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How to Argue about Solar Geoengineering

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ABSTRACT *Should high-income countries engage in solar geoengineering research and possible deployment? On the assumption that the speed of the energy transition will be insufficient to abate catastrophic climate impacts, research into solar geoengineering begins to look like a technically and socially feasible route to mitigate such impacts. But on the assumption that a rapid and relatively just energy transition is still within the realm of political possibility, research into solar geoengineering looks more like an ideological tool designed to divert time and resources from less risky climate solutions. At the heart of debates over solar geoengineering, then, is disagreement over what political actors can be expected to do in the future. In this article, I argue that both objectors to and proponents of solar geoengineering research often make background assumptions regarding expected future actions that are either (a) inaccurate or (b) inconsistent. I propose an account of expected future actions that avoids these problems and sketch what the debate over solar geoengineering looks like with these assumptions in place.*

1. Introduction

To avoid catastrophic impacts, the global economy will need to transition to a net-zero energy system by midcentury. The challenges involved in this transition cannot be overstated. Here are just a few examples. To stay below 1.5° of warming, the stretch-goal temperature target set by the Paris Climate Accords, global coal use will need to plummet by around 80% this decade, which would require almost immediately closing every single one of the more than 4000 coal-fired plants currently in operation.[1] Where electric vehicles now account for 5% of global automobile sales, they will need to represent 60% of new purchases in 2030 if we are to continue driving at current levels.[2] Energy efficiency improvements will need to increase by 4% annually, roughly three times their current rate. The macroeconomic consequences of undertaking this transition will not be trivial: energy prices are likely to rise, workers will need to be retrained, and short-term consumption levels are likely to decline in the face of massive investment in new infrastructure.[3]

Moreover, regardless of the speed of the energy transition, significant climate impacts are already locked in.[4] Climate change has increased the risk of severe storms and wildfires, with one recent study finding that anthropogenic warming has doubled the number of days with fire risk in California.[5] Weather attribution scientists have concluded that the 2021 heat waves that overtook the Western United States were 'virtually impossible' in the absence of human-caused warming.[6] These higher temperatures, which will continue even in the presence of extremely rapid mitigation, are associated with lower productivity, higher violent crime rates, illness, and death.[7]

This dire situation has prompted calls for research into a more radical strategy called solar geoengineering. Several approaches fall under this heading.[8] One idea involves

whitening some of the clouds over the ocean to reflect more sunlight back into space. Another strategy involves thinning high altitude clouds to allow more of earth's heat to escape. In this article, I will focus on a third proposal, which is at present the most widely discussed and well understood.[9] This strategy is called 'Stratospheric Aerosol Injection' (SAI). The basic idea behind SAI is simple: inject tiny aerosol particles – usually sulphur, but other kinds of aerosols are being researched – into the upper atmosphere. These particles reflect sunlight and lead to cooling. Preliminary models suggest that this technology could reduce predicted temperature and precipitation changes under continued warming.[10]

The debate over whether to pursue SAI research and the conditions, if any, under which deployment would be called for is increasingly divisive. In the next section of this article, I will argue that the debate is often also confused. Arguments on either side tend to make two mistakes, each concerning the way the future actions of relevant political actors are treated in their reasoning about what to do now. The first mistake involves making recommendations about what to do now that are based on the unrealistic assumption that political actors in the future will overwhelmingly act as they ought to when it comes to the energy transition. The second mistake involves internal inconsistency. Both parties to the debate make – often in the same argument – different and contrasting assumptions about the sorts of actions that political actors can be expected to make moving forward. In short, defenders of solar geoengineering often assume that deployers of the technology will largely comply with the demands of political morality, but at the same time often argue that the reason deployment is called for in the first place is that political actors are failing to comply with those same demands. Critics of solar geoengineering, on the other hand, assume that it is possible that political actors moving forward will conform with the moral demand to enact an extremely rapid and costly energy transition, yet at the same time worry that those same political actors will fail to comply with the moral demand to use solar geoengineering responsibly. Until each party to the debate comes to the table with an argument that makes assumptions about the future actions of relevant political actors that are (a) roughly accurate and (b) internally consistent, no progress will be made.

But what should those assumptions be? In Section 3, I recommend a particular answer to this question; namely, that when it comes to SAI research, we should reason about what to do now on the assumption that powerful political actors will continue to advance what they take to be their own interests. Finally, in Section 4, I will sketch what the debate over SAI research looks like with this assumption in place. My objective here is not to weigh in on this debate as it is presently being waged, but rather to argue for an alternative and more productive way of conducting the debate itself.

Before I begin in earnest, a bit more background on SAI. In contrast to the vast challenges of a global energy transition, SAI is often characterized as being technically quite simple, and comparably cheap, with estimates in the range of US $30 billion per year.[11] By contrast, the costs of a global transition to renewable energy will amount to trillions of US dollars per year. Despite these potential upshots, scientists widely agree that SAI is not a substitute for mitigation, but rather a strategy to manage the risks of climate change in the short term. There are several reasons for this. SAI does not address some important impacts of climate change such as ocean acidification.[12] It also does not perfectly compensate for greenhouse gas (GHG) emissions. While the technology would have a net cooling impact, regional effects might differ; SAI does not promise to take us to the counterfactual world where no climate change has occurred.[13]

In what follows, I will be primarily concerned with SAI research rather than deployment. I focus on research because the question we are faced with now is whether and to what extent to fund such research. No scientist or public policymaker that I have encountered is arguing for deployment of SAI technology in the next few years. Importantly, when I speak of research, I mean research extensive enough that it would enable deployment on a reasonable time scale. Thus far, research into solar geoengineering has been relatively minimal compared to the billions of dollars spent on other kinds of climate research.[14] Globally, between 2008 and 2021 just over 100 million dollars of funding was allocated to study the technology, with over half of this funding coming from the United States and most of the rest from Australia, the United Kingdom, Germany, and China.[15] If there is to be any chance of the technology being deployed safely in the next 5–15 years, as imagined by its proponents, funding for research must be exponentially increased, especially with respect to consequences in those countries that will be especially impacted by how the climate crisis unfolds. The core question of contemporary debates, then, is this: should massive amounts of time, money, and labor power be devoted to understanding the prospects of SAI?

2. (In)accurate and (In)consistent Arguments

2.1. Full Versus Partial Compliance

Answering this core question involves making assumptions about the future actions of political actors when it comes to the energy transition and the use of SAI. To see two such assumptions in action, consider the 2021 National Academy of Sciences (NAS) Report, the first major report to recommend federally funded geoengineering research. The report states that, when it comes to climate change policy strategies,

> The centerpiece of this portfolio should be reducing GHG emissions, removing and reliably sequestering carbon from the atmosphere, and pursuing adaptation to climate change impacts that have already occurred or will occur in the future. Concerns that these three options together are not being pursued at the level or pace needed to avoid the worst consequences of climate change – or that even if vigorously pursued will not be sufficient to avoid the worst consequences – have led some to suggest the value of exploring additional response strategies.[16]

This passage illustrates two different assumptions one might make when reasoning about the permissibility of pursuing solar geoengineering research. Sometimes, research is motivated by concerns that even if mitigation efforts are 'vigorously pursued', they will not be sufficient to avoid the worst consequences of climate change. In other words, research might be called for even on the assumption that from this point onward, everyone will act as they are morally required to when it comes to the speed of the energy transition. Call this the full compliance assumption.[17]

The NAS report also suggests that, for some, solar geoengineering research is a potential policy response to nations failing to act in the way that is 'needed' to avoid the worst consequences of climate change. Such failure involves, presumably, some political actors failing to act as they are morally required to when it comes to the speed of the energy transition moving forward. Call this the partial compliance assumption.

Let me say a bit more about these two assumptions. As I've already hinted, in what follows I am primarily concerned with compliance and noncompliance when it comes to the speed of the energy transition, which for the purposes of this article we can assume to be in line with the goals set out by the Paris Climate Accords. Full compliance for my purposes here, then, involves political actors acting in ways that bring about this transition without violating any more important moral demand, and partial compliance involves political actors failing to act in these ways.[18] I will not attempt to fill in the content or subject of these demands with any more precision, but we can assume that meeting climate goals will place requirements on many individuals, corporations, and other political actors to do things like vote for particular policies, divest from the fossil fuel industry, and so on.

I draw out the difference not because full and partial compliance are exhaustive of the assumptions one might make when reasoning about what to do now with respect to SAI research, but because marking the distinction will help make clear errors in the way the debate over SAI has proceeded thus far.[19] As I've already mentioned, in what follows I will highlight two such errors. The first involves making recommendations about SAI research that are based on inaccurate background assumptions, and the second involves making recommendations about SAI research that are based on inconsistent assumptions, without sufficient justification for that inconsistency. I detail these objections next.

2.2. Full Compliance Arguments for SAI Research

In a recent op-ed, David Keith, the leader of Harvard's Solar Geoengineering Research Group, argues for SAI research even in a world where all emissions are eliminated by 2050.[20] He asks us to imagine that, in a welcome turn of events, countries take on the challenge of meeting Paris Climate Accord goals. After net-zero emissions are reached, the earth's temperature would stabilize quickly; temperatures would not continue rising. As Keith highlights, however, climate impacts will continue to occur even at 1.5 or 2° of warming. Heat waves and storms like those we are already experiencing will persist, sea levels will continue to rise, and storms of increased severity will be the norm. These disasters, by all estimates, will have a disproportionate impact on the global poor.[21] In light of this, Keith proposes that SAI should be researched and considered as a policy response even on the assumption that from this moment onward, everyone will act as they ought to when it comes to the speed of the energy transition. For Keith, SAI research is called for even on the assumption of full compliance moving forward.

A second argument that can be run on the assumption of full compliance claims that SAI technology has the potential to reduce the required speed of the energy transition.[22] As I've already mentioned, a transition of the scale required will likely have macroeconomic impacts even in developed countries. A slower energy transition could be done in a way that alleviates some of these impacts: societies will have more time to retrain those who will lose their jobs in the fossil fuel industry, more time to create new opportunities for those communities whose economic prosperity depends on coal-fired power plants, more time to figure out the logistics of power grids and develop the technologies that will make for a less disruptive transition. Even if nations would mitigate on the timeline demanded by Paris goals, it may well be the case that even the most well-motivated transition would be less costly and disruptive with more time.[23]

Reasoning under the assumption of full compliance like this can be a valuable exercise. By asking first what ought to be done on the assumption that everyone will act as they should, we can articulate a goal to aim towards. We can also identify the actors that are acting wrongly by frustrating that goal, enabling us to single out who is to blame for the group falling short. For instance, if SAI is called for on the assumption of full compliance because (on those assumptions) it will be put to use to ameliorate climate impacts experienced by the global poor, any actor that puts SAI technology towards alternative purposes (enabling the rich to continue their high emissions lifestyles, for instance) will be acting wrongly.

Full compliance arguments cannot, however, provide a complete answer to the pressing question of what to do now with respect to SAI research. The reason for this is that the full compliance assumption is inaccurate. The energy transition has not proceeded at the morally required pace and looks unlikely to do so in the future. Although many countries have made progress expanding renewable energy production, expansion has not come with a concomitant reduction of fossil fuel use, and under current policies, the earth will warm 2.7°C by the end of the century.[24] The various actors involved in the energy transition have not been acting as they ought to, and although we may hope that they change course, we should not assume that they will when reasoning about what to do now. This is because it does not follow from the truth of the claim that SAI research is permissible or even required under conditions of full compliance that research is permissible or required under conditions of partial compliance. If we are interested in whether SAI research ought to be conducted now, we had better take on more accurate assumptions about how the technology might be used and how the energy transition might unfold.[25] It is for this reason that for the remainder of this article I focus on partial compliance arguments, which I turn to next.

2.3. *Partial Compliance Arguments for SAI Research*

Many arguments offered in favor of advancing SAI research turn on the idea that relevant political actors will not fully comply with the moral demands of the energy transition moving forward. The most straightforward and common argument of this variety looks something like this:

(1) Global mitigation efforts will likely continue to be insufficient to meet climate targets.
(2) The consequences of (1) will be drastic, especially for the global poor.
(3) A well-researched SAI regime has the potential to ameliorate many of those consequences in the short term.
(4) To have any hope of a well-researched SAI regime, significant resources must be devoted to SAI research now.

This argument has several supporters and has been most prominently advanced by Joshua Horton and David Keith in a 2016 article entitled 'Solar Geoengineering and Obligations to the Global Poor'.[26] The central difference between this argument and the argument from full compliance we saw earlier is that the consequences of climate change under partial compliance will be more catastrophic. Assuming a partial compliance energy transition thus strengthens the case for SAI research: while the impacts of

1.5° of warming will be far from trivial, the tragic and irreversible impacts of 3°–5° of warming makes ameliorating those impacts through SAI look like a more appealing option.

2.4. Internal Inconsistencies in Arguments for SAI Research

Critics of SAI have noted a potential inconsistency in the above argument. Marion Hourdequin offers one version of this critique. She writes:

> If nations such as the United States truly cared about the well being of 'the global poor,' they could transfer resources to poorer countries burdened with the costs of adaptation or could shoulder a larger proportion of the global burdens of mitigation. Horton and Keith seem to assume that neither is likely to happen, thus SRM is a better option. But under a scenario in which the wealthy countries care too little about the poor to do their fair share with respect to mitigation and adaptation, how likely is it that research and development of SRM will prioritize the interests of 'the global poor'?[27]

One way of understanding Hourdequin's complaint here is that she is accusing Horton and Keith of making inconsistent assumptions about the actions of political actors in the future at different stages of their reasoning. She contends that, for Horton and Keith, research into SAI is called for on the assumption of noncompliance – the assumption that mitigation measures will be insufficient to meet climate targets and that high-income nations will not be the primary funding sources of adaptation in developing countries. But if Horton and Keith are to assume that high-income nations will be noncompliant in their justification of SAI research, then they must hold this assumption constant across different stages of their reasoning, absent sufficient reason to do otherwise. Thus, Horton and Keith should also assume that high-income nations will be noncompliant when it comes to the research and deployment of SAI technology itself. And if we hold this noncompliance assumption constant, then, says Hourdequin, we should predict that SAI will not be used in ways that 'prioritize the interests of the global poor'. More likely, the technology will be used in ways that advance the interests of high-income countries. Hourdequin accuses Horton and Keith of justifying research into SAI on the assumption of noncompliance, while at the same time assuming that research and deployment will play out in something closer to a full-compliance situation in which the global poor are prioritized.

Horton and Keith have a response to the way I've reconstructed Hourdequin's critique. They are not, in fact, making inconsistent background assumptions about the motivations of high-income nations at different stages of their argument. For Horton and Keith never claim that research into and potential deployment of SAI will prioritize the global poor. Instead, they write that 'local actors pursuing local interests through the use of SAI might, if the intervention was properly designed, benefit the rest of the world (especially the global poor) as a virtual byproduct of their otherwise self interested use of solar geoengineering'.[28]

What Horton and Keith consistently assume throughout their argument, then, is that high-income nations will act in ways that benefit poor nations only when doing so benefits them as well. Rapid mitigation and funding outside adaptation, in a world with resource constraints, makes high-income nations worse off, at least in the short term. But the

deployment of SAI – even holding constant the assumption that high-income nations will act to benefit poor ones only when doing so benefits them as well – still might make poor nations better off as compared to the nondeployment policy scenario, although not maximally so.[29] Although Horton and Keith would be inconsistent if they argued for SAI as a way to prioritize the global poor, they avoid this inconsistency by instead merely suggesting that deployment would benefit the global poor relative to business as usual.[30]

All I've aimed to show here is that Horton and Keith cannot rightly be accused of making different assumptions about the motivations of high-income countries at different stages of their argument – at least in the way Hourdequin claims. However, Hourdequin's exercise of investigating whether arguments make consistent background assumptions about the future actions of political actors is instructive, for it points the way towards a second, more successful argument against SAI research with a similar structure.

2.5. *Partial Compliance Arguments Against SAI Research*

The argument goes like this. When Horton and Keith, and others, argue for advancing SAI research, they assume that rich nations will advance the interests of poorer nations only when it also benefits them. But why, on these assumptions about how high-income nations will act, would we think that once SAI is deployed, these nations will continue their commitment to mitigation? After all, with technology to abate the near-term impacts of climate change, why would a given country take on the costs of mitigation? In other words, if we are holding constant that wealthy nations will continue to act in self-interested ways, we should expect an even slower mitigation response than the nondeployment scenario. Horton and Keith assume that solar geoengineering is necessary, or at least particularly called for due to the partial compliance of high-income nations, but at the same time seem to assume that those nations will largely comply with mitigation requirements moving forward.

The idea that research into or deployment of SAI will lead to wrongfully reduced mitigation has often been called the 'moral hazard' objection to SAI.[31] We can see this concern already playing out in the United States. US Representative Lamar Smith, chairman of the House Science, Space and Technology Committee, noted that, when it comes to solar geoengineering, 'some scientists believe it could achieve substantial environmental benefits at a cheaper cost than regulations'.[32] Similarly, former Republican House Speaker Newt Gingrich has expressed approval for geoengineering for its 'promise of addressing global warming concerns for just a few billion dollars a year'.[33] Geoengineering, on their view, is not just part of an overall package of climate change solutions. Rather, it might be the solution and an alternative to rapid decarbonization.

The worry that SAI research will undermine mitigation is an instance of a more general objection to SAI. The more general objection is the idea that research and/or deployment of SAI will prompt political actors to fail to conform with moral requirements related to the energy transition.[34] In addition to the concern that SAI will prompt slower mitigation than is morally required, critics have articulated several other future wrongs that SAI might make more likely. Some have worried that after a period of deployment, solar geoengineering would be prematurely stopped, leading temperatures to rise rapidly to the level they would have been absent SAI, a phenomenon that has been dubbed 'termination shock'.[35] Some have worried about 'lock-in', where research now will make it significantly more likely that premature and dangerous deployment will occur.[36] Others have

claimed that research and development of the technology will make it more likely that humans develop certain attitudinal vices, such as a view of themselves as separate and above the natural world.[37] And still others have worried that solar geoengineering will perpetuate the current unjust concentrations of political and economic power in the global north.[38]

What these arguments have in common is the claim that research and development of SAI makes certain wrongs significantly more likely moving forward. As such, I will call this family of arguments 'Anticipated Future Wrongdoing' arguments. The force of these arguments in all their forms depends on the fact that there will be partial compliance with the demands of political morality in the future. In what follows, I will focus on the concern that SAI will slow mitigation efforts, although it should be kept in mind that I intend my forthcoming observations to apply to Anticipated Future Wrongdoing more broadly.

2.6. Internal Inconsistencies in Arguments Against SAI Research

We are now prepared to see how those who advance Anticipated Future Wrongdoing arguments often exhibit a similar inconsistency to defenders of SAI. For at the same time as they worry about future wrongdoing such as reduced mitigation ambition, they also tend to believe that it is still possible for present global institutions to meet the climate challenge by transforming the way our societies use and produce energy in a rapid period, and moreover that it is possible to do so in a way that does not deepen existing inequalities and injustices.

For an example of the kind of inconsistency I want to highlight, consider a 2022 letter signed by over 60 scientists and academics in favor of an international solar geoengineering 'non-use agreement'. The authors claim that 'the current world order seems unfit to reach such far-reaching agreements on fair and effective political control over solar geoengineering deployment'.[39] In the same article, they contend that 'decarbonization of our economies is feasible if the right steps are taken, leading also to innovation opportunities through economic transformation and ecological benefits beyond climate change mitigation'.[40] But if the current world order is unfit to reach agreements regarding SAI, why should we think that it is possible for that same world order to decarbonize at anywhere near the rate required? Put otherwise: in order to think that meeting temperature targets is still possible, one must think that, starting from now, it is possible that political actors of all varieties will overwhelmingly fully comply with the moral demands of the energy transition. One must thus hold that assumption constant across different stages of their reasoning absent sufficient justification otherwise. But if one assumes that, starting from now, it is possible that political actors of all varieties will overwhelmingly fully comply with the moral demands of the energy transition, then one must also think that it is possible that SAI research or deployment will not prompt political actors to act wrongly by further delaying the energy transition.

Perhaps, though, these defenders of the Anticipated Future Wrongdoing argument think that the existence of SAI research alone provides sufficient reason to alter our assumptions about the compliance of future political actors in different scenarios. In response to my critique of inconsistency, critics of SAI might reply that prior to widespread and well-known SAI research, it is possible that high-income nations can reasonably be convinced to undertake a rapid energy transition. But if research is conducted, political entities will be far less likely to mitigate at the required speeds. A slightly different

version of this argument does not assume that high-income nations can be reasonably convinced to undertake the required energy transition, but rather it contends that SAI will function meaningfully to slow an already insufficient transition. In either case, the SAI objector attaches a special pessimism to the technology, where the very existence of SAI makes it less likely that actors will do what they should. But what justifies thinking that SAI will prompt even greater noncompliance? In other words, what justifies making different guiding assumptions about the future actions of political actors before and after the introduction of SAI technology?

The critic of SAI has a story they can tell in reply here. The reply is that with less visible climate damages (if SAI is deployed), mitigation will take an (even further) backseat on the political agenda of the electorate. While plausible, I think, the verdict is still out whether this reply is definitive, for there are some reasons to suspect that SAI might elicit increased mitigation. First, some research suggests that the prospects of such an extensive global intervention prompts individuals to strengthen their mitigation commitments.[41] More importantly, if SAI is researched and deployed, it is likely to free up resources to use for mitigation. By reducing the prevalence and severity of costly climate events, SAI could reduce adaptation costs, leaving more labor power and funding for reducing emissions. There is a sense, then, in which the deployment of SAI could enable a more rapid energy transition than would otherwise be expected, or even required.[42] In short, there are plausible political mechanisms that paint a picture of SAI functioning to speed up and slow down the energy transition. Although I cannot resolve this debate here, my central point stands: if one attaches a special pessimism (or optimism) to the use of SAI, one must be prepared to justify it. I think the jury is still out as to whether such a justification exists.

A further reply available to the critics of SAI is that they are not, in fact, as optimistic about the possibility of a rapid and just energy transition as I have portrayed them above. They are, in fact, holding constant that wealthy countries are not motivated to cut emissions at a rapid pace, nor are they motivated to deploy SAI as a complement rather than a substitute for mitigation. Instead, perhaps their claim is that insufficient mitigation is worse than the combination of SAI research and even more insufficient mitigation. I will return to this interpretation in Section 4. To preview, I think this is the right way of thinking about the choice that we presently face.

As it stands, the argument between proponents and opponents of SAI research seems to be at an impasse because neither camp advances an argument that both (a) takes on accurate assumptions about how political actors will act in the future and (b) is internally consistent. Arguments for or against SAI research that assume full compliance with the demands of the energy transition moving forward cannot deliver a verdict regarding what to do now. And many arguments that look at first to assume partial compliance do not do so consistently: on the assumption of partial compliance with mitigation responsibilities, solar geoengineering research looks like it might be positively called for to abate the truly catastrophic impacts on the horizon. Yet assuming a future world of partial compliance should also make us wary, for SAI research may lead to even less mitigation than we would otherwise expect, along with other potential wrongdoings. On the other hand, on the assumption that something much closer to full compliance is possible, where it is still possible to undertake the societal transformation necessary to avoid climate disaster, then research into solar geoengineering may not increase the likelihood of future wrongdoing

at all and indeed could be utilized as part of a well-designed scheme to limit immediate and locked-in impacts.

If opponents and proponents of SAI research are to engage in a genuine debate, the first step is to come to a consensus about what to hold constant regarding the motivations of political actors. I turn to this challenge next.

3. Noncompliance of the Powerful

In the previous sections, I emphasized that it is important that arguments that turn on the future actions of political actors exhibit (a) accuracy and (b) consistency. I argued briefly that it is inaccurate to assume that moving forward, political actors will comply with the moral demand to decarbonize in time to meet Paris targets. But what assumptions about the actions of political actors in the future should we hold constant in our reasoning about what to do now? In this section, I want to sketch my favored answer to this question.

First, let me say a bit more about why accuracy matters. Suppose a group of ten of us are constructing a dam together to avoid a potentially devastating flood. Five members of the group are not, they have demonstrated, going to do their part in building the dam. If what this means is that they sit on the sides of the construction site drinking coffee and gossiping, then the five well-intentioned dam builders can build it on their own, with additional effort of course. The consequences of the flooding are bad enough that it is worthwhile for each 'compliant' individual to pick up the slack left over by their indolent 'noncompliant' peers. However, if the five noncompliers are instead going to actively prevent the completion of the dam – stealing building materials in the night, breaking down sections as they are built – it may no longer be worth it for the five compliers to invest their energy into building the dam. They will do better by individually preparing for the oncoming flood, even though doing so will be very costly and difficult. What this demonstrates is that what compliers ought to do in a given moment will depend on the specific nature of their assumptions about the future actions of the noncompliers.

What would accurate assumptions look like when it comes to debates over what to do about SAI? Recent work on the nature of political feasibility has begun to ask this question. One standard account that we have already encountered assumes some version of the thesis that nations act only in their own self-interest. Mark Budolfson, for instance, adopts what he calls the 'Realist Feasibility Constraint' on which 'nations act only in the interests of their current citizens, so a response to climate change is infeasible if it requires a nation to act contrary to the interests of its current citizens'.[43] We might understand noncompliance in terms of self-interest and ask about whether a particular group should undertake SAI research on the assumption that, moving forward, nations will act only in the interest of their current citizens.

But the Realist Feasibility Constraint just seems like an inaccurate characterization of how nations can be predicted to act, and thus ill-suited as a background assumption on which to base decisions about what to do now with respect to SAI, among other things. State leaders are often corrupt and have perverse incentives, and furthermore it is not even clear if states can be said to have one unified 'interest'. Returning to our earlier example, asking about whether SAI research ought to be conducted on the assumption that nations will in the future act only in accordance with their self-interest is like asking whether or not the compliers should continue dam building on the assumption that the noncompliers will

act in accordance with their own self-interest when all past evidence has shown that the noncompliers, for whatever reason, make all their decisions via Magic 8 Ball.

It seems to me that the right way to think about the future actions of political actors in our deliberations about what to do now is not so much to assume that nations will act in self-interested ways, but rather to assume that powerful political actors will (continue) to advance what they take to be their own self-interest. Call this view 'Noncompliance of the Powerful' (NCP).

Let me make a few clarificatory remarks about NCP, a position I will only be able to outline here. Notice that the position suggests reasoning on the assumption that powerful actors will advance their self-interest as they define it. This leaves room for actors to be wrong about what is in fact in their own interest, as well as to be wrong about what sorts of actions will achieve their ends. NCP also leaves room for subjective self-interest to change over time, as well as for those actors that count as 'powerful' to change over time. Notice also that NCP is consistent with the claim that nations, the powerless, and other entities also act to advance their self-interest.

What NCP does differently is that it shifts our attention from nation states to powerful actors. It asks us – for the purposes of reasoning about what to do now – to focus on the actors with the most ability to influence future policy decisions. It has become increasingly obvious that 'our' collective failure to respond to climate change is heel dragging on the part of a few powerful elites and interest groups.[44] Indeed, this phenomenon goes beyond climate change policy: findings by Martin Gilens among others have shown that wealthier citizens have an outsized influence on policy outcomes in general. When ordinary citizens support a policy that the economic elite do not support, the policy is more likely than not to fail. This is true even if the majority of the population supports the policy.[45] When it comes to SAI, then, the idea is that we may be able to similarly pinpoint a set of politicians, interest groups, and corporations with an outsized influence on the trajectory of policy and practice.

One reminder about reasoning on the assumption of NCP. NCP asks us to think about what 'we', the (hopefully) compliant, should do on the assumption that others will act wrongly. But reasoning in this way is intelligible only if 'we' can in fact be expected to comply moving forward. A conclusion about what to do now that assumes the noncompliance of the powerful cannot justifiably guide the actions of the powerful. For instance, the executive of a fossil fuel company cannot coherently reason on the assumption that fossil fuel company executives will continue to act wrongly moving forward, for she is part of what makes that assumption true in the first place. We – the well-educated and relatively powerful readers of this article – should be wary of making the same mistake.[46]

At this point, I hope to have convinced you of two things. First, the importance of engaging in a debate where both parties share the same assumptions – with each other and across their own arguments – about what future political actors can be expected to do. Second, the importance of making accurate assumptions about what future political actors can be expected to do, at least when attempting to answer the question of what to do now. I've suggested but not fully defended the idea that accuracy in our background assumptions means reasoning on the assumption of the Noncompliance of the Powerful; that is, holding constant the idea that powerful political actors will continue to act in accordance with their own view of what is in their interests.

Although I think NCP is the right way of thinking about how political actors will act moving forward, I have only sketched it here. The reason for this is that my main objective is not to fully defend NCP, but to put it to work. I want to show, in the next section, what the debate between proponents and opponents of SAI looks like with consistent (and, I think, accurate) assumptions about the future actions of political actors.

4. The Debate Over SAI Research on the Assumption of Noncompliance of the Powerful

What does the debate over SAI look like if we take Noncompliance of the Powerful to be our guiding background assumption about how political actors will act moving forward? It seems to me like we are faced with a choice between something approximating the following two scenarios:

> Solar Geoengineering Research Moratorium: Suppose that scientists collectively decide to forgo SAI research. Despite this, powerful fossil fuel interests will continue to slow mitigation progress and promote false solutions such as natural gas and so-called 'green' hydrogen. The energy transition will be slower than required to meet Paris targets: The earth's temperature will rise beyond 1.5°, and likely much higher, causing mass migration and increasing conflict, heat waves, more severe storms and wildfires, and so on. Mitigation and adaptation will take place, but it will be far from enough and adaptation will prioritize richer countries and individuals. Without SAI, there will be no hope to ameliorate many of these impacts in the short term.

> Solar Geoengineering Research Permitted to Continue: SAI is extensively funded, but it is put to illicit use. It is used to stall or halt the energy transition, and mitigation proceeds even more slowly than Scenario 1. If SAI is deployed, it is in ways that prioritize the interests of the developed world: the 'global thermostat' is set at a level that maximizes the economic output of the richest nations. Other impacts of climate change remain unaddressed. Further, the risk of termination shock and global conflict increases.

I do not mean to suggest that these two scenarios are the only way that things could play out. It is important to note here that one might agree with me that we ought to reason on the assumption of NCP yet disagree that these scenarios approximate how things might unfold on the assumption of NCP. Indeed, one thing you will notice is that these scenarios conspicuously leave out different schemes for solar geoengineering governance, which if put in place could change the calculus of powerful political actors.[47] One important role for sociologists and political scientists is fleshing out more realistic predictions about what might happen on the assumption of Noncompliance of the Powerful, or contesting the accuracy of that assumption itself.

I also do not mean to suggest that the answer to the question of whether we (the compliant) should pursue solar geoengineering research turns only on the potential consequences of doing so. I especially do not mean to propose that the answer to the question of whether we should pursue solar geoengineering research turns on which of these two options maximizes the sum of welfare, or GDP, or anything else.

The point, rather, is to show that focusing on the question of whether solar geoengineering research really presents a 'moral hazard' or will prompt future wrongdoing is misguided. All too often, the debate gets hung up on this question, as if an affirmative answer would entail that research ought not be conducted. One main message of this article is that this inference is too quick. Rather, we do better to assume SAI will prompt slower mitigation and other potential wrongs and then ask this: should we still continue to research solar geoengineering technology on these assumptions? The right way of understanding the choice we are faced with, I think, is as one between insufficient mitigation today on the one hand and, on the other, even more heel dragging facilitated by SAI plus bestowing on future decision-makers the potential ability to ameliorate some of the consequences of that heel dragging.

My project in this article has not been to provide a verdict on this choice. Rather, it has been to show that the debate over SAI research has not even arrived at this framing, because parties to both sides of the debate have failed to make accurate and consistent background assumptions about how the technology will be used and the impacts it will have. Some argue for SAI on the inaccurate assumption that a rapid energy transition will occur, illicitly inferring that research into SAI is licensed even in a scenario where it will not. Other proponents of SAI often justify the technology with pessimism about the possibility of a rapid energy transition yet are optimistic that SAI can be used only as a tool to reduce short-term climate harms rather than further slowing or even stopping the energy transition. Critics of SAI, on the other hand, are optimistic that meeting Paris targets is still socially and politically possible, yet pessimistic that SAI could be used in a way that would make that transition easier by staving off locked-in climate disasters. I hope to have shown that these ways of thinking about SAI are misguided and pointed the way towards a more productive model of conversation to use moving forward.

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NOTES

1 Evans, Simon, and Rosemond Pearce. 2020. "Mapped: The World's Coal Power Plants in 2020." https://www.carbonbrief.org/mapped-worlds-coal-power-plants. Accessed May 2022.
2 International Energy Agency. 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector." https://www.iea.org/reports/net-zero-by-2050. Accessed April 2022.
3 Pisani-Ferry, Jean. 2021. "Climate Policy Is Macroeconomic Policy, and the Implications Will Be Significant." *PIIE Policy Brief 21-20*.

4 The reason that such impacts are said to be 'locked in' is that warming is cumulative and greenhouse gasses remain in the atmosphere for 300–1000 years. Although an immediate cessation of emissions would result in temperatures stabilizing rapidly, the level at which they would stabilize represents the rise in temperature caused by cumulative emissions up to that point.
5 Goss, Michael, Daniel L. Swain, John T. Abatzoglou, Ali Sarhadi, Crystal A. Kolden, A. Park Williams, and Noah S. Diffenbaugh. 2020. "Climate Change Is Increasing the Likelihood of Extreme Autumn Wildfire Conditions across California." *Environmental Research Letters* 15(9): 1–14.
6 Philip, Sjoukje, Sarah F. Kew, Geert Jan van Oldenborgh, Faron S. Anslow, Sonia I. Seneviratne, Robert Vautard, Dim Coumou, *et al*. 2021. "Rapid Attribution Analysis of the Extraordinary Heatwave on the Pacific Coast of the US and Canada June 2021." *Earth System Dynamics Discussions [Preprint]*: 1–34.
7 Heilmann, Kilian, and Matthew Kahn. 2019. "The Urban Crime and Heat Gradient in High and Low Poverty Areas." *NBER Working Paper Series*.
8 Carbon capture and storage (CCS) technologies are considered by some to be a type of 'geoengineering'. In this article, I focus on a specific kind of solar geoengineering, leaving CCS aside.
9 SAI is sometimes also called 'Solar Radiation Management', or SRM. In what follows, I will use 'SAI' or the more general term 'solar geoengineering' to refer to these methods.
10 Irvine, Peter, and David Keith. 2020. "Halving Warming with Stratospheric Aerosol Geoengineering Moderates Policy-Relevant Climate Hazards." *Environmental Research Letters* 15(4): 1–12.
11 Smith, Wake. 2020. "The Cost of Stratospheric Aerosol Injection through 2100." *Environmental Research Letters* 15(11): 1–15. Smith's calculations do not include the cost of governance, monitoring, or potential compensation to countries harmed by SAI injection, and thus may be underestimates. See Reynolds, Jesse, Andy Parker, and Peter Irvine. 2016. "Five Solar Geoengineering Tropes That Have Outstayed Their Welcome." *Earth's Future* 4(12): 562–68 for a critique of the narrative that SAI is 'cheap'.
12 Irvine, Peter, Ben Kravitz, Mark G. Lawrence, Dieter Gerten, Cyril Caminade, Simon N. Gosling, Erica J. Hendy, *et al*. 2017. "Towards a Comprehensive Climate Impacts Assessment of Solar Geoengineering." *Earth's Future* 5(1): 93–106.
13 Jones, Anthony, Matthew K. Hawcroft, James M. Haywood, Andy Jones, Xiaoran Guo, and John C. Moore. 2018. "Regional Climate Impacts of Stabilizing Global Warming at 1.5 K Using Solar Geoengineering." *Earth's Future* 6(2): 230–51.
14 For more information about the funding of international SAI projects, see Necheles, Ella, Lizzie Burns, Amy Chang, and David Keith. 2018. "Funding for Geosolar Engineering from 2008 to 2018." https://geoengineering.environment.harvard.edu/blog/funding-solar-geoengineering#disqus_thread. Accessed April 2022.
15 Based on data compiled by Joshua Horton and Masumi Ito; available upon request.
16 National Academies of Sciences, Engineering, and Medicine. 2021. *Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance*. Washington DC: National Academies Press, p. 1. My emphasis.
17 Political philosophers often call reasoning on the assumption of full compliance 'ideal theory', and reasoning on the assumption of partial compliance 'nonideal theory'. But this is not the only way of understanding the ideal/nonideal theory distinction, so to avoid potential confusion I will not use that terminology here.
18 One could, however, adopt a narrower or wider understanding of these terms by, for instance, thinking about compliance and noncompliance when it comes to climate action more generally – which might include things like reparations for past climate harms or procedural demands – or even compliance when it comes to all that morality demands. Despite my focus on compliance when it comes to the speed of the energy transition, the arguments I will present do not depend on a particular understanding of the scope of noncompliance.
19 What exactly do I mean by 'political actors' here? The way I'm using the term is similar to the way many philosophers use the term 'agent', which typically amounts to any individual or group with the capacity to act based on reasons. See List, Christian, and Philip Pettit. 2011. *Group Agency: The Possibility, Design, and Status of Corporate Agents*. Oxford: Oxford University Press, for a standard account.
20 Keith, David. 2021. "What's the Least Bad Way to Cool the Planet?" New York Times. https://www.nytimes.com/2021/10/01/opinion/climate-change-geoengineering.html?smid=url-share. Accessed 1 October 2021.
21 For one overview, see Hallegatte, Stéphane, Adrien Vogt-Schilb, Julie Rozenberg, Mook Bangalore, and Chloé Beaudet. 2020. "From Poverty to Disaster and Back: A Review of the Literature." *Economics of Disasters and Climate Change* 4(1): 223–47.

22 This argument has been gaining traction. For an overview, see Neuber, Frederike, and Konrad Ott. 2020. "The Buying Time Argument within the Solar Radiation Management Discourse." *Applied Sciences (Switzerland)* 10(13): 1–22.

23 Notice that this is not yet an argument that solar geoengineering technology can reduce the required speed of the energy transition now. At present, the technology is not yet well-researched enough to deploy even absent all the political uncertainties involved. There is an important moral difference between slowing the pace of the energy transition when the technology is readily available to mitigate the risks of doing so and slowing the pace of the energy transition in anticipation that such technology may at some point be workable.

24 Climate Action Tracker. 2022. "Despite Glasgow Climate Pact, 2030 Climate Target Updates Have Stalled. Mid-Year Update." Accessed March 2022. https://climateactiontracker.org/publications/despite-glasgow-climate-pact-2030-climate-target-updates-have-stalled/

25 This observation is not a new one: many philosophers have critiqued full compliance theories for failing to give an answer to the question of what to do under conditions of noncompliance. For one example, see Murphy, Liam. 2001. *Moral Demands in Nonideal Theory*. New York: Oxford University Press.

26 Horton, Joshua, and David Keith. 2016. "Solar Geoengineering and Obligations to the Global Poor." In *Climate Justice and Geoengineering: Ethics and Policy in the Atmospheric Anthropocene*, edited by C.J. Preston, 79–92. Lanham, MD: Rowman & Littlefield International, p. 83. For more analysis of arguments with a similar structure, see Gardiner, Stephen. 2010. "Is 'Arming the Future' with Geoengineering Really the Lesser Evil?" In *Climate Ethics: Essential Readings*, edited by S. Gardiner, 284–312. Oxford: Oxford University Press.

27 Hourdequin, Marion. 2018. "Climate Change, Climate Engineering, and the 'Global Poor': What Does Justice Require?" *Ethics, Policy and Environment* 21(3): 270–88, p. 280.

28 Horton and Keith op. cit., p. 83. On my reading of Horton and Keith, they would agree with Hourdequin that there is an obligation to prioritize the global poor in research and deployment. Their point is that the case for SAI goes through even if governments do not live up to that particular obligation.

29 Of course, this depends on the empirical claim that SAI deployed to advance the interests of high-income nations would also benefit poor nations. Some have questioned this empirical situation. Most recently, for instance, some have argued that SAI could increase malaria risk in some developing counties. See Carlson, Colin, Rita Colwell, Mohammad Sharif Hossain, Mohammed Mofizur Rahman, Alan Robock, Sadie J. Ryan, Mohammad Shafiul Alam, *et al.* 2022. "Solar Geoengineering Could Redistribute Malaria Risk in Developing Countries." *Nature Communications* 13(1): 1–9. I suspect, however, that given just how bad the 'business as usual' situation will be, it is not a high bar for SAI to benefit the global poor relative to that scenario.

30 For similar arguments to this effect, see Harding, Anthony, Katharine Ricke, Daniel Heyen, Douglas G. MacMartin, and Juan Moreno-Cruz. 2020. "Climate Econometric Models Indicate Solar Geoengineering Would Reduce Inter-Country Income Inequality." *Nature Communications* 11: 1–9; Buck, Holly Jean. 2012. "Geoengineering: Re-Making Climate for Profit or Humanitarian Intervention?" *Development and Change* 43(1): 253–70.

31 I avoid leaning heavily on the term 'moral hazard', as I find it is often more confusing than it is clarifying. One area of confusion is that those that share this concern often differ as to what level of reduced mitigation counts as acting wrongly. On one view, deviation from the speed of the energy transition that would be required in the absence of solar geoengineering technology counts as the sort of putative wrong that solar geoengineering might make more likely. On a second view, the existence of SAI technology would in fact change the morally required speed of the energy transition. For instance, as Keith notes, on a utilitarian calculation we should slow emissions cuts if geoengineering can reduce the aggregate damages from climate change. For more on the term 'moral hazard' in the SAI debate, see Hale, Benjamin. 2012. "The World That Would Have Been: Moral Hazard Arguments Against Geoengineering." In *Reflecting Sunlight: The Ethics of Solar Radiation Management*, edited by C. Preston, 1–28. Lanham, MD: Rowman & Littlefield.

32 Ellison, Katherine. 2018. "What on Earth? Why Climate Change Skeptics Are Backing Geoengineering." Reveal, March 22, 2018. https://revealnews.org/article/why-climate-change-skeptics-are-backing-geoengineering/

33 Ellison op. cit.

34 The 'significantly' is (significantly) underspecified here. Various versions of the Anticipated Future Wrongdoing argument will also differ with respect to what counts as significant.

35 McKinnon, Catriona. 2020. "The Panglossian Politics of the Geoclique." *Critical Review of International Social and Political Philosophy* 23(5): 584–99.

36 McKinnon, Catriona. 2019. "Sleepwalking into Lock-in? Avoiding Wrongs to Future People in the Governance of Solar Radiation Management Research." *Environmental Politics* 28(3): 441–59.
37 Katz, Eric. 2015. "Geoengineering, Restoration, and the Construction of Nature." *Environmental Ethics* 37(4): 485–98.
38 Surprise, Kevin. 2020. "Stratospheric Imperialism: Liberalism, (Eco)Modernization, and Ideologies of Solar Geoengineering Research." *Environment and Planning: Nature and Space* 3(1): 141–63.
39 Bierman, Frank, Jeroen Oomen, Aarti Gupta, Saleem H. Ali, Ken Conca, Maarten A. Hajer, Prakash Kashwan, *et al.* 2022. "Solar Geoengineering: The Case for an International Non-use Agreement." *WIREs Climate Change* 13(3): 754.
40 Bierman *et al.* op. cit.
41 For one study to this effect, see Merk, Christine, Gert Pönitzsch, and Katrin Rehdanz. 2016. "Knowledge about Aerosol Injection Does Not Reduce Individual Mitigation Efforts." *Environmental Research Letters* 11(5): 1–6.
42 I address this question in a work in progress paper, "Solar Geoengineering and the Speed of the Energy Transition."
43 Budolfson, Mark. 2021. "Political Realism, Feasibility Wedges, and Opportunities for Collective Action on Climate Change." In *Philosophy and Climate Change*, edited by M. Budolfson, T. Mcpherson, and D. Plunkett, 323–45. Oxford: Oxford University Press.
44 Franta, Benjamin. 2021. "Weaponizing Economics: Big Oil, Economic Consultants, and Climate Policy Delay." *Environmental Politics* 31(4): 555–75.
45 Gilens, Martin, and Benjamin Page. 2014. "Testing Theories of American Politics: Elites, Interest Groups, and Average Citizens." *Perspectives on Politics* 12(3): 564–81.
46 G.E. Cohen calls this the 'impersonal test', where we 'test how robust a policy argument is by subjecting it to variation with respect to who is speaking and/or who is listening when the argument is presented. … If, because of who is presenting it, and/or to whom it is presented, the argument cannot serve as a justification of the policy, then whether or not it passes under other dialogical conditions, it fails (tout court) to provide a comprehensive justification of that policy'. Cohen, G.E. 2008. *Rescuing Justice and Equality*. Cambridge, MA: Harvard University Press, p. 42.
47 For an extensive overview of governance proposals, see Reynolds, Jesse. 2019. *The Governance of Solar Geoengineering: Managing Climate Change in the Anthropocene*. Cambridge: Cambridge University Press.