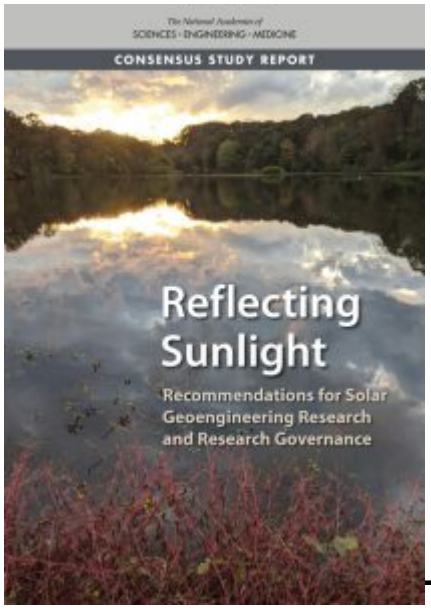
A few of us are part of the Emmett Institute's Geoengineering Governance Project, where we study the legal and policy issues presented by solar geoengineering and carbon dioxide removal technologies. On the former set of technologies—that is, reflecting a little incoming sunlight to cool the Earth and temporarily counteract heating from greenhouse gases—the US National Academies of Science, Engineering, and Medicine recently issued an important report *Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance*. At well over 300 pages, there is much substance to cover. Here, a few of us offer brief initial reactions: Ted Parson offers some in-depth context; Charles Corbett considers whether and how Congress could take up the recommendations; Adrien Abecassis suggests that the report will influence other countries; and I (Jesse Reynolds) highlight a few specific recommendations, including those regarding international cooperation.



Ted Parson:

Last weeks' National Academies' report is an important landmark in debate over solar geoengineering research, which promises a real advance in prospects for mobilizing an effective response to climate change.

To understand the importance of this report, some context is needed. Solar geoengineering became prominent about ten years ago, largely in reaction to long-standing prior failure to curb greenhouse-gas emissions. Around 1990, when the threat of climate change was clear and international discussions began, atmospheric carbon dioxide was about 350 parts per million (ppm), already well

above the pre-industrial level of 270 ppm. Today it reached 420 ppm, and it continues to increase by about 2 ppm per year with no sign yet of the increase slowing. This decades-long failure to cut emissions doesn't mean that we're headed to an inevitable climate catastrophe, or that further efforts to limit climate change are futile. On the contrary, rapid global emissions cuts are more intensely needed than ever, because they are the difference between pretty bad, very bad, and ghastly climate futures. But the delay has real costs. Many easier opportunities to stop climate change have been missed over that 30 years. As a result, prospects for coming climate changes and impacts are worse, and efforts needed to limit these are more extreme—in cost, disruption, and other social and environmental impacts.

In this context, solar geoengineering might be able to extend and complement other climate responses—emissions cuts, adaptation, and removing previously emitted carbon dioxide from the atmosphere—to reduce climate risks more, and faster, than these other responses can by themselves. But it's not a silver bullet. Any solar geoengineering intervention would be an imperfect technical fix that does not address the root cause of climate change. Solar geoengineering would also present new uncertainties, environmental and socio-economic impacts, and legal, policy, and geopolitical challenges. But if climate change is bad enough, other responses are insufficient, and risks of solar geoengineering can be adequately controlled, using it might be less bad than the alternative—for human welfare, especially the most vulnerable, and for non-human species and ecosystems. We really don't know.

The normal response to such high stakes and uncertainties is to do research—and in this case, also to build governance capacity. But even proposals to expand solar geoengineering research have met sharp opposition. This opposition, which has limited research resources and hindered progress in understanding for more than ten years, is mainly based on three claims: identifying research with full-scale operational deployment; asserting that researching solar geoengineering will weaken emissions cuts; and treating solar geoengineering in isolation, divorced from the risks, costs, and injustices of climate change itself, and of other responses if pursued strongly enough to limit climate-change risks. My colleagues and I have addressed each of these arguments and their implications in detail elsewhere, so I will do so only very briefly here.

Identifying research with full-scale deployment

Present and proposed research involves lab studies, computer models, passive

environmental observations (e.g., of volcanic eruptions), and tiny field experiments. The most controversial experiment now proposed would spray one or two kilograms of material in the stratosphere. These are a long way from global deployment. It is sometimes suggested that starting research would create pressure for continuation and expansion, but no plausible mechanism for such lock-in has been proposed, and the analogies sometimes suggested (e.g., early technical competition between VHS and Betamax video-recording formats) don't fit. I can't claim certainty that this would not happen, but it appears unlikely a priori, and easy to control by designing research programs with periodic break-points and re-assessments.

Undermining emissions reduction

Might considering or researching solar geoengineering weaken resolve for needed greenhouse gas emissions cuts? This is the most prominent objection, and it's a plausible concern that needs to be taken seriously, but there are reasons to question the strength of the effect, and even its sign. Emissions reductions have have been inadequate for 30 years, since long before solar geo was discussed. Studies of people's willingness to pay for emissions cuts mostly find the opposite effect: learning about solar geoengineering makes people more, not less, willing to support costly emissions reductions. In effect, solar geoengineering acts like a credible signal of climate alarm that galvanizes support for all responses, not an excuse to stint on emissions cuts. These are early results, which do not decisively refute the concern. But they do suggest the value of further research, and exploration of governance approaches, to identify ways to make climate responses mutually strengthening.

Even-handed precaution: Solar geoengineering in context of climate-change risks

The risks, potential for misuse, and governance challenges of solar geoengineering are serious. But these only warrant categorically refusing to consider it, and thus rejecting research, if they are clearly worse than the alternatives on whatever criteria you care about—e.g., net social benefit, risk, sustainable development, human rights, global justice. The alternatives mean some combination of enduring the disruption and suffering of climate change, and limiting it through other means. Solar geoengineering might fail this comparison—research opponents make this claim with great confidence—but we simply don't know. No one has tried to do the comparison; and since the specific potential contributions and risks of solar geoengineering are unknown without doing the research, rejecting research means refusing to do the comparison. Opponents of solar geoengineering research don't

typically claim climate change risks aren't that bad. That (insupportable) claim is largely the province of those who oppose emissions cuts—mainly fossil-fuel interests—who have, with rare exceptions, been silent on solar geoengineering. But opponents often do assert that solar geo would never be warranted because emissions cuts can still adequately limit climate risks—reliably, rapidly, with low cost and negligible harmful impacts, particularly for the most vulnerable. This claim would probably have been correct for a well designed emissions reduction strategy starting in 1990. It might even still be true today. I'm dubious, but on this one I would be thrilled to be wrong. But we really don't know. Given the late start, we must consider the possibility that emissions policies extreme enough to limit climate risks in time, even if feasible, would bring societal disruption, coercion, and conflict more severe than the effects of solar geoengineering—once again, particularly for the most disadvantaged and vulnerable. To bar solar geo research, or restrict it with burdens so severe as to be equivalent to prohibition, would commit to this pathway without even exploring a potentially less harmful alternative.

Or the consequences of stifling solar geoengineering research might be even worse. Even if research remains blocked or continues at a trickle, nobody today can block governments from ever turning to it in some potential future climate emergency. For all the uncertainty about how to do it effectively, controllably, safely, and with low environmental damage, the basics are widely enough known that a dozen-odd states could very likely do it badly. Rather, continuing to stall research will only ensure that any consideration of future use takes place under conditions of less knowledge, weaker governance capacity and norms, and greater confusion and panic. This prospect embeds a tragic irony in present opposition to solar geoengineering research. The more opponents succeed at blocking and delaying solar geoengineering research out of fear of severe climate change and dangerous, unjust responses, the more likely these outcomes become—including the prospect of future solar geoengineering deployments undertaken in haste, desperation, and ignorance. Their success makes more likely exactly what they fear.

The Significance of the National Academies Report

This context is why the new report is so important, arguably the most important contribution to this debate since the UK Royal Society report of 2009. This is the first time an authoritative expert body, including members with a wide range of expertise and of prior views and concerns, has made a clear, specific recommendation for a new solar geoengineering research program. Moreover, the

committee bolstered that recommendation with a set of concrete, specific proposals for the program's scale, institutional setting and oversight, and broad subject-matter areas. They treated concerns with great seriousness, advancing a long, detailed set of proposals to address them. At the same time, they did not cede advance veto power over research based on unlimited demands for ideal governance.

That is a large step. Given the intensity of this debate and the frequency of personal attacks, it is also a courageous step. It did, however, leave the committee with the challenge of conveying a rather subtle and nuanced message in the context of a highly polarized, and thus simplifying, debate. The response has thus been predictably noisy and confused. For example, a *New York Times* headline (later corrected) erroneously stated that the committee endorsed use of the technologies: No, the committee only supported research into the technologies, not their use.

Now the location of action shifts, in a few ways: To the US Congress, to consider whether and how to implement the recommended US federal research program; to legislators and research agencies in other governments, to decide whether, when, and how to establish similar research programs and international cooperative networks; and to researchers, funders, and other non-governmental actors potentially involved with solar geo research, to decide how to operationalize the Committee's extensive additional governance recommendations for research outside the proposed US federal program. My colleagues and I at the UCLA Emmett Institute's Geoengineering Governance Project look forward to aiding and contributing to these various deliberations.

Charles Corbett:

I was pleasantly surprised to see the National Academies report directly call for a US research program on solar geoengineering. I was even happier with the extent to which the proposal prioritized governance concerns and sociotechnical issues. The suggested funding level—$100 to $200 million total, over 5 years—would substantially expand current federal funding of solar geoengineering research. But it would represent a small portion of the billions the United States spends annually investigating climate change. As it should be. Emissions reduction and adaptation must be the center of US climate policy. Solar geoengineering could, at best, only supplement our core climate strategy.

The report is not a proposal to develop or deploy solar geoengineering. If funded,

the research would aim to better characterize the risks and potentials of solar geoengineering techniques and understand the governance needs of a deployment system. In other words, the program would try to provide decision-makers with the information they need to figure out whether and how to proceed. Maybe the idea would still seem promising after further study. Or maybe the program would demonstrate that solar geoengineering is far too risky to consider further, putting the idea finally to rest. Right now, it is too poorly understood to decide one way or the other.

The National Academies report is only a proposal. It would be Congress's job to bring a just and effective research program to fruition. A good next step would be to hold a committee hearing in Congress. The report's level of detail does not always make for a user-friendly document, and lawmakers may wish to pin down experts to a more concrete set of recommendations. They might also want to gather more facts to inform program design choices. A congressional hearing would also be a great opportunity to invite stakeholder testimony from the climate world at large. The public should be included in the decision-making process from the very start.

One issue the report is fuzzy on is the relationship between a US program and international research and governance. For obvious reasons, it would be a very bad governance outcome for the United States to exclusively control the trajectory of solar geoengineering. That is why I support the report's recommendation to dedicate funding to help build capacity in the Global South in this area. I also echo its call for increased international deliberation. But the US government would need to clarify how it would build international engagement. It would also need to explain how it would ensure the program does not interfere with meeting Paris Agreement obligations.

Solar geoengineering is not an idea that will go away on its own. Nor could it realize itself automatically in the middle of a climate crisis. To resolve this question, we must address it squarely and intentionally. This report is a step in the right direction.

Adrien Abecassis:

If Congress follows the National Academies report's recommendations, it might well be that future historians will recognize it as a landmark in the development of solar geoengineering on a global scale.

The Commission, comprised of 16 members of which only one is not from North America, made its main recommendation that a US federal research program be developed on solar geoengineering. Yet, it already has resonance throughout the world. A $100 million program would represent a dramatic increase in the current scale of current research, elevating solar geoengineering definitely out of the margins of climate research. Such a move would signal, to many countries around the world, that the United States engages seriously in researching this technology. This would “authorizes” the removal of reluctance elsewhere.

Even if the Academy’s recommendations insist that a research program should integrate international cooperation into its design, there is little doubt that many countries will still view this effort as aligned with American interests. By construction, solar geoengineering has a global impact. In the absence of a multilateral research effort, major countries and regions may choose not to rely entirely on the findings of a US-led effort. They might work to examine in greater detail certain angles critical to their own interests, or cross-check the results, or even advance their own agenda.

Some capitals in Europe are already assessing whether they should seek new guidance from their own academies of science on whether to pursue research into this technology, or to initiate their own research programs directly (such as the GENIE program, which will start on May 1st, 2021 for 6 years, funded by the European Commission with $10 million). China and India will most certainly not allow major research effort on a technology to develop that may potentially have a strong impact on them without preparing themselves to be able to participate in this global discussion.

In this sense, the report should not be confined to a national reading, and the effects it will have throughout the world will be as interesting to scrutinize as its direct effect on a potential new US research effort.

Jesse Reynolds:

The National Academies’ report strikes the right tone, particularly considering the committee’s difficult, if not controversial, mandate. It foregrounds solar geoengineering’s apparent ability to reduce climate change while noting that solar geoengineering could also introduce its own risks, governance challenges, and ethical objections. The suggested research program is (and should be) quite small relative to efforts toward other climate responses, would include and integrate

diverse disciplines, and should aim to generate policy-relevant knowledge—not a path toward implementation.

A couple of the specific recommendations resonated with me. First, the report recognizes that, in the absence of state action, diverse nonstate actors—scientists, their research institutions, funders, publishers, and professional societies—can and should play important governing roles in the meantime:

> Recommendation 5.1b Funders of SG [solar geoengineering] research—including government agencies, universities, and philanthropic organizations—should mandate as a condition of funding that SG research adhere to an accepted code of conduct or, if no code has yet been accepted.

This echoes what my Emmett colleague Ted Parson and I wrote last year: that these actors have the capacity, knowledge, and interests, for example, to help enable high-quality research as well as to control potential harms and risks via the development, monitoring, and enforcement of norms, guidelines, and standards. Second, the report says that "SG researchers should pledge not to assert patents relating to SG against other researchers who are conducting related research." This is based on a pair of papers by Jorge Contreras (University of Utah), Joshua Sarnoff (DePaul University), and me. There, we describe how a bottom-up "research commons" centered on "patent pledges" could manage several issues in this space while maintaining scientists' and inventors' incentives to innovate.

Finally, the recommendations' are remarkably international. Granted, that scale was part of the committee's task. Nevertheless, international aspects—variously cooperating, coordinating, consulting, and co-developing—are prominent even in the report's highest level statements. For example:

> Recommendation 4.1…The [research] program should, from the outset, prioritize development of international coordination and co-development of research with other countries.
>
> Recommendation 5.1 A U.S. national solar geoengineering research program should operate under robust research governance and support the development or designation of an international governance

mechanism.

This is notable because the US has been accused—sometimes fairly, sometimes not—of dodging if not undermining international cooperation and governance—including in matters of the environment, climate change, and geoengineering. Some critics purport that solar geoengineering is prone to unilateral action, especially by superpowers, and that the National Academies' report is an indication that the US intends to push and control this issue. In contrast, the report's recommended early international cooperation would foster trust and help prevent conflict. Hopefully this outlook remains as Congress, agencies, and nonstate actors consider and take up the committee's recommendations.