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CLIMATE ENGINEERING
ASSESSMENT

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GOVERNING SOLAR RADIATION MANAGEMENT

Academic Working Group on Climate Engineering Governance

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LIST OF ACRONYMS

APA	Ad-Hoc Working Group in the Paris Agreement
CBD	Convention on Biological Diversity
CO_2	Carbon Dioxide
ENMOD	Environmental Modification Convention
EIA	Environmental Impact Assessment
ELSI	Ethical, legal, and social implications
E-PEACE	Eastern Pacific Emitted Aerosol Cloud Experiment
FAO	Food and Agricultural Organization of the United Nations
FCEA	Forum for Climate Engineering Assessment
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
LC/LP	London Convention and London Protocol
NDC	Nationally Determined Contribution
NGO	Non-governmental organization
RFPs	Requests for proposals
SBI	Subsidiary Body for Implementation to the United Nations Framework Convention on Climate Change
SBSTA	Subsidiary Body for Scientific and Technological Advice to the United Nations Framework Convention on Climate Change
SCoPEx	Stratospheric Controlled Perturbation Experiment
SPICE	Stratospheric Injection for Climate Engineering
SRM	Solar Radiation Management
WMO	World Meteorological Organization
UN	United Nations
UNCLOS	United Nations Convention on the Law of the Sea
UNEP	UN Environment (the United Nations Environment Programme)
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change

ABOUT THE REPORT AND ITS AUTHORS

This report offers a detailed examination, by a team of global governance experts, of governance needs and options for Solar Radiation Management (SRM) technologies. The report focuses on near-term governance, outlining feasible and needed actions that can be taken by approximately 2025, at the national, regional, and international levels and by non-state actors.

The fourteen experts who contributed to this report were convened as the Academic Working Group on Climate Engineering Governance (the Working Group). Starting in March 2016, we gathered for five meetings to consider and define the challenges and opportunities associated with SRM technologies and to craft a set of specific, actionable governance recommendations. During these meetings, the group heard from established experts on SRM as well as experts in the governance of other emerging technologies. Between meetings, group members delved into and contributed to the academic literature on SRM and into related policy conversations.

The report focuses on SRM as a subset of speculative climate engineering or geoengineering responses to climate change. SRM refers to technologies that might reflect a small percentage of incoming solar radiation back into space before it can warm the planet. Although the term "climate engineering" is often used to encompass both SRM and technologies that would remove carbon dioxide from the atmosphere in large quantities, the Working Group decided to focus solely on SRM in order to provide clear, sharp, and implementable recommendations pertaining to the specific governance challenges surrounding SRM.

This is an important moment for consideration of SRM governance. The Paris Climate Agreement has called for limiting global warming to well below 2°C. This ambitious target has invigorated efforts to transform the global energy economy, change patterns of land use, and take other steps to tackle climate change. But more must be done—including, most importantly, much more ambitious efforts to cut greenhouse gas emissions. Some scientists and policymakers have begun to consider supplementing emissions reductions with carbon removal and SRM, both of which have generated controversy and opposition due to concerns about potential dramatic social, economic, ethical, and political implications. This growing conversation about SRM and SRM research calls for robust, anticipatory governance, even though deployable SRM technology is likely very far off.

The report takes no position on whether SRM technologies are needed or desirable. Instead, the starting point for the Working Group's deliberations was the recognition that SRM technologies are already being discussed and researched, thus the need for governance is imperative. The members of the Working Group decided to restrict our focus specifically to governance of near-term research trajectories in part because we hold diverse views on the ultimate wisdom of SRM deployment. This diversity of views resulted from a deliberate effort to assemble a Working Group that would allow interplay between a wide variety of perspectives.

Some members of the Working Group reject SRM development philosophically because they see attempts to control the climate as unacceptably hubristic. Others reject it out of concern that any movement down a path toward research would

normalize SRM technologies, detract attention from the pressing need for ambitious mitigation, or commit the international community to some form of SRM deployment before risks, benefits, and burdens are sufficiently understood, let alone deemed governable. Some question SRM's compatibility with democratic and precautionary decision-making in the global public interest. Others believe that research on SRM should be encouraged and funded now—given that we do not know if any deployable or controllable technology could ever be created—and that an appropriate level of deployment could in principle be possible that avoided the moral, political, and environmental risks many have speculated about up until now. Others hold a "wait and see" position wherein much depends on the advancement of knowledge and confidence around SRM technologies, international mitigation and adaptation efforts, and better understanding of comparative risks of runaway climate change and SRM deployment. Along these lines, some seek more clarity on how SRM might evolve as an integrated element within a broad portfolio of climate response. Still others feel that SRM is inevitable and, neither rejecting nor embracing SRM technologies, remain normatively agnostic to research and potential deployment, but still wish for it to be governed appropriately.

Independent of such diversity, all authors see the need for legitimate and effective governance. Governance mechanisms provide fora within which to debate the virtues and problems of SRM technologies and constitute instruments to bring collective discernment and decision-making power to any SRM trajectory. Put differently, no matter how one feels about the direction of SRM technological development, governance mechanisms provide the essential means for deliberating about possible SRM futures and translating those into concrete practice.

The report outlines four objectives that should guide SRM governance and details twelve concrete, actionable recommendations. The report as a whole is a consensus statement of the Working Group, despite the wide range of views on specific elements of SRM governance.

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ABOUT THE FORUM FOR CLIMATE ENGINEERING ASSESSMENT

The Forum for Climate Engineering Assessment (FCEA) is housed within the School of International Service at American University in Washington, D.C. FCEA was established in 2013 to assess the social, ethical, political, and legal implications of climate engineering technologies (also referred to as "geoengineering" or "climate intervention" technologies). In doing so, our mission is to ensure that the climate engineering conversation maintains a focus on issues of justice, equity, and inclusion. We work to fulfill our mission by creating, catalyzing, and disseminating policy-relevant research and commentary and by acting as a convener and honest broker bridging between academic and policy conversations.

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EXECUTIVE SUMMARY

This report offers a practical guide for policymakers, civil society organizations, and anyone else interested in the governance of Solar Radiation Management (SRM). It details twelve near-term recommendations that should be implemented to govern SRM. In addition, the report explains why the governance of SRM demands immediate attention, outlines the current state of thinking about the risks and opportunities of SRM development, and seeks to define what it means to govern SRM well in the near term with an eye toward the future.

Governance of SRM: Key Considerations

SRM (sometimes called solar geoengineering or albedo modification) is a proposed means to respond to climate change. If they were ever to be successfully developed and used, SRM technologies could cool the Earth by reflecting a small percentage of incoming sunlight back into space. Leading proposals for SRM include depositing reflective particles into the upper atmosphere ("Stratospheric Aerosol Injection") or whitening low-altitude marine clouds ("Marine Cloud Brightening"). There is a possibility that, in combination with emissions reductions and adaptation, such technologies could be used in ways that alleviate some portion of some of the risks associated with a warming planet.

However, consideration of the development of SRM technologies, let alone their use at some future point, is highly speculative and contentious, for a variety of reasons.

One reason is that the development of SRM technologies would need to overcome large technical hurdles. Another, even more important consideration is that while SRM might help address certain risks associated with climate change, it also could create its own risks—including climatic, environmental, social, geopolitical, and ethical risks. Even small-scale research efforts and discussion of SRM could distract from needed climate change mitigation and adaptation activities and could lock in future large-scale research or even deployment.

Ultimately, this report makes the case that a balance must be struck in SRM governance. Governance must avoid too strict a shackling of SRM research, while simultaneously protecting against recklessly conducted research or deployment that could directly and indirectly harm people now and in the future.

Near-term Governance Needed Regardless of Position on SRM

The group of governance experts that prepared this report represent, by design, a diversity of perspectives. Following two years of workshops and deliberation, they are divided on the wisdom, practicality, and desirability of SRM technologies. Still, even with the wide range of perspectives in the group, this report represents a consensus statement about the need for near-term governance and presents a set of consensus recommendations.

The report seeks a path, then, that is not beholden to any of the bold claims that others have made either for or against development of SRM. The report sets out practical steps that ought to be taken now by national governments, international organizations, and civil society actors, whatever one thinks about SRM's potential contributions as a response to climate change or the risks that SRM development could entail.

The report has an explicit focus on the governance of near-term SRM activities up until about 2025. To govern SRM in the near-term entails developing mechanisms that can steer various kinds of SRM research and, in addition, promote broad, vigorous, well-informed societal discussions about that research. Such discussions should include whether and how, if at all, SRM might figure into a broader portfolio of

climate responses. That discussion is crucial because SRM remains in the early stages of technological development, which allows a rare, fleeting opportunity to encourage the development of more responsible research practices in an emerging field. Looking further into the future, near-term governance also means preparing existing institutions for a time when SRM may be considered more seriously as a policy option.

Establishing the Political and Scientific Context for Consideration of SRM

Section 1 of the report provides background, context, and definitions for SRM. The report remains agnostic about whether SRM research of any kind ought to continue or be promoted, as well as about the advisability of future SRM deployment. It argues that the growing conversation about SRM merits near-term efforts to govern small-scale research and foster inclusive and transparent societal deliberation. To that end, Section 1 situates current and emerging research efforts in the context of global climate policy and lays out the potential for, and limits to, SRM as a piece of a broader climate policy portfolio. This section argues that SRM is not, and should not be understood as, a substitute for climate change mitigation and adaptation.

Determining the Objectives of SRM Governance

Section 2 outlines a set of four objectives that should guide near-term efforts to govern SRM:

Objective I — Keep mitigation and adaptation first:

Ensure that, if SRM is considered, it remains subsidiary to mitigation and adaptation measures.

Objective II — Thoroughly and transparently evaluate risks, burdens, and benefits:

Develop the capacity for broad-based assessment of the diverse potential risks, burdens, and benefits of SRM.

Objective III — Enable responsible knowledge creation:

Ensure that any SRM-related research is responsive to societal needs and concerns to the greatest extent possible.

Objective IV — Ensure robust governance before any consideration of deployment:

Begin the near-term work of establishing effective institutions and norms to govern decisions about potential deployment.

Looking at SRM Governance Across Scales

Section 3 describes the governance roles and functions that can be and ought to be played at the national and international levels by state and non-state actors. The section makes clear that governance of SRM is about far more than formal regulation; it involves a wide range of formal and informal mechanisms for shaping outcomes. There is no need for national-level actors and international-level actors to wait on one another to take needed governance steps, though the section details the importance of and avenues for collaboration and coordination between actors and levels of governance.

A Set of Concrete Near-Term Governance Recommendations

Section 4 details three sets of essential activities that ought to be undertaken by the international community, national governments, and civil society organizations to begin the work of effectively and responsibly governing SRM. The activities are: create politically legitimate deliberative bodies; leverage existing institutions; and

make research transparent and accountable. The activities are fleshed out through a set of twelve concrete recommendations for governance action.

The recommendations detail actionable near-term steps, pointing to lessons learned from efforts to govern other complex technologies or issue areas. At the same time, the recommendations try to avoid being overly prescriptive. In this early stage of research and development, society must create governance mechanisms in the context of great uncertainty about the dangers and merits of SRM technologies now and in the future. The recommendations are designed to pave the way to development of politically legitimate processes and arrangements necessary for SRM governance.

The three sets of activities and corresponding recommendations are:

Create politically legitimate deliberative bodies

1. Establish a World Commission on SRM.
   Develop a high-level representative body to engage in a broad-based international dialogue on issues related to governance of SRM. This body's mandate should include, inter alia*, debating first-order questions about whether and to what end SRM should be researched and developed, and how it fits within a broader climate response landscape.*
2. Establish a Global Forum for Stakeholder Dialogue.
   Develop a forum, venue, or process to allow deliberation by stakeholders who might otherwise be marginalized from international deliberations about SRM but may be impacted by any SRM governance decisions.

Leverage existing institutions

3. Strengthen cooperation between international organizations.
   Additional mechanisms for coordination across international organizations on the subject of SRM should be developed to identify existing institutional capacities for SRM governance within the international system.
4. Assess and improve capacities for regional coordination and conflict resolution.
   Coordination at the regional scale is important for understanding the spillover effects of SRM and for encouraging transboundary cooperation. Regional organizations should work to better understand potential positive and negative spillover effects, and link these to other forms of dialogue about regional environmental governance.
5. Continue ongoing assessment role for IPCC and related processes.
   The work of the IPCC and other relevant and legitimate assessment bodies to assess the current state of knowledge on SRM, including both scientific and social scientific work relating to SRM, should continue, in order to ensure that any consideration of SRM research and potential deployment occurs in the context of current climate science.
6. Develop foresight capabilities in decision-making systems.
   National governments and appropriate coordinating UN bodies should work to develop and employ foresight practices to inform consideration and development of governance structures for the research and potential deployment of SRM technologies.

Make research transparent and accountable

7. Report on SRM research and development activities in the global stocktake under the Paris Agreement.
   An evaluation of global research and development trends on SRM should be included in the stocktake exercise of the Paris Agreement on climate change under the UNFCCC, in order to ensure greater transparency regarding the development of these technologies.
8. Institutionalize codes of conduct for responsible SRM research.
   In countries in which SRM research is currently underway, or is foreseen to emerge in the near future, the scientific community should coalesce around a specific and explicit code of conduct for SRM research. Funders should require grantees to adhere to an established code of conduct.
9. Ensure that ongoing research includes international and interdisciplinary collaboration.
   State and private funders of SRM research should prioritize projects that feature substantial international and interdisciplinary partnerships.
10. Clarify funding streams.
    With the goal of ensuring transparency and responsible research, all sources and recipients of research funding should be a matter of public record and there should be clarity that funding is specifically for SRM.
11. Develop a publicly accessible clearinghouse.
    National governments should develop publicly accessible clearinghouses of all publicly funded and, to the extent possible, privately funded SRM research. Such national clearinghouses should, in turn, feed data into an international clearinghouse. The clearinghouses should be designed and developed by an existing authoritative body or ideally through a collaboration among a set of authoritative bodies.
12. Develop best practices for risk and impact assessments.
    National governments, risk assessment and environmental impact assessment (EIA) experts, and SRM researchers should work together to expand risk assessment and EIA procedures and protocols so that they can provide evaluation of potential environmental and social harms as well as enable public notification and consultation, for SRM experiments.

While these recommendations should be viewed as an ideal package and are connected to one another in various ways, the implementation of any one recommendation need not wait on the implementation of all. Whatever one believes about the desirability or feasibility of SRM research or potential technologies, the largely ungoverned status quo is untenable. The actions detailed in this report to govern SRM should begin now.

SECTION 1: INTRODUCTION

This report poses and answers the following questions:

> What near-term steps should be taken toward the governance of solar radiation management (SRM)? What objectives should those actions serve?

Researchers in a number of countries are currently studying SRM as a potential response to climate change. Almost all of the known SRM research to date has been theoretical, including computer modeling and laboratory studies in the physical sciences and engineering, as well as research on the ethical, social, and legal aspects of SRM. Research is beginning to move outdoors with small-scale experiments designed to help understand basic physical processes relevant to SRM. Researchers have discussed larger experiments, including global field trials, but these are unlikely to take place for many years, if ever.

The existing research has elicited strikingly different reactions. Some people have inferred from existing research that SRM, when combined with cuts in greenhouse gas emissions, might prove useful in protecting people and ecosystems from the threat of climate change. Other people have concluded that SRM is a dangerous distraction from the central task of cutting greenhouse gas emissions.

The Academic Working Group on Climate Engineering Governance (the Working Group) responsible for preparing this report itself is divided on the desirability or necessity of SRM research, but we assume that small-scale SRM research is likely to continue in some form, including computer modeling, physical science, engineering, social, ethical, and legal research. Near-term governance of SRM therefore means, first and foremost, governance of various kinds of SRM research and promotion of a vigorous, well-informed societal discussion about that research and about whether and how SRM might figure into a broader portfolio of climate responses. Near-term governance also means preparing existing institutions for a time when SRM might be considered as a serious policy option.

"Work on the governance of SRM must begin now, whatever one's beliefs about the ultimate wisdom of SRM technologies."

Failure to govern SRM wisely in the near term risks a range of bad outcomes, including the failure to learn about the opportunities, limits, and unintended consequences of SRM; an overly narrow decision-making community; a widening gap between global society and policymakers; capture by vested interests; or potential technological and institutional lock-in. Poor governance of research into and discussion about SRM may lead to even more severe risks in the long term, especially insofar as near-term governance and discussions lay the foundation for future decisions surrounding potential deployment. (This report outlines the risk-risk trade-offs involved in decisions surrounding SRM in Box 3 on page 4.)

Therefore, a balance must be struck. Governance must protect against recklessly conducted research or deployment that could directly and indirectly harm people now and in the future. At the same time there are risks associated with too strict a shackling of research. To navigate between these two sets of risks successfully, governance mechanisms must be able to characterize, account for, monitor, and control the potential risks associated with SRM. In light of these challenges and the long lead time needed to establish adequate governance, now is the time to develop anticipatory governance mechanisms to manage these emerging and potentially disruptive technologies.

BOX 1. WHAT IS SOLAR RADIATION MANAGEMENT?

Solar radiation management (SRM) is a proposed method for cooling the planet by reflecting a small percentage of incoming sunlight back into space before it can warm the Earth. This makes it a type of climate engineering, which the UK Royal Society defines as the "deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change." (The other primary class of proposed interventions that has typically been categorized as climate engineering is carbon removal, which is also known as carbon dioxide removal or negative emissions technology. Carbon removal involves capturing carbon dioxide from the atmosphere and disposing of it in various ways. This report does not address carbon removal.)

Reflecting even a small fraction of incoming sunlight back into space could, in principle, offset much or all of the warming caused by humanity's greenhouse gas emissions. The side effects and risks of doing so would increase with the amount of warming offset by SRM. (See Box 3 on p. 4 for an overview of these risks.) To reduce these risks, the dominant ideas for using SRM focus on slowing the rate of warming or temporarily suppressing the global average temperature while society lowers atmospheric greenhouse gas concentrations by cutting emissions and deploying carbon removal on a large scale. Some people have also suggested regional applications of SRM for purposes such as protecting the Arctic or the Great Barrier Reef.

People have imagined various technologies for implementing SRM. Researchers are actively studying several of them, most notably stratospheric aerosol injection and marine cloud brightening.

Stratospheric aerosol injection would involve releasing reflective particles into the upper atmosphere, where the particles would scatter sunlight back into space. One proposal is to release these particles from specialized, high-flying aircraft. These particles would, differentially based on particle size and the quantity of injected material, fall back to Earth from the upper atmosphere over about a year. Thus, they would need to be replenished constantly to maintain their effect.

Marine cloud brightening would involve releasing tiny particles of sea salt or other compounds into the lowest one kilometer of the atmosphere over the oceans. These particles could, under appropriate conditions, cause low-lying clouds to become brighter, thereby reflecting more sunlight back into space. One proposal is to inject sea salt from a fleet of small ships patrolling the oceans. Without constant efforts, the effects would dissipate within days or weeks

Most other ideas for SRM focus on increasing the reflectivity of the Earth's surface. Proposals include painting roofs white, choosing or creating more reflective crop varieties, covering desert areas in reflective plastic, and creating a layer of highly reflective microbubbles just below the surface of lakes or oceans.

A related idea is cirrus cloud thinning. This is sometimes lumped together with SRM under the broader umbrella of "radiation management." Artificially thinning high-altitude cirrus clouds would allow Earth to radiate more energy into space, thereby cooling the planet. Since this would be a technique focused on manipulating Earth's radiation, rather than the Sun's, it is not technically solar radiation management, but it is often discussed alongside SRM.

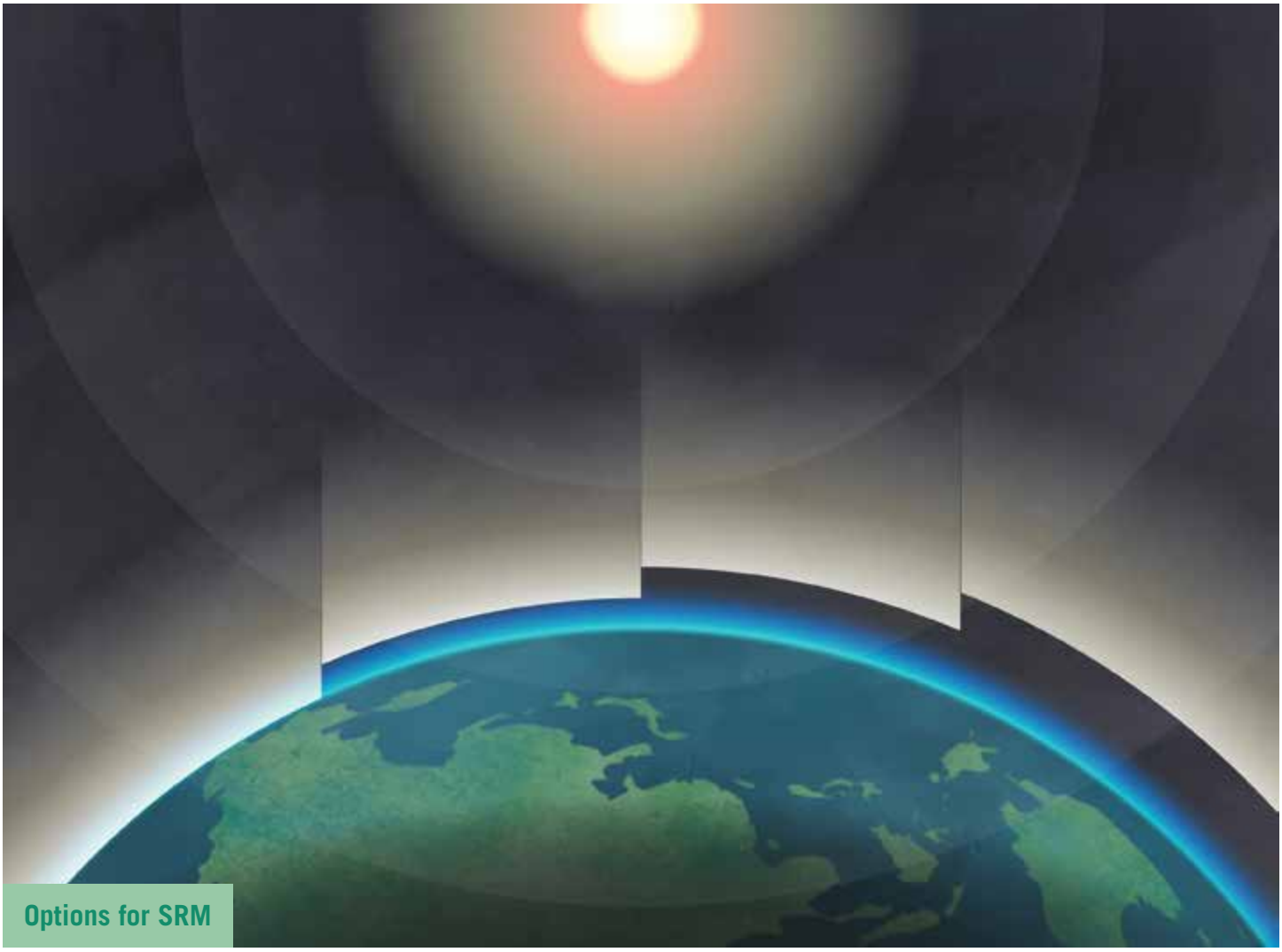

Figure 1: Options for SRM: Artistic representation of proposed solar radiation management techniques, from left to right: surface level albedo modification, marine cloud brightening, stratospheric aerosol injection, and space mirrors.

BOX 2. GOVERNANCE VS. REGULATION

"Governance" is a broader term than "regulation." Regulation typically involves formal international, regional, or domestic laws and policies imposed by governments or international organizations. This report understands governance to include not only regulation in this sense, but any system of formal or informal rules or voluntary guidelines intended to influence research into or deployment of SRM. This includes rules or guidelines that apply internationally, transnationally, within a single country, or at the behest of nongovernmental organizations or civil society more broadly. Governance is inclusive of (but not limited to) monitoring, assessment of impacts, and feedback processes such that new information and developments can be taken into account. Examples of non-regulatory governance mechanisms include: non-binding resolutions by intergovernmental organizations; voluntary codes of conduct for researchers; rules and requirements imposed by funders, universities, or professional associations; memoranda of understandings between nongovernmental organizations, governments, or international organizations; and so on. Effective governance of SRM will require a combination of many different kinds of mechanisms at many different levels.

BOX 3. RISK-RISK TRADE-OFFS RELATED TO SRM

SRM raises three sets of potential risks:

1. risks involved in researching SRM or not researching it;
2. risks involved in deploying SRM or not deploying; and
3. risks involved in governing SRM.

In each category, risks arise both when steering toward SRM and when steering away from it. It is essential in any discussion of SRM risks to stress the deep uncertainties at play, a situation that limits the usefulness of traditional understandings of risk assessment and risk-risk tradeoffs. Below is a summary of the literature on risks associated with SRM, rather than a consensus statement from the Working Group about what the risks associated with SRM actually are.

1. Risks Associated with Decisions about Research

Researching SRM creates risks. The main risks created by SRM research include:

- *Dangerous reductions in efforts to cut greenhouse gas emissions.* Policymakers may use the prospect of SRM to rationalize less ambitious mitigation policies, especially if they or the public mistakenly come to believe that SRM can replace emissions reductions. This is often called the "moral hazard" problem. (See Box 8 on p. 16.)
- *Technological lock-in at the research and development stage.* Excessive focus on specific approaches to SRM could close off opportunities to explore new and more promising approaches.
- *Technological lock-in from research to deployment.* Once a research pathway is established, it could drive towards a deployment scenario whether or not there is broad agreement that such a scenario is desirable or warranted.
- *Capture by special interests.* Special interests of various kinds, from corporate actors to militaries, might capture the research process and redirect it to serve their own ends rather than the public interest.
- *Facilitating reckless or rogue deployment.* Research and development of SRM technologies would make it easier for one or more countries to deploy SRM irresponsibly or without widespread agreement.

At the same time, there are risks associated with forgoing SRM research. The main risks associated with forgoing SRM research include:

- *Ignorance of the potential benefits, risks, limits, and unintended consequences of SRM.* Without a deeper knowledge of SRM, the global community might eventually, at some future point, deploy SRM unwisely or, alternatively, could fail to deploy SRM citing a lack of knowledge and understanding when deploying SRM would significantly reduce climate risk.
- *Inability to deploy SRM quickly if it were needed.* Scientists estimate that it would take roughly twenty years' worth of research to learn how, if at all, SRM could be responsibly deployed. Forgoing SRM research now would mean that it could not be deployed responsibly on short notice in the future.
- *Missing out on potential co-benefits associated with SRM research.* Even if SRM research makes little progress in understanding SRM technologies, SRM research may improve other parts of our understanding of climate science or fundamental atmospheric physics and chemistry

2. Risks Associated with Decisions about Deployment

On the one hand, deploying SRM would create many kinds of risks. These risks would vary significantly with different approaches to deployment (e.g., a Marine Cloud Brightening scheme would have a very different risk profile than an injection of stratospheric aerosols) and with different scales of deployment.

Continued from page 4

At some low levels of deployment, some of the risks listed below may not be present at all. With those caveats, the main risks involved in deploying SRM include:

- *Undesirable climatological impacts*. Cooling the world with SRM would not restore a preindustrial climate; it would create a new climate that humans have never experienced before. This climate might reduce temperatures, both globally and regionally, but there is also a risk of adverse regional or local climate impacts or catastrophic global impacts, including unexpected impacts.
- *Unknown risks*. There is currently limited understanding of the full range of effects of potential SRM deployment or large-scale research. This leaves open the possibility of serious, unanticipated adverse consequences (for species, ecosystems, livelihoods, etc.) over different time scales.
- *Inequitable geographical distribution of burdens and/or benefits*. The regional variations in impact also raise the possibility of an unjust distribution of the burdens and benefits of SRM.
- *Inequitable distribution of benefits and/or burdens across time*. The generational variations in impact raise the possibility of an unjust distribution of the burdens and benefits of SRM across time.
- *Geopolitical conflict*. Disputes over SRM deployment or even large-scale research could lead to international conflict, especially in the absence of adequate governance.
- *Termination shock*. If SRM were deployed for a long time and at high intensity in the absence of large-scale mitigation and/or carbon removal (i.e., if SRM were used while greenhouse gas concentrations were allowed to rise), a sudden termination of SRM would lead to a dangerous spike in global temperatures.
- *Technological lock-in during deployment*. Especially if SRM were deployed in the absence of strong mitigation policies and/or development of large-scale systems of carbon removal, future generations might find themselves in a situation where it is very difficult to phase out deployment, even if serious negative consequences become apparent.
- *Other environmental risks*. Different methods of deployment might create specific kinds of environmental risks, such as ozone depletion or biodiversity loss. Deployment in the absence of strong mitigation policies would also leave the problem of ocean acidification from higher carbon dioxide levels largely unaddressed.

On the other hand, climate change itself poses grave risks—including regional and local climate impacts, inequitable outcomes, and geopolitical conflict. In a business-as-usual scenario, these impacts could turn out to be worse than the risks created by deploying SRM. In that case, declining or failing to deploy SRM could be worse than deploying it, with the proviso that the uncertainty is so great here that there is currently no way to assess whether the risks of deploying are greater than the risks of not deploying. Some have argued that such circumstances warrant a precautionary approach to decision-making.

3. Risks Associated with Governance

Decisions about SRM research and possible deployment involve complex risk-risk trade-offs, and different governance arrangements influence those trade-offs in different ways. In general, good governance of SRM must navigate between the following risks:

- *Channeling SRM research in inappropriate directions*. Overly stringent and top-down governance could incentivize SRM research being conducted in secret or in ways that primarily serve special interests or risk geopolitical conflict. In this regard, it is important to recognize that much SRM research could be conducted under the guise of basic climate science research, which makes attempts to govern SRM research absent buy-in from relevant research communities difficult to enforce.
- *Lack of integration into the broader climate change response agenda*. The failure to integrate SRM research into the mainstream climate science and policy communities and conversations could result in a failure to contribute to our broader understanding of climate change research and governance and a failure to properly vet SRM technologies.

Continued from page 5

- *Inappropriately shackling SRM research and innovation.* Policymakers should recognize that governance could either restrain or facilitate research. Some forms of governance could slow the development of appropriate scientific knowledge about SRM, including knowledge about how to monitor, assess, and govern proposed SRM deployments.
- *Exacerbating the risks inherent in SRM research and deployment.* The risks associated with SRM research and deployment could be exacerbated by inappropriate governance structures, including a continuation of the largely unregulated status quo. These include: policymakers using the prospect of SRM to rationalize less ambitious mitigation policies; technological lock-in to suboptimal technologies or deployment; capture of research or deployment by special interests; reckless or rogue deployment of SRM; geopolitical conflict over the deployment of SRM; and undesirable climatological impacts from SRM deployment or the abrupt cessation of deployment. In other words, bad governance could push SRM in undesirable directions; good governance would both deter undesirable developments and promote desirable ones.
- *Imposing undue costs on those most vulnerable to climate change now and in the future*. There are important equity and justice dimensions to SRM governance decisions. In a procedural sense, the voices of those who will be most impacted by SRM technologies - both now and in the future - ought to be included in decision-making processes. In a substantive sense, it is important to pay attention to the needs of those who are already hit hardest by climate change or who are otherwise in vulnerable positions, to ensure that any benefits or burdens associated with SRM are, to the extent possible, allocated fairly.

Debates about the propriety of research on or potential deployment of some form of SRM in the future have gained new urgency with the adoption of the Paris Agreement in 2015. The Paris Agreement commits the world to "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C." Most modeling studies suggest that it will be very difficult to meet these goals without large-scale carbon removal (also known as negative emissions technologies). It remains unclear, however, whether carbon removal is viable at such scales, leading some to argue that we need to begin the long process of determining whether SRM might serve as a suitable supplement to mitigation in meeting ambitious temperature targets.

"SRM is not, and should not be understood as, a substitute for mitigation."

Any role that SRM might be able to play in support of the Paris targets remains, however, highly contentious. Most importantly, the Working Group affirms that SRM is not, and should not be understood as, a substitute for mitigation. Even if SRM deployment becomes technically feasible and even should it come to be viewed as an essential tool to control unacceptable levels of global warming, the priority in global climate policy should always first and foremost be aggressive reductions in greenhouse gas emissions. This is because while modeling suggests that SRM might be used in ways that slow or suppress the impacts of warming, SRM technologies alone would fail to address the physical cause of that warming—the buildup of greenhouse gases in the atmosphere. Furthermore, it is clear that SRM would, at best, compensate imperfectly for greenhouse warming. For instance, deployment of SRM technologies would fail to perfectly offset the impacts of warming on rainfall patterns, would slow or limit but not prevent sea level rise, would not

stop ocean acidification, and there are concerns that it would expose human populations and ecosystems to a variety of environmental risks that would increase with the intensity of SRM deployment. In this sense, if SRM is advanced in any form, it must be recognized as only a small piece of a larger portfolio of responses to climate change.

There are also political considerations. While some commentators see legal avenues by which SRM might one day be brought into the Paris Agreement and see potential benefit in doing so, others have suggested that formal consideration of SRM under the Paris Agreement may add complexity to already difficult negotiations around liability and burden-sharing for collective climate action or may distract from the climate change mitigation and adaptation agendas (see Box 4 on p. 7).

Furthermore, the Working Group regards actual deployment of SRM in the near term as both highly unlikely and ill-advised if it were ever given serious consideration. Some members of the Working Group believe this is the case for technical reasons; others because there is at present no governance capacity to adequately assess a proposal for deployment; and others because the adverse risks associated with deployment are potentially far too high to imagine its execution in any responsible manner. Any decision about deploying SRM, then, or engaging in large-scale research efforts that could potentially have large-scale climatic impacts must occur only after society has had more time to assess the success of the Paris Agreement and the prospects for carbon removal.

Finally, the Working Group urges that *there be no consideration or development of SRM technologies undertaken in a fashion that exacerbates existing inequalities or otherwise disproportionately affects the poor.* If SRM is ever deployed, it should not be used as a strategy for the rich and powerful to avoid the hardships of global warming at the expense of poor or marginalized people. The implication for near-term governance is that SRM research should only be pursued in the public interest, paying special attention to the needs, interests, and voices of the world's most vulnerable people.

BOX 4. THE PARIS AGREEMENT AND CLIMATE ENGINEERING

To date, the Parties to the Paris Agreement have not entered into considered discussions about the potential role of SRM in achieving the goals of the Agreement. However, this could emerge as a question in the future. The members of this working group do not have a consensus view on the topic, and are not endorsing any of the various views on this matter.

While this report is not focused on it, there are many in the broader climate community that believe that one or another form of proposed carbon removal technologies could play an important role in meeting the Paris Agreement's overarching objective of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C." The scope of potential mitigation options under the Agreement include both reducing greenhouse gas (GHG) emissions and enhancing carbon dioxide (CO_2) sinks, which could include deployment of carbon removal. There are an increasing number of experts who believe that achieving the temperature target under Paris will require large-scale deployment of carbon removal technologies. The draft IPCC report on 1.5°C provides reasons that support this view. Some Parties have included afforestation, which is a form of carbon removal, in their mitigation pledges under Paris, known as "Nationally Determined Contributions" (NDCs), which will eventually be harmonized under regularly sequenced intervals. Parties might someday choose to include other more speculative forms of carbon removal as well. One reason why this might occur is that the Paris Agreement also called on Parties to develop "mid-century long-term low GHG emissions development strategies," or longer-term assessments of how they would eventually achieve deeper decarbonization goals by 2050, beyond their initial NDCs submitted when the Agreement was

Continued from page 7

negotiated in 2015. Many of the Parties that have submitted these mid-century strategies to date have included possible deployment of carbon removal as part of their plan for achieving their goals. There is also however a rich literature that speaks to the criticisms of various proposed forms of carbon removal. Individual carbon removal technologies face particular technical, environmental, and social challenges, especially at large scales. For instance, one form would require diverting arable land to bioenergy crops, endangering biodiversity and food security. More generally, any country that builds its near-term climate policies on the hope of long-term carbon removal is taking a "high-stakes gamble" that could have disastrous consequences if carbon removal proves infeasible at scale.

In contrast, there appears, at the level of national governments, to have been little contemplation of a role for SRM in meeting Paris Agreement targets. SRM, unlike carbon removal, has not found its way into existing NDCs. Discussion of SRM in the context of the Paris Agreement to date has thus remained largely restricted to some academic commentators, representatives from civil society groups, and other non-state actors, speculating about its potential role or lack thereof in meeting Paris targets.

The following description of avenues by which SRM might be formally considered under the Paris Agreement or might be excluded from consideration is meant to characterize an existing academic conversation, rather than be seen as speculation about or endorsement of any position that might actually be taken by Parties to the Agreement. Some commentators have argued that SRM options could not legitimately be incorporated into the mitigation part of a Party's NDC because reflecting sunlight back into space neither reduces GHG emissions nor directly enhances sinks. Other commentators have suggested that SRM options could protect carbon dioxide sinks and reservoirs that are vulnerable to temperature change, such that a Party might argue that SRM is an appropriate part of an NDC in that context. Still other commentators have made the case that some Parties might argue that deployment of SRM technologies—if ever successful—could help to address the "loss and damage" provisions in the Paris Agreement, i.e., those climate impacts to which adaptation is not possible, with SRM serving as a form of emergency preparedness, or as a hedge against slow-onset events like sea level rise.

In terms of the implications of discussing SRM within the Paris Framework, some commentators stress the risk of such inclusion contributing to a moral hazard scenario in which SRM replaces ambitious mitigation.

Regardless of such diverse views, the Parties to the Paris Agreement might take up the propriety of SRM for some reason in the future. It needs to be kept in mind that even if Parties came to an agreement that SRM could not be a legitimate component of an NDC, neither the Paris Agreement nor the UN Framework Convention on Climate Change could, as currently constituted, prohibit any state from doing research on, or eventually deploying, SRM. This underscores the urgent need for a politically legitimate, international body, such as a World Commission established by the United Nations General Assembly (see Recommendation 1 on p 30), to debate the merits of pursuing SRM as a climate response option, and the attendant governance challenges that such research poses.

Figure 2: Artistic representation of stratospheric aerosol injection

Our current system of global governance is poorly equipped to make prudent decisions about large-scale research and deployment of SRM. There is a gap in technical knowledge (and broad access to knowledge) to adequately understand the possible effects of specific SRM technologies on environmental, economic, political, and social systems. National governments and other major actors are engaging in little, if any, policy coordination on SRM. There is no global consensus about the ethics of reengineering the planet, nor about how to appropriately distribute the potential risks and benefits of SRM among existing and future populations. There is no effective global mechanism to represent the voices of populations whose livelihoods could potentially be most directly affected by SRM and, indeed, the voices of the public at large. There are gaps in intellectual property schemes to ensure that SRM research fulfills the public interest, and virtually no risk management or compensation mechanisms to deal with the

"Our current system of global governance is poorly equipped to make longer-term decisions about large-scale research into and possible deployment of SRM."

potential negative consequences of SRM. There are limited means by which to catalyze research that provides essential knowledge and understandings across fields and limited means to nurture the development of shared norms. Finally, to the extent that the development of SRM may require the application of hard law, we lack an effective system of international enforcement of rules and norms.In the face of such challenges, the recommendations in this report constitute the near-term steps that are most urgently required to begin building a more legitimate and effective system of SRM governance. Academics and others have already advanced a range of governance proposals to deal with these complex issues. This report, however, marks the first time that a group convened specifically for their expertise on global governance has issued a set of concrete, actionable governance recommendations that are accessible and relevant to policymakers. This report aims to bridge the gap between the existing academic literature on the governance of SRM and the need for actionable, authoritative advice for governing SRM in the near-term, in particular. The approach of this report is to move beyond high-level statements of good governance principles to propose concrete, workable governance recommendations.

Based on that premise, our report presents a set of governance objectives and specific recommendations. The objectives have been derived from prior academic work and from the Working Group's independent assessment of what it means to manage SRM developments in the next decade. The recommendations translate the objectives into action steps. Throughout, the report focuses on those actions most needed in the near term.

"This report, however, marks the first time that a group convened specifically for their expertise on global governance has issued a set of concrete, actionable governance recommendations that are accessible and relevant to policymakers."

The report is organized as follows. Section 2 outlines a set of objectives that must be met for the effective governance of SRM. Section 3 underscores the need for alignment of governance across scales and sectors and provides a rationale and context for governance in national, international, and non-state domains. Section 4 then details our recommendations for near-term governance of SRM with an eye to the governance requirements associated with any longer-term development of effective SRM management capabilities.

BOX 5. HOW THIS REPORT BUILDS UPON PRIOR SRM GOVERNANCE REPORTS

The idea of SRM has been around for decades, but few people pursued research into any aspect of SRM seriously until the last decade or so. In 2006, Nobel Prize-winning atmospheric chemist Paul Crutzen published an editorial encouraging research into SRM. Physical and social scientists, engineers, lawyers, ethicists, and others took up the challenge. Since then, research on the topic has ballooned.

A significant proportion of that research has focused on the governance of SRM and various kinds of SRM research. The first landmark effort, by a number of scholars at Oxford, University College London, the University of Cardiff, and elsewhere, resulted in the Oxford Principles. These broad principles call for regulating climate engineering as a public good; including public participation in climate engineering-related decision making; disclosing the results of climate engineering research; independent assessment of impacts; and "governance before deployment."

Since the introduction of the Oxford Principles in 2009, many scholars and research bodies have offered their own suggestions for governing climate engineering research. Most of these have come from North America or Europe. A 2017 study by the Forum for Climate Engineering Assessment, undertaken to inform the deliberations of the Working Group, found substantial overlap in the recommendations issued in prior reports on climate engineering prepared between 2009 and 2015.

Note that the account below, which highlights points of agreement in prior reports, is not meant as an endorsement of any particular recommendation or set of recommendations, but rather is meant to indicate the starting point for the Working Group's deliberations. The present report builds from, and in some cases questions and challenges, the assumptions and conclusions of prior efforts.

Prior reports on SRM governance have indicated general agreement on the following ten points:

1. If SRM is ever deployed, it should be in addition to traditional mitigation and adaptation.
2. Existing national and international laws and institutions provide partial governance of SRM, but additional governance mechanisms are needed.
3. A moratorium on SRM research is inadvisable at this time.
4. Governance structures should encourage international cooperation and coordination on SRM research.
5. If research does proceed, transparency and openness are critical.
6. Public engagement is desirable.
7. Governance should be proactive rather than reactive.
8. Governance arrangements should be flexible and adaptive.
9. For now, informal, soft-law approaches to climate engineering governance are better than formal, hard-law approaches.
10. Governance must strike the right balance between legitimacy and effectiveness.

Beyond this general consensus on the basic principles for governing SRM, there is comparatively little agreement on concrete recommendations for putting those principles into practice.

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SECTION 2: THE OBJECTIVES OF SRM GOVERNANCE

Deciding which objectives SRM governance should serve requires understanding both the current state of SRM research and anticipating how it might develop over the coming decades.

SRM remains very much an emerging technology. Although research into SRM has intensified quickly over the last decade and will likely continue to do so, researchers remain almost exclusively focused on theoretical studies, computer modeling, social science, ethics, and governance. Exceptions to this rule include an outdoor experiment that was planned and then abandoned in the United Kingdom in 2011, as well as a small outdoor experiment off the coast of California that was loosely related to marine cloud brightening.

This situation is likely to change in important ways in the near future, especially with respect to physical science and engineering research. A small but growing number of philanthropic funders and national government funding agencies are beginning to take an interest in the area, and scientists are slowly moving toward taking their research outside the laboratory. For instance, researchers at Harvard University's Solar Geoengineering Research Program are planning a small outdoor experiment called SCoPEx in the near future, and researchers at the Marine Cloud Brightening project are looking to run an experiment of their own, as well. (See Box 7.)

BOX 6. LESSONS FROM PAST SRM EXPERIMENTS

E-PEACE Experiment

The Eastern Pacific Emitted Aerosol Cloud Experiment (E-PEACE) was an experiment off the coast of central California in 2011 to learn more about interactions between aerosols, clouds, and radiation. A team of university researchers led by the University of California, San Diego used an aircraft, satellites, and a research ship to study the effects of particle emissions on marine clouds.

Although the researchers explicitly mentioned the relevance of their experiment to Marine Cloud Brightening, they regarded it primarily as a cloud-physics experiment. As a result, it did not attract any special scrutiny or governance beyond any that would accompany another physically similar outdoor experiment. In a sense, however, E-PEACE could be considered an early SRM experiment. This highlights the challenge of distinguishing SRM experiments from experiments with other aims.

SPICE

The Stratospheric Particle Injection for Climate Engineering (SPICE) project was a 2011–2012 research project in the United Kingdom, led by researchers at the University of Bristol and other UK universities and funded by the UK government. One part of the project involved a proposal to float a balloon at an altitude of one kilometer and then pump a small amount of water up through a hose attached to the balloon. The motivation for this experiment was to study a model of a potential delivery mechanism for stratospheric aerosols.

The researchers driving the SPICE project labeled it as a climate engineering project, planned public engagement components that evolved and broadened over the course of the project, and were required by UK funding agencies to follow a "stage-gate" review process. Eventually, however, the research team cancelled the balloon experiment. While a range of factors have been credited for the cancellation, perhaps the most important was discomfort within the research team about potential conflicts of interest related to a patent application.

BOX 7. SRM Experiments on the Horizon

SCoPEx

Researchers at Harvard University are planning a small outdoor experiment to help them understand how tiny particles behave in the stratosphere. They call this experiment SCoPEx, which stands for "Stratospheric Controlled Perturbation Experiment." The researchers propose to lift scientific equipment into the stratosphere utilizing a specialized balloon. The equipment will release up to a few pounds of water ice or powdered limestone in the balloon's wake. Instruments on the balloon will monitor the wake to observe the physical and chemical processes affecting the released particles. Researchers involved with the project have said that they "may also release other materials such as sulfates in response to evolving scientific interests."

This experiment is at far too small a scale to have any discernible impact on local, regional, or global climate. The motivation for the experiment is to test and improve researchers' understanding of the atmospheric chemistry of the upper atmosphere, which will improve their ability to predict the effectiveness and risks of stratospheric aerosol injection.

SCoPEx has attracted some attention because, like the canceled balloon experiment in the SPICE project, it would be an outdoor experiment aimed primarily at understanding some aspect of SRM. Critics worry that it opens the door to more and larger-scale research. Both critics and supporters of the experiment see it as adding urgency to the need for institutions and mechanisms for governing SRM research.

MARINE CLOUD BRIGHTENING EXPERIMENT

Researchers in the Pacific Northwest and Silicon Valley have laid out an initial plan for a decade-long process of research and development for marine cloud brightening. Having begun with the engineering challenge of designing nozzles that could spray tiny salt particles into low-lying clouds, this Marine Cloud Brightening Project hopes to begin the next phase of their research by testing the nozzles outside the lab.

The first experiment in their proposed research program would involve building a series of machines similar to the snow-making equipment used at commercial ski areas. Rather than making snow, these machines would pump water through the researchers' specialized nozzles, creating tiny droplets and spraying them upward toward low-lying clouds. Placing several of these sprayers somewhere on the U.S. Pacific coast, the researchers would observe the droplets' behavior and their effects on the brightness of nearby clouds over a short period of time.

If that stage of the project is undertaken and yields promising results, the researchers would plan to begin experiments at sea. Initial experiments would place sprayers on one or more ships and use ships and aircraft to monitor their effects on nearby clouds. Larger experiments might deploy more ships over an area roughly the size of Jamaica for a period of two or three months. The motivation for such experiments is to better understand how clouds respond to brightening efforts over more varied conditions.

Small-scale outdoor experiments like these have negligible, if any, direct environmental impacts. They aim to sharpen understandings of the physical and chemical processes related to SRM, to test hypotheses about the ways particular SRM technologies might operate, or to test equipment that might be used to implement SRM.

Importantly, these small-scale "process" tests are the only sorts of outdoor SRM-related experiments the Working Group expects to happen in the near term. Some researchers have sketched out potential research pathways that would build on these initial experiments to test SRM technologies at larger scales—maybe up to 1,000 square kilometers—and then, if it were justified, at a global scale. If tests were to scale up in size they would also likely scale up in duration. Global experiments carried out over significant spans of time would be the only way to fully test the global climate response to any SRM technology, blurring the line between large-scale tests and actual deployment of SRM technologies. The Working Group does not expect any such large-scale experiments in the near term. Furthermore, while the members of the Working Group disagree about whether such large-scale experiments could ever be justified, we all agree that no such experiment could be justified in the absence of robust governance mechanisms.

Even at the smallest scales, however, outdoor experimentation could have significant social and political impacts. This is because taking an idea beyond laboratory walls can capture the public imagination by making it seem more immediate and real, as has been seen with biotechnology, artificial intelligence, and other complex emerging technologies. Furthermore, because SRM research remains in its infancy and because of the deep, layered uncertainties faced in trying to anticipate technological developments over the long term, it is hard to predict how SRM might evolve. It is difficult to foresee, for instance, what details further research would reveal about SRM's potential risks and benefits, what technologies and approaches to deployment would prove most promising, and so on. It is even harder to predict how climate policy and the geopolitics of SRM will change over the coming decades.

The challenge of governing SRM becomes even more daunting in light of the fact that governing any technology involves governing an entire "socio-technical system," not just the use of particular pieces of equipment. In the case of SRM, this socio-technical system would involve a range of actors, technologies, and social and political forces. In concrete terms, this means that policymakers should think about the need for SRM, and the prospects of governing SRM, as part of climate policy more broadly.

Given the uncertainties about how SRM, climate change, and climate politics will evolve over the coming decades, initial governance efforts should target a range of plausible near-term developments. At the same time, early steps in building governance arrangements can potentially shape the path of technological development and the social and political conversation about those developments. Depending on how the future unfolds, policymakers will want to hold on to some degree of flexibility when it comes to either stimulating, restraining, or otherwise guiding various kinds of SRM research. Therefore, policymakers should aim to build flexible institutions that can eventually handle decisions about the pathways of technology development, field experiments, and potential deployment.

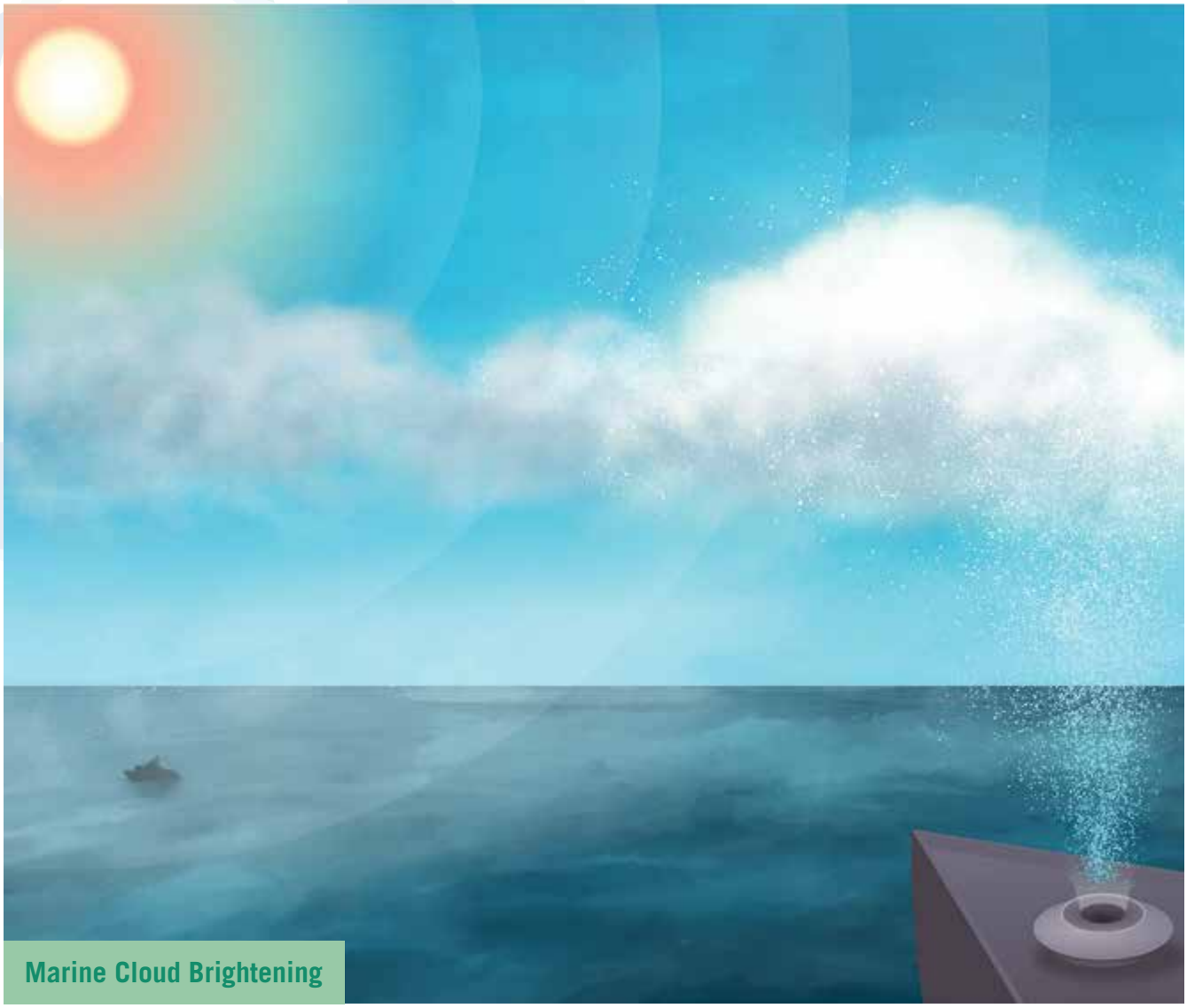

Figure 3: Artistic representation of marine cloud brightening

BOX 8. MORAL HAZARD

Among the oldest and most widespread concerns about SRM is that simply considering it might weaken society's resolve to cut greenhouse gas emissions. This is often called the "moral hazard" problem, by analogy to moral hazard in insurance. In insurance, "moral hazard" refers to the tendency to be less careful with property that is insured (e.g., by driving less carefully or by investing less to protect a building against fire or theft). There is fear that if policymakers or the public come to perceive greenhouse gas emissions as less risky because of the prospect of SRM, they will invest less money and effort in cutting emissions. Because SRM would be at best an imperfect supplement to mitigation—and, furthermore, because future research may show it to be so risky or so difficult to govern that it could never be used safely and justly—this potential slow-down in emissions reductions could leave the world worse off than it would be if society had never considered SRM in the first place. It is with this problem in mind that the Working Group reiterates the view broadly held in the SRM research community that SRM should not be seen as a substitute for mitigation.

The Working Group arrived, through a process of careful deliberation based on immersion in the existing SRM governance conversation and application of general principles of good governance, at four objectives that should guide the governance of SRM. The remainder of this section explains how the Working Group understands each objective and why policymakers would be wise to develop effective, participatory, accountable, and transparent multilevel institutions and norms to pursue these objectives. The following sections then look at the specific domains in which governance should be undertaken (Section 3) and offer concrete recommendations for fulfilling these larger objectives (Section 4).

SRM GOVERNANCE OBJECTIVES

I. **Keep mitigation and adaptation first:** Ensure that, if SRM is considered, it remains subsidiary to mitigation and adaptation measures.

II. **Thoroughly and transparently evaluate risks, burdens, and benefits:** Develop the capacity for broad-based assessment of the diverse potential risks, burdens, and benefits of SRM.

III. **Enable responsible knowledge creation:** Ensure that any SRM-related research is responsive to societal needs and concerns to the greatest extent possible.

IV. **Ensure robust governance before any consideration of deployment:** Begin the near-term work of establishing effective institutions and norms to govern decisions about potential deployment.

We turn now to further elaboration of each of the governance objectives.

Objective I: Keep mitigation and adaptation first

SRM is not an adequate or acceptable replacement for emissions reductions. This view is shared broadly by SRM researchers. Recognizing and endorsing this consensus, the Working Group emphasizes that a primary objective of SRM governance is to ensure that, if SRM is considered, it remains subsidiary to mitigation and adaptation measures. Ensuring that mitigation and adaptation remain paramount involves, among other things, keeping the prospect of SRM from weakening society's resolve to cut its greenhouse gas emissions. (See Box 8.)

One basic reason that SRM cannot replace mitigation is that a planet heated by additional greenhouse gases and then cooled by SRM would not have the same climate as one that was never warmed by additional greenhouse gases in the first place. In particular, precipitation patterns may differ (depending on the scale and duration of possible deployment), as potentially would regional temperature patterns. The only way to avoid adding even more uncertainty in the face of an already changing climate is to reduce and eventually eliminate humanity's net greenhouse gas emissions. While the climate impacts of SRM might be relatively minor if SRM were used as a small supplement to mitigation, they would be increasingly large and increasingly dangerous if SRM were used as the primary response to climate change. Some in the Working Group take very seriously the possibility that small-scale use of SRM could beget large-scale use, such that great care must be taken about the scientific, social, or political sanctioning of research efforts.

A second reason that SRM cannot replace mitigation is that SRM does not directly address ocean acidification. The oceans absorb a large share of the carbon dioxide that humanity emits into the atmosphere. This is gradually acidifying ocean waters, which threatens marine ecosystems and the people who depend on them. While modeling work suggests that SRM

would help slow ocean acidification by preserving existing carbon sinks that are vulnerable to rising temperatures, it would not directly address the acidification caused by further emissions from human activity. In the absence of mitigation, then, ocean acidification will continue.

Another important reason that SRM cannot replace mitigation is that a significant fraction of humanity's carbon dioxide emissions will remain in the atmosphere for a very long time. For every ten tons of carbon dioxide emitted, two or three tons will remain in the atmosphere for a thousand years, and roughly one ton will remain for tens of thousands of years. Thus, if SRM were used instead of mitigation, it would need to be maintained continuously for millennia. If SRM were interrupted in such a context, the consequences could be catastrophic. Treating SRM as some kind of replacement for mitigation would invite disaster.

Similarly, there is no scenario in which SRM does away with the need to adapt to climate change. Even if SRM is used and even if it does reduce overall climate risk, people and ecosystems will still need to adapt to regional changes in temperature and precipitation patterns caused by the combination of greenhouse gases and SRM—changes that some believe would become more severe and more dangerous with more intense deployment of SRM.

Objective II: Thoroughly and transparently evaluate risks, burdens, and benefits

Decisions about the development and deployment of SRM involve decisions about risk. Different kinds of SRM research could create various risks, as could deploying—but deciding not to research SRM carries its own risks, and if SRM technologies were actually developed, then even the decision not to deploy it would require balancing different kinds of risks. Box 3 on p. 4 outlines the

"To call for "broad-based" assessment is to call for an inclusive and transparent approach to assessing SRM that allows for meaningful input from diverse voices."

various risks associated with decisions about whether to research or deploy SRM. The question of how to govern SRM in the face of these difficult risk-risk tradeoffs is particularly acute from the perspective of what people today owe to future people for whom these risks could ripen.

In order, then, to understand, balance, and manage these risks, society should develop the capacity for broad-based assessment of the diverse potential risks, burdens, and benefits of SRM, including the risks, burdens, and benefits associated with both deployment and research.

To call for "broad-based" assessment is to call for an inclusive and transparent approach to assessing SRM that allows for meaningful input from diverse voices, paying particular attention to those most vulnerable both to the impacts of climate change, and to any potential risks in ongoing research into, and possible deployment of, SRM. The "potential risks, burdens, and benefits" of SRM include not only environmental and financial impacts, but also social impacts. Most of these risks, burdens, and benefits are currently difficult or impossible to quantify, and they depend crucially on the circumstances of deployment. For instance, some environmental risks of SRM would likely increase as the intensity of deployment increased, and the risks to global security and equity would likely be greater if SRM were deployed in the absence of good international governance mechanisms. A key objective of SRM governance, therefore, is to

ensure that society has the capacity to anticipate, understand, reduce, and manage these risks, insofar as this is possible, and to steer away from or halt research pathways that unduly exacerbate risks. Anticipating, comprehending, and managing risks will require both social capacities, such as institutions for managing conflict, and technological capacities, such as satellites for monitoring deployment.

Objective III: Enable responsible knowledge creation

Governance can play an important role in ensuring that any SRM-related research is responsive to the greatest extent possible to societal needs and concerns. While the members of the Working Group disagree about the wisdom of certain kinds of SRM research, we agree on the importance of developing institutional arrangements that enable responsible knowledge creation. Such arrangements serve two complementary functions. First, they make it possible for researchers to conduct their research in ways that are transparent, accountable, and respectful of societal values; and to ensure that research efforts, considered collectively, are inclusive, anticipatory, and guided by societal needs and concerns. Second, such arrangements can guard against undesirable research pathways and outcomes.

More concretely, pursuing this objective means pursuing various smaller goals. These include but are not limited to: making the funding of SRM research transparent; ensuring that information about research and its results is publicly accessible and widely disseminated; clarifying the ethical and social responsibilities of individual researchers or research groups and developing mechanisms that enable and encourage them to fulfill those responsibilities without unduly stifling the production of new knowledge; developing the capacity to anticipate the diverse ways that SRM research or deployment could influence or be influenced by future developments; developing mechanisms by which the voices, needs, and concerns of diverse groups, including marginalized groups and future people, can be heard, considered, and addressed in shaping research programs; limiting perverse incentives that might lead research to serve special interests rather than the public interest; and, in the longer term, possibly developing mechanisms of participation and redress for those who might be harmed by SRM research if it ever progresses to the stage that it causes demonstrable damage.

It must be noted that the various responsibilities identified here are *shared* responsibilities, to be fulfilled by a collection of institutions and individuals. This list should not be interpreted as a checklist of responsibilities that each individual researcher must fulfill with respect to each individual research project.

Objective IV: Ensure robust governance before any consideration of deployment

The consensus view of the Working Group is that any large-scale deployment of SRM technologies in the near term is highly unlikely and ill-advised. Near-term governance efforts will therefore focus on governance of research and shaping social and political deliberations about SRM. At the same time, they will lay the foundation for governing decisions about potential deployment. Thus, now is the time to begin the near-term work of establishing institutions and norms to govern decisions about potential deployment, with a view toward having robust governance arrangements in place by the time deployment becomes a serious possibility, if it ever does. Echoing the Oxford Principles' call for "governance before deployment," the Working Group urges that deployment should not be considered as a climate response option unless such governance is in place.

Embracing this objective means acknowledging that existing institutions and domestic and international laws are inadequate, in themselves and in their current arrangements, to the task of governing SRM deployment.

Governing deployment would require expanding the capacity of existing national and international institutions and perhaps creating new ones. This is a difficult and slow process because it typically requires coordination among large numbers of countries with diverse interests. Laying the groundwork for such coordination requires ensuring that the institutions responsible for governing near-term research are flexible enough to evolve alongside any SRM research. A component of promoting this flexibility is to ensure an adequate match between the governance needs of SRM and the forums in which SRM is discussed. SRM governance deserves careful consideration within national and multilateral institutions. There is no reason to believe SRM will be discussed everywhere, however, and no reason to believe discussion everywhere would be a good thing. If SRM governance is to be advanced within existing institutional arrangements, there must be a good fit between mandates and the resources of institutions, on the one hand, and the demands of SRM governance, on the other.

"The long-term nature of SRM research offers a chance to pursue novel institutions, rather than being bound too tightly by what is feasible here and now."

By anticipating future governance needs now, policymakers have an opportunity to stay ahead of the curve on SRM governance. In particular, policymakers can help promote equitable processes and outcomes by developing mechanisms to adjudicate disputes, address concerns about the distribution of environmental risks, and manage the details of any possible deployment. The long-term nature of SRM research offers a chance to pursue novel institutions, rather than being bound too tightly by what is feasible here and now.

At the same time, the fact that SRM is so new also poses challenges for designing effective governance institutions. While stratospheric aerosol injection and marine cloud brightening dominate the conversation today, further research will likely reveal new technological possibilities. Comparing stratospheric aerosol injection with marine cloud brightening suggests that such novel proposals could raise very different governance questions that need to be handled by different institutions: these two proposals differ in their geographical scope, the duration of their effects, the location of their operation, whether they disperse materials across international boundaries, and so on, implying that different organizations could claim jurisdiction over each of them. Furthermore, it is impossible to predict the geopolitical and environmental circumstances the world might face decades from now. Policymakers should therefore strive to build institutions that can anticipate technological, political, and environmental developments and respond flexibly to them.

Behind these objectives lie the following principles of good governance: equity, accountability, transparency, flexibility, and participation. In the context of SRM governance:

- *Equity* concerns both fair procedures for governing research and deployment as well as fairly distributed benefits and burdens, both within and across generations. Equity requires decision-makers to prioritize the needs and basic rights of the most vulnerable populations. Given the gross inequalities of power and resources confronting the world today, especially as it relates to climate change, promoting equitable procedures and outcomes poses a significant governance challenge.
- Holding researchers and policymakers *accountable* involves enabling publics to direct research and governance decisions so as to ensure that SRM is only developed and used in the public interest.
- To this end, *transparency* in research and deployment-related decisions is critical. Genuine transparency requires the wide dissemination of information in forms and along channels that enable policymakers and civil society to understand and use that information in their own deliberations.
- Governance institutions will need to be *flexible* in two respects: first, they will need to be able to anticipate and adapt to new information and changing geopolitical circumstances; second, they will need to co-evolve along with SRM research so that governance does not fall behind technical progress.
- Finally, *participation* serves both normative ends, as a constituent in democratic governance, and practical ends, by promoting responsible decision-making.

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SECTION 3: NATIONAL, INTERNATIONAL, AND NON-STATE GOVERNANCE

Meeting the SRM governance objectives laid out in Section 2 will require coordinated actions by actors, agencies, and institutions at the national and international levels. This section looks at each of these levels of action and at the various roles that can be played by governmental, intergovernmental, and non-state actors. The goal is to sketch out how SRM governance activities can and should be taken up in a variety of different places. Section 4 then moves to concrete recommendations.

Governance at the National Level

Although there is broad agreement that the problem structure surrounding SRM demands international governance, national level initiatives need not wait for international institutions to emerge. In fact, national-level policies are often the driver of international policy development as countries are more likely to agree and adhere to international policies that reflect pre-existing domestic policies. In the near term, practically all research on SRM will be funded through national governments, philanthropic foundations or private philanthropists, or the private sector. In the longer term, initial decisions about deployment might be taken by nation states unless adequate international institutions arise in the meantime. While this state of play makes a strong case for discussing SRM governance at the national level, it also raises several challenges, given the diversity among the parties that we imagine could eventually be engaged in discussions about SRM research activities or their governance.

There are several issues that any discussion of national-level governance will need to take into account and possibly grapple with.

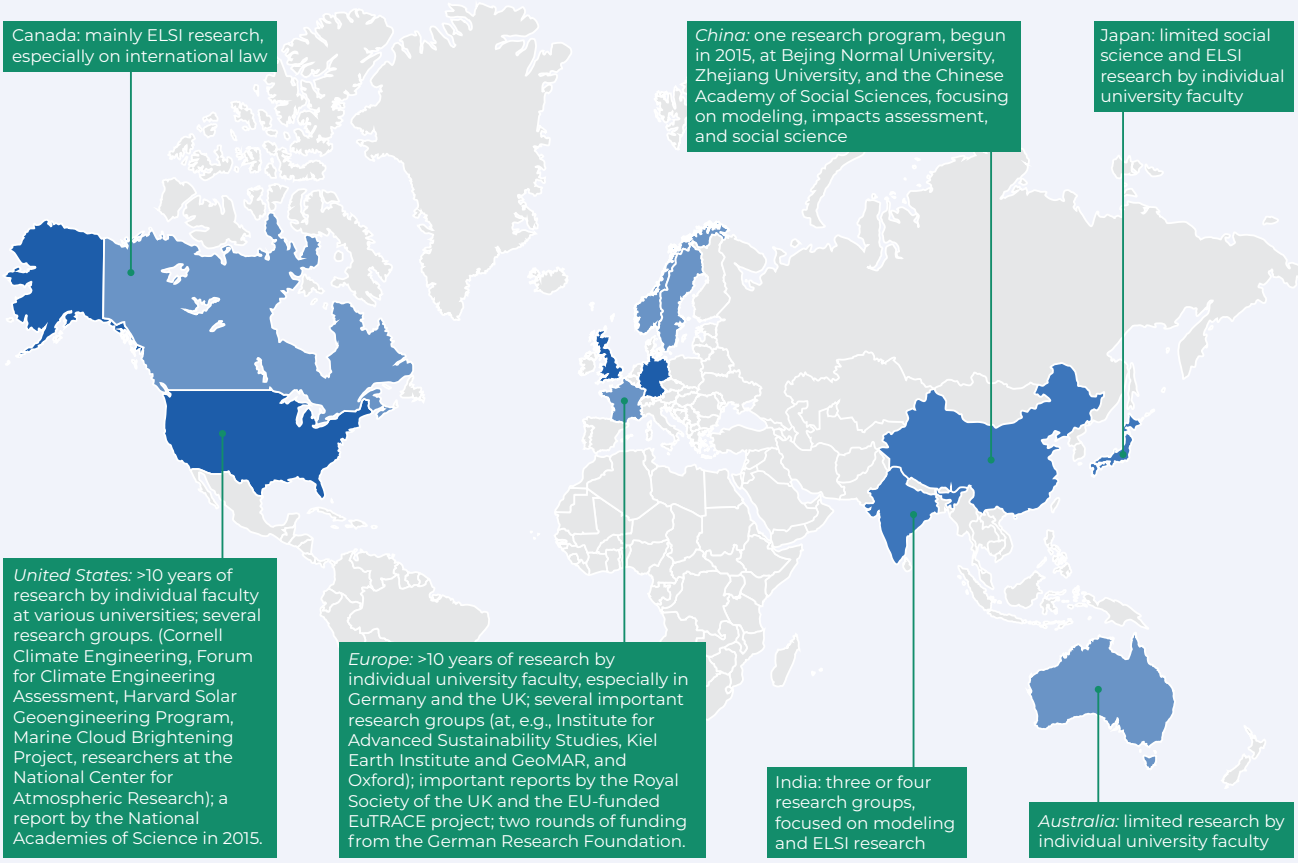
First, there are several existing governance mechanisms that may be relevant to SRM governance. For example, within each country there are existing regulatory structures that apply to government grants in different jurisdictions, as well as environmental, occupational safety, or substance control rules and regulations that may be pertinent to research, field experiments, field testing, or deployment of SRM technologies, depending on the specific application. Any national-level discussion of SRM should begin with a comprehensive overview of these applicable regulations or voluntary safety guidelines, which will vary significantly across countries. Existing rules and regulations that were originally developed for other kinds of research may apply (or fail to apply) to SRM in ways that create either too permissive or too restrictive a regulatory environment. A critical first step, then, is to have a good understanding of how existing structures relate to the governance of SRM, with the goal of facilitating sharing, cooperation, and co-learning across research and governance communities.

Second, there has been little discussion of *specific* national-level governance structures tailored to SRM. Although there are several voluntary guidelines or codes of conduct for researchers under development, no national government has championed or adopted any of these. (The UK House of Commons Select Committee on Science and Technology did endorse the Oxford Principles in 2010, calling the five high-level principles "a sound foundation for developing future regulation" while noting that "several aspects. . . need further development." See Box 5 on p. 11 for a brief discussion of the Oxford Principles.) This lack of formalized governance neither holds researchers accountable with respect to risks associated with their research or protects researchers with

respect to real or imagined concerns that may arise about their work. Though still largely invisible to most of the public, SRM has attracted enough attention in the press to raise some concerns that it is too risky to pursue. Furthermore, many observers have historically been either dismissive or antagonistic toward work on SRM, arguing that it is a distraction from the need to pursue more mainstream mitigation and adaptation efforts. A lack of any governance discussion at all can exacerbate these concerns.

BOX 9. PROMINENT SRM RESEARCH EFFORTS

Transnational: GeoMIP (Geoengineering Model Intercomparison Project), an academic project funded partly by the U.S. National Science Foundation; the Geoengineering Governance Research Project, and the DECIMALS Fund, a project to encourage SRM impacts modeling in developing countries, organized by the SRM Governance Initiative and The World Academy of Sciences.



SRM research has historically been dominated by North American and European researchers, particularly in the United States, Germany, and the United Kingdom. Important research efforts have recently emerged in India and China, as well. This research has focused almost exclusively on modeling and theoretical studies, including research on governance and the ethical, social, and legal implications (ELSI) of SRM. A handful of researchers have undertaken preliminary engineering research on equipment that could be used to implement SRM, such as nozzles for spraying fine salt particles into low-lying marine clouds.

BOX 10: SRM, Governance, and Classified Research and Development

On the basis of past experience with emerging technologies, there is a possibility that classified or secret research and development activities will take place under the auspices of one or more governments with an eye toward future military and commercial applications, and as a hedge against such applications by other countries. Given the short-term horizons of this report, there is little ground for anticipating SRM applications derived from classified undertakings prior to 2025, but undisclosed research and development programs of this sort, were they ever to emerge, would deeply erode the benefits of the governance procedures and structures recommended in this report, especially if momentum is created by such activities that make future applications all but inevitable. This has happened in the past, most prominently with respect to nuclear technology. This report does not address these concerns but takes note of their possible relevance.

Third, some elements of national-level governance will both inform and be informed by international governance. The impacts of global field trials or deployment, both good and bad, could not be contained within any one country's borders. If any SRM technologies ever reach that stage, they would require transboundary monitoring and coordination. To date, the most (relatively) successful international agreements on chemical hazards, conservation and biodiversity, as well as protection of the atmospheric commons have been built on top of the foundation of sound national policies. From the Basel Convention to the Paris Agreement, we have seen that successful implementation of national policies generally paves the way for sovereign states to enter into international agreements. Both realms of governance can take steps in the same direction, though at different levels of ambition, with the intent that action at one level helps support and drive action at the other.

All of this is to say that national action on SRM governance need not wait for international action, and indeed would do well to precede it.

Governance at the International Level

Just about any conceivable SRM intervention beyond a very modest scale will have transboundary implications. It is therefore relevant to the work of many existing international institutions, and its responsible governance may require some new institutions in the longer term. Research and possible future deployment of SRM falls within the purview of institutions addressing a wide swath of issues, including not only climate change, but also human and economic development, oceans, education, food systems, and many others. Governance discussions, therefore, should be broadly inclusive of the needs of relevant institutional stakeholders, and should be coordinated among them. Such coordination avoids duplication of effort, encourages efficient use of resources, and maximizes synergies across institutions. Critically, it allows for the immediate development of governance mechanisms rather than waiting for new institutions to emerge.

Several international institutions are already addressing climate engineering to some limited degree. For example, the Convention on Biological Diversity (CBD) adopted a decision inviting Parties to prevent any climate engineering activities "that may affect biodiversity," except for "small scale research studies" that meet certain conditions; the London Protocol regulates ocean fertilization; and the Intergovernmental Panel on Climate Change (IPCC) has briefly discussed the state of knowledge about SRM in its forthcoming report on limiting global warming to 1.5° C. Yet, these initiatives need to be more systematic, interdisciplinary, and coordinated across scientific and social scientific scholarship on SRM.

BOX 11. CBD & LONDON CONVENTION/LONDON PROTOCOL

As of now, decisions under the Convention on Biological Diversity (CBD) represent the only explicit attempt to govern SRM under international law. In addition, there has been an effort to govern some forms of carbon removal under the London Convention and London Protocol (LC/LP), which serves as a potential model for governing some SRM technologies.

The CBD was opened for signature at the UN Conference on Environment and Development (the "Earth Summit") in Rio de Janeiro in 1992, alongside the United Nations Framework Convention on Climate Change (UNFCCC). Every member of the UN, except for the United States, is a Party to the Convention. In 2010, the Parties adopted a decision that "invites Parties…to consider the guidance below…," which includes the following:

Ensure. . . in the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering. . . that no climate-related geo-engineering activities that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies that would be conducted in a controlled setting. . . .

Another decision in 2012 "reaffirms" the 2010 decision but also invites Parties to "address" specific "gaps in the understanding of the impacts of climate-related geoengineering on biodiversity."

While some commentators have argued that these decisions amount to a moratorium on deployment and outdoor experimentation, the decisions explicitly allow for certain kinds of research studies and ask parties to consider refraining from undertaking certain other kinds of research activities. Other commentators point out that the language of the decision does not create any binding legal obligations, merely asking parties to "consider" this guidance.

The London Convention—or, as it is more formally known, the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter—dates to 1972, with a significant modernization in 1996 known as the London Protocol. In response to carbon-removal–related ocean fertilization experiments, the Parties to the LC/LP issued non-binding advice restricting "marine geoengineering" in 2008 and 2010. An amendment proposed in 2012, if it enters into force, would provide for legally binding international regulation of "the placement of matter into the sea . . . for marine geoengineering." The proposed amendment explicitly prohibits specific forms of marine geoengineering except for "legitimate scientific research" that would be authorized through a permitting process. While this proposed amendment is primarily concerned with various forms of carbon removal and may not impact any form of SRM, it offers a concrete model for the international regulation of climate engineering activities.

Other treaties may have implications for SRM governance, but none of them currently address SRM explicitly.

Given the wide-ranging risks and potential benefits of SRM, a more coordinated governance approach is necessary. Typically, international environmental organizations and institutions coordinate on particular issues by drawing on existing capacities and mandates within each institution to contribute to common governance solutions. For example, we see horizontal coordination across institutions in chemicals governance and efforts to protect biodiversity. (Even though the CBD was originally conceived as an overarching coordinating convention, inter-organizational coordination among biodiversity conventions has evolved into a more horizontal structure.) Such a horizontal structure would be well suited to SRM governance in the near term since several

treaties and international organizations have existing capacity and relevant expertise and mandates to contribute to various aspects of SRM governance. The experience of other efforts at horizontal coordination suggest that such a structure would work best if governments play an active role.

With regard to international governance of SRM, the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) may choose to include SRM as a topic of discussion in the future, and thus the UNFCCC may serve as one forum for debating SRM and its role in a broader climate governance landscape. In addition, there are several other international institutions that already address SRM in various ad hoc ways or might be well-positioned to do so in the future. These organizations and treaties include but are not limited to the London Convention on Prevention of Marine Pollution by Dumping, World Meteorological Organization (WMO), UN Educational, Scientific, and Cultural Organization (UNESCO), UN Convention on the Law of the Sea (UNCLOS), Environmental Modification Convention (ENMOD), UN Office for Space, Montreal Protocol on Substances that Deplete the Ozone Layer, UN Environment (UNEP), and the Food and Agriculture Organization of the United Nations (FAO). As the research develops, a need for new institutions to address research and possibly deployment is likely to emerge.

Non-State Governance

Although state-led action will be central in designing and deploying governance institutions for SRM, non-state actors can support such efforts. We know that non-state actors can be instrumental in designing and securing compliance with governance mechanisms, as well as in ensuring that core principles of good governance are meaningfully embedded in governance processes.

Non-state actors, such as NGOs, local authorities, corporations and other private sector actors, scientists, and the general public have a long history of active participation in global governance, particularly with respect to climate change and other environmental issues. Non-state actors have played important roles in ensuring wider participation in state decision-making, making international negotiations more transparent, driving innovation, holding state actors accountable to their commitments, providing technical expertise, and pushing states to adopt more ambitious and equitable (or in some cases, precautionary) policies, among many other important functions.

> **"Non-state actors can help ensure that governance does not escape the attention of institutions that ought to be paying attention."**

Importantly in the context of SRM, non-state actors can help ensure that governance does not escape the attention of institutions that ought to be paying attention. The danger is that technological development around SRM might move too rapidly for those tasked with formulating rules of the road—a fate that has befallen other complex emerging technologies, such as gene editing and artificial intelligence. It is likely that many countries will not develop formal governance because of inertia, other priorities, and domestic opposition. This raises the stakes for—and importance of—non-state governance.

In particular, self-governance within the scientific community will be crucial. This might include developing norms of responsible research, including research ethics, and coordinating mission-driven research agendas to avoid the possibility of dangerous outcomes or research programs that lack clear societal

benefit. In addition, codes of conduct based on precaution and clear norms should be developed with and for private actors working on technology development. Finally, public interest NGOs should extend their expertise in supporting good governance to this arena.

Non-state actors have already been involved in "de facto governance" of SRM through the production of several reports, which call for and aim to shape future state-led governance efforts. These reports have tended, on the governance side, to focus on the presentation of broad guidelines rather than specific policy recommendations.

As in the public sphere, dialogue and coordination among non-state actors and between researchers and other stakeholders is also likely to prove beneficial. The focus of SRM governance will surely evolve over time as stakeholder positions become clearer, science and technologies develop, and risks and opportunities become better understood. The initial stages of institutional cooperation on this issue should allow for future flexibility by focusing on creating a strong governance foundation based on core principles of good governance.

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SECTION 4: RECOMMENDATIONS

The Working Group concluded that in the near term—meaning out to 2025—governance should focus on *creating politically legitimate deliberative bodies* for SRM governance, *leveraging existing institutions*, and *making research transparent and accountable*. This section of the report offers twelve concrete, actionable recommendations for carrying out these essential governance activities, keeping in mind the urgency of anticipatory action, the relatively slow pace to date of SRM developments, and the long lead times required to create effective governance arrangements. Table 1 below shows how these recommendations comport with the objectives outlined in Section 2, which are reprinted immediately below the table.

We have restricted our recommendations to the near term for two main reasons. First, SRM technologies are still very much in the development stage. Our understanding of them and the social and political context in which they might be used are still evolving. That makes it premature to issue firm recommendations about the long-term governance of those technologies. Second, research is underway and could accelerate, making it important to establish effective mechanisms to govern research and guide discussion in the near-term while laying the foundation for long-term governance.

TABLE 1: Relationship between Governance Objectives and Recommendations

			OBJECTIVE			
			I	II	III	IV
Create politically legitimate deliberative bodies	1	Establish a World Commission on SRM	◆	◆	◆	◆
	2	Establish a Global Forum for Stakeholder Dialogue		◆		◆
Leverage existing institutions	3	Strengthen cooperation between international organizations		◆	◆	◆
	4	Assess and improve capacities for regional coordination and conflict resolution				◆
	5	Continue ongoing assessment role for IPCC and related processes			◆	
	6	Develop foresight capabilities	◆	◆	◆	◆
Make research transparent and accountable	7	Report on SRM research and development activities in the global stocktake under the Paris Agreement		◆		
	8	Institutionalize codes of conduct for responsible SRM research	◆	◆	◆	
	9	Ensure that ongoing research includes international and interdisciplinary collaboration		◆	◆	
	10	Clarify funding streams		◆	◆	
	11	Develop a publicly accessible clearinghouse	◆			
	12	Develop best practices for risk and impact assessments	◆	◆	◆	◆

Each recommendation serves at least one of the four objectives of SRM governance (p. 17): I. Keep mitigation and adaptation first. II. Thoroughly and transparently evaluate risk, benefits, and burdens. III. Enable responsible knowledge creation. IV. Ensure robust governance before deployment. Dark shapes (◆) indicate a strong connection between a recommendation and an objective. Light shapes (◆) indicate a weak connection. Empty cells indicate little or no connection.

Pursuing these governance activities simultaneously means that the ordering of the recommendations is not chronological or hierarchical. They will need to be pursued more or less simultaneously within and across a diverse set of stakeholders. The recommendations also seek to balance specificity with flexibility. In some cases, we have offered specific suggestions about who should do what. In other cases, we seek to preserve flexibility by outlining the key choices that decision makers will confront in implementing a recommendation: this institutional setting versus that; quick action versus a more deliberate approach; broader consultation versus more delegated modes of interest representation. Together, if undertaken now, these recommendations represent the essential next steps in establishing effective near-term governance of SRM.

CREATE POLITICALLY LEGITIMATE DELIBERATIVE BODIES.

1. Establish a World Commission on SRM

Who should take action? *Established by the UN General Assembly, with members appointed by the UN Secretary-General*

A World Commission should be established as a high-level representative body to engage in a broad-based international dialogue on issues related to governance of SRM. The Commission's mandate should include, inter alia, debating first-order questions about whether and to what end SRM should be researched and developed, and how it fits within a broader climate response landscape. Central issues for consideration should include the need for SRM, its governability, and how to ensure that ongoing research into these technologies serves the public interest, now and in the future. In this context, the World Commission should include within its core mandate discussions about whether a moratorium is needed on certain types of SRM research or deployment, and how to design an intellectual property regime that steers ongoing technology development toward the public interest.

A politically legitimate body, appointed by the UN Secretary General on the basis of geographic and other diversity criteria, should be created to intervene on this issue, taking on board the valuable input from previous expert bodies. Such a representative appointment process should ensure political legitimacy for the process and help garner the resources necessary for the extensive engagements we recommend that the Commission undertake. Centrally, such a Commission can bring together actors across international institutions in order to provide a forum for the development of shared norms surrounding SRM governance on the basis of broad-based consultation. A high-level World Commission should not replicate the work of several self-appointed expert bodies (including this one) that have produced valuable but politically unrepresentative reports on the topic of SRM governance, but rather should build on such prior work.

We generally endorse the design elements of a World Commission that have been adopted in other assessment processes and in the literature.[1] Desired design elements include, for example, distinguished and international commissioners, high-level authorization, a flexible mandate to respond to emerging governance needs as they arise, adequate staff and resources to carry out its mandate, and a broad mandate to

1 Parson, Edward A. "Starting the Dialogue on Climate Engineering Governance: A World Commission." Centre for International Governance Innovation. Fixing Climate Governance Series Policy Brief No. 8 (2017).

engage a wide array of stakeholders, including experts, local governments, and civil society. We view this latter part of the Commission's work as particularly important. We therefore take up the relevant design elements in more detail in the subsequent recommendation (see Recommendation 2) on a Global Forum for Stakeholder Dialogue, the establishment of which should be a core element of the Commission's mandate.

The Commission's precise mandate will necessarily be the subject of political negotiation but should be framed such that SRM is never considered a substitute for mitigation and adaptation, and that potential risks, burdens, and benefits of SRM are thoroughly evaluated in an internationally collaborative and legitimate manner before any political decisions on deployment are ever made. We also recognize that SRM may be seen as too narrow a subject matter for a stand-alone Commission, and so can foresee establishment of a broader Commission focused on climate engineering (including carbon removal) or on emerging technologies and climate change or a related subject matter, such that investigation of SRM would be a piece of a broader mandate.

BOX 12. MORATORIUM

The potential risks of SRM, combined with the current lack of adequate governance, have led some to call for development of a formal mechanism such as a moratorium or ban to prohibit some or all SRM research or to prevent any deployment of SRM until certain criteria related to scientific knowledge and governance structures are fulfilled. Such proposals vary in design, scope, and purpose. Others argue that a moratorium is neither necessary nor desirable at this time, noting that physical science research has progressed slowly and has coincided with significant social science and governance research, as well as that existing international laws around consultation and prevention of harm constitute a de facto prohibition on field testing or deployment.

If a moratorium is desirable, its design and scope cannot be determined without first determining its purpose and motivation. A moratorium might be intended to delay research—or certain kinds of research—until robust governance mechanisms are established and our understanding of the risks and benefits improves; to create space for public and political deliberation unconstrained by technological lock in; to create a safe space for small-scale research by allaying fears of a slippery slope toward larger field trials; or to halt research in the hope of taking SRM off the table as a climate response option. A moratorium intended to prevent physical harm from research or deployment would prohibit a narrower range of activities than would a moratorium concerned with mitigating moral hazard and other social and political impacts.

Once the purpose of any possible moratorium is clarified, a range of design choices must be made. First, what is the scope of research activities that fall under the moratorium? Second, which international body would administer and enforce such a moratorium, and how would such an arrangement impact the current diffuse nature of SRM governance? Third, what are the conditions and the mechanism for ending or altering the moratorium?

The Working Group believes that the desirability and purpose of a moratorium must be evaluated by a representative, politically legitimate body, which can also debate these design choices.

BOX 13. INTELLECTUAL PROPERTY

Many researchers and commentators have expressed concerns about how intellectual property in SRM-related technologies might direct their possible deployment in ways contrary to the public interest. Claims to certain forms of intellectual property in SRM-related technologies, and in particular claims to privately held exclusive intellectual property rights, could limit transparency and incentivize patent holders to try to influence SRM governance for their own private ends. On the other hand, precluding private intellectual property in SRM-related technologies could stifle technological innovation, such as the development of specialized high-altitude aircraft for dispersing aerosols in the stratosphere.

In most areas of technology, intellectual property regimes aim to strike a balance between incentivizing private sector research and technological development, on the one hand, and ensuring public access and benefit, on the other. The SRM conversation has a different character. The special nature of SRM and particularly the risks associated with large-scale deployment arguably tilt the balance heavily towards the development of intellectual property mechanisms that promote the public interest or that keep technological developments in the public domain. In addition, intellectual property considerations around the development of SRM technologies are tied to concerns about the extent of private sector involvement in the development of patented knowledge, private sector control over rights and access to scientific data, and private sector control of engineering capacity and ability. While efforts to improve understandings of SRM or to deploy it might involve innovation and goods provision by private sector actors, there is a need to ensure a broad public oversight of SRM.

The design of an adequate intellectual property regime or the effective application of existing intellectual property instruments in the specific case of SRM is another issue that ought to be taken up by a World Commission or other politically legitimate body.

The World Commission on Environment and Development—widely known as the Brundtland Commission—provides a promising model for the type of high-level consultative project outlined in this recommendation. Centrally, the Brundtland Commission received high-level political authorization from the UN General Assembly to offer guidance on critical and emergent environmental issues of global concern. Its final report, issued in 1987, outlined the core concept of sustainable development and has helped guide environmental policy and practice for decades. A similar high-level report could give much-needed shape to the core questions and shared norms that should undergird governance of SRM. While we offer the Brundtland Commission as a model, we deliberately refrain from prescribing the Commission's institutional design, so as to ensure that any political barriers to specific design elements do not prevent the formation of a politically legitimate deliberative body to undertake these important tasks. These design elements should be fleshed out via high-level negotiations on the basis of the considerations we articulate here.

2. Establish a Global Forum for Stakeholder Dialogue.

Who should take action? *The World Commission on SRM*

A Global Forum for Stakeholder Dialogue (the Forum) should be established by the World Commission on SRM to initiate and facilitate cross-border and cross-scale discussions on SRM and its governance. The Forum should play a central role not only in facilitating dialogue processes surrounding the central governance questions discussed above, but also in identifying a broad range of stakeholders, including the stakeholders

who might otherwise be marginalized from international processes, but who are likely to be impacted by any SRM governance decisions. These marginalized groups might include local governments, local communities, indigenous peoples and other climate-vulnerable groups, youth organizations, women's groups, and others who can speak to ethical issues, such as inter-generational concerns and issues related to distributive justice.

The impacts of SRM research and potential future deployment could possibly affect critical ecosystem functions and in turn social systems. Although there remains much uncertainty surrounding the degree and form of these potential impacts, as with climate impacts more broadly, they will be unevenly distributed. Further, in all likelihood, they will impact poorer communities disproportionately, if for no other reason than these communities' comparatively diminished capacity to adapt to large-scale environmental change. These communities are also those that tend to have weaker institutional access to the international decision-making bodies that will likely be steering governance surrounding SRM. Therefore, decisions about whether and how SRM should be researched and deployed must hear, respond to, and integrate concerns of vulnerable and marginalized communities.

With these concerns in mind, we recommend that the high-level World Commission outlined in Recommendation 1 have, as one of its most important acts and functions, establishment of a Global Forum for stakeholder dialogue. Stakeholder dialogue is hard to do well, and the costs of process failure can be high. As such, the Global Forum should *not* be a group convened with the intent of arriving at consensus on issues central to SRM governance and research. While the Global Forum should have formal avenues for sharing insights and findings with the World Commission, the Global Forum's central purpose should be to initiate a learning-oriented dialogue, bringing together voices and perspectives that might otherwise not be engaged in dialogue about SRM.

The Forum's substantive mandate should include, *inter alia*, engaging stakeholders on the current state of SRM research; facilitating debate over desirability of and institutional arrangements related to SRM; and collecting information about policy preferences from stakeholder populations.

Centrally, the Forum must be built on a foundation of strong connections to national and sub-national bodies. At the national level, the Forum must ensure that stakeholders in climate-vulnerable countries and those that are vulnerable to the potential future impacts of SRM are meaningfully engaged in the process. Because SRM's impacts, if SRM were ever to be developed and deployed at scale, could be unevenly distributed, not only between countries but also within them, with the poor disproportionately impacted, input from sub-national bodies will also be crucial for ensuring equity in decision-making.

It ought to be underscored that the Forum must provide for *meaningful* public engagement. That is, it must not merely be established as a body that hears and dismisses concerns that do not align with paths of least policy resistance or existing frameworks and structures of public and private power. Rather, there must be mechanisms for feedback and response to *all* concerns. In collecting and aggregating concerns and issues, the Forum must have institutionalized mechanisms for communication at both global levels (i.e., to bodies such as a World Commission) and at the grassroots, such as direct responses to stakeholders.

The Global Forum should be constituted by the World Commission but treated as a stand-alone entity and effort. The Forum should ideally play an agenda-setting and advisory role for the Commission, identifying issues to be taken

up by the Commission and reflecting on issues central to the Commission's mandate. Being responsive to input from the Forum must be a core component of the World Commission's mandate.

One relevant example to guide the Global Forum's development is the World Commission on Dams (WCD), which was set up to produce a set of international guidelines for the design, construction, operation, and decommissioning of large dams and options on their alternatives. The WCD has been described as a watershed in global public policymaking on contentious issues of environment, development, and justice. Independent assessments of the WCD process, and recent analyses of multi-stakeholder forums more broadly, suggest that they are likely to be more successful when 1) a broad cross-section of stakeholders is represented and they acknowledge that their voices were adequately heard, and, 2) their explicit goals are limited to dialogue, social learning, and building trust, without necessarily seeking to generate convergence around a particular set of understandings or norms or the operationalization of governance.

There are considerable challenges in facilitating meaningful and representative dialogue at a time when the idea of SRM is still nascent and most stakeholders are not yet engaged. Establishing a Global Forum now is an opportunity to build a lasting venue for inclusive deliberation that can evolve along with the SRM policy and research conversations and to bring more stakeholders to the table upstream in the research process.

LEVERAGE EXISTING INSTITUTIONS.

3. Strengthen cooperation between international organizations.

Who should take action? *Secretariats of international organizations with relevant mandates, national heads of government research offices, and UN Chief Executives Board for Coordination*

Additional mechanisms for coordination across international organizations on the subject of SRM should be developed to identify existing institutional capacities for SRM governance within the international system and to facilitate the development of national contact points for SRM governance across institutions.

SRM is relevant to the work of many international organizations, including organizations working on human development, oceans, education, food systems, and many other issues. Coordinating across these institutions has many benefits. First, it makes governance discussions more broadly inclusive of the needs and portfolios of institutional stakeholders. Doing so, especially early in the governance process, is critical for developing and maintaining effective and equitable governance in any issue area, including SRM, because it helps to build shared knowledge and norms. Second, coordinating across institutions also helps to avoid duplication of effort and encourages efficient use of resources and maximization of synergies across organizations as they navigate the environmental and geopolitical risks related to climate change and SRM technologies. Third, coordinating between relevant international institutions can help to identify capacities within existing institutions to fill immediate governance needs in the areas of,

for example, database creation and maintenance, scientific assessment, and stakeholder engagement. Such near-term governance initiatives can further play an important role in catalyzing discussions on longer-term governance needs and priorities.

Coordinated international institutions can also work with national governments to identify appropriate focal points. Such national focal points will be crucial as governance develops. They can help, for example, to streamline reporting requirements and solicit and translate input from national-level stakeholders to the international processes and discussions.

Secretariats of international institutions are well positioned to facilitate this type of work. They can use existing networks and institutional resources to identify organizational partners and facilitate inter-institutional cooperation. Although there are a host of mechanisms for inter-institutional cooperation (e.g., working groups, joint work plans, participating in one another's official meetings, and hosting side events), in the near-term secretariats should focus on high-level coordination. Centrally, secretariats should use their typically broad mandates for inter-institutional cooperation to launch high-level discussions among the executive directors of international institutions to begin identifying a network of institutions with interest and relevant capacities to engage in SRM governance and begin to identify priority areas for governance in this space. Importantly, this high-level process should incorporate stakeholder input from the Global Forum process (see Recommendation 2) as well as any other new or existing relevant stakeholder engagement processes across their individual institutions. Ideally, some membership cross-over between this high-level initiative and the World Commission (see Recommendation 1) would help to coordinate these processes, avoid duplication, and increase consistency.

There are several specific models that could be considered in designing a high-level forum for discussion across secretariats. These include the Biodiversity Liaison Group between the biodiversity conventions, the Joint Liaison Group between the Rio Conventions, and the UN Chief Executives Board between 31 specialized UN agencies.

The UN Chief Executives Board for Coordination would be a promising location to initiate these discussions.

4. Assess and improve capacities for regional coordination and conflict resolution.

Who should take action? *Regional intergovernmental, scientific, or nongovernmental organizations with relevant mandates*

The regional scale is important for understanding possible spillover effects of SRM research or deployment and for encouraging transboundary cooperation. Regional organizations should work to better understand potential positive and negative spillover effects, and link these to other forms of regional dialogue about environmental issues such as shared river basin agreements and regional seas accords.

States should engage in regional and bilateral dialogue in the near term in order to prepare for the potential transboundary implications of possible large-scale SRM field research and deployment and to govern regional scale SRM interventions such as in the Arctic or over coral reefs. In addition, bilateral and regional cooperation over near-term SRM research can serve the following governance functions: consideration of funding joint research projects; sharing data and assessing risks; resolving disputes that may arise from potential spillover effects of SRM projects; and considering whether standards of liability and compensation need to be created or modified to deal with possible

transboundary harm. Regional coordination can help facilitate SRM research, regulate and guide its operational form, and provide some level of accountability for its effects.

Bilateral and regional dialogue and cooperation will take place in a variety of institutional forums, depending on the geographic region and the physical environment involved. Organizations like the Arctic Council, Asia-Pacific Economic Cooperation (APEC), and the Association of Southeast Asian Nations (ASEAN) all have existing programs of work that might be extended to consider aspects or implications of SRM. Such organizations have also utilized work or negotiated agreements on environmental issues to increase monitoring of environmental hazards, lower hurdles for trade in environmental technologies, and set common standards and practices for response to environmental hazards. Some regional regimes, such as shared river basin agreements and regional seas conventions, have existing mechanisms that can be adapted to promote dialogue on the transboundary implications of SRM research. Organizations that seek to combine science and policy are another possible venue, as are multilateral development banks and forums that bring together NGOs.

Given the existence of regional institutions that can serve as forums for dialogue on SRM, such as the European Environment Agency, the International Centre for Integrated Mountain Development, the Nile Basin Initiative, and others, formal regional institutions specific to SRM research and deployment may not need to be created in the near term. To the extent possible, regional coordination should be fostered within existing institutions, allowing norms governing SRM research to evolve according to changing circumstances and technologies. When SRM research with transboundary implications is undertaken in areas that are not covered by existing regional institutions, stakeholders should voluntarily pursue ad hoc dialogue with all parties that are potentially affected.

5. Continue ongoing assessment role for IPCC and related processes.

Who should take action? *IPCC, national governments, and other relevant technical bodies and participatory processes*

The work of the IPCC and other relevant and legitimate assessment bodies to assess the current state of scientific knowledge on SRM should continue, in order to ensure that any consideration of SRM research and potential deployment occurs in the context of current climate science.

To better inform the conversation around SRM, assessments on the state of knowledge about SRM are needed. Such assessments should examine not only the current state of SRM science but also incorporate and be informed by the current state of the literature critical of SRM, social scientific work related to SRM, and proposals on SRM governance. If the IPCC does not assess SRM, then there is a risk that discussions on the technology will happen in a vacuum outside of this internationally established assessment mechanism of the current state of research on climate change. Assessing SRM outside climate science writ large may increase the possibility that SRM will be considered as some promising alternative to mitigation and adaptation activities rather than as, at best, a potential supplement to such activities. Given that there are now many years of model runs attempting to contribute to our understanding of the potential role for SRM in, for example, slowing the rate of atmospheric temperature increase, it is important that the IPCC assess the robustness of this work and of other claims made about SRM.

An authoritative assessment of the current state of knowledge and ongoing research efforts in SRM can also help to enhance public understanding of this research.

As is customary with IPCC reports, they will not produce new science but instead rely primarily on peer-reviewed scientific work. The IPCC should use its normal processes of determining whether and how to assess the state of knowledge relating to SRM. Such proposals are generally more compelling when they come simultaneously from multiple actors, including the IPCC secretariat and representatives from various states that participate in the IPCC. In addition, while the IPCC should use its normal internal processes to determine how to assess SRM and in what reports and working groups it is most appropriate to do so, it is also important to note that SRM raises risk-risk trade-offs that are not resolvable through standard scientific assessment processes alone.

This suggests that assessment of SRM by the IPCC should be multi-disciplinary, with contributions from the social sciences and humanities to an extent not seen in previous reports. It also suggests that while the IPCC and other scientific assessment processes are important for understanding SRM, assessments by the IPCC, if taken alone, may prove incomplete or too narrow in their focus and so must be supplemented by processes that have ethics and social scientific understandings as their chief concerns. It is important, therefore, that alternative technical bodies and participatory processes continue to be nurtured with respect to assessment of the current state of research on SRM. These can include national climate assessments, assessments by national science academies, broader academic-driven processes, and non-governmental assessments.

National and subnational bodies responsible for assessing domestic or regional climate impacts and research should also assess the current state of SRM research, with special attention paid to research occurring within their state.

This is not, all told, a recommendation to promote new research in SRM but rather to encourage all relevant bodies to take stock of developments in SRM research. This assessment should include both physical and social science research.

6. Develop foresight capabilities in decision-making systems.

Who should take action? *National governments and the UN*

National governments and appropriate coordinating UN bodies should work to develop and employ established foresight practices to inform consideration and development of governance structures for the research and potential deployment of SRM technologies.

National governments and appropriate UN bodies should develop foresight processes that anticipate the impact and interactions of technological, climatic, and political developments as they relate to SRM. Doing so will increase the likelihood that governance mechanisms can meet the challenges posed by SRM research and potential deployment or its regulation and restraint. In addition to the environmental and geopolitical risks surrounding climate change and SRM, these foresight processes should account for the possibility of risks such as technological lock-in, corporate capture, moral hazard, and termination shock.

Great uncertainties surround any future research, development, and deployment of SRM. These include uncertainties related to an evolving governance landscape, climatic changes (perhaps including “tipping points” in the climate system), and the ways that emerging technologies will interact with climate change mitigation, adaptation, and governance. In the face of such uncertainties and the potential for catastrophic errors and unintended

consequences, governance should be oriented toward the development of robust policies, such as appropriate systems for monitoring activities of accounting for loss and damage, that anticipate varied outcomes. Robust policies allow governments and organizations to respond flexibly across a wide range of plausible futures.

National governments and international organizations should conduct "Governance with Foresight" pilot tests. These pilot tests should incorporate a variety of foresight practices (e.g., the delphi method, scenario-building, cross-impact assessment, and alternative reality games) in cooperation with a broad, international stakeholder base (public officials, engineers and researchers, NGO representatives, citizens) and via appropriate processes (e.g., citizen panels and wisdom councils). Their purpose would be to iteratively develop and test processes that anticipate a wide range of potential futures—for example, rogue deployment, climate surprise, or technological breakthroughs in non-climate arenas. The results of such pilot tests could help guide efforts to develop appropriate institutions for governing SRM.

Corporations, business associations, armed forces, and some public service agencies have used foresight practices to guide their decision-making. Interested national or international organizations should seek out organizations that have conducted such exercises to develop a timeline and plan for their own "Governance with Foresight" exercises.

MAKE RESEARCH TRANSPARENT AND ACCOUNTABLE.

7. Report on SRM research and development activities in the Global Stocktake under the Paris Agreement.

Who should take action? *National governments and the UNFCCC*

An evaluation of global research and development trends on SRM should be included in the global stocktake exercise of the Paris Agreement on climate change under the UNFCCC, in order to ensure greater transparency regarding the development of these technologies. Importantly, however, inclusion of an item in the stocktake does not suggest endorsement of its development or deployment. Furthermore, the Working Group reiterates that calling for reporting requirements on SRM under the stocktake does not endorse including SRM in meeting the objectives of the Paris Agreement, particularly mitigation. Our recommendation to include SRM research and development activities in the stocktake is intended to serve the narrow end of enhancing transparency.

Article 14 of the Paris Agreement on climate change requires a periodic stocktake of the implementation of the Agreement to assess collective progress towards achieving its goals and purposes. The general guidance from the Agreement is that the stocktake should be conducted in a comprehensive and inclusive manner, considering mitigation, adaptation, and the means of implementation and support. The stocktake will precede the cycles of pledging of Nationally Determined Contributions (NDCs) for each party to the Agreement and is designed in general to inform those pledges. The terms of reference for the stocktake are still being developed under

the auspices of the Ad-Hoc Working Group on the Paris Agreement (APA). There are a number of extant issues involving the stocktake to be resolved. Among them is whether the stocktake should be narrowly focused on providing an assessment of where the world is globally on meeting the goals of the Paris Agreement under Article 2,[2] or whether its scope should be broader and also provide an opportunity to assess the current state of development of technologies, instruments, and policies that could potentially impact the goals of the Agreement.

If a narrow remit for the stocktake is authorized and does not include an assessment of the current state of research and development on climate-related technologies, then SRM will not be included in the stocktake.

If, however, a broader remit for the stocktake is authorized, then it is our recommendation that including SRM in this process will act as an important transparency mechanism, ensuring that parties are better informed about individual and collective efforts and developments in this area. In addition, insofar as it may be the case that some parties decide to pursue SRM (which is why we need to address issues of governance writ large), calling for the inclusion in the stocktake of any planned or in-progress SRM-related activities would provide another mechanism to support the objective that SRM is never a substitute for mitigation or adaptation.

As with many other such processes in the UNFCCC, the stocktake will involve inputs from bodies constituted under the UNFCCC and the Paris Agreement, other UN agencies, the IPCC and other scientific bodies, regional groups, and civil society. Insofar as we have recommended that many of these bodies track the progress on development of SRM (or continue to do so if they already are), then this information should be an appropriate input for the stocktake. Parties should be responsible for filling any gaps in information in the stocktake on development of SRM, either relating to their own research programs on SRM, or research that may be on-going by institutions in their jurisdictions, even if it is not supported by the party. It is currently envisioned that the subsidiary bodies under the UNFCCC—the Subsidiary Body for Implementation (SBI) and the Subsidiary Body for Scientific and Technological Advice (SBSTA)—will play an important role in identifying gaps in information provided under the stocktake. As such, the subsidiary bodies should begin creating the capacity to track developments in SRM that may be on-going even if this information is not submitted as input from these other sources.

At the time of writing, the parties are considering a flexible process that would allow for adjustment of the modalities of the stocktake over time so that its elements can be refined on the basis of experiences gained, including from the 2018 Facilitative Dialogue (Talanoa Dialogue) under the Paris Agreement, and after the first and subsequent stocktakes. The first stocktake will take place in 2023.

8. Institutionalize codes of conduct for responsible SRM research.

Who should take action? *SRM researchers, governance experts, national governments, and secretariats of international organizations*

In countries in which SRM research is currently underway, or is foreseen to emerge in the near future, the scientific community should

2 Article 2 of the Paris Agreement reads: "This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by: (a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change; (b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and (c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development. 2. This Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances."

coalesce around a specific and explicit code of conduct for SRM research. Until broad international agreement on what constitutes responsible research on SRM is possible, national-level codes of conduct for research should establish and outline what constitutes responsible research in national contexts. Funders should require grantees to adhere to an established code of conduct.

A number of codes of conduct pertinent to SRM research have been proposed or are currently in development (see, for instance, Box 14 on p. 41). It is likely that in the future, multiple codes for SRM research will exist simultaneously and that various actors or professional bodies will adopt one or more of them. In this context, we recommend that those countries in which SRM research is currently underway, or is foreseen to emerge in the near future, develop or review and endorse a code of conduct for research on SRM. It is crucial that international institutions well placed to do so also review and endorse existing codes, or launch a process to negotiate a new code, as necessary.

Public and private organizations that fund research into SRM should require grantees to follow an established and accepted code of conduct for research. Where state and private funders create identifiable funding streams for research into SRM, those receiving such funds should follow a code of conduct identified by the funder. Depending upon the size of the funder, it is likely that the responsibility for monitoring and enforcement will fall to the researcher's home institution, requiring that the institutions themselves receive training on assessing compliance with the code of conduct. The funder must establish a reporting process for institutions to flag violations of the code of conduct and determine a protocol for intervening with the researcher, including the potential withdrawal of funding.

At the national level, codes of conduct that capture elements of responsible research not already covered by domestic law may be voluntary or enforced as a condition for receiving public funding. Given that there are no international regulatory bodies at the moment tasked with regulating SRM research, codes of conduct endorsed by international institutions are likely to be voluntary in the near term. Optimally, at some point in the future, these efforts will build upon each other to allow for broad international consensus on a code of conduct for SRM research. International institutions, such as UNEP, for example, could aid in the harmonization of these codes of conduct over time, which would be critical if SRM research gains momentum.

In evaluating these existing codes and potentially endorsing them or adapting them, a number of crucial design considerations arise. First, who designed the code and for what purpose? Second, by what processes was agreement on it reached? Third, who is being asked to adhere to the criteria and principles of responsible research? Finally, an overarching design consideration is the general challenge facing various other recommendations as well: defining the scope of SRM research. To what kinds of research should a voluntary code of conduct apply—for instance, to outdoor experimentation only or also to computer modeling, social science, and/or other forms of research?

BOX 14. CODE OF CONDUCT FOR RESPONSIBLE SRM RESEARCH

The Geoengineering Research Governance Project has developed a voluntary code of conduct which "seeks to provide principles and procedures for the responsible conduct of outdoor experiments on geoengineering." The code was developed through a "process of engagement involving expert peer review, semistructured interviews with national and international policymakers on the need for, and potential effectiveness of, a code of conduct, an open call for comment, and stakeholder workshops." The code is aimed at states, international organizations, and individuals and institutions involved in the research process. The code outlines specific responsibilities related to access to information, environmental assessment of planned outdoor experiments, public participation, and cooperating in the assessment of research.

See: Hubert, Anna-Maria, Tim Kruger, and Steve Rayner. "Geoengineering: Code of Conduct for Geoengineering." *Nature* 537, no. 7621 (2016): 488.

9. Ensure that ongoing research includes international and interdisciplinary collaboration.

Who should take action? *State and private funders of SRM research*

State and private funders of SRM research should prioritize projects that feature substantial international and interdisciplinary partnerships.

If SRM research is to be pursued, then it should be pursued through international collaboration. State and private funders that choose to fund SRM research should give priority to SRM research efforts that include substantial international and interdisciplinary partnerships, keeping in mind that the scale and type of research will influence what level of partnership is possible for any particular undertaking.

International research partnerships offer at least four key benefits. First, international research programs are opportunities to build trust among parties, especially bridging gaps of wealth and power, and establish channels for cooperation that may translate into channels for international cooperation on governance. Second, international cooperation on SRM research can also contribute to more equitable and transparent outcomes of the research by broadening the conversation on the need for any research and the possible effects of it at larger scales, especially on poorer populations that face disproportionate risks from climate change. If SRM research is to proceed, it is essential that researchers from as many states as possible, including the least well off, participate in that research. Third, international cooperation in science is a channel for the diffusion of norms such as transparency, and protocols for environmental and health safety that are essential for well-governed SRM research. Finally, international cooperation on a specific research program necessitates information sharing, which contributes to stronger research design and outcomes.

Furthermore, by its very nature, research into SRM raises questions that go beyond the natural sciences and engineering. SRM research does more than address scientific questions about the nature of cloud formation or aerosol dynamics in the atmosphere. It also raises questions of human welfare that go well beyond the natural sciences, affecting such a wide range of natural and social systems that it can only be understood if examined through multiple lenses. Ethical and governance questions should thus be asked and answered alongside physical science and engineering questions in climate engineering research.

States with multiple funding or research agencies funding SRM research should first coordinate internally (as well as with subnational programs if they exist) prior to international engagement. Second, funders should consider whether to focus on partnerships with countries

with existing capacity to research SRM or prioritize partnerships that would build capacity in states that currently lack capacity.

10. Clarify funding streams.

Who should take action? *Public and private research funders and SRM researchers*

With the goal of ensuring transparency and responsible research, all sources and recipients of funding for SRM research should be a matter of public record and there should be clarity that funding is specifically for SRM.

Some countries have been funding SRM research (in particular modelling studies) without labeling it as such, or funding projects under research programs that are not explicitly identified as being on SRM or inclusive of SRM. Those parties that are funding SRM research should do so as transparently as possible. With the goal of promoting SRM research and development in the public interest, all sources and recipients of funding should be a matter of public record and there should be clarity that funding is specifically for SRM. All researchers, potential and existing funders, and the public at large should be aware of what is being funded, by whom, and with what intent.

Toward that end, public and private institutions that are funding SRM should clearly identify requests for proposals (RFPs) for SRM as SRM. It should be made as clear as possible that broader RFPs that are inclusive of SRM research, but not only focused on SRM, are also labeled as such. All approved SRM projects should be clearly tagged as such in research databases. Projects that are intended to have implications for SRM should be so identified, even though the research may be broader and relevant beyond the scope of SRM.

Consistent with this, we encourage policy makers at the national level to illuminate and collect information on SRM funding streams. We also encourage them to engage civil society actors and other stakeholders to ensure that these efforts are transparent and accessible. A clear challenge will be collecting information about not only public but also private sources, including commercial investment. To include such streams, states could offer reporting incentives—e.g., publicizing philanthropic efforts to respond to climate change or to endow cutting-edge technological research, or create a consortium of funders and recipients to make clear the funding landscape.

Once existing funding streams are identified, and future ones are clearly identifiable as on SRM or relevant to SRM, then it will be possible to create a publicly accessible clearinghouse for information about SRM (Recommendation 11), which is essential for creating a climate of trust around this research. Funders willing to make their activities public should be invited to come together to create such institutions as they see fit. This should help to ensure that such bodies possess the requisite organizational components to collect and report on all stages of funding and to gain early support by the research community.

11. Develop a publicly accessible clearinghouse.

Who should take action? *SRM researchers, research funders, NGOs, and national governments*

National governments should develop publicly accessible clearinghouses of all publicly funded and, to the extent possible, privately funded SRM research. Such national clearinghouses should, in turn,

feed data into an international clearinghouse. Clearinghouses would help coordinate development of research priorities during early stages of technological assessment. The clearinghouses should be designed and developed by an existing authoritative body or ideally through a collaboration among a set of authoritative bodies.

As a near-term step towards ensuring accountability and transparency, national governments should develop publicly accessible clearinghouses of all publicly funded and, to the extent possible, privately funded SRM research.[3] Such national clearinghouses should, in turn, feed data into an international clearinghouse.

By providing access to information about current knowledge and research efforts, a central, authoritative, and accessible clearinghouse would enable a level of public understanding that is crucial for effective public engagement. Such a clearinghouse would also help coordinate development of research priorities during early stages of technological assessment.

An immediate challenge is defining the scope of research to include, both in terms of what counts as SRM research as opposed to, for example, basic climate science as well as what kinds of SRM research to include. On the former question, the clearinghouse will have to rely initially on voluntary self-identification of research. On the latter question, at a minimum, all open air experimentation should be included. With varying degrees of depth and specificity, the clearinghouse should also include the full range of climate engineering research, which might include work streams from computer modeling to field experimentation to social science research. Relevant social science research should include, for example, research on risk assessment and equity issues.

A further challenge relates to security or commercial interests that may make some actors less willing to contribute to the clearinghouse. While it may be impossible to prevent some clandestine research, states would ideally endorse a mechanism so that commercial actors would be required to participate with reasonable restrictions on the types of proprietary information that should be included.

Public registries or clearinghouses have become commonplace for potentially powerful or high-risk/high-reward technological endeavors or production activities. There are two relevant models:

1. A *research database* containing large amounts of categorized and searchable information logged by individual researchers. Examples include the Food and Agriculture Organization's Genetically Modified Food platform or the U.S. National Institutes of Health's clinicaltrials.gov
2. A *curated clearinghouse* that displays a standardized set of information sought, logged, and curated by a centralized authority. Examples include the Nanomaterials Registry, managed by RTI International.

While both models aim to make information transparent and accessible, the second option, a curated clearinghouse, best allows data to be contextualized and displayed in ways that assist non-expert audiences in understanding the data and highlight larger trends and relationships beyond the details of an individual experiment. We recommend, therefore, the curated clearinghouse mode.

Developing a set of clearinghouses calls for coordinated efforts by national, international, and non-state actors. National-level reporting engagement has generally proceeded in a

3 Craik, Neil A., and Nigel Moore. "Disclosure-Based Governance for Climate Engineering Research." Centre for International Governance Innovation. CIGI Papers, No. 50 (2014).

haphazard way, with different levels of country engagement and with countries operating according to different reporting frameworks. An international institution might overcome this problem by serving as a coordinating mechanism through which national governments can mandate the creation of domestic clearinghouses that connect to an overarching international clearinghouse. Existing organizations with an established track record of disseminating scientific information would be well suited to play this role. Non-state actors, such as Publish What You Pay's support of the Extractive Industries Transparency Initiative, have typically taken the lead, building working prototypes and developing curated databases of existing information. They could do so again in this instance, particularly in helping to develop domestic-level clearinghouses in countries with limited capacity.

Two other important steps in this process are identifying some institution responsible for curation, which would ease the burden placed on scientists for reporting, and beta testing the clearinghouse with various stakeholders in order to ensure its usefulness and accessibility to all stakeholders.

12. Develop best practices for risk and impact assessments.

Who should take action? *National governments, risk assessment and Environmental Impact Assessment (EIA) experts, and SRM researchers*

National governments, risk assessment and EIA experts, and SRM researchers should work together to expand risk assessment and EIA procedures and protocols so that they can provide precautionary evaluation of potential direct social and environmental harms, as well as enable public notification and consultation, for SRM experiments.

SRM experimentation should be formally and transparently evaluated for risks and impacts. This entails tailoring established tools for risk and impact assessment to the specific set of issues raised by SRM experimentation of different types and at different scales. We emphasize two specific challenges. The first is to create a process for a stream of decisions that indicate the depth and scope of assessment required. In many statutory Environmental Impact Assessment (EIA) regimes, for instance, this takes the form of a process flow chart. For example, in the US state of California, a public agency first determines whether a given activity requires assessment for impact, or whether likely impacts are deemed to be minimal or trivial enough that the activity can be exempted from the evaluation process. Any activity that may have "significant effects" is then subjected to a staged process of expert and public scrutiny and evaluation. Such systems create specific decision points as "forks in the road" to greater or lesser levels of screening, which in turn provide actors with predictability and regularity as they design specific projects or experiments.

In other cases, such as the process used by the World Bank, projects receive a tiered classification from an initial screening (in the Bank's case, categories A, B, or C) with varying levels of assessment triggered by the category of classification. Again, the goal is a predictable system that shapes design choices to minimize undesirable impacts.

The second and larger challenge is the need to determine precisely how to conduct risk assessments and social and environmental impact assessments for SRM technologies. Both techniques have seen a significant degree of standardization, institutionalization, and professionalization in recent decades, which can be built upon.

Still, as the example of nuclear power has shown, non-incremental new technologies create the need for both new forms of assessment expertise and new protocols of assessment, as well as careful thinking about how to integrate elements of probabilistic assessment (risk) into the characterization of the range of likely outcomes (impact).

To do this, it will be critical to engage entities such as the Society for Risk Analysis and the International Association for Impact Assessment—early, and in a sustained manner—to develop a better understanding of the task. Panel discussions at the annual meetings of such entities, bringing together SRM researchers and experts in risk and impact assessment, would be a useful near-term step.

Focusing on EIA procedures in particular, there are three major questions that will need to be addressed as EIA experts determine the fit between the current EIA landscape and the ideal one needed to govern SRM research effectively.[4]

The first question has to do with threshold and scope. Most existing domestic EIA procedures focus strictly on likely environmental or human health impacts. Near-term planned SRM field experiments or computer modelling would almost certainly be exempted because they do not pose significant environmental risks. In the same vein, the current trigger in international law for whether an impact assessment should be undertaken is the creation of the potential for physical change which may have an impact which is beyond transitory. However, and again, the primary concerns about small SRM field experiments have little to do with direct environmental impacts, but rather with the "downstream" political, social, and environmental impacts associated with SRM development.

The second question has to do with jurisdiction should SRM experimental activities take place in or pose risks that threaten the global commons. No international body currently has the explicit mandate to conduct or call for EIAs for experiments in the atmosphere, though there is substantial use of EIAs in international law as a way for states to meet their obligation of due diligence to avoid harming another state. Ideally, this system will be strengthened for SRM experimentation such that a single body or collection of bodies is responsible for assessments. An additional point here is that the public consultation aspect of EIAs is both essential and challenging for SRM experiments, as the community of concern is not only those that are directly impacted but also those that are interested in the outcome, and these two communities might be geographically - and temporally - distant from one another.

The third question has to do with implementation. Many states do not have the capacity to design and implement an EIA for an SRM field experiment. All assessments should meet standards of transparency and be third-party based to avoid capture or undue influence.

To bridge the gap between the current EIA landscape and the one needed to properly assess SRM experiments, the existing EIA expert community should be engaged directly. It is especially important to engage experts in social impact assessments given the concern about the downstream social and political impacts of SRM research. EIA professionals, through their professional societies, should be engaged, and over time, their inputs should feed into changes to domestic EIA legislation.

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SECTION 5: CONCLUSION

Actions to govern SRM should begin now. Whatever one believes about the desirability or feasibility of SRM research or potential technologies, the largely ungoverned status quo is untenable. This report has detailed a set of twelve consensus recommendations that, if implemented, will provide much needed transparency and coordination.

"The idea of SRM can neither be wished away nor delegated to technicians. Instead, SRM research and any potential avenue to deployment must be managed using humanity's best available tools and governance resources."

SRM technologies and policies will remain contentious. This is to be expected and is appropriate given the scope of the climate challenge and the far-reaching impacts of any response to it. Recognition of disagreement, though, should not delay governance action. At this point, the idea of SRM can neither be wished away nor delegated to technicians. Instead, SRM research and any potential avenue to deployment must be managed using humanity's best available tools and governance resources. The recommendations detailed above are essential, practical first steps to manage controversies around research, guide the emerging public conversation about SRM, and help build the scaffolding for whatever long-term governance may be required.

APPENDIX 1: ACADEMIC WORKING GROUP MEMBER BIOGRAPHIES

Netra Chhetri, PhD

Netra Chhetri is Senior Sustainability Scientist at Julie Ann Wrigley Global Institute of Sustainability and Associate Professor at the School of Geographical Sciences and Urban Planning (SGSUP) as well as the Consortium for Science, Policy and Outcomes (CSPO) at Arizona State University (ASU). Dr. Chhetri's expertise lies in the area of climate adaptation, energy and water, agriculture and food security, vulnerability assessment, grassroots innovation, participatory development, and citizen engagement. A common thread of his scholarship sits in the nexus of science and society and the scope of his work is by its nature both local and global.

He is currently a principal investigator on a USAID-funded project in Nepal on climate adaptation and food security. He is also a part of a team studying the sustainability of second-generation biofuel crops in the U.S.

Dr. Chhetri's research publications include over 20 articles in the high impacts journals such as *Nature, PNAS, Annals,* and *Applied Geography*. He has been one of the contributing authors of the AR4 and AR5 to the WG II of the IPCC.

At CSPO, Dr. Chhetri helped create a research cluster on *Alternative Imagination* that explores the plurality of science, society and sustainability.

Dan Chong, PhD

Dan Chong is an Arthur Vining Davis Fellow and Associate Professor at Rollins College, teaching courses in international human rights, global poverty, and peace and conflict resolution. His research focuses on the application of the international human rights framework to contemporary issues such as socioeconomic inequality and climate change. His first book, *Freedom from Poverty: NGOs and Human Rights Praxis* (University of Pennsylvania Press, 2011), analyzes the methods that NGOs use to advocate for economic and social rights. He has also contributed to journals such as *Development and Change, Human Rights Review, and Global Environmental Politics*. His most recent book, *Debating Human Rights* (Lynne Rienner Publishers, 2014), examines major controversies in the field of human rights. He has led international field study courses focused on human rights and poverty to Guatemala, South Africa, Tanzania, and the Thai-Burma border. He also serves as the Faculty Director of the Social Innovation Hub at Rollins College.

Ken Conca, PhD

Ken Conca, PhD is a Professor at the School of International Service, American University. Conca's research and teaching focus on global environmental governance, environmental peacebuilding in war-torn societies, environmental politics and policy in the United Nations system, water governance, and environmental policy analysis. He is the author/editor of several books on international environmental politics and the widely used teaching anthology Green Planet Blues. His latest books are *An Unfinished Foundation: The United Nations*

and Global Environmental Governance (Oxford University Press, 2015) and *The Oxford Handbook of Water Politics and Policy* (Oxford University Press, 2018). Dr. Conca is a two-time recipient of the International Studies Association's Harold and Margaret Sprout Award for best book on international environmental affairs and a recipient of the Chadwick Alger Prize for best book in the field of International Organization. He is a member of the United Nations Environment Programme's Expert Advisory Group on Conflict and Peacebuilding.

Richard Falk, SJD

Richard Falk is a Fellow at the Orfalea Center for Global & International Studies. Dr. Falk is also an Albert G. Professor of International Law and Practice Emeritus and Professor of Politics and International Affairs Emeritus at Princeton University. He is the author of *Law, War, and Morality in the Contemporary World; The Role of Domestic Courts in the International Legal Order; Legal Order in a Violent World; The Status of Law in International Society; This Endangered Planet; A Study of Future Worlds; Human Rights and State Sovereignty; The End of World Order; Reviving the World Court; The Promise of World Order; Revolutionaries and Functionaries; Revitalizing International Law; Explorations at the Edge of Time; On Humane Governance: Toward a New Global Politics; and Law in an Emerging Global Village: A Post-Westphalian Perspective*, and editor or co-editor of more than twenty additional books.

He has been a Fellow at the Center for Advanced Study in the Behavioral Sciences, a Guggenheim Fellow, the Olaf Palme Visiting Professor in Stockholm and Visiting Distinguished Professor at the Mediterranean Academy of Diplomatic Studies, University of Malta. J.S.D. Harvard University.

Alexander Gillespie, PhD

Alexander Gillespie is Professor, Te Piringa, Faculty of Law, The University of Waikato, New Zealand.

Professor Gillespie obtained his LLB and LLM degrees with Honours from The University of Auckland. He did his PhD at Nottingham and post-doctoral studies at Columbia University in New York City. His areas of scholarship pertain to international and comparative environmental law; the laws of war; and a number of pressing issues of social concern such as drug policy; and refugees.

Alexander has published sixteen books. The latest works have been *Waste Policy: International Regulation, Comparative and Contextual Perspectives* (Edward Elgar, London, 2015); *International Environmental Law, Policy and Ethics* (OUP, Second edition, 2015); and *The Causes of War: 1000-1600* (Volume II, Bloomsbury, NYC, 2015). He has also written over forty academic articles.

Alexander has been awarded a Rotary International Scholarship, Fulbright Fellowship, Rockefeller Fellowship, and the the New Zealand Law Foundation International Research Fellowship. Alexander has also been the lawyer/expert on a number of international delegations and advised the New Zealand government on multiple matters of international concern. Professor Gillespie was the first New Zealander to be named Rapporteur for the World Heritage Convention, involving international environmental diplomacy under the auspice of UNESCO. Alexander has also been engaged in policy formation for the United Nations, the Commonwealth Secretariat, and governmental, commercial and non-governmental organisations in New Zealand, Australia, United States, United Kingdom, Ireland and Switzerland.

Aarti Gupta, PhD

Aarti Gupta is Associate Professor with the Environmental Policy Group at the Department of Social Sciences in Wageningen University, the Netherlands. Her research is in the field of global environmental governance, with a focus on anticipatory governance of novel technologies and the role of science and knowledge therein, as well as questions of transparency and accountability, in the empirical domains of climate, forests, and safe use of biotechnology. Publications include *Transparency in Global Environmental Governance: Critical Perspectives* (MIT Press 2014), as well as numerous journal articles, including most recently on climate engineering governance. Aarti holds a PhD in Environmental Studies from Yale University. She has also held predoctoral and postdoctoral fellowship positions at Harvard and Columbia Universities. Her disciplinary background is political science and international relations, as well as science and technology studies. Aarti is currently co-lead on the 'Reimagine' project on 'Climate Anticipation in Vulnerable Regions of the Global South', together with colleagues from Utrecht and Oxford Universities. She also coordinates the "Governing Climate Futures" research theme within the Environmental Policy Group at Wageningen University, and is co-founder of the REDD@WUR network, an interdisciplinary network of over 80 researchers working on the interface between climate and forest governance. Internationally, she is a Lead Faculty in the Earth System Governance research alliance (a network of social science researchers on global environmental change), and one of five Coordinating Lead Authors of the ESG New Directions Science Plan. She is co-founder of the ESG Task Force on Anticipatory Governance and a member of the ESG Task Force on Planetary Justice. She is also Associate Editor of the journal *Global Environmental Politics*, and member of Climate Strategies, and the Climate Equity network. She has supplemented this academic journey with working outside of academia as well, including, *inter alia*, with the United Nations Development Programme in New York, Oxfam-Novib in the Hague, and Transparency International in Berlin.

Sikina Jinnah, PhD

Sikina Jinnah is an Associate Professor of Politics at University of California, Santa Cruz, and a 2017 Andrew Carnegie Fellow. Her research focuses on the shifting locations of power and influence in global environmental governance, in particular in the areas of climate change, climate engineering, and the nexus between international trade and environmental politics. Her first book, *Post-treaty Politics: Secretariat Influence in Global Environmental Governance* (MIT Press 2014) received the 2016 Harold and Margaret Sprout Award for best book in international environmental affairs from the International Studies Association. Her second monograph, *Trading the Environment: The Politics of Environmental Protection through Trade Agreements*, is currently under review at MIT Press. Jinnah is Co-Editor of the journal *Environmental Politics*, is on the editorial board for the journal *Global Environmental Politics*, and is a Senior Research Fellow with the Earth System Governance project. Dr. Jinnah's research has also been published in several scholarly journals, including: *International Studies Review, Global Environmental Politics, the Journal of Environment and Development, Environmental Research Letters, Berkeley Journal of International Law Publicist, Georgetown International Environmental Law Review, Global Governance, Climate Policy*, and *Science*. You can learn more about Dr. Jinnah's work at: www.sikinajinnah.com.

Prakash Kashwan, PhD

Prakash Kashwan is an Associate Professor in the Department of Political Science, University of Connecticut. His research and scholarship focus on political economy of institutions, climate justice, and environmental policy and politics. He is the author of *Democracy in the Woods: Environmental Conservation and Social Justice in India, Tanzania, and Mexico* (Oxford University Press, 2017) and articles in *Ecological Economics, Regional Environmental Change, Land Use Policy, Journal of Environmental Management, International Journal of the Commons, Journal of Theoretical Politics, Global Environmental Politics, and World Development*. He has also contributed popular commentaries to the Washington Post and the Guardian, among others.

Dr. Kashwan is a senior research fellow of the Earth System Governance Project and a member of the Taskforce on Planetary Justice. He was among the winners of 2009 Young Scientist Research Award from the International Foundation for Science (IFS), Stockholm. For more information about his research and scholarship, see https://prakash-kashwan.uconn.edu/.

Myanna Lahsen, PhD

Myanna Lahsen is an Associate Professor in the Department of Social Sciences at Wageningen University and Research, on leave from a position as Senior Researcher in the Center for Earth System Science at the Brazilian Institute for Space Research (INPE), Brazil. A Cultural Anthropologist and Science and Technology in Society scholar by training, she studies socio-cultural dynamics related to global environmental change, environmental sustainability and development, with central focus on knowledge politics and policy. She is the recipient of numerous prestigious awards and fellowship in the United States, including the Jacob K. Javits and EPA "STAR" fellowships, and two postdoctoral Fellowships, in the Advanced Study Program at the U.S. National Center for Atmospheric Research and in the John F. Kennedy School of Government, respectively. Before assuming her current position in Brazil, she held positions as Science Officer with the International Geosphere-Biosphere Programme, as Research Scientist in CIRES at the University of Colorado and as Lecturer on Environmental Science and Public Policy at Harvard University. She has served on review panels at the U.S. National Science Foundation and in Expert Groups advising the United Nations on the dynamics of the science-policy interface and the formation of a global sustainability report. She currently serves as advisor to *Nature Climate Change* and as Executive Editor of Environment: Science and Policy for Sustainable Development.

Andrew Light, PhD

Andrew Light is University Professor of Philosophy, Public Policy, and Atmospheric Sciences and Director of the Institute for Philosophy and Public Policy at George Mason University. He is also Distinguished Senior Fellow in the Climate Program at the World Resources Institute. From 2013 until March 2016, he served as Senior Adviser and India Counselor to the Special Envoy on Climate Change, and as Staff Climate Adviser in the Secretary of State's Office of Policy Planning in the U.S. Department of State. In this capacity he was on the senior strategy team for the UN climate negotiations, directed the U.S.-India bilateral Climate Change Working Group, and chaired the U.S. government's Interagency Working Group on Climate Change in the Sustainable Development Goals. Prior to his government service he was Senior Fellow and Director of International Climate Policy at the Center for American Progress in Washington, D.C., where he advised the Center's founder John Podesta, and worked primarily on comparative mitigation ambition, transparency, climate finance, and mitigation of short-lived climate pollutants. In his academic work, Light is the author of over 100 scholarly

articles and book chapters primarily on the normative dimensions of climate change, restoration ecology, and urban sustainability, and has authored, co-authored, and edited 19 books including *Environmental Values* (2008), *Controlling Technology* (2005), *Moral and Political Reasoning in Environmental Practice* (2003), *Technology and the Good Life?* (2000), and *Environmental Pragmatism* (1996). He has previously taught at New York University and the University of Washington, Seattle.

Catriona McKinnon, PhD

Catriona McKinnon is a Professor of Political Theory in the Department of Politics and International Relations at the University of Reading, UK. She has a background in political philosophy. Her most recent research is focused on climate ethics and justice, with a particular interest in intergenerational questions. She has held a number of prestigious research fellowships and awards, including two Leverhulme Trust Research Fellowships (2006 and 2014), a British Academy/Leverhulme Trust Senior Research Fellowship (2007), and an Arts and Humanities Research Council Research Fellowship (2000). Her published work in climate ethics has addressed just compensation for climate damages, the precautionary principle, hope for climate justice, climate denial, climate displacement, and other topics. She is the director of the Leverhulme Trust Doctoral Programme in Climate Justice and is the founder and director of the Centre for Climate and Justice, both at the University of Reading, UK. She is the editor of the successful textbook *Issues in Political Theory*, now going into its fourth edition with Oxford University Press. She has co-edited seven books including *Climate Change and Liberal Priorities* (2011), and *The Ethics of Climate Governance* (2015). She is the author of *Liberalism and the Defence of Political Constructivism* (2002), *Toleration: A Critical Introduction* (2006), and *Climate Change and Future Justice: Precaution, Compensation, and Triage* (2011). She is presently completing a book defending the idea of a new international criminal offence of 'postericide' (committed by conduct fit to bring about the near extinction of humanity), and she is also writing an introductory book on climate justice for Polity Press. She has previously taught in the Politics departments at the University of York, and the University of Exeter. She holds a PhD, MA, and BA (Hons) from the Philosophy Department of University College London.

Leslie Paul Thiele, PhD

Leslie Paul Thiele is Distinguished Professor of Political Science at the University of Florida, where he serves as Director of Sustainability Studies and Director of the Center for Adaptive Innovation, Resilience, Ethics and Science. His interdisciplinary research focuses on the intersection of political philosophy and the natural sciences, sustainability, and emerging technologies. His central concerns are the responsibilities of citizenship and the opportunities for leadership in a world of rapid technological, social, and ecological change. His articles have appeared in the American Political Science Review, Political Theory and a dozen other journals. His books include *Friedrich Nietzsche and the Politics of the Soul* (Princeton 1990), *Timely Meditations: Martin Heidegger and Postmodern Politics* (Princeton 1995), *Environmentalism for a New Millennium* (Oxford 1999), *Thinking Politics* (2nd edition, CQ Press 2003), *The Heart of Judgment: Practical Wisdom, Narrative, and Neuroscience* (Cambridge 2006), *Indra's Net and the Midas Touch: Living Sustainably in a Connected World* (MIT 2011), *Sustainability* (Polity 2016) and *The Art and Craft of Political Theory* (Routledge 2019).

Walter D. Valdivia, PhD

Walter D. Valdivia is Senior Policy Editor at the Mercatus Center at George Mason University. Dr. Valdivia was also a senior fellow at the Consortium for Science Policy and Outcomes, Arizona State University and a fellow in the Center for Technology Innovation at the Brookings Institution.

Valdivia's published work covers a wide range of topics in science, technology, and innovation policy. He has published extensively on university technology transfer and academic entrepreneurialism and is now finishing a book manuscript on the topic. Other areas of focus include the governance of innovation, federal R&D trends, the economic impact of emerging technologies, and constraints to academic freedom.

His current interests are on the future of higher education, networks of knowledge in international development, and the politics of science and innovation policy.

Valdivia holds a B.S. in economics from Universidad Católica Boliviana, and an M.S. in economics and a Ph.D. in public administration from Arizona State University.

Paul Wapner, PhD

Paul Wapner is a Professor at the School of International Service, American University. Wapner's research focuses on global environmental politics, environmental thought, transnational environmental activism, and environmental ethics. He is particularly concerned with understanding how societies can live through this historical moment of environmental intensification in ways that enhance human dignity, compassion, and justice, and come to respect and nurture the more-than-human world. His books include: *Environmental Activism and World Civic Politics, Principled World Politics: The Challenge of Normative International Relations, Living Through the End of Nature: The Future of American Environmentalism, Global Environmental Politics: From Person to Planet* (co-edited with Simon Nicholson), and *Reimagining Climate Change*. He continues to lead workshops for professors that explore contemplative practices and environmental engagement.

APPENDIX 2: MEETINGS OF THE WORKING GROUP

Washington, DC, March 6–9, 2016

The first meeting of the Working Group served to introduce members to the state of knowledge and major debates concerning SRM. The group met with leading global experts on SRM, engaging directly researchers studying SRM and authors of prior reviews of governance. The group debated questions such as whether to address both SRM and carbon removal, how the context of the conversation has shifted post-Paris, and why governance is needed now.

The Pocantico Center of the Rockefeller Brothers Fund, NY, September 22–24, 2016

The second meeting served both as an opportunity to provide an update on the work the individual working group members had undertaken since the initial meeting, and to begin structuring and synthesizing the group's joint report. The discussions highlighted several key issues: what exactly is to be governed; why and; how. The Working Group members decided to develop a concise report targeted specifically at policymakers. The group chose to move beyond the development of a list of governance principles, and to make short, medium, and long-term recommendations for the operationalization of those principles in policy terms. The group also settled on one unifying rationale for the development of SRM governance, namely, that as SRM research is taking place and is likely to continue to do so, governance is required.

Berkeley, CA, February 9–11, 2017

The third meeting of the Working Group convened external experts to identify lessons from the governance of other emerging technologies, including artificial intelligence, nuclear energy, and nanotechnology. The Working Group also identified a set of key governance principles to undergird its policy recommendations. The group discussed the structure of the report, which was to include an articulation of governance principles, a justification for near-term governance, and a set of policy recommendations.

Washington, DC, September 9–10, 2017

In the fourth meeting of the Working Group, the group refined the organizing themes of its joint report, examined in more detail what it means to translate key principles of good governance like equity into workable and concrete policy actions, and spent significant time building out the group's set of recommendations. The focus of the report was sharpened so that it is more specifically aimed at near-term governance activities (0-5 years) and in particular to governance of research, with an eye to establishing the conditions necessary for governance of deployment in the long term. While affirming the inclusion of guiding principles including equity, accountability, and participation, the group stressed the need to move beyond such principles by developing actionable recommendations responding to clear governance objectives.

The Pocantico Center of the Rockefeller Brothers Fund, NY, February 22–24, 2018

In its fifth and final full-group meeting, the Working Group finalized a set of objectives and recommendations for the near-term governance of SRM research. Among other important areas of discussion, the Working Group looked at how to acknowledge differences of opinion in the report, how to frame issues such as risk and the public interest, and how to deepen the report's discussion of the practical impediments to desirable forms of governance. FCEA presented a plan to finalize and publish the report and to promote the report globally through a series of meetings and other outreach efforts.

A full set of meeting reports is available at: www.ceassessment.org/SRMreport

APPENDIX 3: ADDITIONAL PUBLICATIONS

The Working Group was intentionally designed to bring new voices to the conversation about SRM governance by involving governance experts who had not previously engaged with in-depth consideration of the governance challenges associated with SRM. This process has resulted in a number of papers on aspects of SRM governance by Working Group members, including:

Conca, Ken. "Prospects for a multi-stakeholder dialogue on climate engineering." *Environmental Politics*. Forthcoming.

Flegal, Jane A., and **Aarti Gupta**. "Evoking equity as a rationale for solar geoengineering research? Scrutinizing emerging expert visions of equity." *International Environmental Agreements: Politics, Law and Economics* 18, no. 1 (2018): 45-61.

Gupta, Aarti, and Ina Möller. "De facto governance: how authoritative assessments construct climate engineering as an object of governance." *Environmental Politics* (2018): 1-22.

Jinnah, Sikina. "Why govern climate engineering? A preliminary framework for demand-based governance." *International Studies Review* 20, no. 2 (2018): 272-282.

Jinnah, Sikina, and Douglas Bushey. "Bringing Politics into SAI." *Ethics & International Affairs* 31, no. 4 (2017): 501-506.

Jinnah, Sikina and Simon Nicholson. "Governing Solar Radiation Management: How, Why, and For Whom?" *Environmental Politics*. Forthcoming.

McKinnon, Catriona. "Sleepwalking into lock-in? Avoiding wrongs to future people in the governance of solar radiation management research." *Environmental Politics* (2018): 1-19.

Nicholson, Simon, **Sikina Jinnah**, and **Alexander Gillespie**. "Solar radiation management: A proposal for immediate polycentric governance." *Climate Policy* 18, no. 3 (2018): 322-334.

Thiele, Leslie Paul. "Geoengineering and sustainability." *Environmental Politics* (2018): 1-20.

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