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PERSPECTIVE

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Solar geoengineering: The case for an international non-use agreement

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Abstract

Solar geoengineering is gaining prominence in climate change debates as an issue worth studying; for some it is even a potential future policy option. We argue here against this increasing normalization of solar geoengineering as a speculative part of the climate policy portfolio. We contend, in particular, that solar geoengineering at planetary scale is not governable in a globally inclusive and just manner within the current international political system. We therefore call upon governments and the United Nations to take immediate and effective political control over the development of solar geoengineering technologies.

Specifically, we advocate for an International Non-Use Agreement on Solar Geoengineering and outline the core elements of this proposal.

This article is categorized under:
Policy and Governance > International Policy Framework

KEYWORDS

climate engineering, solar geoengineering, solar radiation management, solar radiation modification

1 | INTRODUCTION

Solar geoengineering is gaining prominence in climate change debates as a topic worth studying. Some see it also as a potential future policy option. Solar geoengineering describes a set of hypothetical technologies to reduce incoming sunlight on earth, that is, to "dim the sun" (National Academies of Sciences, Engineering, and Medicine, 2021). Such speculative interventions are sometimes also referred to as solar radiation management or solar radiation modification (the latter term is used in the Intergovernmental Panel on Climate Change's Special Report on Global Warming of 1.5°C). Solar geoengineering differs from an alternative set of technologies that would remove carbon dioxide from the atmosphere; both approaches are sometimes together referred to as geoengineering or climate engineering. Our focus here is solely on solar geoengineering.

Solar geoengineering is mainly discussed as an intervention at planetary scale to lower global mean temperatures in response to global warming. The most prominent proposal is the injection of aerosols in the stratosphere to inhibit the influx of solar energy. Interventions that are more regional or local in intent, such as marine cloud brightening to protect fragile ecosystems such as the Great Barrier Reef, are also conceivable, but they differ significantly in terms of governance, politics, and scale.

The idea of solar geoengineering is gaining traction in a few industrialized countries. In March 2021, for instance, a report by a committee of the US National Academy of Sciences concluded that the United States should establish, ideally in international collaboration, a research program to assess the feasibility of solar geoengineering as a stopgap measure for addressing anthropogenic climate change (National Academies of Sciences, Engineering, and Medicine, 2021). Individual researchers in the United States have called for a globally organized "mission-driven research program" on solar geoengineering (Morrow, 2020) and for a special IPCC report on this topic (Reynolds, 2021). Harvard University has set up a Solar Geoengineering Research Program that plans among others a Stratospheric Controlled Perturbation Experiment to study the behavior of stratospheric aerosols. Yet there is also fierce resistance to such experiments. A planned field test by the Harvard group over Sweden met significant local resistance from Indigenous people and environmentalists, eventually scuttling the test for now. In short, in some expert circles, solar geoengineering is now seen as a legitimate research topic and potential future climate policy option (Dai et al., 2021).

Advocates of solar geoengineering research argue, implicitly or explicitly, that international climate governance has been largely ineffective and that the Paris Agreement's goal of limiting global warming to well below 2°C and preferably to 1.5°C is unlikely to be met, given current trends and policies (e.g., Svoboda et al., 2018; Wagner, 2021). Therefore, proponents argue, solar geoengineering should be researched now to better understand its potential efficacy and to have it available, if deemed feasible, as a future option (Keith, 2013). According to these perspectives, solar geoengineering could be used in the future either as a temporary measure to buy time to realize full decarbonization ("peak-shaving" of temperature increases) or as a failsafe to limit climate hazards in the event that decarbonization or carbon neutrality cannot be achieved in time (Irvine et al., 2019; Keith et al., 2017).

To us, these proliferating calls for solar geoengineering research and development are cause for alarm, as they risk the normalization of these technologies as a future policy option. So far, the risks and efficacy of solar geoengineering are poorly understood (Barrett et al., 2014; Kravitz & MacMartin, 2020; Lawrence et al., 2018; Schneider et al., 2020). Impacts are likely to vary across regions, as artificial cooling will affect some regions more than others. There are also uncertainties about the effects on regional weather patterns, agriculture, and the provision of basic needs of food and water. Current research is also often based on idealized modeling schemes and presumes facilitative politics that will be impossible to realize in today's fractious international order (Corry, 2017; Low & Honegger, 2020; McLaren, 2018).

Even with more research, there is deep-seated disagreement about whether the risks and effectiveness of solar geoengineering could ever be fully understood before deployment, and whether specific effects could be attributed afterwards to such interventions (Oomen, 2021). Furthermore, there are serious concerns about "locking in" solar geoengineering as an infrastructure and policy option (e.g., Cairns, 2014; Flegal et al., 2019; McKinnon, 2019; McLaren & Corry, 2021), as well as about militarization and security (e.g., Chalecki & Ferrari, 2018; Corry, 2017; Heyen et al., 2019; Robock, 2015).

2 | CAN WE GOVERN SOLAR GEOENGINEERING FAIRLY AND EFFECTIVELY?

Our main concern, however, is with the global governance challenges posed by the confluence of technical, political, and ethical risks of such large-scale interventions at planetary scale. We see the deployment of solar geoengineering as impossible to govern fairly and effectively in the current international political system, under assumptions of effective global participation, inclusiveness, and justice. Other critics have argued in the past that solar geoengineering is "undesirable, ungovernable, and unattainable" (Hulme, 2014) and incompatible with democratic decision-making (Stephens et al., 2021; Szerszynski et al., 2013). We share these worries and turn them into a concrete policy proposal.

Our core concern as governance scholars is that solar geoengineering at planetary scale would require complex global decisions on the places and manner of deployment, the intensity of deployment (i.e., the degree of cooling), the duration of deployment, and the responsibility and compensation for any harm that may be caused (Jinnah et al., 2019). As solar geoengineering would impact all countries, fair and just governance would require the effective control over the deployment of such technologies by all countries (Holahan & Kashwan, 2019). Importantly, the type and degree of deployment would affect different countries differently, and risks would be unevenly spread. As the specific manner of deployment would influence the distribution of these risks, democratic decision-making at planetary scale would be even more crucial—and even harder to safeguard in a fair and just manner.

Globally inclusive decision-making and political control over solar geoengineering would be especially important for the poorest and most vulnerable countries. Six-hundred and ninety-six million people live in extreme poverty, on less than USD 1.90 a day, and 3.2 billion people live on less than USD 5.50 a day (Aguilar et al., 2021). Over 820 million people suffer from hunger, which is equal to one in every nine people worldwide (UN Food and Agriculture Organization, 2019). These global poor are extremely vulnerable to any change in their environment and threatened the most by any risks or side effects that might result from the deployment of solar geoengineering at planetary scale. Conversely, the global poor would also be the first to suffer from drastic climate change. Various researchers have argued that this suffering could be alleviated by solar geoengineering (Harding et al., 2020; Wagner, 2021), leading some to postulate a moral obligation of industrialized countries to engage in solar geoengineering research to compensate for past and current greenhouse gas emissions (Svoboda et al., 2018). Yet one cannot achieve climate justice by addressing one aspect of justice and violating another (Schlosberg & Collins, 2014). While historical responsibility for the inequitable impacts of climate change is an important demand of climate justice, so is inclusion and participation in planetary-scale decisions. Both the all-affected principle of democracy and procedural justice require governance that is globally inclusive.

Because of the high vulnerability of the least developed countries and many other countries in the Global South, their governments would need to have decisive control over whether and how to deploy solar geoengineering technologies. Yet there is little evidence to suggest that countries most able to develop technologies for solar geoengineering would be willing to transfer effective control of such geopolitically important technologies to the most vulnerable countries in the Global South. Considering the stakes for the Global South, mere consultation of least developed and other developing countries over technology development and potential deployment—as suggested by some proponents of solar geoengineering—would not be sufficient. Full knowledge integration for the Global South is important, for sure (Rahman et al., 2018; Winickoff et al., 2015). But eventually, it is *effective* and *enforceable* political control by the Global South that would be required.

To guarantee such globally inclusive and effective governance, countries powerful enough to develop and deploy technologies for solar geoengineering would need to place their technologies under the control of effective multilateral institutions, with guarantees of collective veto rights for the most vulnerable nations. The current world order seems unfit to reach such far-reaching agreements on fair and effective political control over solar geoengineering deployment. The United Nations General Assembly, as the highest organ of the world organization, declared climate change in 1988 a "common concern of humankind", but the assembly lacks enforcement powers and its decisions are not binding. The United Nations Environment Programme (UNEP) with its United Nations Environment Assembly, which deals with many environmental issues, is constrained in its mandate and operational capacity. In 2019, a proposed UNEP resolution to undertake a cautionary assessment of geoengineering options, including solar geoengineering, was blocked by the United States, Brazil, and Saudi Arabia (Chemnick, 2019). Like the United Nations General Assembly, the United

Nations Framework Convention on Climate Change also lacks the institutional force that could guarantee just, equitable and effective multilateral control over deployment of solar geoengineering technologies at planetary scale.

In addition, any global decisions on the details of the deployment of solar geoengineering are unlikely to find consensus. Disagreements about some parameters—for example, the degree of cooling, the duration of deployment, or the specific latitudes and distribution of aerosols—will inevitably occur. Such situations would require clear and reliable decision-making procedures for solving these disagreements. Most United Nations bodies follow the principle of sovereign equality, which grants each country one vote. It is unlikely that technologically advanced nations such as the United States or Russia would accept such a system of oversight for planetary-scale use of solar geoengineering. Universally accepted alternatives to one-country-one-vote decision-making, however, are not in sight.

Importantly, any decision by a global body to deploy solar geoengineering technologies would require enforcement power in case some countries disagree with a majority decision and threaten counteractions. The literature even discusses scenarios of counter-geoengineering by countries that disagree with the solar geoengineering programs of other countries (Heyen et al., 2019). The United Nations Security Council has a mandate to act if it deems a situation to be a threat to international peace and security. Yet the Security Council, with five countries having permanent seats and veto rights, does not enjoy the global legitimacy to effectively regulate future global deployment of solar geoengineering technologies. And it cannot take actions against any of its five permanent members (i.e., China, France, Russia, the United Kingdom, and the United States).

These concerns about formal governance also arise with more informal governance arrangements, such as multi-stakeholder dialogues or voluntary codes of conduct (Jinnah et al., 2019). Such arrangements face similar barriers to entry by less powerful actors, and they risk contributing to premature legitimization of these speculative technologies as well (Conca, 2019). Science networks in general are heavily biased towards a few industrialized countries, with less economically powerful countries having little or no direct control over them (Biermann & Möller, 2019; Stephens et al., 2021). Moreover, technocratic governance based on expert commissions or scientific modeling of distributive consequences cannot adjudicate complex global conflicts over values, risk allocation, and differences in risk acceptance (Flegal & Gupta, 2018).

In short, the deployment of solar geoengineering at planetary scale would require entirely new international organizations with convincing means of democratic control and unprecedented enforcement powers. Such organizations do not exist.

Without effective global and democratic controls, however, the geopolitics of possible unilateral deployment of solar geoengineering would be complex and frightening. International law remains vague when it comes to development and deployment of such technologies (Reynolds, 2019). In the absence of effective governance mechanisms, expert debates and scientific research assessments within a few industrialized countries could develop into a form of "de facto governance" (Gupta & Möller, 2019), but often in ways not legitimized or supported by developing countries in particular (Biermann & Möller, 2019). Given the anticipated low monetary costs of some of these technologies, such as stratospheric aerosols injection, a few countries could engage in solar geoengineering unilaterally or in small coalitions even when other countries oppose such deployment—a possibility economists have presented as the "free-driver effect" (Wagner & Weitzman, 2012). Some proponents from the Global North see it even explicitly as an advantage of solar geoengineering that it could be deployed "without broad international cooperation" (Reynolds, 2021).

Last but not least, speculative hopes about the future availability of solar geoengineering technologies could threaten commitments to mitigation and reduce incentives for governments, businesses, and societies to do their utmost to achieve decarbonization or carbon neutrality as soon as possible (Asayama et al., 2019). Powerful industry interests, notably from the energy sector, have long invested in delaying stringent climate policies; seeking out technical alternatives such as carbon dioxide removal and sequestration (Carton et al., 2020; Lamb et al., 2020; Low & Boettcher, 2020; McLaren & Markusson, 2020); or denying the phenomenon of climate change altogether (Oreskes & Conway, 2010). The looming possibility of future solar geoengineering could become a powerful argument for energy companies and oil-dependent countries to further delay decarbonization policies. This risk is particularly high now, with a surge of countries announcing their intention to reach net-zero emissions by 2050 or earlier.

3 | THE CASE FOR A NON-USE AGREEMENT ON SOLAR GEOENGINEERING

For these reasons, we call for immediate political action from governments, the United Nations and other actors, such as civil society organizations, to forestall further normalization of solar geoengineering as a future climate policy option. Governments and the United Nations need to take effective political control and restrict the development of solar geoengineering technologies before it is too late.

Our call for international political control over the development of contested, high-stakes technologies with planetary risks is far from unprecedented. The international community has a rich history of international restrictions and moratoria over activities and technologies judged to be too dangerous, undesirable, and risky. For example, governments have issued a moratorium on mining in Antarctica and have banned the emission of substances that deplete the ozone layer. Various nuclear activities, the dumping of most types of waste at sea, some uses of outer space, the production of many harmful chemicals, exports of hazardous waste, and so forth are also banned. Notably, international agreements have already adopted measures to restrict some types of geoengineering, such as fertilizing parts of the oceans with iron filings to increase their biological productivity and carbon dioxide uptake (under the London Protocol on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and under the Convention on Biological Diversity). While some of these prohibitions relate to existing technologies, others ban the future development of harmful technologies, such as certain activities in outer space, the development of new biological or chemical weapons, or ocean iron fertilization. Importantly, decades of biological, pharmacological, and chemical research and development demonstrate that international bans on the development of specific technologies such as biological or chemical weapons do not limit legitimate research or stifle scientific innovation.

With these precedents in mind, and among numerous legal and political options, we advocate for an international regime specifically and narrowly targeted against the development and deployment of solar geoengineering technologies: an *International Non-Use Agreement on Solar Geoengineering*.

This International Non-Use Agreement could begin with a coalition of like-minded governments that would jointly declare not to support the active development and potential future deployment of solar geoengineering technologies. The agreement would bind only those countries that signed it. However, its effectiveness does not need to depend on support from all countries: even if not universal, a non-use agreement by a broad coalition of governments would already send a strong message about the undesirability of solar geoengineering to the global research, technology and climate communities. Such a message would resonate with funding agencies, philanthropic foundations, and large corporations that otherwise might be inclined to invest in the development of these technologies. If for example the European Union, the African Union, and a few other developing countries supported such an agreement, voting majorities in international institutions would also be within reach, making the acceptance of solar geoengineering as a policy option in formal international climate agreements unlikely. Widespread action by civil society and other political actors could add further momentum against the normalization of solar geoengineering. Once a critical mass of countries and civil society object to the prospect of solar geoengineering at planetary scale, the development of such technologies will lose support and funding. The non-use agreement that we propose will thus help slow and most likely stop the creeping normalization of this speculative technology in climate debates.

More concretely, an International Non-Use Agreement on Solar Geoengineering could commit signatory countries to five core prohibitions and measures:

1. The commitment to prohibit their national funding agencies from supporting the development of technologies for solar geoengineering, domestically and through international institutions.
2. The commitment to ban outdoor experiments of solar geoengineering technologies in areas under their jurisdiction.
3. The commitment to not grant patent rights for technologies for solar geoengineering, including supporting technologies such as for the retrofitting of airplanes for aerosol injections.
4. The commitment to not deploy technologies for solar geoengineering if developed by third parties.
5. The commitment to object to future institutionalization of planetary solar geoengineering as a policy option in relevant international institutions, including in assessments by the Intergovernmental Panel on Climate Change.

To be clear: an international non-use agreement would not prohibit atmospheric or climate research as such, and it would not place exceedingly broad limitations on academic freedom. The agreement would focus solely on a specific set of measures targeted purely at the development of solar geoengineering technologies under the jurisdiction of the parties to the agreement, including outdoor experiments with that specific purpose. At its core would be the mutual assurance of its signatories that they would not develop or deploy solar geoengineering technologies in the future. Such widespread statements by governments on future non-use alone will suffice to reduce incentives for further research and technology development for solar geoengineering. As such, the non-use agreement would not be different from other existing agreements that ban the development or proliferation of specific technologies that are widely seen as harmful, risky, or undesirable.

Problems of "dual-use" research—that is, studies intended for other purposes but useable also for solar geoengineering—seem limited in this case, as the non-use agreement would be primarily concerned with development of specific technologies and programs that explicitly aim at solar geoengineering at planetary scale (as evidenced, for instance, in research proposals or funding requests) or that require public licensing and approval, such as the Stratospheric Controlled Perturbation Experiment that was planned in Sweden in the summer of 2021. Likewise, a non-use agreement could provide for exceptions to reflect the considerable and important differences between technologies for solar geoengineering in terms of scale, aim and geopolitical risks, for example by allowing the use of localized surface albedo-related technologies. Finally, the duration of such a non-use agreement—that is, as a permanent ban or a temporary moratorium—would remain open to political debate and further decision-making.

Importantly, the international non-use agreement that we propose, while being primarily designed as an intergovernmental accord or treaty, could draw on the engagement and support of numerous other actors. For example, philanthropic foundations could express their support for the non-use agreement and publicly declare not to fund the development of solar geoengineering technologies. Universities and science associations could join the global movement as well. Civil society organizations, parliaments, local government authorities, and even individual citizens could publicly support the global case for an International Non-Use Agreement on Solar Geoengineering. All of this would make such technologies increasingly unattractive for any serious research group to invest in, including in countries that might not immediately sign the international non-use agreement.

In sum, an International Non-Use Agreement on Solar Geoengineering would be timely, feasible, and effective. It would inhibit further normalization and development of a risky and poorly understood set of technologies that seek to intentionally manage incoming sunlight at planetary scale, and it would do so without restricting legitimate climate research. It would prevent a dangerous distraction from current climate policies by removing the false promise of a cheap and feasible alternative “Plan B" in the form of solar geoengineering. 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. Solar geoengineering is not necessary. Neither is it desirable, ethical, or politically governable in the current context. With the normalization of solar geoengineering research moving on with rapid speed, a strong political message to block these technologies is needed. And this message must come soon.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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Frank Biermann: Conceptualization (lead); data curation (lead); formal analysis (lead); investigation (lead); methodology (lead); writing – original draft (lead); writing – review and editing (lead). **Jeroen Oomen:** Conceptualization (lead); data curation (lead); formal analysis (lead); investigation (lead); methodology (lead); writing – original draft (lead); writing – review and editing (lead). **Aarti Gupta:** Conceptualization (lead); data curation (lead); formal analysis (lead); investigation (lead); methodology (lead); writing – original draft (lead); writing – review and editing (lead). **Saleem H. Ali:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Ken Conca:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Maarten A. Hajer:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Prakash Kashwan:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Louis J. Kotzé:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Melissa Leach:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Dirk Messner:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Chukwumerije Okereke:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Åsa Persson:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Janez Potočnik:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **David Schlosberg:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Michelle Scobie:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting). **Stacy D. VanDeveer:** Conceptualization (supporting); writing – original draft (supporting); writing – review and editing (supporting).

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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