# The Governance of Solar Geoengineering

## MANAGING CLIMATE CHANGE IN THE ANTHROPOCENE

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# 13

# A Path Forward

Since the rise of the solar geoengineering discourse, the questions of how it could and should be governed have loomed large (see Kellogg and Schneider 1974). Although until now this book has remained mostly descriptive and analytical, this final prescriptive chapter suggests further governance.[1] This begins by making my goals and approach explicit and by reviewing solar geoengineering's relevant characteristics that inform my suggestions. The proposals then follow, divided into three rough stages of small-scale research, large-scale research, and implementation (akin to those in Solar Radiation Management Governance Initiative 2011, 26; Keith 2013, 80–8).

## 13.1 GOALS, APPROACH, AND CHARACTERISTICS

My goal in proposing further governance for solar geoengineering is to maximize current and future humans' well-being (that is, welfare) in ways that are sustainable, consistent with widely shared norms such as the need for governance to be legitimate, and seemingly feasible. Like any set of multiple goals, these sometimes are in tension with one another. Well-being is meant to broadly encompass all about which people care, including the natural world. In addition, because conditions at one point in time shape those at subsequent ones, governance should aim not only to improve well-being at the present but also to facilitate future desirable conditions. Climate change is and solar geoengineering would be multigenerational – if not multicentennial – phenomena, and governance should consequently consider future generations and sustainability. Legitimacy recognizes the importance of democracy and the rule of law to maintaining a functioning and well-governed society. Feasibility is a minimal criterion because, in its absence, the apparent benefits of idealistic proposals that are highly unlikely to be adopted would dominate the suggestions. Patterns of past individual, state, and collective behavior offer a reasonable guide to future possibilities. One of the strongest feasibility constraints arises from the fact that people and institutions – including states – act to pursue

[1] Note that in Chapters 11 and 12, I offer policy suggestions regarding compensation and intellectual property.

their own diverse objectives given their limited resources. Proposals for governance should thus attempt to align actors' self-interests with increasing wider well-being. Greater international cooperation could make for more effective governance of solar geoengineering but might not be in states' own perceived interests, at least in the short term (see Jinnah 2018). For this reason, the second and third stages of proposed governance concerning large-scale research and deployment, which substantially rely on state activity, include some suggestions that rely less on international cooperation.

The characteristics of a given challenge will have a large bearing on suggesting and assessing governance (see Chapters 2 and 4). Climate change will have generally negative impacts on humans, other species, and the wider environment. These might be severe and will be most harmful to already vulnerable populations and ecosystems. Furthermore, there is a small chance of very large harm from climate change. Greenhouse gas emissions abatement, adaptation, and negative emissions technologies (NETs) can reduce climate change and its impacts but will be unable to eliminate them. Abatement and NETs pose difficult global collective action problems, and those countries that need to adapt the most tend to have the least capacity to do so. Importantly, these actions' beneficial effects will occur – for the most part – decades after their undertaking. These responses will continue to be substantially insufficient to prevent dangerous climate change and its impacts.

The current evidence is that solar geoengineering could greatly reduce climate change and the resulting harm. It appears to be technologically feasible, relatively inexpensive, rapid, and reversible in its direct climate effects. The first two characteristics imply that some states could implement it on their own and for their own net benefit, at least in principle (see Chapter 4). Its speed of action would allow it to manage short-term – that is, on the order of years to a couple of decades – climate risks in ways that abatement, adaptation, and NETs cannot. At the same time, solar geoengineering would pose genuine environmental risks and social challenges. Although which of these are most serious is a matter of judgment, I am most concerned about premature, uncoordinated, or excessive implementation; international disagreements regarding deployment decisions and responsibility for perceived negative impacts; and lessened efforts for other responses to climate change (see Chapter 3). For these reasons, and because it would imperfectly reduce climate change, solar geoengineering is not a solution to climate change and offers instead a possible complementary response option that poses a risk-risk trade-off with substantial uncertainty.

Additional, dedicated governance of solar geoengineering is warranted because it could help solar geoengineering proceed responsibly while reducing these risks and challenges. This does not mean that additional governance is *required*. The proposed technologies' development and use would proceed in some fashion in the absence of additional intentional guidance by states and other authoritative institutions. However, in the absence of governance that is specific to solar geoengineering, the risks and challenges would likely be greater. There would be less research, and what is undertaken would be less coordinated. Implementation would be more likely to be done with a weak knowledge base by a small number of countries contrary to the wishes of others, increasing international tensions. Deployment systems would be less redundant and resilient, increasing the chance of sudden and sustained termination.

There is already substantial governance of solar geoengineering, despite regular claims of a regulatory vacuum (for example, McKinnon 2019, 443). Existing national and subnational law would apply to small-scale activities that would not pose transboundary risks (see Chapter 9). Large-scale outdoor activities would implicate a wide range of international law, including treaties and custom; binding and nonbinding agreements; and in environmental, human rights, and other issue areas (see Chapters 5 through 8). Nonstate governance has apparently already influenced solar geoengineering activities and can continue to do so in ways that can be more flexible, open-ended, and better informed than legal governance and can lay a foundation for future legalized governance (see Chapters 10 and 11). Furthermore, at all scales, most actors have incentives, such as maintaining reputations, for responsible behavior. Together, this extant heterogeneous, polycentric governance is incomplete, fragmented, and inconsistent, but it is also adaptable and offers opportunities for learning (Galaz 2014; Reynolds 2018b).

Claims of a regulatory vacuum implicitly point to the absence of a binding, in-force international legal instrument that is specific to solar geoengineering. Yet this is not a problem, and in fact, it remains too early to develop one. Doing so under the present conditions of great scientific, social, and political uncertainty and low knowledge would lock-in rigid governance that might turn out to be ineffective or otherwise inappropriate. As research and development proceed, we will learn more about solar geoengineering as well as what we do – and do not – want from it. That is, solar geoengineering and its governance should co-evolve (Parker 2014; Parson 2017b). Meanwhile, a broad societal conversation as to whether developing and perhaps using solar geoengineering would be an acceptable means to reduce the risks of climate change is necessary. Moreover, a new dedicated international legal instrument is very unlikely in the near term. Ironically, demanding one only makes it more probable that solar geoengineering would proceed without appropriate additional governance.

Crafting governance of solar geoengineering will not be simple, and I highlight five key challenges here. First, one must define the activities to be governed. In general, solar geoengineering is the intentional modification of the Earth's radiative balance, excluding changes to greenhouse gases, and including the research and development activities that would inform and enable such interventions. However, the definition's boundaries for governance purposes remain unclear. For example, should intentionality – whether to modify energy fluxes or reduce climate change – always be a requisite? These definitional issues manifest differently at small- and large-scales. At the former, other research activities – such as those examining the interactions of aerosols, clouds, and climate – can resemble solar geoengineering research yet should generally not be subject to its additional regulation. On the other hand, solar geoengineering researchers could evade this regulation by misrepresenting their intentions. At large scales, research and deployment are difficult to distinguish. An actor who wished to implement might be able to avoid certain governance requirements by claiming to be conducting research.

Second, because climate change, solar geoengineering, and global politics are uncertain, there is a tension between developing governance early, before problems manifest, and doing so late, when more will be known.[2] Climate change impacts and efforts to reduce them via emissions abatement, adaptation, and NETs might be more or less severe than we presently believe. Solar geoengineering might turn out to be expensive, unacceptably risky, or politically rejected. It could consist of one or more of the currently leading techniques or something new and unexpected. For example, it is also not out of the question that, at some point in time, a combination of miniaturization and information technology could enable solar geoengineering through numerous small drones that would both be regional in effect and rapidly responsive to climatic conditions. If so, then solar geoengineering could develop to reduce extreme weather events, and distinctions among categories of activities would further blur. Moreover, we cannot know how widespread deployment capacity would be, which climatic conditions countries would prefer, and the value that states would place on having their preferred climate. Global politics could be cooperative or conflictual, and the distribution of states' relative power could have many forms from highly concentrated to widely dispersed. Likewise, the preferences of political leaders and laypersons regarding the environment, risk, and technology will continue to evolve. Because of this increasing uncertainty as one considers the more distant future, my suggestions for governance of the large-scale research stage and especially the implementation one are tentative.

However, this uncertainty should not paralyze decision-making. Research can reduce uncertainty, although some uncertainty will probably be irreducible. The governance of solar geoengineering should not only coevolve with its research and development but also remain adaptive to changing conditions and improved knowledge.[3] Although I consider here what I believe to be a middle range of possible futures, this range widens as we consider the further future. To be clear, although the future might be quite different than that described in this chapter, I assume in each section that the activities would, in fact, be undertaken without claiming that this would be certain or even to be expected.

[2] This is the Collingridge dilemma (Collingridge 1980).

[3] Adaptive governance is an established line of research and practice with respect to feedback from natural systems but is less so with respect to human ones (Folke et al. 2005; Bennear and Wiener 2019).

Third, I expect solar geoengineering to remain controversial, at least for some time, which presents challenges to developing governance. Its legitimacy will be particularly important. One implication is that governance processes should engage the public relatively early and deeply. Another is that, for the near future, state actors – which offers a basis of legitimacy – will probably remain reluctant to engage with the topic. Nonstate actors could consequently fill governing roles, offering effectiveness and expertise as bases of legitimacy (see Chapter 10). This need will be heightened by solar geoengineering's complexity and dynamism, indicating that traditional national regulators might have insufficient state-of-the-art knowledge. Furthermore, researchers could – especially early on – see themselves as a reputationally sensitive community of shared fate and have incentives to not only act responsibly but also monitor each other to maintain a social license to operate. A final implication of controversy, coupled with countries' possible suspicions of others' intentions, is that too strong a push for an early debate on international governance could result in a premature ban, taboo, or excessive regulation. There could be substantial costs to human well-being and sustainability of such undue restrictions.

Fourth, governance should not be based solely upon the reduction of aggregated physical risks of climate change and solar geoengineering and the maximization of any co-benefits. At the very least, impact assessments should give additional weight to those who are already disadvantaged. Moreover, decisions should be driven by people's preferences as expressed through legitimate channels. This reinforces the fact that informing and engaging with the public as well as diverse social science research will be essential. Nevertheless, maintaining a connection between governance and the public's preferences will be difficult, given solar geoengineering's global impacts, the world's diversity, and the complexity of how people perceive the environment, technology, and risk.

Finally, reliance upon law as a centerpiece of governance offers benefits and limitations. Perhaps the greatest advantage is law's legitimacy through states' centrality. At the same time, law is slow to change, whereas technology and technical knowledge often advance rapidly. Furthermore, the governance of large-scale solar geoengineering activities must in some ways rely on international law, which lacks centralized development, monitoring, and enforcement. Independent of the pros and cons, solar geoengineering will be researched and developed in a pre-existing governance landscape with numerous norms, rules, procedures, and institutions of diverse scale and legal character. In developing additional governance, these conditions should be acknowledged and even seen as an opportunity, not a barrier to be overcome (Nicholson, Jinnah, and Gillespie 2018).

## 13.2 SMALL-SCALE RESEARCH

The first of three rough stages of governance is that of small-scale solar geoengineering research. This includes indoor work as well as outdoor experiments whose impacts can be expected to be moderate. Here, the primary goals would probably be to reduce uncertainty regarding impacts and technical feasibility. Governance at this stage would be decentralized and heterogeneous. Developing governance will be constrained by uncertainty both in solar geoengineering's potential benefits and risks as well as in what we normatively want from it.

Like the other stages presented here, this one requires definitional boundaries. Activities that otherwise appear to be solar geoengineering research should be exempted based upon the researchers' reasonable stated intentions, but only if the expected impacts are *de minimus*. Although this raises the possibility of solar geoengineering research not being governed as such, this should be balanced with that of other research being subjected to unnecessary rules. If some genuine solar geoengineering research with *de minimus* expected impacts escapes additional oversight due to researchers' misleading statements, the consequences may be acceptable.

At the "upper" end, beyond which research would be large-scale, should be activities whose impacts are expected to be transboundary, widespread, long-lasting, or severe. The first criterion is important as this is where international law becomes salient. The other trio of terms is found in two international agreements.[4] A document related to the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) defined them as:

> "widespread": encompassing an area on the scale of several hundred square kilometres; "long-lasting": lasting for a period of months, or approximately a season; "severe": involving serious or significant disruption or harm to human life, natural and economic resources or other assets. (ENMOD Understandings)

The upper boundary for small-scale research activities could use the expected radiative forcing – a measurement of the change in the Earth's energy balance – as one criterion to determine severity. For example, Parson and Keith suggest 0.01 watts per square meter, which is less than one percent of current anthropogenic radiative forcing due to greenhouse gases (Parson and Keith 2013).

Reducing the uncertainty regarding solar geoengineering's effectiveness, capability, costs, speed, reversibility, and risks is important and requires substantial investments. Although nonstate sources can contribute, state support is necessary. Especially as research moves outdoors, funders should consider allocating supplemental resources for compliance with governance as well as for insurance for compensating for potential harm. Furthermore, as research grows, funding would benefit from coordination within and among countries. This could take a range of forms and degrees of centralization including informal communication, a formalized consultation forum, and a genuine international program.

[4] The three words are in ENMOD itself (Article I.1) as well as in the approved amendment to the London Protocol to regulate marine geoengineering (Article. 1).

Governance should help ensure that solar geoengineering research should, as it proceeds, include three specific aspects. First, specialized clusters of scientists should aim to demonstrate either solar geoengineering's effectiveness and safety or its ineffectiveness and risks (Bipartisan Policy Center's Task Force on Climate Remediation Research 2011, 24). Second, efforts should explore diverse proposed technologies and approaches to help prevent technological lock-in. Third, international cooperation should be a priority, in order to capitalize on scientists' knowledge and skills worldwide, to foster socialization and build trust, and to avoid perceptions of rivalry or hostile activities. Moreover, international cooperation should not be mere sporadic collaboration and co-authorship but also include active recruitment, exchange programs, and capacity building in developing countries, which ideally could eventually develop their own research programs. The Solar Radiation Management Governance Initiative (SRMGI) is currently taking important steps in this direction.

Independent synthesis and assessment of results is also essential to reducing uncertainty. The Intergovernmental Panel on Climate Change (IPCC) appears qualified and authorized to do so and possesses the legitimacy that could help solar geoengineering integrate better into the broader climate change discourse.[5] However, because its members might be resistant to seriously considering solar geoengineering, David Victor argues that geoengineering is a poor match for the IPCC due to its open, weak, and consensus-oriented character (Victor 2008). One or more alternative forums – such as multiple national academies of science – might be warranted.

Much, if not most, of the environmental, safety, and other risks of small-scale solar geoengineering research can be effectively managed through existing national and subnational law (see Chapter 9). The industrialized countries, which are the most probable locations and funders of research, generally have robust regulation regarding air pollution, protection of vulnerable species and ecosystems, environmental assessment, public notification and participation, aviation, marine vessels and structures, weather modification, and liability for harm. Institutions that intend to conduct or support outdoor solar geoengineering research should undertake legislative analyses to confirm the extent to which existing mechanisms can appropriately govern environmental and other risks (Chhetri et al. 2018, 23). If there are gaps, then state or nonstate governing institutions should address them. In some cases, new national legislation or administrative regulations specific to solar geoengineering might be warranted.

[5] The IPCC's original mandate included reviewing "Possible response strategies to delay, limit or mitigate the impact of adverse climate change," although its own current principles for governing its work is limited to "options for adaptation and mitigation" (UN General Assembly Resolution on Protection of Global Climate for Present and Future Generations of Mankind; Intergovernmental Panel on Climate Change 2013). The latter might need to be amended to consider solar geoengineering.

Nevertheless, states should not be the sole source of governance of solar geoengineering. It would be unwise to fully rely upon them, either through domestic law or international cooperation, at least initially, due to the need for expertise, insufficient incentives for state actors to engage with the issue, the possibility of forum shopping, and normative uncertainty. Instead, in these circumstances, nonstate governance can offer adaptiveness, expertise, and an ability to operate across borders (see Chapter 10). Therefore, the further bottom-up development of norms and codes of conduct is important (Victor 2008; Parker 2014). Steps in this direction are evident in the various – and notably overlapping – sets of principles, particularly the Oxford ones (Rayner et al. 2013; Chhetri et al. 2018, 11). Most of the important features of the governance of small-scale sole geoengineering have been put forth in the proposed principles, including transparency; public participation; independent assessment; cooperation among researchers; monitoring, reporting, and verification; adaptive governance; reducing risk and maximizing benefit; and compensation for harm. Further development and crystallization of norms will require actual practice of solar geoengineering research, and their contours thus remain presently unclear. Nonstate governance could be linked to the proposed research commons (see Chapter 11), which could attract researchers, their institutions, funders, and publishers, bringing them into the fold of governance.

One central principle that warrants some elaboration is transparency, which is essential to responsible solar geoengineering research. Governance standards should include open publication of methods and results, including negative ones as well as disclosure of funding sources. Some of the precise details of transparency still need to be resolved. For example, should all research activities – including indoor modeling work – be publicly described before they are undertaken? To what extent should data be standardized (see Chapter 11)? Should researchers be required to publish in open access journals and to include laypersons' summaries? Are there any exceptions for confidentiality? Transparency could be linked to independent assessment and could be furthered through an online clearinghouse of researchers, projects, programs, and results (Craik 2015).

The principles for solar geoengineering research should, at some point in time, be gradually legalized; that is, their precision, delegation, and obligation should be increased (Abbott et al. 2000). The first process is one of providing greater specificity, through for example codes of conduct, to clarify the norms and to align expectations. The proposed Code of Conduct for Responsible Geoengineering Research is an important step in that direction, in part through helping keep nonstate governance aligned with existing international law (Hubert 2017). At the same time, its reliance upon international law as a basis also limits its utility, particularly for small-scale research. Some issues – such as the proper roles of commercial actors – remain unsettled and will need to be confronted. Legalization's second process – delegation – refers to authorizing governing actors distinct from the targets to develop, monitor, and enforce rules, standards, and norms. In other words, this would be a shift from self- to private regulation, meta-regulation, or – where possible and appropriate – state governance. Numerous nonstate actors, including research institutions, funders, professional societies, publishers, and nongovernmental organizations, could assume some delegated authority.[6] This points to the final process of legalization, that of obligation. At the very least, as a reputationally sensitive community of shared fate, solar geoengineering researchers have both the incentives and means to punish clear violators among them through naming, shaming, and exclusion. Furthermore, the potential delegated governing nonstate institutions listed above could offer rewards and punishments for those who comply with or contravene the nonbinding governance. During this legalization process, multiple sites of nonstate governance might develop. Ideally, any competition among them could foster those that are more effective, efficient, and just, instead of creating fragmented governance thickets.

A possible model for the nonstate governance of solar geoengineering's physical risks is independent, institutionally affiliated committees. These currently review research with recombinant DNA, animals, and human subjects. For example, the International Ethical Guidelines for Health-Related Research Involving Humans, the Declaration of Helsinki, US federal law, and European Union law each call for proposals for research with human subjects to be approved by the appropriate ethics committees before proceeding (Council for International Organizations of Medical Sciences and World Health Organization 2016; World Medical Association 2018; Common Rule, 45 CFR 46; Clinical Trials Directive; see Chapter 7). Analogous solar geoengineering research review boards could help ensure that experiments, projects, and programs proceed in a manner that minimizes risks relative to expected benefits and are consistent with widely shared norms. Their members should be independent from both the research and, to the extent possible, from the home institution. Research that presents negligible environmental impacts could be subject to an expedited review. Importantly, establishing the boards does not require state action. Instead, research institutions can act soon, and nonstate actors such as funders can demand these boards from the institutions that they support. Initially, these review boards could each operationalize general principles in their own diverse ways. Indeed, central coordination would not initially be needed and might not even be beneficial. Instead, the boards could experiment and learn from each other's approaches and experiences. However, as research scales up, greater coordination and harmonization – such as sharing more elaborate principles and best practices – would be warranted and increasingly feasible (Chhetri et al. 2018, 44–5). Here, professional societies, major research funders, public agencies, and nongovernmental organizations could participate.

With respect to the standards' substance, the emerging international governance of ocean fertilization provides a model that could, in some ways, be transposed to

[6] Whether governance by a research institution of its own researchers should be considered self-regulation or delegated private regulation depends upon the institution-researcher relationship.

outdoor solar geoengineering experiments that would be expected to have significant environmental impacts. In this, proponents are to demonstrate that a proposed activity would be legitimate scientific research; that it would fulfill its purpose; that its "rationale, goals, methods, scale, timings and locations as well as predicted benefits and risks" are justified; and that the researchers have the financial resources to carry it out adequately (Marine Geoengineering Amendment to the London Protocol). The proposal to conduct outdoor ocean fertilization research must be subject to an environmental impact assessment that includes, among other things, site selection and description, exposure assessment, risk characterization, and risk management. Furthermore, proposals should describe how the activity would be as encapsulated and reversible as possible; contain risk management plans, including regarding monitoring and contingencies for emergencies; consider alternatives to the suggested activity; and be peer reviewed. However, some caution is warranted in replicating this regulatory framework. No legitimate ocean fertilization research has been proposed since it was developed, implying that it might be too cumbersome.[7]

Growing solar geoengineering research would provoke social challenges. Most of these would not be related to any particular project or experiment and are thus not best managed through institutionally affiliated boards.[8] A wide social discourse is necessary and should ideally involve elected officials, state and intergovernmental bureaucrats, experts, thought leaders, and the general public. To some degree, this can be facilitated. Institutions that are active in solar geoengineering research should engage with the public, assess its opinions, and ensure that its members have appropriate opportunities to participate in decision-making. Indeed, the Carnegie Climate Geoengineering Governance Initiative (C2G2) and the SRMGI are currently initiating and carrying out international dialogues of growing breadth and depth. At the same time, some of this discourse must occur organically from the bottom-up. Although such engagement and conversations might not lead to consensus, it is important that its participants form their opinions, to the extent possible, based upon the best available evidence. Given solar geoengineering's present controversy, the public's low levels of awareness, and the popular media's frequently inaccurate and sensationalist coverage, active outreach will remain necessary.

Two related salient social challenges are that solar geoengineering research might unduly catalyze deployment and that a capable actor might prematurely implement it. To address these, this stage of small-scale research should have explicit predefined conditions under which research would end (Parson and Herzog 2016). These criteria should include a range of physical and social aspects such as the expected

7 Another explanation is that previous ocean fertilization research has indicated little potential to reliably sequester carbon dioxide and relatively great environmental risks.

8 In fact, US institutional review boards for human subjects research "should not consider possible long-range effects of applying knowledge gained in the research (for example, the possible effects of the research on public policy) as among those risks that fall within the purview of its responsibility" (45 CFR 46.101–409).

benefits and risks of further research as well as their distributions, the best understanding of solar geoengineering's potential, the presence of key characteristics of legitimate scientific research, support and opposition among the public and elites, the risks of climate change, and the apparent likelihood of sufficient emissions abatement, adaptation, and NETs.[9] At relatively small scales, establishing these breakpoint criteria and deciding whether they have been satisfied would be decentralized, such as at the level of research institutions or funders. As activities scale up, the criteria should be stricter and the breakpoints decisions should be more centrally managed, perhaps functionally linked to the assessment of research carried out by the IPCC or other bodies. How these criteria are formulated and how decision-making is informed would be essential to the overall research endeavor.

In principle, these breakpoint criteria could be coupled with a moratorium on solar geoengineering activities beyond a certain scale. A moratorium, which has been frequently proposed for solar geoengineering, can be thought of as a breakpoint that defaults to prohibition. However, a moratorium would face interrelated challenges of intertemporal credibility, legitimacy, and effectiveness (see Parker 2014; Chhetri et al. 2018, 11, 31). Adoption of a moratorium at an earlier time – such as when outdoor research remains small scale – initially seems to confer greater benefits of both making premature large-scale activities less likely and reassuring a potentially concerned public and other actors. At this stage, governance would remain decentralized, and those who could propose and implement a moratorium might be a few states, professional and scientific societies, research institutions, funders, and scientists. They might diverge on details, including the threshold of temporarily prohibited activities and the conditions for the moratorium's removal. Indeed, multiple moratoria are feasible. Independent of the number of moratoria, the developers of one could impose it credibly – more or less – on themselves, but whether others would accept it depends, among other things, on their perception of the developers' legitimacy to govern in this manner. Because of changing circumstances and knowledge as well as generational turnover, this credibility challenge becomes greater as a moratorium's length of time and of intended geographic reach increase. Would researchers at one time in one region of the world perceive as legitimate a moratorium that had been established much earlier in another region? What if the expected impacts of climate change had greatly increased in the meantime? What if various institutional leaders, scientists, and other experts disagreed as to whether a vague criterion, such as "an adequate scientific basis . . . and appropriate consideration of the associated risks" had been met?[10] What if there were

[9] Regarding legitimate scientific research, the emerging regime under the Marine Geoengineering Amendment to the London Protocol bases its assessment of this upon whether a proposal would add to scientific knowledge, be subject to peer review, be published in a peer-reviewed outlet, and make data publicly available, as well as whether the researchers stand to directly financial gain from the research (Annex 5, Article 8).

[10] The quotation is from the 2010 CBD COP decision (X/33, paragraph 8(w)).

multiple moratoria and the lifting conditions for some of them had been met and others not?

To these components of governing small-scale research, I add three specific components, the first of which is the upstream development of a novel policy for intellectual property that is related to solar geoengineering. By extension, this will shape commercial actors' roles in small-scale research. This policy should be organized by nonstate actors in a bottom-up manner. In Chapter 11, I proposed four components of such as regime: the sharing of appropriately standardized research data, an intellectual property pledge community, monitoring of patenting activity, and clarification of states' intentions regarding compulsory licensing and march-in powers.

Second, the military's role in solar geoengineering should ideally be restricted. Some observers have claimed that the technologies could be used for hostile purposes or their operation subsumed by the military, perhaps even inevitably so (Horton and Reynolds 2016, 444–5). Although solar geoengineering's potential tactical utility is often overstated, the involvement of the military – particularly in hegemonic states – could undermine international public confidence and trust. At the same time, militaries possess useful equipment and knowledge regarding complex logistical operations at high altitudes and at sea. A complete rejection of any military role might be harmful. One possible boundary would be to allow military institutions to serve as secondary partners in research projects but not as primary ones or as funders and to require full disclosure of their involvement. Nevertheless, given governance's decentralized nature at this stage, it is unclear how such limitations could be adopted and effective.

Third, the governance of small-scale solar geoengineering should lay the foundation for that of responsible larger-scale activities. One way would be to educate and engage with the public, thought leaders, decision-makers, and other elites, as described. State and intergovernmental leaders should become informed so that their decision-making, at this time and in the future, would be based upon a more robust knowledge base and so that solar geoengineering integrates into the mainstream climate change debates in a balanced, responsible manner. C2G2 is doing this, especially with intergovernmental organizations. Such work should continue and expand, particularly to national policy-makers.

This raises the question of what intergovernmental organizations should do at this stage with respect to solar geoengineering. Many of them, especially those that are more advisory and facilitative in nature, such as UN Environment, World Meteorological Organization (WMO), the UN Education, Social and Cultural Organization (UNESCO), the International Maritime Organization (IMO), and the Food and Agriculture Organization, should undertake processes and establish subsidiary bodies, as appropriate, through which they could grow organizational knowledge, identifying capacities, and clarify some responsibilities. In fact, UN Environment's governing assembly has considered a resolution on geoengineering.

Those in which states' leaders could negotiate their positions, such as the UN General Assembly, its Security Council, and the UN Framework Convention on Climate Change (UNFCCC) Conference of the Parties (COP), should not directly engage with solar geoengineering too early, especially if the objective were a multilateral agreement. If they were to do so, then they might adopt poorly-informed policies and catalyze international polarization (Victor 2008, 331). There may be some exceptions, such as whether solar geoengineering research and development could be included as part of nationally determined contributions and global stocktaking under the Paris Agreement (see Chapter 6; Chhetri et al. 2018, 38–9; Nicholson, Jinnah, and Gillespie 2018).

A foundation for subsequent governance of large-scale activities could be laid by a high-level commission. Edward Parson has proposed a World Commission on Climate Engineering that would be authorized at a high level, such as by the UN; empowered by a broad, strong mandate; include diverse and distinguished members; and be supported with sufficient support resources. Such a body could offer a path forward in a controversial domain with great uncertainty. Importantly, this would not be directly connected to states yet probably would be widely perceived as legitimate. Notably, its mandate need not include the challenging and contentious task of developing specific rules and process for deployment but instead could "make a contribution simply by clarifying questions to be addressed, issues at stake, broad response options and factors militating for and against each" (Parson 2017a, 5; see also Chhetri et al. 2018; Nicholson, Jinnah, and Gillespie 2018, 327). In a similar vein, international relations scholar Joseph Nye points to a more state-affiliated group of governmental experts, such as that one regarding cybersecurity, to develop and help crystalize norms as well as lay a foundation for subsequent international cooperation (Nye 2018b).

## 13.3 LARGE-SCALE RESEARCH

The second stage of governance is that of large-scale outdoor solar geoengineering research, which would strive to further reduce uncertainty and to develop equipment, materials, and techniques for possible deployment. Governance would be characterized by managing expected transboundary impacts through rules and procedures that would be increasingly centralized, legalized, and promulgated by states and intergovernmental institutions. International law and international relations would be more salient as well.

"Large scale" encompasses outdoor experiments or tests that would go beyond small scale and expected to have transboundary, widespread, long-lasting, or severe impacts, as described in Section 13.2. The "upper" boundary is not sharply distinct from deployment but could still be drawn, albeit somewhat arbitrarily. For example, research could be limited to significant impacts up to some intensity (that is, radiative forcing). Intention should not be a criterion at this scale; any project that would change the Earth's radiative balance and be expected to have transboundary, widespread, long-lasting, or severe impacts should be governed as large-scale solar geoengineering. If future technologies enable effective regional solar geoengineering, then an additional spatial criterion might be needed.

Because new issues of international law and international relations as well as heightened demands for legitimacy would arise, states and intergovernmental organizations should at this stage assume more prominent if not leading roles in governance. At the very least, greater financial support from public sources for research would be needed. Furthermore, states, intergovernmental organizations and the parties of relevant multilateral agreements such as the UNFCCC, the Convention on Biological Diversity (CBD), and the UN Convention on the Law of the Sea (UNCLOS), should communicate and coordinate their actions and policies with respect to solar geoengineering governance in order to avoid undue fragmentation of governance. Moreover, the authorization of large-scale experiments should remain with the states. This process should comply with states' international legal commitments and obligations, including those under customary international law to prevent and reduce risks of transboundary harm. States should thus commit to prosecute, to the extent appropriate, any nonstate actor under their jurisdiction who conducts unauthorized large-scale solar geoengineering activities.

The centerpiece of my proposed governance of these large-scale activities is an intergovernmental institution, here called the Solar Geoengineering Organization (SGO) as a placeholder.[11] Although some of its functions would be possible through non-institutionalized international cooperation, these would probably be done less effectively or perceived as less legitimate in the absence of institutionalization. The first of the SGO's five core functions would be to facilitate research. This would include providing a forum for debating priorities; coordinating projects so that resources are used efficiently and outdoor experiments do not interfere with each other; fostering the growth and utilization of countries' research capacity, especially in developing ones; and standardizing and centralizing data sharing and other salient information. To help prevent technological lock-in, the SGO should support research that aims to identify solar geoengineering's limitations and risks and that explores nondominant proposed technologies and approaches. The SGO could assess and synthesize research, but there is a good argument that, to counter possible institutional momentum, these functions should be conducted by an institution that is independent from the SGO. Because this could conflict with the IPCC's work, the allocation of responsibilities between these organizations would need to be clarified.

Second, the SGO should help ensure that research is done responsibly. It could provide advice and models for national legislation that would be specific to solar

[11] This approach is inspired in part by the International Atomic Energy Agency (IAEA) due to similarities between nuclear technologies and solar geoengineering, and the IAEA's success in promoting the peaceful use of nuclear energy while preventing weapons proliferation (see Reynolds 2014a).

geoengineering. The SGO could also continue increasing the precision, delegation, and obligation of the research standards that arise from principles, codes of conduct, and the work of institutionally affiliated review boards. Among the standards' most important aspects would be impact assessment, monitoring, and reporting, each of which the institution could help operationalize. If some solar geoengineering methods and applications were regarded as unacceptably dangerous or contrary to widely shared norms, the SGO could facilitate processes through which these would be not pursued or even prohibited, likely through national laws or administrative regulations. Precision also points toward increasing specificity in the form of, for example, detailed best practices. Although greater precision can reduce risk, the standards should also remain adaptable because research projects would likely be diverse, knowledge would grow, and the social acceptability of risk would change. Delegation should include the refining, promulgation, and maintenance of the standards by the SGO and their implementation and enforcement by state and nonstate bodies. Greater obligation would be most clearly manifested in states' implementation of the standards, including by requiring that proposed research projects meet the standards. Likewise, the SGO could assume responsibility for managing the research commons, including its governance of patents related to solar geoengineering and, indirectly, of commercial actors.

The SGO's third function would be preventing premature escalation of large-scale research or deployment. This could be done through a continuation of the breakpoint criteria. However, in contrast with those for small-scale research, the rules could at this stage default to negative, at least in principle. In other words, research and development should arguably proceed only if certain criteria are met. This could be desirable beyond helping address environmental risks, "slippery slope," emissions abatement displacement, and public confidence. A moratorium – which is what such negative defaulting breakpoints would amount to – could, depending on its design, also catalyze greater precision, delegation, and obligation of governance and help build trust among countries that might be suspicious of others' intentions (Parson and Herzog 2016). The SGO might be able to resolve the problems of intertemporal credibility and legitimacy that a moratorium raises. It could assume the management of any previously developed moratoria and address related uncertainties. Yet even at the large-scale research stage, governing actors should be cautious with adopting a moratorium. Past moratoria such as those on commercial whaling, growing genetically modified crops, and mining in Antarctica ossified into hard-to-lift de facto prohibitions, even when they were developed by a single clear institution or mechanism (Bodansky 2013). Furthermore, like other strong regulations, a moratorium could have the perverse effect of being followed by only the responsible states and other actors, creating an opening for the less responsible ones to take the lead (Victor 2008). Ultimately, however, the states with the capacity to conduct large-scale solar geoengineering activities – which would be necessary for such a moratorium – might be unwilling to participate in one.

Another, perhaps more advantageous way in which the SGO could help prevent premature deployment would be through a nonproliferation mechanism. The reason for this is that, as with nuclear weapons, states might each simultaneously prefer to have the capacity to implement solar geoengineering and desire that few other states have such a capacity. Yet if all states pursue the former, then the latter would be clearly undermined. This would present a collective action problem. The international nuclear nonproliferation regime has largely resolved this by offering international assistance in developing the peaceful uses of nuclear power to those states that forego nuclear weapons. In the case of solar geoengineering, those states that commit to not developing deployment capacity could be offered a substantial role and voice, both in current research activities and in future implementation. Although this might call for a multilateral agreement, a less formal instrument might suffice. The necessary states might find a nonproliferation mechanism more appealing than a moratorium.

A final way to help prevent premature implementation is through monitoring solar geoengineering activity. For example, satellites and atmospheric sampling could detect changes in the Earth's radiative balance and observe high-altitude aircraft, while modeling may be able to help locate any source of undeclared activities. Such monitoring could also identify, and thus help prevent, secretive research programs. The SGO could coordinate and secure the requisite financial, technical, and other resources as well as ensure that a widely respected, independent institution is responsible for managing the actual monitoring work and publicly disseminating the results.

Related to preventing possible premature deployment is the question of how states might respond to revelations that one or a small number of actors was, in fact, undertaking solar geoengineering with global impacts. In principle, the SGO could provide a platform where states could have initial discussions regarding how they would react. However, such conversations may be better suited to an institution with an appropriate mandate and longer history in managing security issues, such as the UN Security Council.

The fourth core function of the SGO would be to maintain and foster international trust in and the perception of fairness of the solar geoengineering undertaking. This chapter has already suggested some activities that would do so, such as providing a forum for debating and establishing research priorities; facilitating transparency and data sharing, possibly through a research commons and a clearinghouse; preventing premature implementation; nonproliferation; international cooperation and capacity building, especially in developing countries; limiting the roles of the military; and monitoring. These should be continued. Ensuring that state and nonstate governance of major research programs and projects are consistent with existing international law, such as the customary obligation to reduce transboundary risks through, among other things, impact assessment, notification, and consultation, would also help maintain international trust. In some cases, the SGO could facilitate these procedural obligations, such as by providing a forum for international notification and consultation.

The SGO could also do more to foster international trust. For one thing, large-scale research would be a fairly expensive endeavor (although not when compared to aggressive emissions abatement, adaptation, and climate change damages), perhaps on the order of tens of billions of dollars annually. The SGO could offer a site where states negotiate the sharing of these costs based upon factors such as their ability to pay, historical greenhouse gas emissions, and expectations of benefits from solar geoengineering. Although this would be a collective action problem, the apparent large benefits-cost ratio implies that this could be managed. The SGO could also provide a forum where participating countries work to prevent and resolve disputes. For example, a requirement for participation could be that states commit to negotiate in good faith in the event of a conflict related to solar geoengineering. Related to that, and more speculatively, the SGO might be able to provide a home for a compensation mechanism, although this might require a multilateral agreement (see Chapter 10). Finally, it could liaise with and help coordinate the relevant activities of other intergovernmental bodies, including associated with relevant multilateral agreements, particularly the UNFCCC.

The SGO's final function would be to try to minimize emissions abatement displacement (see Chapter 3). The SGO's facilitation and coordination of research would help reduce uncertainties regarding solar geoengineering's potential, risks, and limitations. To help keep decision-making connected to the public's preferences, the SGO could ensure that public opinion studies and engagement exercises are undertaken. Furthermore, it could be the site of international linkage of solar geoengineering policies with those for emissions abatement and adaptation. For example, aggressive domestic abatement and adaptation actions could be prerequisites for membership (Parson 2014). However, this might have the pernicious effects of both encouraging unambitious abatement and adaptation targets as well as causing some states to remain outside the institution's governing framework.

This all raises the questions of the proposed intergovernmental institution's legal architecture, its relationship with existing international law, and states' participation in the SGO. Although its functions are largely coordination and facilitation, participation would entail some firm commitments, such as international cooperation, financial contributions to research and monitoring costs and a compensation fund (if appropriate), nonproliferation, good faith negotiation to resolve disputes, domestically governing large-scale research, and a possible moratorium or other breakpoint mechanism. Therefore, one or more new international legal instruments appear to be necessary to constitutionalize the institution and to outline participants' commitments and rights. The agreement(s) could resemble those of the International Atomic Energy Agency (IAEA), which was established by an initial Statute and subsequently oversaw almost twenty multilateral agreements on topics that include safety, liability, research, and technology transfer. Simplicity points to fewer agreements, while gradually building international trust and allowing states to opt-in and opt-out of agreements implies a greater number.

The development of a foundational multilateral agreement should occur under the auspices of an existing intergovernmental agency with broad membership and high perceived legitimacy. There are three clear candidates for this role. First, UN Environment has facilitated many such agreements. Second, the UN General Assembly enjoys both global participation and a nearly universal mandate.[12] Third, the UNFCCC bodies serve as the leading international forum for international discussions regarding reducing climate change and its risks.[13] Regardless, once established, the SGO should work to establish congenial relations with these other international institutions and avoid adversarial ones.

However, there are good – although not overwhelming – arguments for separating the governance of solar geoengineering from the UNFCCC architecture (Reynolds 2018a; see also Armeni and Redgwell 2015c). For one thing, the UNFCCC's objective is the stabilization of atmospheric greenhouse gas concentrations, which solar geoengineering would not address. For another, keeping the coordination and other governance of solar geoengineering activities at arm's length could reduce the displacement of emissions abatement and adaptation (although there is also a case for the reverse logic, in which coupled governance could minimize displacement). Furthermore, the UNFCCC may be so institutionally committed to emissions abatement and adaptation that it could be hostile to solar geoengineering. Finally, not only is it in some ways a politicized forum, but legal scholar Daniel Bodansky also notes that "the UNFCCC is seen as dysfunctional by many countries, and few trust its ability to make decisions" (Bodansky 2013, 550; but see Barrett 2010). However, if separate from the UNFCCC institutions, the SGO would need to cooperate closely with them, as some solar geoengineering activities would be governed to a limited extent by the UNFCCC and its protocols. For example, the building of capacity for solar geoengineering research in developing countries would be a form of technology transfer, and states may be able to include solar geoengineering research and development in their nationally determined contributions under the Paris Agreement.

An additional way in which the SGO could integrate with existing international law would be to help revive ENMOD, an agreement with widespread participation which prohibits the military or hostile use of environmental modification, implicitly including solar geoengineering (see Chapter 8). Although it has no standing bodies, its parties can call a meeting. The SGO could facilitate such meetings and encourage more states to ratify ENMOD to help ensure that solar geoengineering is used for only peaceful purposes.

[12] An alternative site to develop the foundational SGO agreement might be UNCLOS, whose objective includes protecting the marine environment (see Chapter 8).

[13] The WMO could also play an important role (see Chapter 5).

In terms of participation, a broad base would strengthen the SGO's international legitimacy, which would be critical given solar geoengineering's political contestation. Those states that would lack the capacity to undertake large-scale research and deployment appear to have little to lose through participation and something to gain. As proposed here, their greatest prices would be foregoing the development of implementation capacity under a potential nonproliferation mechanism and contributing to shared research and monitoring costs, while they could gain a voice and participation in international research as well as a means to seek compensation for demonstrated harm. The challenge would be attracting those countries that would have the relevant capacity, all of which would be necessary for the SGO to be genuinely effective. After all, at this stage the problem structure would largely be one of mutual restraint in order to prevent premature implementation (see Chapter 4). In terms of their costs, these states of deployment would commit to domestically governing research according to international standards, foregoing outdoor activities above the threshold of any moratorium, helping build capacity in developing countries, negotiating in good faith to resolve disputes, contributing to a possible compensation fund, and funding monitoring and research, possibly disproportionately so. In turn, they would gain in three ways. First, a nonproliferation agreement would limit the number of countries with the capacity to implement solar geoengineering. This would not only help stabilize international relations but also implicitly maintain or even increase these capable states' relative political power. Second, their participation in the SGO could reduce any international opposition to their solar geoengineering research activities, which are likely to be controversial. Third, those countries with implementation capacity would benefit through their restraint from moving forward too rapidly.

I concede that my suggestions for the governance of large-scale solar geoengineering research could be too state-centric. It might be that such international cooperation will be too difficult, or at least the costs in terms of international political capital too great. An approach that relies less on national leadership and cooperation, yet indirectly accountable to states, could be sufficiently effective. For example, a high-level commission that had been authorized by the UN, as introduced in Section 13.2, might have enough legitimacy, influence, and flexibility to guide governance through the challenges described in this section. Nevertheless, my sense is that transboundary climatic impacts that are significant – even if not substantial – would be too contentious and close to state's core interests for them to relegate it to an international institution in which they do not have direct say.

## 13.4 IMPLEMENTATION

The final stage of governance is that of the possible deployment of solar geoengineering. Here, there would be substantial transboundary and presumably global climatic effects. The purposes of governance would now include preventing, managing, and resolving international disputes; encouraging cooperation regarding deployment; and ensuring that any implementation is done in ways that are close to states' preferences and that are consistent with widely shared norms. The boundaries of this stage would be any solar geoengineering activity that exceeds large-scale research by, for example, having an expected impact on the Earth's radiative balance beyond a certain magnitude.

States would be central to the governance of deployment. Nevertheless, they could likely benefit by establishing or empowering an intergovernmental decision-making institution through a multilateral agreement. To be effective, it should aim to count as participants all states with the capacity, international political clout, and willingness to implement solar geoengineering (or counter–solar geoengineering) in a sustained manner (Virgoe 2009; Benedick 2011; Barrett 2014). These presently number perhaps one or two dozen. The institution should also try to attract any other states with the relative power and willingness to retaliate in other issue areas in response to solar geoengineering activities with which they disagree. This would be a handful of great powers, most or all of which would also be capable states (see Chapter 4). I collectively call these two groups the "target states," whose participation would be an objective – but not a requirement – of establishing an institution for decision-making regarding solar geoengineering deployment. Ultimately, the core challenge is thus making it in target states' perceived self-interests to relinquish some of their sovereign authority.

An important first question is whether states capable of sustained deployment would, to be a member of the institution, need to commit to refraining from deploying solar geoengineering outside of or contrary to the institution's decision-making process. An affirmative answer might be tempting, but requiring this could cause some of them to not join. These resistant target states might claim that they intend to generally abide by the institution's decisions but are unwilling to commit. Moreover, superpowers and states that are weakly integrated into the national order might see little negative consequences – such as reputational costs or retaliation – to taking this somewhat ambivalent position. My sense is that the international community would be better served by ensuring that as many target states as possible participate, even at the "cost" of weaker commitments. To that end, the founding agreement's parties should not prohibit unauthorized solar geoengineering implementation but instead use language with reduced force. For example, an article could provide that participants "should" refrain from undertaking deployment-scale solar geoengineering activities that have not been endorsed by the decision-making institution. Others could call on all deploying states to publicly notify the international community prior to solar geoengineering activities and to report on them afterwards; to coordinate among themselves; to take other states' interests into account in decision-making; to comply with prevailing best practices, including prior impact assessment; to try in good faith to resolve international disputes; and to not use solar geoengineering for military, hostile, or otherwise intentionally harmful purposes. The agreement could even include an explicit right for parties to deploy solar geoengineering, perhaps limited to safeguarding their citizens from clear and substantial threats (as implied by Barrett 2014, 11). It could reiterate existing obligations under international environmental law, specifically the customary law of the prevention of transboundary harm through means such as prior assessment, notification, and consultation. In other words, the agreement and the institution would not aim to prevent all uni- and minilateral deployment but instead to "cabin" it (Bodansky 2013, 549). This is a compromise that all target states might be willing to make.

There are reasons that an agreement should exclude or – more likely – limit the roles of some nontarget states. Wide participation, especially with a requirement of unanimity or a large supermajority, can cause decision-making to be slow, unduly conservative, and vulnerable to gridlock. These outcomes can arise due to objections of one of a handful of states that lie on the fringes of the international order. Recognizing this, some target states would be reluctant to join an institution with such decision-making architecture. At the same time, broad participation and stringent voting rules would increase the institution's perceived legitimacy and could help distribute costs and other burdens more widely. A potential middle ground could be two tiers of decision-making among countries' leaders. Like at the UN, a general assembly could be open to all states and agree to nonbinding resolutions, while an executive committee of target states plus, if necessary, a handful of representative nontarget ones would make operational decisions. The rules for decision-making within the executive committee would be critical. One approach would be to strive for consensus and, in its absence, to agree to vote, perhaps with a supermajority threshold.

In addition to two tiers of states, there is another axis of decision-making. Decisions regarding deployment would vary in their resolution, that is, their degree of detail. Low resolution decisions would address general goals, less technical issues, long temporal scales, and large spatial scales. For example, should solar geoengineering be used to reduce climate change and its risks? Is the objective to maintain present climatic conditions, to return to preindustrial ones, or to slow the rate of climate change? Do the interests of the northern and southern hemispheres and of the high and low latitudes diverge, and if so, could multiple objectives be balanced? How should solar geoengineering be altered once atmospheric greenhouse gas concentrations have begun to decline due to net negative emissions (that is, through abatement and NETs)? Should solar geoengineering be phased out due to a return to acceptable greenhouse gas concentrations or changes in preferences? States will probably insist on retaining decision-making authority for these matters. In contrast, high resolution decisions would address specific goals, more technical issues, brief temporal scales, and regional and local scales. For example, in the cases of stratospheric aerosol injection or cirrus cloud thinning, what types, quantities, locations, and timings of injected material would most likely achieve the general goals? If the weather had been globally warmer or cooler than expected for a few years, is this an indication that these parameters should be modified or is it mere climatic "noise"?

If there was evidence that anomalous precipitation at the continental scale had been caused by solar geoengineering, could that be reduced, and if so how? These sorts of matters should be delegated to an expert body. In its short-term management of solar geoengineering deployment, the expert body would be able to respond to feedback on various time scales ranging from seasonal to decadal (MacMartin and Kravitz 2019; see also Chris 2015).

Because national leaders could be tempted to interfere in these decisions for political reasons, there should be institutional firewalls to shield the expert body from undue influence from the executive committee and other political actors. In these ways, monetary policy offers a useful analogy, in which politicians set general goals that are implemented by boards of economists and other experts. Although this proposed arrangement might raise concerns of technocracy to some, it is within the current bounds of experts' roles in democratic societies, albeit at a global scale (Parson 2015; Horton et al. 2018). Nevertheless, the distinction of responsibilities between those of the state-led general assembly and executive body, on the one hand, and the expert body, on the other, would not necessarily be clear. For example, solar geoengineering might be able to reduce impending extreme weather events such as hurricanes and droughts. Or after such an event, a participating country might claim that it had been harmed by solar geoengineering and demand immediate changes to the parameters of implementation. These would be high-resolution decisions, yet responses to them appear to go beyond the expert body's justified remit.

A multilateral agreement that would establish such an institutionalized means to make solar geoengineering implementation decisions might need to include assurances of compensation for harm or other concessions. One reason for this is that it might be necessary to obtain the consent, or to end the opposition, of target states that believe that solar geoengineering would cause them more harm than benefit (see Chapter 10). Another related reason is that even those necessary target states that would not expect net harm might hold out their support to try to obtain a greater share of the welfare surplus. If so, then side payments might be necessary to expand participation. Distinguishing between demands for compensation for harm and those for mere side payment might not be possible, as those in the latter group would likely portray themselves as belonging to the former. Regardless, a multilateral agreement could include a compensation fund for harmed states. As with that at the research stage, contributions should ideally be based upon ability to pay, historical greenhouse gas emissions, and expectation of benefits from solar geoengineering, as described in Chapter 10.

An intergovernmental institution to make decisions regarding solar geoengineering deployment could have a handful of additional responsibilities, some of which are common with those of the SGO. First, assessment of solar geoengineering deployment would be critical to help ensure that decisions are made on a sound scientific basis. An independent assessment body should regularly report to the institution, but its core activities should be kept at arm's length from the latter. Second, the agreement should include a mechanism to share financial and other burdens in ways that are considered fair. Third, its bodies should, to the extent possible, cooperate and be integrated with other relevant international institutions, include those for climate change in general, weather, the environment, oceans, food, and international security.[14] In some cases, these institutions should ex ante delineate their respective responsibilities, whereas in others it would be preferable to do so on a case-by-case basis. Fourth, the agreement and institution should, again to the extent possible, seek to prevent, minimize, and resolve international conflicts related to solar geoengineering. As in the SGO, a requirement for participating – and thus having a voice in implementation decisions – could be to commit to negotiate in good faith and to try to peacefully resolve disputes with other potentially affected parties. Finally, the institution should help prevent dramatic changes in the deployment regime, especially sudden and sustained termination. One way would be to ensure that the systems, equipment, supplies, relationships, and knowledge necessary for implementation would be redundant and secure from disruption. Another would be to develop a plan to reduce and, if appropriate, phase out solar geoengineering activities.

How a multilateral agreement to launch such an international institution would come about depends on the previous stage of large-scale research. If it were to proceed as I describe, then the SGO could be the vehicle for this and perhaps even evolve into the decision-making institution. Alternatively, it could arise from other international climate change institutions such as through a solar geoengineering protocol to the UNFCCC. Alternatively, other international bodies, including the UN General Assembly, the WMO, UN Environment, or even the UNCLOS parties, could catalyze an agreement. A final option is that the UN General Assembly and Security Council assume the roles of the proposed institution's general assembly and executive committee.

My suggestions thus far have been of optimistic but arguably realistic international cooperation. However, a legalized intergovernmental institution with operational decision-making authority might not be necessary or feasible. To the extent that monetary policy offers an instructive analogy to solar geoengineering, as noted above, then the lack of highly centralized decision-making there is notable. The most important institution in that domain, the International Monetary Fund, neither sets global monetary policy nor dictates its members' policies (apart from conditional loans). Instead, it monitors economic conditions, conducts research, provides a forum for sharing information, coordinates, offers advice, helps build capacity, and responds to crises. Perhaps such a model would be more appropriate for an international solar geoengineering institution. Furthermore, states'

[14] For an analysis of the needs of solar geoengineering governance with respect to potential conflicts and security, see Parson and Ernst (2013).

preferences regarding deployment might not diverge so greatly, which would reduce the benefits of deep cooperation. Likewise, the costs of cooperation to form a legalized decision-making institution in terms of limited negotiating resources, political capital, and the risk of forcing unnecessary divisive debates might be too great. And credible threats of counter–solar geoengineering could foster mutual restraint by decreasing states' incentives to use solar geoengineering earlier or to a greater degree than the wishes of the international community, or at least those of the states capable of sustained implementation.

If so, then an intergovernmental institution with the functions and the mandate of the SGO might suffice. That is, it could continue to facilitate research and monitoring; help ensure that solar geoengineering is done responsibly by assisting states with their domestic legislation and other regulation, developing and maintaining nonbinding governance instruments, and encouraging the prohibition of specific solar geoengineering methods and activities; prevent undue and premature escalation of deployment through, among other means, a nonproliferation mechanism; maintain and foster international trust and the perception of fairness by providing a forum for international discussions and consultation, limiting the roles of the military, facilitating transparency and procedural obligations; help share costs and other burdens; coordinate the relevant activities of other intergovernmental bodies; and try to minimize emissions abatement displacement.

Yet states might not cooperate, especially if international relations are fragmented. In the absence of both an international decision-making body with sufficient participation by target states and a coordinating agency in the model of the International Monetary Fund, existing international law, legal institutions, and norms could offer minimal and perhaps sufficient governance. First, all states are bound by the customary international law of preventing transboundary environmental harm (see Chapter 5). Any state that planned to deploy solar geoengineering would be obligated to practice due diligence, undertake all appropriate measures to reduce the risk, perform an environmental impact assessment, require prior authorization for any nonstate actors' solar geoengineering, notify and consult with potentially affected states, inform the public, and develop plans for possible emergencies. Second, under the UNFCCC, when states undertake activities to reduce climate change risks, they are to minimize adverse effects including those on the economy, public health, and the environment (Article 4.1(f)). Furthermore, if solar geoengineering were considered adaptation, then under the Paris Agreement it may not threaten food production and must be done "with a view to contributing to sustainable development" (Articles 2.1(b), 7.1). Third, parties to the UNCLOS have several commitments regarding protecting the marine environment, which would be affected by solar geoengineering (see Chapter 8). Fourth, ENMOD prohibits the hostile or military use of solar geoengineering and has fairly widespread participation (Article I.1). Finally, states could utilize traditional international diplomacy and negotiation to address potential disputes. In this, the UN Security Council could act as a backstop forum of last resort under its remit to maintain international peace and security.

Independent of the degree of formalized cooperation, nonlegal norms, including unwritten ones, of international behavior can have compliance pull. Economist and strategist Thomas Schelling – who was the first social scientist to write on solar geoengineering – dedicated his Nobel Prize lecture to the power of taboos and other norms in preventing nuclear war (Schelling 2006). It might seem remarkable that mere norms would have substantial influence on decision-making in arguably the most consequential of international affairs. However, it is precisely in such high-stakes issue areas that states are often less willing to make explicit commitments. Norms can thus fill a void, take hold for solar geoengineering, and play a substantial role in shaping states' behavior. After all, assuming that international law can guide their decision-making in novel domains puts the cart before the horse. Instead, practice gives rise to norms, which in turn can crystalize into international law.[15]

## 13.5 SUMMARY AND CONCLUSION

Geographer Mike Hulme asserts that solar geoengineering is "*ungovernable* because there is no plausible and legitimate process for deciding who sets the world's temperature" (Hulme 2014, xii; italics in original). I disagree. The legitimate and effective international governance of solar geoengineering is plausible. In this chapter, I have described possible governance that could increase current and future humans' well- being in ways that are sustainable, consistent with widely shared norms, and feasible. To be clear, I am not claiming that the future will unfold in this way. Importantly, the world might be much more conflictual. If so, then solar geoengineering – like numerous other phenomena with transboundary impacts – would have substantially suboptimal outcomes. Likewise, solar geoengineering's risks might outweigh its expected benefits, or society might reject it for noninstrumental reasons.

[15] Consider the examples of humanitarian intervention and international cyber conflict (Buchanan 2003; Nye 2018a).