

PRACTICE BRIDGE

Building capacity to govern emerging climate intervention technologies

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Capacity building is needed to enable effective and inclusive governance of emerging climate intervention technologies. Here we use solar geoengineering (SG) as a case of an emerging climate intervention technology to highlight the importance of focusing attention on building capacity to govern these and similar technologies. We propose the concept of “governance capacity building” to help focus research and practice toward building and strengthening the knowledge, skills, tools, practices, or resources needed to govern SG. Centrally, we argue that “governance capacity building” is needed to enable multiple types of actors to contribute to all stages of the governance process, should be owned by recipients, and aimed toward building long term and durable forms of capacity. These capacity building efforts must center climate vulnerable communities and countries that stand to gain or lose the most from decisions about whether and how research and deployment of these technologies will move forward. To ensure governance capacity remains with these populations over the long term, governance capacity building should embrace a new model of capacity building envisioned primarily by actors in the Global South. We use these insights to demonstrate that gaps and limitations in how capacity building is understood in the SG governance literature and implemented in practice are stifling the potential for capacity building to enable effective and inclusive governance in the SG issue area. To help rectify this, we chart a path toward building successful governance capacity building programs for climate intervention technologies.

Keywords: Capacity building, Solar geoengineering, Climate change, Emerging technology, Governance, Environmental justice

Introduction

Emerging climate intervention technologies including carbon dioxide removal (CDR), atmospheric methane removal, and solar geoengineering (SG) offer tremendous opportunities and challenges for the global response to climate change and sustainability more broadly. These forms of climate intervention technologies are receiving growing public, political, and scientific attention as it appears increasingly likely that relying on mitigation and adaptation alone will not be sufficient to avoid severe climate impacts (Intergovernmental Panel on Climate Change, 2022). However, these emerging technologies also present a range of ecological and social risks and challenges, necessitating inclusive and effective forms of governance (National Research Council, 2015; National Academies of Sciences, Engineering, and Mathematics [NASEM], 2021; NASEM, 2022). Governance refers to the institutions and

processes through which public and private actors work to address political goals in a given issue area, in this case around climate intervention research or potential deployment (Chhetri et al., 2018; Dove and Talati, 2023). Governance is needed to accomplish several important functions, such as detecting and deterring irresponsible research or unauthorized deployment, and it can take many different forms, including for different climate intervention techniques and for different stages of any potential research or deployment activity. Some of the forms it might take include, for example, rules and regulations, incentives, voluntary guidelines, public engagement, international cooperation, and disclosure mechanisms that aim to bring transparency to any climate intervention activity. And yet, developing and implementing governance that is just, inclusive, and effective is challenging. Authoritative assessments of climate intervention technologies generally agree that the technologies are currently insufficiently governed, as existing forms of governance are incapable of addressing all risks and challenges associated with their research and deployment (e.g., NASEM, 2021; NASEM, 2022; United Nations Environment Programme [UNEP], 2023).

Governance requires capacity, which can be understood as knowledge, skills, tools, practices, or resources. Those forms of capacity required by governance can be understood as

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governance capacity. Where and when governance capacity is lacking—in order for governance to effectively meet its goals—it must be built. Capacity building is therefore needed to enable governance efforts that can ensure emerging climate intervention technologies contribute positively to sustainability transitions by enhancing, and not degrading, human and environmental well-being.¹ Capacity building can generally be understood as a process through which actors, institutions, or societies enhance their ability to solve problems and achieve goals by building or strengthening relevant skills, knowledge, tools, or practices (Khan et al., 2018). Here we argue for a concerted effort toward what we term “*governance capacity building*” for climate intervention technologies. We define governance capacity building (GCB) as:

A process through which individuals and/or organizations mobilize and sustain knowledge, skills, tools, and practices that enable them to engage in the development and implementation of local, national, and international forms of governance of research and deployment of emerging climate intervention technologies. (Dove and Talati, 2023)

Governance capacity building is needed to strengthen governance of research and/or deployment of all forms of emerging technologies, including climate intervention technologies. Here we focus on the SG case to illustrate the need for near term *governance* capacity building that is inclusive and comprehensive. Research and discussion of SG as a potential response option to climate change has been steadily growing for almost 2 decades. SG, also called solar radiation management (SRM), refers to a set of technologies and techniques that aim to artificially cool the planet by reflecting a small proportion of incoming sunlight back into space (National Research Council, 2015; NASEM, 2021). The most commonly studied method to implement SG is stratospheric aerosol injection, which could potentially achieve this cooling effect by dispersing particles into the atmosphere to scatter sunlight (National Research Council, 2015; NASEM, 2021). SG presents the possibility of both risks and benefits. For example,

1. We retain the use of the term “capacity building” mainly to remain legible to other scholars and practitioners working in this space, and because capacity building is the established term in the climate issue area, as the term is used by the United Nations Framework Convention on Climate Change (UNFCCC). We are concerned that adding new terminology would unnecessarily further complicate an issue area already overburdened by the use of many terms to refer to similar phenomena. Some aid agencies and scholars prefer to use the term “capacity development” to acknowledge that there are existing capacities that should be strengthened. There is some debate over whether they refer to the same thing; at times they are used interchangeably (Khan et al., 2018). We use capacity building but emphasize that it entails strengthening existing capacities. Moreover, we wish to acknowledge that NGOs and various actors in the Global South have done impressive work to improve how capacity building is conceptualized and practiced. We think it is worthwhile to continue to build off of this work rather than to start from scratch.

stratospheric aerosol injection may decrease the health impacts of rising temperatures, but it may also come with harmful impacts on global environmental systems (Tracy et al., 2022). Research is needed to “identify potential costs and benefits and, equally important, the regions, people, or systems that bear them” (Allenby, 2014; Patrick, 2021).

We focus on SG for 2 reasons. First, the risks of irresponsible research and unilateral deployment of SG are compounded in the absence of insufficient governance capacity across nations. SG could be deployed by a single country or a small group of countries and the unintended consequences of an irresponsible large-scale field test or deployment could be severe, with potentially devastating impacts on humans and the ecosystems we depend on. Failing to build sufficient governance capacity for SG compounds the risk that global governance institutions are unable to deter one country from deploying SG in a way that reduces climate risks in its own territory but that also creates harm elsewhere, for example by weakening the East-Asian monsoon, thereby sparking regional famine (NASEM, 2021). Moreover, failing to build governance capacity in the communities and countries that are most vulnerable to climate change, and that thereby have the most at stake in SG decision-making, would risk creating a severe procedural injustice, whereby disproportionately affected populations are not meaningfully engaged in key decisions about whether and how to research or deploy SG. This would reinforce and exacerbate current patterns of international domination (Smith, 2018).

Second, the recent uptick in political attention to SG makes such irresponsible research or unilateral deployment more likely. Recent activity has elevated SG as a topic of public, political, and scientific discussion, and deployment stunts and field experiments are quickly ushering SG from the realm of speculation and into reality. SG has been the focus of several recent reports and assessments conducted at national and international levels, including within: the U.S. White House Office of Science and Technology Policy, the U.S. NASEM, the United Nations (UN) Human Rights Council Advisory Committee, the Climate Oversight Commission, and the World Commission of UNESCO on the Ethics of Scientific Knowledge and Technology (COMEST). A resolution on SG was also a topic of debate at the recent Sixth Session of the United Nations Environment Assembly (UNEA-6) as well as the previous UNEA-4. Moreover, in 2022, a U.S.-based startup company recently performed what it calls the first deployment of SG by releasing 2 weather balloons filled with sulfur dioxide in Mexico—without notice or consent—and is promising to continue through its sale of “cooling credits” (Temple, 2022). Mexico responded by banning SG outdoor experiments (Ministry for the Environment and Natural Resources, 2023), however governance capacity will be needed to monitor SG activity and to enforce the ban. Additionally, in April 2024, a research group led by scientists at the University of Washington initiated an outdoor experiment without public engagement near San Francisco to study another SG technique, marine cloud brightening (Thorsberg, 2024). The experiment was ultimately forced to stop after city officials voted to end it in response to public concern

(Karlamangla, 2024). Highlighting the lack of existing regulations, an expert petition to the U.S. National Oceanic and Atmospheric Administration (NOAA) recently warned that under existing rules in the United States, anyone intending to release aerosols into the atmosphere would only need to notify and provide limited information to NOAA 10 days in advance (Bravender, 2024). Private funding for SG research has increased dramatically with several nonprofits based in the United States and United Kingdom announcing tens of millions of US dollars for SG research and government advocacy (Temple, 2024).

Centrally, our article demonstrates that GCB is needed to establish effective and inclusive governance of SG. However, gaps in how capacity building is understood in the SG literature and implemented in practice threaten to stifle the potential for capacity building to establish inclusive and effective governance. Our paper is a practice bridge, a theoretically informed paper for improving the practice of capacity building in the SG issue area. We advance several arguments toward this end. First, GCB is needed for both “upstream” aspects of policymaking (e.g., related to research, assessment, imagination, anticipation, societal deliberation, and policy development and design), as well as “downstream” aspects (e.g., related to implementation and enforcement) (Sagar and VanDeveer, 2005). This requires a move beyond current efforts that are focused on scientific capacity building, which builds an important but on its own incomplete set of capacities required to govern SG.² Second, GCB efforts must center climate vulnerable communities in the Global South, who are the populations most susceptible to climate impacts and thus have the most at stake in SG decision-making. To do so requires building off of existing expertise in these populations and addressing power relations that are associated with an unequal distribution of the capacities needed to research, govern, and deploy SG. Third, durable forms of governance capacity must remain in the Global South for the long term. Governance capacity building efforts should therefore embrace a new model wherein the process and products of capacity building efforts are owned by recipients, meaning climate vulnerable communities and countries are empowered to decide, for example, which capacities need building or strengthening and what is the best way to do so within their local context.

2. The same focus on scientific capacity building exists in the CDR issue area as well. For example, NASEM (2022) outlines a recommended research program for ocean CDR, which called for “[c]apacity building among researchers in the United States and other countries . . .” (NASEM, 2022, p. 17, emphasis added). Much of the CDR literature also discusses “capacity building” in the context of scaling up carbon removal and storage capacity or reporting and monitoring capacity (e.g., Mace et al., 2021; Low et al., 2022); or in the context of transferring CDR technologies to build capacity to implement CDR, not in terms of building capacity to govern CDR (e.g., Honneger et al., 2022). Partial exceptions include Harvey et al. (2023), who call for “public capacity building,” in terms of strengthening public understanding of CDR to enable engagement, ultimately for the purpose of achieving large-scale CDR deployment; and Batres et al. (2021), who ask “who should be responsible for building capacity in communities? And what does the process for capacity building look like in policy or regulatory decision-making?” (p. 3).

The article proceeds as follows. First, we discuss how capacity building has been defined in global environmental politics. We then highlight several advantages of our new concept of “GCB,” which seeks to remedy some of the critiques of traditional approaches to capacity building, using SG as an illustrative case. We then explain why GCB must center the Global South, highlight several limitations in how capacity building is conceptualized in the literature on SG governance, and assess existing capacity building efforts on SG, including by identifying major gaps in that work. To address these gaps and limitations, we conclude with a proposal for how to develop a successful GCB program for emerging climate intervention technologies.

Overall, the SG case illustrates why capacity building for equitable and effective governance of emerging climate intervention technologies is urgently needed. As SG is largely ungoverned, actors currently have tremendous leeway to move forward with SG activity, even where that activity may be irresponsible, secretive, or harmful to others. But governance is needed to also enable responsible SG activity, not just to deter irresponsible activity. Building capacities required for effective, inclusive, and just governance of SG could go a long way toward enabling a responsible and legitimate SG research program that produces critical knowledge needed to inform decision-making. In short, governance capacity is required to both enable and restrict SG activity. Governance capacity building should therefore be an endeavor that unites people who ultimately hold a wide range of opinions on the ultimate wisdom of moving forward with SG research or development.

Capacity building landscape in environmental politics

Capacity building is firmly established as a key element of global environmental politics (Khan et al., 2018; Klinsky and Sagar, 2022), especially within the climate change regime (Ferraz da Silva, 2022). In this section, we review the literature on capacity building in global environmental politics, with a view toward identifying best practices in the field.

Most academic studies of capacity building suggest that the term is imprecise and somewhat problematic because it has no established definition and often refers to a wide range of different activities. Writing in 2001, VanDeveer and Dabelko (2001) state that although capacity building is “widely alluded to in international organizations, assistance programs, and scholarship,” it “often has no clear definition, nor does the term evoke a common set of strategies among its users” (p. 20). The same is true over 20 years later. Morgan (2006) explains that because capacity building evolved as a blend of precursor concepts with different theoretical underpinnings, such as “human resource development” and “institutional economics,” different disciplines and relevant actors hold a wide range of diverse perspectives on what capacity is and what it means to build it. Capacity building has therefore been described as “puzzling, confusing, and . . . vacuous” because there is “no broadly accepted definition” (Morgan, 2006), and it is instead often used as a catch-all term that encompasses a wide variety of aid initiatives (Khan et al., 2018, see also Klinsky and Sagar, 2022).

Table 1. Definitions of capacity building and related concepts from relevant organizations

Definition	Source
“the process through which individuals, organizations, institutions and societies develop abilities to perform functions, solve problems and set and achieve objectives.”	United Nations Development Programme (2009)
“a locally driven process of learning by leaders, coalitions and other agents of change that brings about changes in sociopolitical, policy-related, and organizational factors to enhance local ownership for and the effectiveness and efficiency of efforts to achieve a development goal.”	Otoo et al. (2009, World Bank)
“the process whereby people, organisations and society as a whole unleash, strengthen, create, adapt and maintain capacity over time.”	Organization for Economic Co-operation and Development (2008)
“the process of partnering with local actors—individuals, organizations, and networks—to jointly improve the performance of a local system to produce locally valued and sustainable development outcomes.”	United States Agency for International Development (2022)

While the concept remains imprecise, there is some similarity in how capacity building has been defined by development and aid agencies (see **Table 1** and Khan et al., 2018). We note that the structure of various definitions shows a general formula:

A process through which [actor or societal level] [develops / enhances / builds / mobilizes] its [abilities / capabilities / skills] to [perform functions / accomplish goals / solve problems].

A key takeaway from this formula is that capacity building only becomes a meaningful concept after the “what,” “who,” “how,” “why” are articulated: what sort of capacities are built, whose capacity is built and by whom, how is that capacity built, and for what purposes? (see also Eade, 2007; Klinsky and Sagar, 2022).

Additionally, Khan et al. (2018, pp. 86–87) note that the definitions share several broad parameters:

- It is a dynamic, not static, process, adapting to evolving developments.
- It invokes change and improvement.
- It is not a one-off, quick-fix solution, but a long-term issue, requiring investment of time and resources.
- It involves people, organizations, institutions, and society as a whole and their interactions, ultimately as society-wide development of capabilities.
- It is driven from the inside as an endogenous process and requires ownership.
- It strengthens existing capacities to ensure sustainability.

Capacity building has been integral to global environmental governance, especially following the major 1992 Rio Earth Summit where capacity building issues came to the fore (Sagar and VanDeveer, 2005; Khan et al., 2018). Khan et al. (2018) note that this is because transboundary environmental policy and management emerged in the last several decades as a new issue that created a governance challenge. This was particularly true in Southern countries, who were experiencing gaps in capacity across

a broader range of issue areas. Capacity building for environmental management has become a pillar of development cooperation as a result. It is also a key element of almost all environmental agreements and protocols (Khan et al., 2018). This can be seen throughout, for example, the Montreal Protocol, United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity, The UN Convention to Combat Desertification, the Stockholm Convention, the Nagoya Protocol, and the Sustainable Development Goals.³ Here, the focus is on the capacity for primarily Southern countries to *implement* international environmental agreements, as opposed to capacities related to the “upstream” aspects of policymaking, such as agenda setting, framing, and assessment (Sagar and VanDeveer, 2005).

In climate change politics, capacity building has become increasingly important throughout the UNFCCC system over time (Khan et al., 2018; Ferraz da Silva, 2022). Article 6 of the UNFCCC requires parties to promote: education, training, and public awareness of climate change; public participation in addressing climate change; and training of scientific, technical, and managerial personnel. Article 10 of the Kyoto Protocol similarly requires parties to cooperate and promote education and training, including national-level capacity building. Other key developments within the UNFCCC include the 2001 Marrakesh Accords at Seventh Conference of the Parties (COP7), which set a framework, guiding principles, and priority areas for capacity building (UNFCCC, 2001); the creation of the 2011 Durban Forum on Capacity Building at COP17, a multistakeholder forum for sharing ideas and best practices; the 2012 Doha Work Programme on Convention Article 6 adopted at COP18 (UNFCCC, 2012), which requested an annual dialogue on capacity building; the decision to hold a ministerial dialogue on capacity

3. See Khan et al. (2018, pp. 7–9) for further capacity building-related excerpts from the text of these agreements and for a fuller demonstration of how capacity building is integral to environmental and climate governance, including an elaboration of the institutions, funding, mechanisms, and processes devoted to capacity building under the UNFCCC.

building at COP20; and most recently in 2015, at COP21, the establishment of the Paris Committee on Capacity Building to coordinate capacity building efforts under the Convention and the establishment of the Capacity Building Initiative for Transparency to strengthen countries' ability to meet reporting and transparency obligations under the Agreement.

Prior work has identified 2 general capacity building models (Khan et al., 2018). First, a "classic" model characterizes most capacity building efforts across the past several decades.⁴ This model is built around ad hoc short-term workshop-based technical training projects that "parachute" outside consultants into an area to train personnel (Khan et al., 2018; Casado Asensio et al., 2022). These efforts are often uncoordinated and provide participants with little control over the process or outcome (Eade, 2007). Nobody explicitly ascribes to the classic model, yet this is often how capacity building is done in practice.

Second, a "new" capacity building model that aims to improve upon common critiques and limitations of the classical model has emerged from primarily least developed country perspectives on their experiences with capacity building as well as from expert assessments and from innovative nongovernmental organizations (NGOs). This new capacity building model aims to build long term, systemic, and sustainable capacity systems that enable countries to effectively address issues, accomplish goals, and solve problems over time by ensuring participants have ownership of capacity building processes and outcomes (e.g., Lafontaine, 2000; Lopes and Theisohn, 2003; Commission for Africa, 2005; Virji et al., 2012; Khan et al., 2018). Ensuring these countries have ownership of capacity building programs means enabling these countries to decide, for example, what specific capacities are needed in their local context and how they will build them. This follows from the recognition that there is no one-size-fits-all solution to capacity building and what is successful in one context may not be so in another (Khan et al., 2018). Among other actors, the new capacity building model is being developed within some NGOs seeking to embrace a spirit of innovation and change. For example, after a year of dialogue and review, the International Institute for Environment and Development (IIED) published a manifesto that acknowledges "achieving our mission means we cannot continue doing more of the same and instead must challenge ourselves to take a bold new direction," including by "taking a systems approach and working in dynamic teams to develop new ideas, test innovations and scale what works" (IIED, 2024). While innovative NGOs are implementing promising elements of the new model, it remains aspirational; it has yet to be fully implemented in practice, as we demonstrate below in the case of SG.

Why GCB matters

Inclusive and effective governance of climate intervention technologies requires multiple types of capacities and appropriate capacities must be available to the many types of actors that are expected to play important roles in

governance. To help widen our understanding of who needs to be involved in capacity building efforts, what capacities need to be built, and for what purposes, we articulate more fully a conceptual vision for GCB for emerging climate intervention technologies.

In response to previously discussed critiques of the ambiguity of capacity building, we aim to be clear and transparent here about what we understand governance and capacity building to mean. Our definition is based on previous definitions for capacity building in development and environment issue areas, particularly from aid agencies and NGOs, as well as from discussions of capacity needs in relevant literature. These definitions are also applicable to a range of different capacity building providers, such as government agencies, NGOs, or academic institutions. While our definitions are currently specific to climate intervention technologies, they can apply as well to GCB for other emerging technologies, which may require similar forms of governance capacity.

We define GCB as:

A process through which individuals and/or organizations mobilize and sustain knowledge, skills, tools, and practices that enable them to engage in the development and implementation of local, national, and international forms of governance of research and deployment of emerging climate intervention technologies. (Dove and Talati, 2023)

Whereas the capacity to implement climate intervention governance entails:

the ability to formulate, implement, and enforce local and national actions to govern climate intervention research or potential deployment. This includes the development of policies, rules, practices, procedures, and other regulatory tools or regimes that aim to directly govern climate intervention research or potential deployment. (Developed from Khan et al. [2016] broad groupings for capacity needs for addressing climate change [cited in Khan et al., 2020, p. 4])

Sometimes actors will be able to implement governance in their own right, but actors will also need to engage in governance processes implemented by others. Implementation and engagement both require an overlapping but distinct set of capacities. The capacity to engage in climate intervention governance entails:

the ability to analyze, negotiate, and articulate individual, community, and national interests in international fora and other transnational, regional, and global governance processes related to climate intervention technologies. This includes the development of civic knowledge, skills, resources, tools, and practices that enable meaningful engagement in discussion, assessment, and

4. Pandey and Kumar (2018) also refer to this model as the "Fly-In & Fly-Out" approach.

governance of climate intervention research occurring in other countries or facilitated by other actors. This also includes skills and practices that enable communities and countries to oppose or dissent to unjust climate intervention research. (Developed from Khan et al. [2016] broad groupings for capacity needs for addressing climate change [cited in Khan et al., 2020, p. 4])

GCB provides several advantages that enable researchers and practitioners to conceptualize capacity building more holistically. First, related to the “how” and “why,” GCB internalizes the need to put governance front and center in climate intervention activities. The 2009 Royal Society report emphasized that “the greatest challenges to the successful deployment of geoengineering may be the social, ethical, legal and political issues associated with governance, rather than scientific and technical issues” (Royal Society, 2009, p. xi). This acknowledgment catalyzed a rich scholarly discussion surrounding SG governance and a wide range of governance needs, rationales, and functions have since been identified (Chhetri et al., 2018; Jinnah et al., 2018; Reynolds, 2019). GCB similarly urges us to build capacity to address the social, ethical, legal, and political issues associated with climate intervention governance, in addition to the scientific and technical issues.

The second advantage of GCB is that it comprehensively addresses the need to build a range of capacities that are needed across the entire governance process, rather than only those capacities that are needed for one narrow part of the governance process, such as research or assessment (Sagar and VanDeveer, 2005). In contrast to capacity building efforts in climate politics which focus on implementation, GCB internalizes the need for capacity building “upstream” in the governance process, where activities such as framing, anticipation, imagination, consensus building, societal deliberation, and policy design can be thought of as capacities in themselves, as well as governance tasks that require additional underlying capacities to perform. Capacities required to initiate and engage in imaginative and other creative processes, such as scenarios and other foresight activities, are important as well to enable people to imagine just and inclusive governance systems and worlds (Pereira et al., 2019). The breadth of capacities needed to fully govern climate intervention technologies is also captured in our distinction between the ability to implement and engage in governance (see also Dove and Talati, 2023).

As we demonstrate below, the focus in the SG governance literature as well as in existing SG capacity building efforts is on scientific capacity building, which aims to build scientific and other research capacities in scientists and researchers primarily by funding scientific research. Scientific capacities help us understand and make informed decisions about SG and are therefore one important set of capacities that are required to effectively govern SG and other climate intervention technologies. However, scientific capacities are not sufficient on their own, as nonscientific capacities—such as the capacity to formulate national interests and

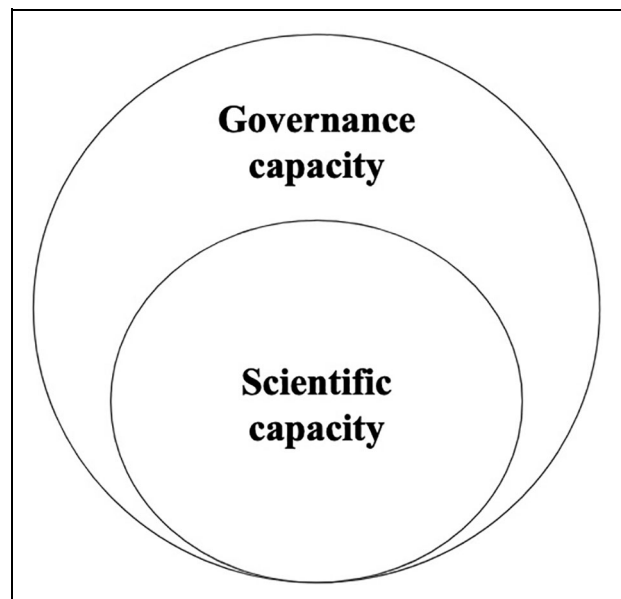


Figure 1. The relationship between governance and scientific capacity. Scientific, research, and assessment capacities are vital governance capacities and scientific capacity building contributes in important ways to governance. At the same time, there are also important nonscientific governance capacities and a comprehensive governance capacity building program encompasses but stretches beyond scientific capacity building.

negotiate international agreements in line with those interests—are also needed to manage all risks associated with SG research and deployment. **Figure 1** visualizes this relationship.

We also note that while questions about deployment capacity intersect with governance and scientific capacity, considerations of whether and how to build deployment capacity are beyond the scope of this paper. However, it is useful here to illustrate a fuller range of potential capacities that may be needed in the future to govern a deployment of SG. First, authorities will need to identify capacities that are required to enable informed and legitimate decision-making about large-scale research or deployment interventions. If actors were to authorize an SG deployment they would need to develop deployment capacity, which would entail sets of technical capacities to implement and monitor a SG technique as well as nontechnical capacities to manage the deployment and its interactions and consequences. For example, if deployments are authorized, there is a need to identify and build capacities to:

oversee and control them; to adequately monitor and assess their effects; to modify actions in response to advances in knowledge or capabilities; to deal with the consequences of interventions, particularly claims that they have caused harm; to coherently manage strategic interactions of climate engineering with other forms of response to climate change; and to manage associated conflicts. (Parson, 2017, p. 3)

Efforts to better identify specific governance capacities can benefit from insights from multiple literatures, including on anticipatory governance, which has generally focused on enabling effective and democratic governance of emerging technologies and integrating public values into the innovation process (Guston, 2014; see also Barben et al., 2008; Davies and Selin, 2012). Anticipatory governance specifically focuses on the need to develop capacities related to foresight, engagement, and integration, where:

Foresight focuses on the construction and evaluation of plural sets of rich and plausible futures as occasions for reflection, tools for planning, and exercises for capacity-building to prepare and respond for a broad swathe of potential developments and implications in emerging technologies. Engagement centers on the substantive exchange of ideas and reasons within and between publics and technoscientific decision-makers, aiming to identify public values at stake in technological development and implementation and to build capacities in publics and decision-makers to shape technologies to respect and support them. Integration refers to development among core research actors and decision-makers of capabilities and institutionalized processes to consider and respond to the social and normative contexts of their work. (Nelson et al., 2021, p. 385)

These examples demonstrate that ultimately a wide array of governance capacities will be needed and—while scientific expertise is vitally important for the functioning of these capacities—building scientific expertise by itself does not enable, for example, the crafting and implementation of policy that effectively manages conflict between SG and mitigation, nor the identification of public values at stake and the shaping of technologies by publics and decision-makers to respect and support them.

Governance arrangements for all emerging climate intervention technologies are likely to share a need for certain capacities, such as the ability to detect and deter irresponsible research and unauthorized interventions (Parson, 2017). At the same time, different ways of researching and implementing climate intervention technologies may also raise different governance capacity needs. The capacity needed to govern research or deployment of a technology may also vary depending on specific circumstances, such as the scale of impact, who is researching or deploying a technology, who is directly affected, and where a project occurs. Depending on the context, different capacities could be needed for different reasons, including in different combinations (Khan et al., 2018, p. 90). For example, the forms of capacity needed to govern even different forms of marine CDR are likely to vary in part (Brent et al., 2019). An ocean alkalinity enhancement research project within a country's territorial waters is likely to require, at least in part, different forms of governance capacity than an artificial upwelling

and downwelling project in international waters (NASEM, 2022). Different capacity needs may also arise at different times. For example, the capacity to conduct large-scale meaningful community engagement in the United States is needed now as the Department of Energy (DOE) is already funding projects that aim to develop regional hubs for direct air capture, an industrial form of CDR (DOE, n.d.). Other forms of governance capacity may only be needed in the future, with the question being what near term steps should be taken to ensure this capacity is available when needed (Parson, 2017). For example, the capacity to decide when and how to terminate a deployment is not needed yet, however this capacity would need to be built as soon as deployment is under consideration. GCB should therefore proceed based on the specific needs and context of each form of climate intervention.

Finally, the third advantage of the GCB concept is related to the “who” of capacity building. The concept highlights that a wide range of actors, including but not limited to lay publics, policymakers, and government officials; NGOs; farmers and workers; indigenous communities; and others should be involved in climate intervention governance, and therefore need to build capacity to discuss, develop positions on, and make and implement decisions about climate intervention technologies.⁵ As such, GCB internalizes the need to build relevant governance capacities within a range of both state and non-state actors in the near term (e.g., Jinnah et al., 2018; Jinnah et al., 2019; Reynolds and Parson, 2020). The concept of GCB is therefore more inclusive of the types of actors that require sustained capacity building efforts on climate intervention, moving beyond a narrow focus on scientists or policymakers and their advisors (see also VanDeveer and Dabelko, 2001; Klinksy and Sagar, 2022). For example, environmental or climate NGOs and other civil society organizations will need the capacity to understand SG, to craft an informed position, and to advocate that position effectively in multiple fora. NGOs may need the capacity to facilitate public engagement efforts on SG, inform the public about SG, to capture public perspectives and values, and to ensure these are reflected in policy and scientific decision-making. NGO observers were active players in the past 2 UNEA negotiations surrounding SG. Their ability to play a constructive role in establishing effective and inclusive SG governance rests on their efforts to build several capacities that are needed to engage in these and other governance processes.

Overall, the GCB concept emphasizes the need to build a wide range of capacities that enable diverse types of actors to effectively implement and engage in both upstream and downstream governance processes of research and deployment. As research, discussion, and (in the case of CDR) deployment of climate intervention technologies quickly ramp up, GCB needs to be discussed, planned, and initiated now.

5. For those groups that have sovereignty, including indigenous nations, any engagement, which is an inadequate term here, must be premised on indigenous rights, sovereignty, and leadership (Whyte, 2020; Liboiron and Cotter, 2023).

Why focus on the Global South?

In order for SG governance to be both effective and inclusive, and as a requirement for justice more broadly, climate vulnerable communities and countries in the Global South, who are the populations that are most susceptible to climate impacts and thus have the most at stake in SG decision-making, must play leading roles in SG decision-making and other governance activities (Hourdequin, 2019; Táiwò and Talati, 2022). Capacity building efforts should focus on building and strengthening existing governance capacities in the Global South. Our argument advances recommendations from the 2021 National Academy of Sciences report, which recommended the creation of a public SG research program. One aspect of the recommended research agenda focuses on capacity building, specifically surrounding how to build “the capacities needed for all countries to engage meaningfully with SG research and research governance activities” (p. 204). A 2023 UNEP expert report similarly concludes that SG decisions “require an equitable, transparent, diverse and inclusive discussion” and that marginalized stakeholders from the Global South must be brought into a globally inclusive conversation (UNEP, 2023, p. 2). Principles related to good governance and justice also require that these communities are meaningfully engaged in SG governance and research (Carr et al., 2013; Hourdequin, 2019; Táiwò and Talati, 2022). The social and justice dimensions of sustainability transitions are often neglected, and yet attention toward them may be the key to ensuring human and environmental well-being (Iles, 2019). Climate intervention, as one potential component of a broader sustainability transition, is no different. However, meaningful engagement in and effective implementation of governance is challenging, and it requires capacities that are not yet sufficiently available. Aganaba-Jeanty asserts that in the Global South, “the majority of actors do not yet have the [capacity] systems required for basic research governance” (2019, p. 1; see also Patrick, 2021).

One indicator of this lack of capacity is unequal geographical involvement in academic research and discussion of SG so far, leading some to characterize SG as a “rich man’s solution” (Biermann and Möller, 2019). For example, according to a Web of Science Database search, of the 845 total SG-related articles published between 2009 and May 2024, 54% have at least one author with an institutional affiliation in the United States; 22% in England, and 16% in Germany.⁶ There are far fewer

articles with author institutional affiliations in the Global South. Of the 845 SG articles, only 12% have at least one author with an institutional affiliation in China; 4% in India; and 2% in South Africa. **Figure 2** shows the total number of SG-related articles with at least one author from each country. At least part of the reason for this disparity lies in the fact that discussion, research, and governance requires forms of capacity that are currently disproportionately distributed. Capacity gaps, such as those related to participating in international negotiations and fulfilling international reporting obligations are well documented in Southern countries in the climate issue area, including in the Nationally Determined Contributions of these countries under the Paris Agreement (Khan et al., 2020; Casado Asensio et al., 2022). Capacity building must therefore be a key topic of concern for those who believe that a wider array of countries and communities, and in particular those that are most vulnerable to climate impacts, need to be included in decision-making surrounding climate intervention technologies.

To be clear, identifying capacity gaps and acknowledging an uneven distribution of capacities do not suggest that the Global South does not have any relevant expertise or capacity, nor that they lack agency to shape the trajectory of SG governance, research, or deployment. To the contrary, the Global South has existing forms of expertise and capacity that will be invaluable in collective efforts to research and govern SG, to design capacity building efforts, and to catalyze sustainability transitions more broadly. The new model of capacity building we are endorsing, for example, was largely developed by actors in the Global South. Embodied in the Least Developed Countries (LDC) Initiative for Effective Adaptation and Resilience’s (LIFE-AR) 2050 vision, these countries have created an impressive LDC-led vision for an “effective, ambitious response to the climate challenge, with all countries and communities—from the least to the most vulnerable—working hand in hand for a climate-resilient future” (LIFE-AR, 2019, p. 1). This experience and leadership will be vital in collective efforts to establish effective and inclusive SG governance in a manner that advances this vision.

Capacity building efforts focused on the Global South are also vital because much of the Global South’s governance capacity was previously systematically dismantled, and justice demands collective support for their efforts to rebuild it, including through transformative social, political, and economic change. This spirit of collective responsibility—in tandem with Global South leadership—is at the heart of the new capacity building model and LIFE-AR. Recognizing that achieving their vision of a climate resilient future is “an ambitious goal that requires partnership on both sides” they invite the international community to “join us in making our climate-resilient vision a reality,” and urge the international community to “be part of this historic shift by committing to this long-term collective response to the climate emergency with climate justice at its heart” (LIFE-AR, 2019, p. 5). Specifically, the international community is asked to “[w]ork with us in the long

6. Results are from the Web of Science Database. To create this analysis, visualized in **Figure 2**, we ran an advanced search in the Web of Science Database using the following search query: ALL = (“solar geoengineering” OR “solar radiation management” OR “solar radiation modification” OR “stratospheric aerosol injection” OR “marine cloud brightening”). We set the publication date range to between January 1, 2009, and May 1, 2024. We then used the analyze results feature to analyze the search results by “Countries/Regions” and selected a bar chart visualization style, including 20 results; 26 records (3.081%) do not contain author institutional affiliation data. To distinguish countries in the Global South, we used the Preview software to overlay an orange rectangle onto the respective bar for each country.

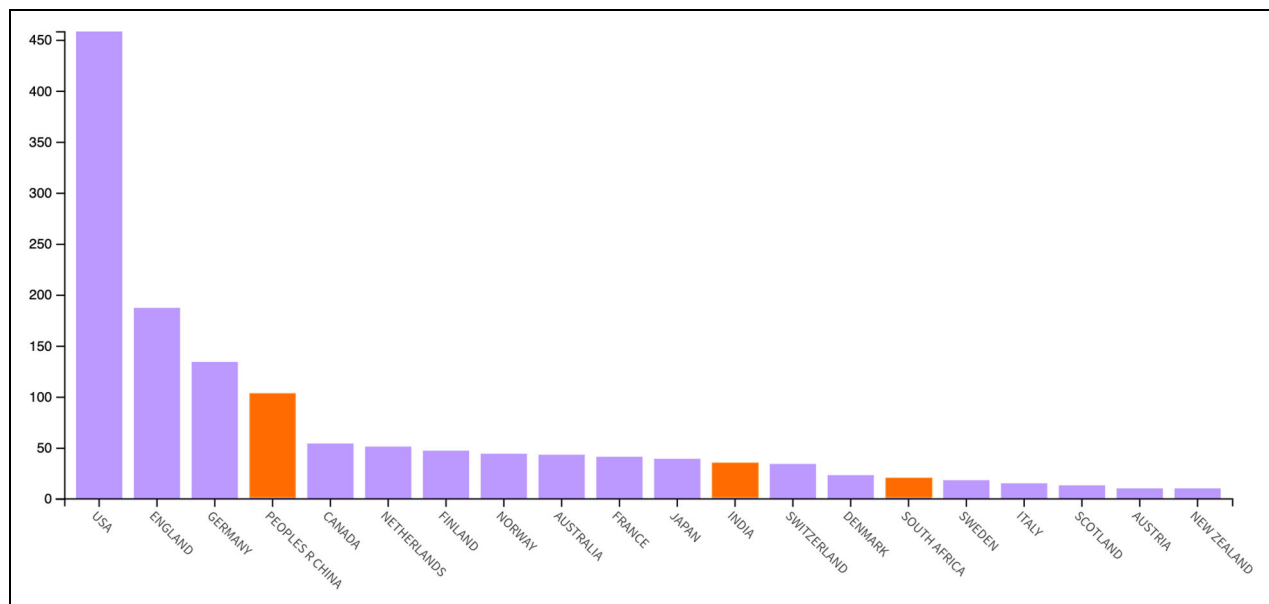


Figure 2. Total number of solar geoeengineering (SG)-related articles by author's country published between 2009 and May 2024 ($N = 845$). The bars represent the number of SG articles with at least one author from each country, based on addresses of institutional affiliations of authors. A paper is attributed to a country if the paper has at least one address from that country. Addresses for all authors are considered, not only of the first or corresponding author. If more than one author on a paper is from a single country, the paper is only counted for that country once. Countries in the Global South have an orange bar. Figure displays results for only the top 20 countries. Results from Web of Science Database. The data for this analysis can be found in the Supplemental Material.

term to strengthen our national and local institutional capabilities”:

We need adequate time and finance to build the knowledge and skills required to strengthen our national and local systems sustainably. Help us strengthen our in-country expertise by drawing in our home-grown experts and younger professionals to deliver technical support, investing in whole-of-society responses, with a special focus on women and youth and working closely with [LDCs Universities Consortium on Climate Change and other LDC institutions] and other LDC institutions in-country to develop tomorrow's leaders and national experts, investing in capabilities, curriculums, training, research and knowledge. (p. 5)

There also appears to be demand for SG-related capacity building in the Global South. In the limited efforts thus far to engage climate vulnerable communities on SG, the need for capacity building to enable broader populations to contribute to SG conversations has emerged as a common theme in discussions. For example, at 3 workshops in Senegal, South Africa, and Ethiopia, “participants agreed that it will be important for African stakeholders to be actively involved in deliberations on [SG] research governance, but that capacity-building would be necessary to make this possible” (African Academy of Sciences and SRMGI, 2013, p. 10). Similarly, a published analysis of workshops in 2014 that brought together environmental leaders, primarily from the Global South, concluded that

capacity building is needed to “institutionalize inclusion” of the Global South in SG research and governance (Winickoff et al., 2015).

As with any form of international cooperation, great care must be taken by all parties involved to address differences in power and resources between and within North and South to avoid reproducing relationships and interactions dominated by Global North ideas and interests. The failure of the classic capacity building model to do so is a primary impetus behind the development of the new model. In contrast, the new model aims to rapidly transfer ownership of capacity building efforts to the Global South so that GCB is ultimately an endogenous and Global South led effort, and the role and potential influence of Global North capacity building providers is diminished over time (Khan et al., 2018). To wit, GCB, driven by the new model of capacity building, is needed to enable the development of Global South-led SG capacity building initiatives. Waiting for bottom-up Global South-led SG capacity building initiatives to develop on their own would be problematic because it is unlikely that this would occur in a sufficient time frame given the near term urgency to govern SG. Failing to start the GCB process early—even if initially catalyzed by the Global North funders or organizations—risks leaving the Global South without sufficient capacity to engage in critical decision-making on the horizon regarding research and possibly deployment. Governance capacities should be built prior to when they are needed, and some governance capacities are needed now, whereas other governance capacities may be needed in the very near future.

Building capacity to govern SG does not mean communities and countries must adopt any particular position or policy with respect to SG. To the contrary, capacity building efforts should be agnostic about the eventual positions communities and countries take—each country should be empowered to decide for themselves whether they will, for example, support an international agreement that restricts or enables research including outdoor field experiments. Capacity building initiatives funded or initiated by the Global North must take steps to limit any potential influence they may have over how their partners in the Global South think about SG. But regardless of whether populations ultimately prefer a more restrictive or enabling form of SG governance, GCB is needed to design and implement both, and similar forms of capacity are needed to both deter and authorize research and deployment activity (Parson, 2017).

Capacity building in the SG governance literature

A growing body of literature explores governance issues and challenges related to SG, as well as proposals for why and how its research and deployment should be governed (see Morrow, 2017; Reynolds, 2019). How is capacity building understood in this literature? We identified and selected relevant literature using a ProQuest search to identify all articles in the SG governance literature that discuss capacity building, including those that use different terminology used to refer to both SG and capacity building. We initially used the following search term: (“solar geoengineering” OR “solar radiation management” OR “solar radiation modification” OR “stratospheric aerosol injection” OR “marine cloud brightening” OR “climate intervention”) AND (“capacity building” OR “capacity strengthening” OR “capacity development”) for all publication dates, restricting our search to scholarly journals. This search yields 50 articles, however only 7 focus on SG (Winickoff et al., 2015; Sugiyama et al., 2017; Carr and Yung, 2018; Delina, 2020; Horton and Koremenos, 2020; Reynolds and Parson, 2020; Delina, 2021). To broaden our search to capture literature that discusses capacity—though not necessarily how to build it—and at the same time to attempt to restrict the results to the governance literature—we then used the following search term: (“solar geoengineering” OR “solar radiation management” OR “solar radiation modification” OR “stratospheric aerosol injection” OR “marine cloud brightening” OR “climate intervention”) AND (“capacity building” OR “capacity strengthening” OR “capacity development” OR capacity OR capacities OR capability OR capabilities) AND (governance OR govern). However, this search yielded 424 results, and the vast majority of papers either did not focus on SG or used “capacity” in nonrelevant ways, for example to refer to the capacity of SG to reduce surface temperatures. Many articles also discuss what capacities would be required to deploy SG from a mostly technical perspective.⁷

7. Deployment, governance, and scientific capacity overlap and interact with each other. However, a full exploration of the relationship between these forms of capacity is beyond the scope of this article.

Nonetheless, we reviewed a sample of these articles to further identify articles that discuss various forms of capacities needed to govern SG and how to build or transfer them. We also searched for mentions of capacity building or capacity development in authoritative assessments and governance reports on SG based on the author’s familiarity with the issue area (e.g., Royal Society, 2009; Chhetri et al., 2018; NASEM, 2021).

We identified only 12 articles that discuss capacity building in the SG context. Of these articles, capacity building is not the focus of the papers, and the majority of those papers mention it only tangentially. No papers in the SG governance literature treat capacity building as an important line of inquiry deserving of focused attention. Where it is discussed, the focus has been on scientific capacity building, and the need to build a broader array of governance capacities has not been adequately addressed. That the need for GCB has been largely neglected in this literature is curious because the literature generally agrees that sufficient capacity to govern SG effectively is currently lacking. While there is considerable attention in the literature toward proposing different possible or desirable forms of SG governance, there has been little interest in exploring the capacity needs specific to those governance arrangements, and virtually no attention toward discussing what sort of capacity building would be required to meet those needs.

We found that 5 articles address the need for capacity building but in terms of scientific capacity or expertise. For example, Horton and Koremenos (2020) usefully demonstrate that the Solar Radiation Management Governance Initiative’s (SRMGI) “scientific capacity building” is a significant governance activity occurring in the SG field, alongside other governance activities such as lobbying or disseminating knowledge. However, conceptualizing capacity building primarily as a governance activity distinct from, for example, lobbying or disseminating knowledge, limits our ability to understand the need for capacity building underlying a wider range of governance efforts and activities. Capacity building may be needed to, for example, enable effective lobbying or knowledge dissemination activities in the first place.

Scientific capacity building has also been discussed as desirable in the context of broadening SG research and assessment activities. For Sugiyama et al. (2017), “capacity building can more specifically indicate the activities that stimulate the technical capacities for local scientists in the Asia-Pacific to participate in an international research program of impact analysis of climate engineering” (p. 5). For Delina (2020), capacity building is needed to create interdisciplinary expertise on geoengineering in Southeast Asia (see also Delina, 2021). Hubert’s (2021) code of conduct also calls for capacity building “to assist and strengthen the capabilities and capacities of those in developing countries to participate in geoengineering research and to support decision-making through, *inter alia*, joint programmes to provide education and training of scientific and technical personnel” (p. 91). Scientific capacity building builds vital governance capacities, especially to the extent that scientists are expected to self-regulate under an Asilomar paradigm of governance (see e.g., McLaren

and Corry, 2021). However, the focus on scientific expertise, technical capacities, participation in research, and scientific and technical training provides a limited model for GCB as vital nonscientific and nontechnical capacities are neglected.

Several articles do address a broader range of governance capacities. Reynolds and Parson (2020) consider multiple forms of non-state governance based in part on various types of actors' capacity, but they are concerned here with existing capacity, rather than the need to build this capacity. They also argue that non-state governance can "provide early considerations, guidance, and capacity building toward the more extensive, robust, and legalized governance that will be warranted" (p. 338). Reynolds and Parson (2020) usefully acknowledge the need for GCB; however, they understand this as a secondary benefit of non-state governance in terms of its ability to build capacity for future state-led governance arrangements. The need for capacity building in the near term to enable the forms of non-state governance they are proposing is not addressed.

Several exceptions also provide early and valuable explorations of needed governance capacities and pathways to build them. These include Parson (2017), who addresses the need to determine what capacities are needed to govern SG and how they should be built, and Chhetri et al. (2018), who underscore the need to govern SG in the near term, identify several needed capacities, and provide recommendations to govern SG, including by building relevant capacities (see also Parson and Ernst, 2013; Aganaba-Jeanty, 2019; NASEM, 2021). Parson (2017) argues that "international exploration of associated governance challenges, needed capabilities and ways to develop these must start promptly" (p. 4), and calls for a World Commission on Climate Engineering to discuss, for example, "what international capacity and authority would be needed to make informed, prudent, legitimate decisions regarding proposed large-scale interventions" and "what feasible near-term steps could start moving international processes toward developing them?" (p. 3). Additionally, Foley et al. (2018) discuss the need to build anticipatory governance capacities related to foresight, engagement, and integration to responsibly govern SG, where anticipatory governance "refers most directly to building the capacity to manage emerging technologies while such management is still possible."

Other scholars tangentially and briefly mention capacity building as a potential outcome of a multitude of governance mechanisms. These include, for example, public participation (Flegal et al., 2019); a multistakeholder dialogue (Conca, 2019); a dedicated network of researchers and stakeholders (Sugiyama et al., 2017); and an "interdisciplinary knowledge community" (Delina, 2020). While these governance mechanisms may indeed build capacity, understanding capacity building primarily as a follow-on or secondary goal is limiting. Capacity building must also be understood as a necessary prerequisite for establishing these and other governance mechanisms. More work is needed to consider what forms of capacity are needed to organize and participate in, for example, a multistakeholder dialogue on SG.

The SG governance literature can better address the importance of capacity building by recognizing the multifaceted and foundational role capacity building plays within a governance system. Some see capacity building as both a discrete governance activity (Horton and Koremenos, 2020) and an end that governance activities contribute to (e.g., Sugiyama et al., 2017). We suggest that it is both a means and end. Conceptualizing capacity building as a central governance process could yield important analytical insights into, for example, how power, authority, and agency is constituted, distributed, and transformed through the capacity building process.

Finally, another key gap relates to an area of the literature that advocates ending SG research and development altogether on sociopolitical grounds including through the adoption of a non-use agreement (e.g., Stephens and Surprise, 2020; Biermann et al., 2022). This literature voices very real concerns about the lack of inclusion of the Global South in SG research, discussion, and governance (e.g., Biermann and Möller, 2019). However, perspectives from the Global South affirm that capacity building is needed to "institutionalize" that inclusion (e.g., African Academy of Sciences and SRMGI, 2013; Winickoff et al., 2015), and yet there has been little attention in the SG critical literature toward *how* capacity building could be leveraged to redress exclusions and inequities, including by building capacity in climate vulnerable communities and countries to govern SG. There has also been no effort to identify capacities required to negotiate, implement, and enforce a non-use agreement for SG that would prohibit its development and deployment and to imagine the sort of capacity building initiatives that could help ensure its effectiveness (e.g., Biermann et al., 2022; Gupta et al., 2024).⁸

Existing capacity building efforts focused on SG

How well do existing capacity building efforts on SG conform to the core ideas behind GCB and the new model of capacity building? Existing efforts to build capacity on climate intervention technologies are conducted on an ad hoc basis, generally focus on building scientific expertise, and have largely neglected building governance-related capacities in civil society. This section details the most significant capacity building efforts on SG to date. Based on our understanding of the SG landscape, we looked at all organizations in the issue area working on capacity building–related activities and reviewed their missions and activities using publicly available website material to assess how well they practice GCB using the new capacity building model. Whereas some of these efforts explicitly call their activities capacity building, others do not. We include here efforts that have the impact of increasing a target population's ability to engage in scientific research or governance discussions surrounding SG through some sort of information provision or

8. Gupta et al. (2024) identify precedents and key lessons from international law for a prohibitory SG non-use agreement. This is a helpful step, but still falls short of identifying what specific governance capacities are needed and where, how they could be built, and by whom.

training activities. Capacity building efforts focused on SG began not long after Nobel-prize winner Paul Crutzen broke the taboo on SG research in 2006 (Crutzen, 2006).

The largest and most sustained effort so far to build capacity on SG has been spearheaded by The Degrees Initiative, led by Andy Parker, which was previously known as SRMGI. SRMGI was launched in March 2010 as an organized joint effort by the Royal Society, the United Kingdom's academy of science; Environmental Defense Fund, an environmental NGO based in the United States; and The World Academy of Sciences, an international organization serving as the academy of sciences for the developing world and based in Italy. SRMGI initially "aimed to foster an interdisciplinary and international discussion to develop ideas on how SRM research could appropriately be governed, appropriately scrutinized and carried out responsibly" (SRMGI, 2011, p. 12). In the longer term, SRMGI aimed "to build a diverse community of well-informed international stakeholders engaged and able to contribute to" ongoing debates surrounding SG research and its governance (SRMGI, 2011, p. 12).

SRMGI began to document different perspectives of SG research governance in order to "open up" discussions on governance rather than "close down" on specific recommendations (SRMGI, 2011). This was "done by assembling a working group and a range of international partner NGOs, and by producing background papers on SRM research governance, hosting an international conference, and by publishing [a] report of the process" (SRMGI, 2011, p. 12). These early background papers were produced by a working group of experts, 27 members from 17 different countries. Papers were solicited by a public call for submissions, and through invited input from experts from a range of stakeholder NGOs, primarily from the Global North but with some from the Global South (see appendix 1 in SRMGI, 2011). The papers covered a range of topics: mechanics of SG governance; international dimensions; thresholds and categories of research; and goals and concerns regarding research.

SRMGI was to be phased out in 2011 but Parker switched its focus to capacity building in the Global South and reached out to local partner organizations to start running workshops in Southern countries, initially in India, China, and Pakistan. From then on, SRMGI's initial capacity building strategy revolved around workshops in Southern countries for educating, deliberating, and gathering perspectives primarily from climate experts from the Global South. All workshops were convened in partnership with local partner organizations.⁹ By working with local partner organizations, SRMGI's activities demonstrated the potential to implement the "new" capacity building model in the SG issue area. However it is not clear what role these local partners played in shaping the process or aims of the workshops, leaving it difficult to assess to what extent these workshops or the broader strategy were led by recipients in the Global South. To date the organization has run more than 25 of these events.

9. For a full list of workshop partners, see: The Degrees Initiative (n.d.a.).

In 2018, SRMGI expanded the scope of its work and launched the DECIMALS Fund (Developing Country Impacts Modelling Analysis for SRM). This is the world's first international SG research fund and the first aimed exclusively at developing countries. The launch of the fund reflected a belief that it is not possible to effectively build capacity by running workshops and writing reports, and that enabling research in the Global South was also a necessary component. Importantly, the creation of a SG research fund for scientists in the Global South was an idea often proposed and widely supported by participants at SRMGI's workshops in developing countries. Here SRMGI demonstrated the potential of the "new" capacity building model by ensuring that recipients have ownership of the capacity building process, in this case by implementing a capacity building method that was widely called for and supported by recipients.

In 2022 SRMGI transformed into the Degrees Initiative to focus on the fund, now called the Degrees Modelling Fund (DMF). The DMF aims to "build developing country capacity to research and evaluate SG" by directly funding SG modeling research conducted by developing country scientists. The fund has successfully distributed over \$1.8 million in research grants across 26 modeling projects in 21 developing countries (The Degrees Initiative, n.d.b.). Funding comes from philanthropic organizations based in Northern countries, currently from Open Philanthropy (The Degrees Initiative, n.d.c.). Degrees publishes an open call for proposals to solicit new research projects and uses an independent peer review process to select which projects will be funded. Underlining the potential to give Southern countries ownership of the capacity building process, "[a]pplicants are free to define their own research questions and methods for answering them—the Degrees Initiative does not tell teams what to study or how to do it" (The Degrees Initiative, n.d.b.). At the same time, because the funding originates in the Global North, the real or perceived risk that there is a Northern bias in funding decisions could undermine the credibility of the researchers, by creating the perception that researchers' perspectives on SG have been inappropriately shaped by Northern experts and practitioners.¹⁰ Based on personal author experience, the peers that evaluate research proposals and make funding decisions are not as diverse or inclusive as the recipients of the funds, suggesting a greater need to transfer ownership to the Global South by initiating joint research funding decision-making.

Reflecting on the fact that SG expertise has generally developed where climate experts have received funding to work on SG for extended periods—typically through

10. We acknowledge the possibility that the perspectives of Southern researchers involved in the Degrees Initiatives' activities are shaped throughout their interactions with the organization and with the Northern SG experts they collaborate with. At the same time, we are not aware of this occurring in an inappropriate or coercive manner, and we do not believe that Southern researchers are necessarily conditioned through their involvement in these activities to think about SG in a particular way. We suggest that Southern researchers have the agency to form their own opinions on the matter even when they learn about it alongside Northern experts.

research support—the Degrees Initiative has primarily focused on building capacity surrounding SG expertise through funding scientific research. They argue that creating SG experts across the Global South will “ensur[e] informed and confident representation from developing countries” at SG governance activities (The Degrees Initiative, n.d.c.). The organization’s approach states: The Degrees Initiative builds “the capacity of developing countries to evaluate SRM” by “Bringing climate experts from the Global South into the SRM conversation”; “Supporting the creation of Global South SRM expertise through the Degrees Modelling Fund”; and through “activities that build an international community of experts” (The Degrees Initiative, n.d.c.). Recently, the Degrees Initiative created a second fund dedicated to social scientific research. According to the Initiative, the Degrees Socio-Political Fund “marks a major expansion of Degrees’ work, becoming the first-ever fund aimed exclusively at researchers in the Global South to study the social and political dimensions of [SG]” (The Degrees Initiative, n.d.d.). Seven research projects were selected for funding by an independent grants committee and the research teams further planned their projects during a research planning workshop alongside Northern research collaborators (The Degrees Initiative, 2024).

The Degrees Initiative is fulfilling a critical need to build SG expertise in the Global South, and this will go a long way toward enabling effective and inclusive governance. At the same time, its current focus on building scientific- and research-related capacities in scientists and other researchers addresses only one limited set of needed governance capacities, and in only one type of actor. The addition of a social science research fund is a welcome first step to broadening the type of expertise that is valued. At the same time, the focus remains on building expertise and scientific or research capacity. From a comprehensive GCB perspective, which emphasizes the need to build a range of governance capacities across diverse actor types, this alone is insufficient. Degrees’ capacity building efforts therefore largely focuses on building an international community of SG experts to enable informed and global participation (“why”), by providing research funding and hosting workshops (“how”) for developing country scientists and researchers (“who”).

In contrast to the Degrees Initiative’s scientific capacity building efforts, C2G (the Carnegie Climate Governance Initiative) focused its efforts on raising awareness and convening discussions among policymakers and their advisors and other key actors (C2G, 2022). C2G, an initiative of the Carnegie Council for Ethics in International Affairs, was created as an intentionally time-bound initiative and ceased operations at the end of 2023, aiming to transfer its expertise, products, and practices into intergovernmental and NGOs before it dissolved (C2G, 2022). C2G aimed to “catalyse the creation of effective governance for climate-altering techniques, in particular for [SG] and large-scale [carbon dioxide removal].” While C2G did aim only to catalyze governance, from the perspective of the new capacity building model, which emphasizes the long-term nature of the capacity building process, a short-term

time-bound initiative is inherently limiting and may fail to produce capacity that remains with recipients over long periods of time. C2G was led by Janos Pasztor, who has held many high-level positions in global environmental politics, most recently as UN Assistant Secretary-General for Climate Change. Funding came from several philanthropic organizations based in Northern countries, which again raises questions about power relations between C2G and policymakers particularly in Southern countries (C2G, n.d.a.).

C2G aimed to catalyze governance, in part, by raising awareness among “[p]olicymakers and their advisors, and other key actors” to “learn about new approaches, their implications, and why they need to be governed” (C2G, 2022). C2G produced a range of information material including briefs and reports, blogs, infographics, and videos to “to raise awareness, build understanding and stimulate discussion in support of its mission” (C2G, n.d.b.). These materials include, for example, information on solar and geoengineering and carbon removal methods, key governance issues associated with particular methods, technical analysis, and insight into specific themes, such as the relationship of geoengineering to the Sustainable Development Goals. The initiative also hosted a series of online events “designed to catalyse learning about climate-altering approaches and their governance,” including formal webinars and informal chats with question and answer opportunities (C2G Learn), one-to-one interviews (C2G Talk), and moderated in-depth conversations (C2G Discuss) (C2G, n.d.c.). Information and recordings of 49 of these online events can still be found on C2G’s website.

In addition to raising awareness, C2G also convened key actors with the aim to discuss and develop “shared understanding and collaborative approaches to governance” (C2G, 2022). C2G targeted policymakers and their advisors, including those in intergovernmental organizations such as UNEA and the UNFCCC, “key relevant government positions” in national governments, and non-state actors, including “key civil society organizations” and “influential individuals from the international policy world, academia, and media” (C2G, 2022). Although C2G did not explicitly aim to build capacity, their activities did contribute to overall capacity building efforts. While C2G restricted its focus to those actors it considers “key” to catalyzing governance discussions, C2G took important first steps toward GCB by focusing on multiple types of state and non-state actors that can be expected to play important roles in governing SG. However, the focus on “key actors” who are already influential suggests that this effort fails to build capacity with the people most in need of SG capacity building, including those from marginalized and vulnerable communities. Additionally, it’s unclear how effective C2G’s efforts to raise awareness and develop shared understanding among key actors were. Part of the reason why a Swiss resolution on SG failed at UNEA-4 in 2019 was because there was a limited understanding of what SG was—awareness of SG did not reach many countries and their officials (Jinnah and Nicholson, 2019). C2G’s capacity building activities therefore largely

focus on catalyzing effective forms of governance (“why”) by raising awareness among and convening (“how”) policy-makers, their advisors, and other actors in influential roles (“who”).

Other international workshops and conferences have also been held in recent years. For example, a 2014 workshop in Fiji hosted by the Institute for Advanced Sustainability Studies and the Pacific Centre for Environment and Sustainable Development at the University of the South Pacific aimed to “*inform Pacific stakeholders about the current state of the scientific, political and ethical debate on climate engineering*” and to provide a platform for discussion and exchange of views between science and policy communities as well as among the Pacific island countries” (Beyerl and Maas, 2014, p. 7, emphasis added). In its short-term transfer of knowledge developed by international consultants, this workshop was more in line with the “classic” model.

Other “classic” and research-oriented capacity building activities include discrete trainings and presentations. For example, several geoengineering focused short-term “schools” have been organized with the aim of enhancing interdisciplinary research capacity among scholars. The Emmett Institute on Climate Change and the Environment at the University of California, Los Angeles (UCLA) School of Law has hosted 6 such events, mostly recently in 2019, in partnership with the Forum for Climate Engineering Assessment, SRMGI, the Harvard Solar Geoengineering Research Program, and C2G. The weeklong school held in 2019 aimed to “bring together an international group of leading experts with post-graduate students, early-career researchers, and professionals seeking to develop expertise in the field . . . [and to] facilitate intensive, collaborative explorations of the societal, political, governance, and ethical aspects of geoengineering” (UCLA Law, n.d.). Moreover, research presentations related to SG have also been held within several academic conferences, such as at meetings of the American Geophysical Union and the International Studies Association.¹¹ These efforts contribute to overall capacity building efforts within the research community because they develop individuals’ capacities to understand SG and related issues and challenges. However, they demonstrate how entrenched the classic capacity building model is because they are short term and largely uncoordinated.

To summarize, capacity building efforts surrounding SG have had a diverse mix of target recipients (i.e., scientists, government actors, and influential actors in civil society [“who”]) and approaches (i.e., funding research, raising awareness, and convening discussion [“how”]). Although these efforts have included the aim of catalyzing governance and governance-related discussion (“why”), this has been done primarily through short-term efforts to develop basic SG literacy and by funding scientific research. There remains a significant need for more GCB among a wider

set of civil society that is more representative of the diversity across marginalized and climate vulnerable communities. This is true for other emerging climate intervention technologies as well.

A critical evaluation of existing SG capacity building efforts

Overall, existing capacity building efforts on SG show several promising developments and future prospects, including as related to working with and taking direction from researchers and other actors in the Global South. However, these efforts remain overall ad hoc and fragmented, with individual initiatives targeting specific target populations for capacity building but without apparent multisectoral coordination and collaboration. Much of the focus has remained on building SG expertise and basic literacy among scientists, researchers, policymakers, and other influential actors. Additionally, with the exception of the Degrees Initiative, all efforts are short term, undermining the need to initiate long-term processes that develop and sustain capacity over long periods of time. Most of these efforts also generally suffer from a lack of diversity of staff. This lack of diversity, together with funding coming primarily from philanthropic bodies in the Global North, raises the need to consider more seriously how ownership over the capacity building processes and outcomes can be transferred to the Global South. The existing field therefore has a ways to go to fully implement comprehensive GCB initiatives in line with the new capacity building model.

Where do we go from here?

GCB is needed to establish effective and inclusive governance of climate intervention technologies. We have demonstrated here the critical importance of initiating in the near term a comprehensive GCB program using the new capacity building model as a guide in order to enable climate vulnerable communities and countries to govern SG and climate intervention technologies more broadly. Centrally, this means that capacity building programs are needed to build a wide range of governance capacities—including but stretching beyond scientific capacity and expertise—within a wide range of actors and sectors of society. These efforts must also focus on strengthening existing capacities in climate vulnerable communities and countries by transferring ownership of the capacity building process and products to these populations. By falling short on these insights, we also demonstrated that gaps and limitations in how capacity building is understood in the SG literature and implemented in practice can stifle the potential of capacity building to enable inclusive and effective governance in this issue area. We close with a discussion on where we go from here to build a successful GCB program.

First, the scholarship on SG governance can better support existing and future capacity building efforts by treating it as an important line of inquiry deserving of focused attention. To do so, the literature must rethink existing framings of capacity building as a governance objective that other mechanisms merely contribute to. Rather,

11. For example, the Fall 2022 Meeting of the AGU hosted several solar geoengineering related events, such as “Advances in Solar Radiation Modification (SRM) Research.” See for example Visioni et al. (2022).

capacity building should be understood as a necessary prerequisite for establishing a wide variety of effective climate intervention governance mechanisms and ultimately achieving a range of goals or functions that stretch across the entire governance process. Scholarship can therefore support efforts to identify a full range of governance capacities that are needed to govern SG in different ways, including as related to specific governance proposals and mechanisms. Researchers can also support practical efforts to develop GCB strategies and best practices by identifying lessons from other issue areas and by developing innovative assessment methodologies. Moreover, by investigating cross-cultural perspectives on SG and its governance, public perspective researchers are well positioned to support efforts to identify capacity gaps and needs and to help determine the most appropriate ways to build capacity within local contexts, all of which can help inform decisions about how to distribute resources to best support capacity building efforts.

In practice, a new organization is also needed that can spearhead a broader and more inclusive GCB program for SG, thereby filling important gaps in existing capacity building efforts. The Alliance for Just Deliberation on Solar Geoengineering was founded in April 2023 by Shuchi Talati with the aim of working toward just and inclusive deliberation on SG.¹² The organization does so by building capacity in climate vulnerable communities and countries to engage in and lead deliberations on SG. In contrast to other capacity building efforts, DSG focuses on building capacity primarily in civil society, including but not limited to NGOs and universities, as well as in policymakers in climate vulnerable countries. DSG's work currently focuses on meeting with civil society organizations in several target countries and learning about their needs, awareness, and perspectives on SG as part of a trust-building process and subsequently partnering with some of these organizations to expand activities to build a range of governance-related capacities in civil society and policymakers across many national and local contexts. DSG is developing an iterative capacity building strategy, inspired by the new model of capacity building, that revolves around a series of modular learning projects that can be tailored through joint decision-making with local partners to meet local capacity needs and circumstances. Importantly, DSG aims to empower its local partners and communities to form their own opinions and positions on SG; it does not advocate for or against SG. We believe DSG's approach is an imperfect but important first step toward improving capacity building in the issue area. Here we discuss some aspects of how DSG is aiming to implement our recommendations for developing successful GCB programs.

DSG and any other capacity building initiatives for climate intervention are likely to face multiple challenges. These challenges are not specific to these technologies; still, capacity building surrounding these technologies may

present novel challenges due to the controversial and scientifically complex nature of climate intervention. As the following practice-oriented recommendations that are designed to address these challenges follow from general lessons in the capacity building literature, they likely apply as well to GCB programs surrounding broader classes of emerging technologies, including artificial intelligence, human genome editing, and nanotechnology. DSG aims to use these recommendations as a starting point for working alongside other SG capacity building initiatives to improve how capacity building is practiced in the issue area.

The first recommendation for improving existing SG capacity building efforts in practice relates to a widely agreed element of what makes capacity building successful. According to Khan et al., "Whatever way capacity building is conceptualized, there is an agreement in the literature that the key to success is ownership [by recipients] of the process and products" (2020, pp. 501–502). Perspectives on capacity building from Southern countries also emphasize the need for partnership between recipient and donor to balance power relations (Hagelsteen et al., 2021). In other words, capacity building should ideally be led by recipient countries or communities and should be "demand-driven" rather than donor or "supply-driven" (Godfrey et al., 2002; Khan et al., 2018). This is important because it ensures that capacity building efforts address the specific capacity needs identified as most important by the recipients and that decision-making and responsibility, and ultimately capacity, remains with the recipients.

However, the early stages of a GCB program catalyzed, for example by NGOs from Northern countries, is unlikely to be sufficiently "owned" or driven by Southern countries. This includes DSG's efforts so far. This is in part because immediate socioeconomic priorities may take precedence over climate change capacity building (Pandey and Kumar, 2018). Yet additionally, capacity building efforts take place within a context characterized by unequal distributions of resources, including money, knowledge, and technology (Khan et al., 2018). In this context, NGOs from the Global North such as DSG will be providing and coordinating, albeit increasingly with Southern SG expertise, the resources needed to initiate a capacity building program. Funding from democracy-oriented philanthropic bodies in the Global North is not intrinsically problematic, however, important questions of power and partnership arise when considering who makes decisions about how resources will be used (Khan et al., 2018).¹³ As such, achieving genuine partnership with capacity building recipients in the Global South becomes challenging and the task is to figure out how to transfer ownership to these recipients. A genuine partnership entails recipient communities and countries "setting the [capacity building] agenda from the outset and remaining in control throughout" (Brohman, 1996; Khan et al., 2018, p. 101).

12. The authors recognize affiliations with The Alliance for Just Deliberation on Solar Geoengineering (DSG). Shuchi Talati is the Founder and Executive Director of DSG; Zachary Dove is a Research Fellow at DSG; and Sikina Jinnah is an external collaborator.

13. We suggest moreover that the Global North may be morally obligated to fund governance capacity building work in the Global South, possibly under a climate debt or adaptation finance framework.

Silver bullet solutions do not exist but several paths forward seem promising. The risk of insufficient ownership by recipient countries can be mitigated by developing genuine relationships with local partners in participating countries early in the capacity building process including by practicing joint decision-making and by investing resources to build their own capacity to demand, coordinate, and lead capacity building efforts. This could be done, for example, by developing a local “legacy partner” that would closely follow the entirety of the capacity building process and would continuously build its own capacity to advance capacity building efforts in the long term. The IIED is developing the idea to ensure long-term capacity building by working with a local partner institution to “follow the process and capture lessons learned, with a focus on building the capacity of individuals and relevant institutions through ‘learning-by-doing’” (IIED, n.d.a.). Khan et al. (2018) argue that Global South universities are particularly suited for this role because they tend to exist for long periods of time, they have existing expertise, and they are well positioned to train young people for positions in a variety of sectors.

Initiating joint decision-making to the greatest practical extent is also needed to create meaningful partnerships and transfer ownership of SG capacity building programs to the Global South. This means local partners would have an equal if not leading role in deciding what SG governance capacities need building or strengthening, how to best do so, and how to use money, expertise, and other resources toward this end. DSG is initiating joint decision-making in program and workshop planning by working with individuals from partner organizations in the design and implementation of SG capacity building activities. In practice, this can look like co-creating agendas and activities, highlighting local experts and speakers, and jointly deciding outcomes and next steps. Evidence from other issue areas also shows that partner institutions in participating countries can play a central role in shaping how external capacity building projects are implemented (Biedenkopf et al., 2017).

The second recommendation is for donors and facilitators of capacity building programs to take seriously the need to build their own capacities (Sagar and VanDeveer, 2005) to successfully provide capacity building interventions. In other words, there appears to be an acute need for *capacity building for capacity building*. For example, participants in capacity building processes emphasize that capacity building providers must have the capacity to understand the local context including what work has already been done and where capacity already exists (Hagelsteen et al., 2021). This requires that capacity building providers develop capacities to learn from mistakes and successes and adapt over time in response to assessments and input, including, crucially, from capacity building recipients. DSG is embracing a “learning-by-doing” approach to building its own capacities by learning about local context from institutional consultations and partnerships, developing a better understanding of approaches from capacity building experts and facilitators, and hiring

diverse staff with a range of geographical and disciplinary expertise.

One critical area where capacity must be built is in how to define and measure success in capacity building efforts. There are currently few assessments of capacity building activities and there is no standard way to define and measure success in this area. A core element of the “new” capacity building model is the importance of building long-term sustainable systems that can continue capacity building efforts in order to effectively address long-term problems (Khan et al., 2018). Khan et al. (2018) for example propose that “the main indicators used to judge value for money for climate change capacity building should be whether in-country capacity systems and capacity suppliers have been left behind in each target country” (p. 13). However, donors are likely to want evidence of short-term impacts to renew funding.

There are also methodological challenges involved in assessing the effectiveness of capacity building. For example, a rigorous evaluation method would need to separate the impacts from capacity building programs from other interventions and factors in order to demonstrate that it was the capacity building that contributed to beneficial impacts or outcomes. Attribution of causality remains a challenging endeavor in the social sciences and would similarly present challenges for capacity building assessments. To compound this challenge, capacity building efforts can also become structurally complex as more projects, levels, funders, partners, and targeted communities are included in the overall capacity building space. Complex arrangements can generate their own capacity needs, as different actors grapple with their roles and responsibilities within a broader system (Soal and Merrill, 2021). In a comprehensive SG GCB program, many types of actors working across multiple levels will be working together to build a wide array of capacities required to govern different forms of SG research and deployment. Care must be taken to assess the effectiveness of both individual efforts and the capacity building system as a whole, including for different capacities, actor types, and locations.

To address these challenges, NGOs including DSG are developing their own capacities in “impact assessment, value for money and cost-benefit analysis, monitoring mechanisms, performance and process evaluation,” or systemic monitoring, evaluation, and learning (IIED, n.d.b.). For example, sophisticated methodological tools such as the Capacity Building Assessment Matrix developed by the Council on Energy, Environment and Water aims to quantify the progress of capacity building in the Global South (Prasad and Gupta, 2019). These tools hold the potential to enable systematic and rigorous assessment of capacity building efforts, which is needed to improve capacity building methods and models over time. Overall, while the new capacity building model looks promising and may enable a more successful phase of capacity building efforts, it is also unproven. Time is needed to assess how successful it is in transgressing the limitations of the classic model and in achieving long-term sustainable impacts. Despite some promising developments, tried-and-true capacity building methods and solutions do not exist, and

experimentation and ongoing evaluation and reflexivity is required to develop these.

In sum, initiatives for building governance capacity for emerging climate intervention technologies should build their own capacities related to anticipation, reflexivity, and adaptability to assess whether and how their capacity building efforts are successful and if not, what and how they can change to build locally owned and durable capacity systems.

If followed, the path we have outlined here can enhance the potential for GCB to enable inclusive and effective governance of climate intervention. This important work is needed to help ensure that the capacities required to either restrict or enable climate intervention activity are widely available as communities and countries begin or continue to make critical decisions about whether and how research or deployment activity will move forward or not.

Supplemental files

The supplemental file for this article can be found as follows:

Text S1 Web of Science Analysis Data.txt

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