now."

[30] Ibid.

[31] Haywood et al., "Asymmetric Forcing from Stratospheric Aerosols Impacts Sahelian Rainfall," 2013; Haywood et al., "Asymmetric Forcing from Stratospheric Aerosols Impacts Sahelian Rainfall," March 2013.

[32] Robock, Oman, and Stenchikov, "Regional Climate Responses to Geoengineering with Tropical and Arctic SO2 Injections"; Jones et al., "Geoengineering by Stratospheric SO2 Injection: Results from the Met Office HadGEM2 Climate Model and Comparison with the Goddard Institute for Space Studies ModelE."

[33] Crutzen, "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?"; Tilmes, Muller, and Salawitch, "The Sensitivity of Polar Ozone Depletion to Proposed Geoengineering Schemes."

[34] Izrael et al., "The Ability of Stratospheric Climate Engineering in Stabilizing Global Mean Temperatures and an Assessment of Possible Side Effects"; Matthews and Caldeira, "Transient Climate–carbon Simulations of Planetary Geoengineering"; McCusker et al., "Rapid and Extensive Warming Following Cessation of Solar Radiation Management"; Keller, Feng, and Oschlies, "Potential Climate Engineering Effectiveness and Side Effects during a High Carbon Dioxide-Emission Scenario."

[35] Barrett, "The Incredible Economics of Geoengineering."

[36] Blackstock et al., "Climate Engineering Responses to Climate Emergencies"; Keith, *A Case for Climate Engineering*.

[37] Victor et al., "The Geoengineering Option A Last Resort Against Global Warming?"

[38] Barrett, "The Incredible Economics of Geoengineering."

[39] Gardiner, *A Perfect Moral Storm*, chapter 3; Gupta, "A History of International Climate Change Policy."

[40] Ricke, Moreno-Cruz, and Caldeira, "Strategic Incentives for Climate Geoengineering Coalitions to Exclude Broad Participation."

[41] Ibid.

[42] Horton, "Geoengineering and the Myth of Unilateralism : Pressures and Prospects for International Cooperation."

[43] Lane, "Climate Engineering and the Anthropocene Era."

[44] Barrett et al. make the similar point that SRM is unlikely to be simultaneously effective and politically feasible. See Barrett et al., "Climate Engineering Reconsidered."

[45] Svoboda et al., "Sulfate Aerosol Geoengineering: The Question of Justice."

[46] Whyte, "Now This! Indigenous Sovereignty, Political Obliviousness and Governance Models for SRM Research."

[47] Ricke, Moreno-Cruz, and Caldeira, "Strategic Incentives for Climate Geoengineering Coalitions to Exclude Broad Participation."

[48] Ibid.

[49] Baum, Maher, and Haqq-Misra, "Double Catastrophe."

[50] Barrett et al., "Climate Engineering Reconsidered."

[51] Tuana et al., "Towards Integrated Ethical and Scientific Analysis of Geoengineering: A Research Agenda."

[52] Dilling and Hauser, "Governing Geoengineering Research: Why, When and How?"; Hale, "What's so Moral about the Moral Hazard?"; Gardiner, "Is 'Arming the Future' with Geoengineering Really the Lesser Evil? Some Doubts about the Ethics of Intentionally Manipulating the Climate System"; Morrow, Kopp, and Oppenheimer, "Toward Ethical Norms and Institutions for Climate

Engineering Research"; Tuana et al., "Towards Integrated Ethical and Scientific Analysis of Geoengineering: A Research Agenda."

Bibliography

Barrett, Scott. "The Incredible Economics of Geoengineering." *Environmental and Resource Economics* 39, no. 1 (December 2008): 45–54. doi:10.1007/s10640-007-9174-8.

Barrett, Scott, Timothy M. Lenton, Antony Millner, Alessandro Tavoni, Stephen Carpenter, John M. Anderies, F. Stuart Chapin III, et al. "Climate Engineering Reconsidered." *Nature Climate Change* 4, no. 7 (July 2014): 527–29.

Baum, Seth D., Timothy M. Maher, and Jacob Haqq-Misra. "Double Catastrophe: Intermittent Stratospheric Geoengineering Induced by Societal Collapse." *Environment Systems & Decisions* 33, no. 1 (March 1, 2013): 168–80. doi:10.1007/s10669-012-9429-y.

Betz, Gregor. "The Case for Climate Engineering Research: An Analysis of the 'arm the Future' Argument." *Climatic Change* 111, no. 2 (August 2011): 473–85. doi:10.1007/s10584-011-0207-5.

Betz, Gregor, and Sebastian Cacean. *Ethical Aspects of Climate Engineering*. Karlsruhe: Kalrsruhe Institut für Technologie, 2012.

Blackstock, Jason J, D Battisti, K Caldeira, D E Eardley, J I Katz, D W Keith, S E Koonin, A A N Patrinos, D P Schrag, and R H Socolow. "Climate Engineering Responses to Climate Emergencies," February 2009. http://arxiv.org/pdf/0907.5140.

Ciais, P., C. Sabine, G. Bala, L. Bopp, V. Brovkin, J. Canadell, A. Chhabra, et al. "Carbon and Other Biogeochemical Cycles." In *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Thomas F Stocker, D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xiz, . Bex, and Pm.M. Midgley, 465–570. Cambridge, 2013.

Clarke, L., K. Jiang, K. Akimoto, M. Babiker, G. Blanford, K. Fisher-Vanden, J.-C. Hourcase, et al. "Assessing Transformation Pathways." In *Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, 2014.

Colyvan, Mark, Damian Cox, and Katie Steele. "Modelling the Moral Dimension of Decisions." *Noûs* 44, no. 3 (2010): 503–29.

Crutzen, P. J. "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?" *Climatic Change* 77, no. 3–4 (2006): 211–19. doi:10.1007/s10584-006-9101-y.

Dilling, Lisa, and Rachel Hauser. "Governing Geoengineering Research: Why, When and How?" *Climatic Change* 121, no. 3 (December 1, 2013): 553–65. doi:10.1007/s10584-013-0835-z.

Doney, S. C., V. J. Fabry, R. A. Feely, and J. A. Kleypas. "Ocean Acidification: The Other CO2 Problem." *Annual Review of Marine Science* 1 (2009): 169–92. doi:10.1146/annurev.marine.010908.163834.

ETC Group. "Geopiracy: The Case against Geoengineering," 2010. http://www.etcgroup.org/content/geopiracy-case-against-geoengineering.

Gardiner, Stephen M. *A Perfect Moral Storm: The Ethical Tragedy of Climate Change*. Oxford University Press, 2011.

———. "Ethics, Geoengineering and Moral Schizophrenia: What's the Question?" In *Climate Change Geoengineering: Philosophical Perspectives, Legal Issues, and Governance Frameworks*, edited by William C G Burns and Andrew Strauss, 11–38. Cambridge: Cambridge University Press, 2013.

———. "Is 'Arming the Future' with Geoengineering Really the Lesser Evil? Some Doubts about the Ethics of Intentionally Manipulating the Climate System." In *Climate Ethics*, edited by Stephen M. Gardiner, Simon Caney, Dale Jamieson, and Henry Shue. Oxford: Oxford University Press, 2010.

Gupta, Joyeeta. "A History of International Climate Change Policy." *Wiley Interdisciplinary Reviews: Climate Change* 1, no. 5 (September 2010): 636–53. doi:10.1002/wcc.67.

Gupta, S, J Harnisch, DC Barua, L Chingambo, P Frankel, RJG Vázquez, L Gómez-Echeverri, E Haites, Y Huang, and R Kopp. "Cross-Cutting Investment and Finance Issues." In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, 2014.

Hale, Benjamin. "The World That Would Have Been: Moral Hazard Arguments Against Geoengineering." In *Engineering the Climate: The Ethics of Solar Radiation Management*, edited by Christopher J. Preston, 113–31. Lexington Books, 2012.

———. "What's so Moral about the Moral Hazard?" *Public Affairs Quarterly* 23, no. 1 (2009): 1–26.

Hamilton, Clive. *Earthmasters: The Dawn of the Age of Climate Engineering*. New Haven, CT: Yale University Press, 2013.

Haywood, Jim M., Andy Jones, Nicolas Bellouin, and David Stephenson. "Asymmetric Forcing from Stratospheric Aerosols Impacts Sahelian Rainfall." *Nature Clim. Change* advance online publication (2013). doi:10.1038/nclimate1857.

———. "Asymmetric Forcing from Stratospheric Aerosols Impacts Sahelian Rainfall." *Nature Climate Change* 3, no. 7 (March 2013): 660–65. doi:10.1038/nclimate1857.

Horton, Joshua B. "Geoengineering and the Myth of Unilateralism : Pressures and Prospects for International Cooperation." *Stanford Journal of Law, Science & Policy* IV (2011): 56–69.

Izrael, Yu. a., E. M. Volodin, S. V. Kostrykin, a. P. Revokatova, and a. G. Ryaboshapko. "The Ability of Stratospheric Climate Engineering in Stabilizing Global Mean Temperatures and an Assessment of Possible Side Effects." *Atmospheric Science Letters* 15, no. 2 (April 2014): 140–48. doi:10.1002/asl2.481.

Jones, A., J. Haywood, O. Boucher, B. Kravitz, and A. Robock. "Geoengineering by Stratospheric SO2 Injection: Results from the Met Office HadGEM2 Climate Model and Comparison with the Goddard Institute for Space Studies ModelE." *Atmospheric Chemistry and Physics* 10, no. 13 (July 2010): 5999–6006. doi:10.5194/acp-10-5999-2010.

Keith, David. *A Case for Climate Engineering*. Cambridge, Mass: The MIT Press, 2013.

Keith, David, E. Parson, and M. G. Morgan. "Research on Global Sun Block Needed Now." *Nature* 463, no. 7280 (January 2010): 426–27. doi:10.1038/463426a.

Keller, David P., Ellias Y. Feng, and Andreas Oschlies. "Potential Climate Engineering Effectiveness and Side Effects during a High Carbon Dioxide-Emission Scenario." *Nature Communications* 5 (February 2014): 1–11. doi:10.1038/ncomms4304.

Lane, Lee. "Climate Engineering and the Anthropocene Era." In *Climate Change Geoengineering: Philosophical Perspectives, Legal Issues, and Governance Frameworks*, edited by William C G Burns and Andrew L. Strauss, 115–45. Cambridge: Cambridge University Press, 2013.

MacCracken, Michael C. “On the Possible Use of Geoengineering to Moderate Specific Climate Change Impacts.” *Environmental Research Letters* 4, no. 4 (October 2009): 045107–045107. doi:10.1088/1748-9326/4/4/045107.

Mathesius, Sabine, Matthias Hofmann, Ken Caldeira, and Hans Joachim Schellnhuber. “Long-Term Response of Oceans to CO2 Removal from the Atmosphere.” *Nature Climate Change*, 2015.

Matthews, H Damon, and Ken Caldeira. “Transient Climate–carbon Simulations of Planetary Geoengineering.” *Proceedings of the National Academy of Sciences of the United States of America* 104, no. 24 (June 2007): 9949–54. doi:10.1073/pnas.0700419104.

McCusker, Kelly E, Kyle C Armour, Cecilia M Bitz, and David S Battisti. “Rapid and Extensive Warming Following Cessation of Solar Radiation Management.” *Environmental Research Letters* 9, no. 2 (January 2014): 024005–024005. doi:10.1088/1748-9326/9/2/024005.

Moellendorf, Darrel. “Climate Change Justice.” *Philosophy Compass* 10, no. 3 (2015): 173–86.

Morrow, David R. “Starting a Flood to Stop a Fire: Some Moral Constraints on Solar Radiation Management.” *Ethics, Policy & Environment* 17, no. 2 (2014).

Morrow, David R, Robert E Kopp, and Michael Oppenheimer. “Toward Ethical Norms and Institutions for Climate Engineering Research.” *Environmental Research Letters* 4, no. 4 (2009): 045106.

National Research Council. “Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration.” National Academy of Science, 2015.

Preston, Christopher J. “Ethics and Geoengineering: Reviewing the Moral Issues Raised by Solar Radiation Management and Carbon Dioxide Removal.” *Wiley Interdisciplinary Reviews: Climate Change* 4, no. 1 (January 2013): 23–37. doi:10.1002/wcc.198.

Preston, Christopher J. “Re-Thinking the Unthinkable: Environmental Ethics and the Presumptive Argument against Geoengineering.” *Environmental Values* 20, no. 4 (2011): 457–79.

Rawls, J. *A Theory of Justice*. Cambridge, MA: Belknap Press, 1971.

Ricke, Katharine L, Juan B Moreno-Cruz, and Ken Caldeira. “Strategic Incentives for Climate Geoengineering Coalitions to Exclude Broad Participation.” *Environmental Research Letters* 8, no. 1 (March 2013): 014021–014021. doi:10.1088/1748-9326/8/1/014021.

Robock, A., L. Oman, and G. L. Stenchikov. “Regional Climate Responses to Geoengineering with Tropical and Arctic SO2 Injections.” *Journal of Geophysical Research-Atmospheres* 113, no. D16 (2008): D16101. doi:10.1029/2008jd010050.

Sen, A. *The Idea of Justice*. Cambridge, MA: Belknap Press, 2009.

Shepherd, John G, Ken Caldeira, Peter Cox, Joanna Haigh, David W Keith, Brian Launder, Georgina Mace, et al. “Geoengineering the Climate: Science, Governance and Uncertainty.” London: Royal Society, 2009.

Shue, Henry. *Climate Justice: Vulnerability and Protection*. Oxford University Press, 2014.

Simmons, A John. “Ideal and Nonideal Theory.” *Philosophy & Public Affairs* 38, no. 1 (2010): 5–36.

Smith, Patrick Taylor. “Domination and the Ethics of Solar Radiation Management.” In *Engineering the Climate: The Ethics of Solar Radiation Management*, edited by Christopher J. Preston. Plymouth, UK: Lexington Books, 2012.

Strong, Aaron, Sallie Chisholm, Charles Miller, and John Cullen. “Ocean Fertilization: Time to Move on.” *Nature* 461, no. 7262 (2009): 347–48.

Svoboda, Toby. “Aerosol Geoengineering and Fairness.” *Environmental Values*, forthcoming.

———. “Is Aerosol Geoengineering Ethically Preferable to Other Climate Change Strategies?” *Ethics & the Environment* 17, no. 2 (2012): 111–35.

Svoboda, Toby, and Peter J. Irvine. “Ethical and Technical Challenges in Compensating for Harm Due to Solar Radiation Management Geoengineering.” *Ethics, Policy & Environment* 17, no. 2 (2014).

Svoboda, Toby, Klaus Keller, Marlos Goes, and Nancy Tuana. “Sulfate Aerosol Geoengineering: The Question of Justice.” *Public Affairs Quarterly* 25, no. 3 (2011): 157–80.

Tilmes, S., R. Muller, and R. Salawitch. “The Sensitivity of Polar Ozone Depletion to Proposed Geoengineering Schemes.” *Science* 320, no. 5880 (2008): 1201–4. doi:10.1126/science.1153966.

Tuana, Nancy, Ryan L. Sriver, Toby Svoboda, Roman Olson, Peter J. Irvine, Jacob Haqq-Misra, and Klaus Keller. “Towards Integrated Ethical and Scientific Analysis of Geoengineering: A Research Agenda.” *Ethics, Policy & Environment* 15, no. 2 (June 2012): 136–57. doi:10.1080/21550085.2012.685557.

Valentini, Laura. “Ideal vs. Non-Ideal Theory: A Conceptual Map.” *Philosophy Compass* 7, no. 9 (September 2012): 654–64. doi:10.1111/j.1747-9991.2012.00500.x.

Victor, D. G., M. G. Morgan, F. Apt, J. Steinbruner, and K. Ricke. “The Geoengineering Option A Last Resort Against Global Warming?” *Foreign Affairs* 88, no. 2 (2009): 64–76.

Whyte, Kyle Powys. “Now This! Indigenous Sovereignty, Political Obliviousness and Governance Models for SRM Research.” *Ethics, Policy & Environment* 15, no. 2 (2012): 172–87.

Wiens, David. “Prescribing Institutions Without Ideal Theory.” *Journal of Political Philosophy* 20, no. 1 (March 2012): 45–70. doi:10.1111/j.1467-9760.2010.00387.x.

Wigley, T. M. L. “A Combined Mitigation/geoengineering Approach to Climate Stabilization.” *Science* 314, no. 5798 (2006): 452–54. doi:10.1126/science.1131728.

Wu, Peili, Jeff Ridley, Anne Pardaens, Richard Levine, and Jason Lowe. “The Reversibility of CO2 Induced Climate Change.” *Climate Dynamics*, 2014, 1–10.