Cooling a Warming Planet? Public Forums on Climate Intervention Research

November 2019

Final Results Report

Acknowledgments

This project was supported through a generous grant from the Alfred P. Sloan Foundation (grant number G-2017-9921). The project team included Daniel Sarewitz (PI), Mahmud Farooque (Co-PI), Ariel Anbar (Co-PI), Stephen Romaniello, John Nelson, Leah Kaplan, Ira Bennett, Jason Lloyd, and Kimberly Quach from Arizona State University (ASU); David Tomblin from the University of Maryland; David Sittenfeld and Emily Hostetler from the Museum of Science (MOS); Mark Neff from Western Washington University; and Bjørn Bedsted from the Danish Board of Technology Foundation.

The project team members wish to thank Lizzie Burns (Harvard University) and Jane Flegal (Bernard and Anne Spitzer Charitable Trust) for their early guidance and timely support; Simon Nicholson (American University), Anna-Maria Hubert (University of Calgary), John Dykema (Harvard University), and Simone Tilmes (National Center for Atmospheric Research) for expert reviews and comments; Malorie Landgreen (Colorbox Industries) and Fabio Cutró (Cutró Design) for graphic design; Justin Dent (Dent Digital) for informational videos; Eric Workman (MOS) for photography; Deron Ash (ASU) for research administration; Melissa Waite (ASU) for event management; Boston Urban College for participant outreach; our wonderful teams of facilitators, note-takers, and observers in Boston and Phoenix; and the solar geoengineering experts and stakeholders who participated in our forum design and results integration workshops. We are especially grateful to the 171 forum participants who spent an entire day in informed, civil, and respectful dialogue with each other, sharing their views so that we could write this report.

Edited & Compiled by

Leah Kaplan
John Nelson
David Tomblin
Mahmud Farooque
Jason Lloyd
Mark Neff
Bjorn Bedsted
and Dan Sarewitz

Appendices

Report appendices are available online at:
http://bit.ly/SRMappendices

School for the Future of Innovation in Society
Arizona State University

Consortium for Science, Policy & Outcomes
at Arizona State University

ECAST

ASU PlanetWorks
Arizona State University

Museum of Science.

Disclaimer

Table of Contents

Executive Summary

The political and technological difficulties of addressing climate change have prompted a growing number of experts to seek additional approaches to the conventional strategies of mitigation (reducing the emission of warming greenhouse gases) and adaptation (adjusting to or increasing resilience to anticipated climate changes). Among these approaches, geoengineering, or the direct manipulation of the climate to reduce the negative impacts of global warming, is increasingly discussed as a potential approach that warrants serious research and policy consideration.

The highly uncertain nature of geoengineering impacts and the complex socio-technical decisions surrounding its research and governance, especially for a class of methods called solar radiation management (SRM), make it a prime issue for which public deliberation can provide valuable input. With SRM research advancing to the field-research phase, Arizona State University's Consortium for Science, Policy & Outcomes (CSPO) designed this project to explore the potential for bringing public values and perspectives into the governance of geoengineering research. Specifically, CSPO aimed to investigate how public deliberation on questions of trust, transparency, consent, safety, collaboration, and other value-driven issues might allow researchers, funders, and policy stakeholders (the primary audience groups) to benefit from citizen insights and priorities.

CSPO and its partners, including the Expert and Citizen Assessment of Science and Technology (ECAST) network and the ASU-based PlanetWorks initiative, used participatory technology assessment (pTA), a method of determining public values and opinions to help inform up-stream decision-making, as an instrument to elicit views on the governance of SRM research. After an iterative design process with both technical experts and members of the lay public, CSPO hosted two day-long public deliberations on the governance of SRM research in Boston and Phoenix in September 2018.

During the deliberations, 171 diverse citizens discussed SRM research directions, prospective funders, and governance parameters. The deliberations demonstrate that informed lay citizens can productively discuss SRM research governance, acquiring both new knowledge and, through collective reasoning, new perspectives on the subject. Our results offer insights into some concrete constraints and conditions under which members of the public could support SRM research.

Three broad areas of concern emerged from these deliberations:

1. *Naturalness is preferred*. Citizens strongly prefer research on SRM approaches that seem to them more "natural" over those that add new chemicals and materials to the atmosphere. The collective intuition here is a concern for unintended environmental risks created by the introduction of unnatural substances into the climate system. This appears to be a robustly held sentiment among our participants, and pushes against current expert assumptions. Stratospheric aerosol injection, which is probably the approach most widely discussed by scientists, was favored by less than 20% of our deliberative groups.
2. *Transparency is required.* The governance principle most strongly articulated and shared in our forums is transparency, although the meaning of the term is not sharply delineated. Yet the sentiment being expressed by our citizens seems quite clear: they expect that SRM research be sponsored by trusted institutions, conducted openly and in a publicly accountable manner, and protected from capture by biased or interested parties.
3. *Who shall govern?* That SRM research does indeed require good governance was also a shared sensibility among our participants, as we have emphasized. But when it comes to institutional choices about where funding, governance responsibilities, and decision making should be located, disagreement emerges. This disagreement may in part reflect the different political environments of our forum locations, Phoenix and Boston. It may also reflect a lack of strong criteria for choosing among the options that we presented in the background material. Yet results do reflect some general sense that "independent" and "self-governing" approaches to governance are preferred to those of formal government bodies at either the national or local level. Given the lack of consensus on these matters, we want to flag these questions of institutional choice as an important area for future research on public concerns and how best to meet them.

Ultimately, SRM researchers and stakeholders should proceed—but with caution.

1. Introduction

1.1 History

The political and technological difficulties of adequately dealing with climate change have prompted a growing number of experts to seek additional approaches to the conventional strategies of mitigation (reducing the emission of warming greenhouse gases) and adaptation (adjusting to or increasing resilience to anticipated climate changes). Some experts argue that geoengineering, or the direct manipulation of the climate to reduce the negative impacts of warming, needs to be taken seriously as a climate policy strategy and research agenda.
Solar radiation management (SRM) is one broad category of geoengineering. SRM would directly reduce heating from the sun by either reflecting sunlight before it reaches the Earth's surface or reducing barriers to the escape of heat back into space.[1] SRM as a technology or suite of technologies does not yet exist. Government organizations in the United States have cautiously recommended proceeding with some forms of SRM research,[2] while noting that such research must be responsibly governed and must proceed in concert with vigorous mitigation and adaptation efforts.

In the United States, very little field research has been funded to date. As part of a larger interdisciplinary program on solar geoengineering research launched at Harvard University in 2017, a group of scientists are currently planning a field experiment to study how aerosols deployed in the atmosphere interact with lower stratospheric physical processes.[3]
Other researchers have expressed interest in field experimentation on other SRM geoengineering ideas, including increasing the reflectivity of clouds over the ocean and thinning high-level cirrus clouds to allow more heat to escape into space.[4]

Despite these initiatives, SRM remains controversial among experts.[5] A review of existing SRM literature indicates that the roots of this controversy are linked to differences in expert opinion on issues including:

- **Moral hazard:** Potentially quick and cheap technological fixes may decrease pressure to cut emissions and reduce society's reliance on fossil fuels, undermining existing climate policies.[6]
- **Uncertainty:** The social and physical effects of intervening in a system as complex as the global climate are "radically unknowable"[7] and thus cannot be accurately assessed in terms of potential costs and benefits.
- **Slippery slope/lock-in:** Attention from researchers can provide legitimacy and momentum to the deployment of SRM in particular and geoengineering more broadly. Deployment resulting from momentum rather than an intentional process could exacerbate the aforementioned issues of moral hazard and uncertainty.
- **Governance:** The uncertainties, planetary impact, and comparatively low cost of deployment make SRM incompatible with the principles of democratic governance, since these factors may cause conflicts within existing institutions and necessitate autocratic governance.[8]

The highly uncertain nature of SRM impacts and the complex socio-technical decisions surrounding the technology's research and governance make it a prime issue for which public deliberation can provide valuable input.

1.2 Purpose and Goals

With SRM research advancing to the field-research phase, Arizona State University's Consortium for Science, Policy & Outcomes (CSPO) designed this project to explore the potential for bringing public values and perspectives into the governance of geoengineering research. CSPO partnered with other members of the Expert and Citizen Assessment of Science and Technology (ECAST) network, which brings together nonpartisan think tanks, universities, and science museums to engage citizens on decision-making related science and policy. PlanetWorks, an ASU-based initiative focused on the challenges of managing Earth's systems in the Anthropocene, served as an additional project partner. The project was generously funded by the Alfred P. Sloan Foundation.

The public engagement at the core of this project aimed to develop a balanced framing of the many social, ethical, legal, and political questions raised by the prospect of SRM research in an effort to substantively incorporate diverse—and potentially conflicting—perspectives on research governance.[9] The project explored how public deliberation on questions of trust, transparency, consent, safety, collaboration, and other value-driven issues might allow researchers, funders, and policy stakeholders (the primary audience groups for the project) to benefit from the insights and priorities of citizens. Specific objectives included:


Solar Radiation Management
research plan

1. Design, test, implement, and assess two demographically and geographically diverse citizen forums for mapping informed public views on geoengineering governance, with a particular focus on SRM;

2. Explore integration of public views into existing and emerging governance frameworks for geoengineering technologies to address greenhouse gas emissions and the impacts of climate change; and

3. Demonstrate and specify the potential role of citizens in governance of current and future research on SRM technologies.

1.3 What Is Participatory Technology Assessment?

In the last decade, a range of efforts to investigate public perceptions of geoengineering has been undertaken,[10] mostly in the United Kingdom. These engagements revealed the need for responsible democratic governance of geoengineering, yet scholars note that "very few [public] engagements have considered climate engineering governance, and none at all have considered what such governance could or should look like in its architecture."[11]

Our project thus attended to key gaps in scholars' understanding of whether and how public deliberation can contribute to the governance of geoengineering in general and outdoor SRM experimentation in particular. We used participatory technology assessment (pTA), a method of determining public values and opinions to help inform key decisions, in order to elicit public views on the governance of SRM research. Using the pTA method, we engaged experts, stakeholders, and lay citizens. In this report, we define "experts" as scientists and engineers studying geoengineering; "stakeholders" as decision-makers in government and nongovernment sectors; and "lay citizens" as members of the general public. We connected with these audiences via three primary activities, described in greater detail in the adjacent box.

What is pTA?

1. **Problem framing:** The first step in developing a balanced framing of the questions raised by the prospect of SRM research was to review the published literature on governance and public engagement (see Appendix 1.1). This research was followed by two small, demographically diverse focus groups in Phoenix and Washington. These focus groups and their "open framing" of citizen concerns about SRM research helped inform the Public Engagement Design Workshop, which brought together a group of experts and stakeholders from academic, governmental, and non-governmental sectors in Washington to deliberate on how to frame the policy problem, what basic knowledge is necessary for informed input, and what questions are relevant for public deliberation.

2. **Citizen deliberation:** The second major activity of the research project involved implementing the citizen pTA forums, which included:
   - designing forum materials (background information, deliberation questions, etc.) from the expert and stakeholder perspectives derived from Workshop 1;
   - recruiting a demographically diverse group of participants;
   - training facilitators;
   - convening two pTA forums of approximately 85 citizens each; and
   - compiling and analyzing material generated by the deliberations to understand public values and rationales about SRM research and governance.

3. **Results integration:** The third major activity was to hold a Public Engagement Results Workshop where the same experts and stakeholders who participated in Workshop 1 provided input on the usability of the pTA outcomes. Attendees described what information on citizen perspectives would be useful for their decision-making processes, how that information can best be incorporated into SRM governance. structures, and how the pTA process can be improved as a tool of SRM governance.

2. Methods

2.1 Focus Groups

We convened focus groups in Phoenix and Washington in April 2018 to provide independent citizen input to the pTA deliberation design. Participants were invited through email lists, community interest groups, posters, flyers, social media, and online advertisements. Out of over 100 applicants at each location, the final participants (14 in Phoenix and 17 in Washington) represented a diversity of genders, ethnic backgrounds, education levels, ages, and ideologies.

We used a two-tiered deliberation model to elicit both unstructured and structured responses from focus group participants.[12] The first tier was open-ended, with very little background information provided to participants. This allowed participants to draw primarily from their own experiences in expressing hopes and concerns about SRM research.[13] The second tier introduced information about SRM research, elaborated on concerns that emerged in the first tier, and then mapped them against issues raised by experts and other stakeholders derived from our literature review.[14] This two-tiered structure allowed us to collect two types of participant responses: initial unfiltered reflections in the first session and responses to issues participants might not have previously considered in the second session (see Appendix 2.1). Participants expressed concerns that overlapped with and differed from those of expert stakeholders, putting forward additional issues such as "messing with nature." We subsequently incorporated these concerns into our forum design as considerations.

2.2 Deliberation Design Workshop

We hosted a two-day workshop with expert stakeholders on May 7-8, 2018 in Washington, DC. Attendees included a total of 21 external experts (18 in-person and 4 remotely) and 12 project team personnel and event staff (see Appendix 2.2 for attendee list and agenda). The workshop included informational presentations and small- and large-group facilitated deliberative sessions. Participants represented academic, governmental, non-governmental, and philanthropic sectors, primarily from the United States, but also from Canada, Denmark, and Japan. Prior to the workshop, we consulted with experts who were unable to attend, including a representative from the Heinrich Böll Foundation, to garner their perspectives. Though we reached out to Friends of the Earth and ETC Group, neither organization was able to send a representative to the workshop due to scheduling challenges and neither ultimately provided feedback on the design. After the workshop, we formed a review panel with six of the participating experts. We incorporated these experts into the deliberation design, having them answer participant questions through an online interface during the public forums in Phoenix and Boston.

Project Expert Committee

1. John Dykema, Harvard University
2. Jane Flegal, Spitzer Foundation
3. Anna-Maria Hubert, University of Calgary
4. Simon Nicholson, American University
5. Simone Tilmes, National Center for Atmospheric Research

2.3 Background Materials

In order to promote a thoughtful, informed deliberation, participants were briefed both prior to and during the forum on the facts, issues, and areas of uncertainty related to SRM. These background materials included a 20-page information packet sent to participants before the forum, themed videos shown during the forum, and deliberation materials aimed at introducing additional information and considerations throughout the forum. These briefing materials were evaluated by the review panel to ensure that they were accurate, balanced, and accessible. More information on the structure and content of the background materials is provided at the beginning of each forum results analysis section and in Appendix 2.3.

2.4 Deliberation Overview and Analysis Methods

The day-long deliberations consisted of four main sessions: 1) SRM Research Directions, 2) SRM Research Funding, 3) SRM Research Decision Making (Governance), and 4) Hypothetical Scenarios (see Appendix 2.4 for the full agenda). The formats of these sessions are explained in further detail at the beginning of their respective results analysis sections. Participants were assigned to tables of 6-8 other individuals and were guided through the deliberation by a trained facilitator. Throughout the forum,

participants completed both group activities and individual worksheets. These served as the principal data collection methods, though data were also collected via written table observations and table recordings. These data were analyzed through a combination of quantitative and qualitative methods, described in Appendix 2.4.

2.5 Who Were the Participants? Demographics, Expectations, Knowledge, Preconceptions, and Attitude Change

Understanding who attended the forums, the perspectives they brought to the deliberations, and the way in which they engaged in the conversations is critical for interpreting the meaning of the forum results. This section provides context on the participants who attended, which in turn provides insights into how our report should be interpreted. This information informed our analysis of forum results, especially as it pertains to the diverse demographic representation of the forum sites, the quality of deliberation, and participant perceptions of deliberation outcomes. Due to time and resource constraints on the project, this deliberation analysis is not fully integrated into the subsequent results sections. A description of the methodology used recruit participants and to analyze the demographic data is available in Appendix 2.5.

Forum Participant Recruitment and Selection Process

Participant selection: During the application process, participants answered demographic questions related to gender, age, education, income, race, political orientation, and ethnicity. This information was used to select a pool of participants that:

- Maximized the representation of the demographic diversity of the host states (Arizona and Massachusetts); and
- Minimized the representation of climate research professionals and advocates.

In total, 171 people participated in the forums (88 in Arizona, 83 in Massachusetts). These participants were divided into 26 discussion groups of 6-8 individuals (14 in Arizona, 12 in Massachusetts), to ensure diverse representation at each table. Figure 2.5.1 shows a breakdown of the forum participant demographics (a comparison to census data is available in Appendix 2.5). During the participant selection process, we emphasized diversity over statistical representation to ensure that the perspectives of statistically minority populations would be adequately represented.

Limiting the participation of "the usual suspects"

The public forum component of the project was designed to limit participation by individuals who are actively involved in climate research—and geoengineering in particular—for three reasons. First, their views are already known because they (or people like them) are more likely to be organized to express their perspectives through advocacy groups and other channels. Second, they are more likely to dominate the conversation at the forum because other participants are likely to defer to the depth of their knowledge and strength of their convictions.[15] Finally, we sought to understand the views of citizens who were introduced to geoengineering through a balanced framing of the issue, rather than a preexisting political or ideological filter. We did select a small number of citizens with an active interest but no formal position in the forum topic (in Arizona, 8 participants; in Massachusetts, 8 participants).

Participant Demographics

One reason that pTAs such as this one provide useful information that is not otherwise easily discoverable is that they include participants from a variety of socioeconomic backgrounds, rather than solely stakeholders with a vested interest and established channels for making their views known. The following data show that we recruited a relatively neutral (people without vested interests) and diverse group of people to assess the governance of SRM research.

The demographic distribution of participants at each site closely aligned with the general population of Arizona and Massachusetts, respectively. The largest discrepancy between participants and the population was in education, where those without a high school degree were significantly underrepresented and

those with graduate or professional degrees were overrepresented. This is frequently the case for deliberative forums.[16] However, the distribution of participants across the other educational categories (some college, bachelor's degree, etc.) was relatively representative (see Figure 2.5.1).

Participant Perceptions

Understanding what motivates people to attend a pTA forum and the expectations they have of such an event provides more contextual background for assessing to what degree people's preconceived perceptions may influence the quality and outcomes of deliberation results. We used pre- and post-forum surveys to measure what motivated people to participate in the SRM forum, their general expectations concerning participation in scientific research decision-making, and their overall evaluation of the forum experience.

The top motivating factors for participant participation were learning about climate change research and SRM research in particular (see Appendix 2.6 for more details). Another highly rated item was the desire to hear viewpoints that differed from their own. Coming into the forum, participants at both sites tended to agree that public participation in decision-making leads to better decisions and that non-experts can develop valuable inputs for effective decision-making. Participant opinions on these matters shifted toward even stronger agreement by the end of the forum. In contrast, prior to the forum, participants were divided on whether they felt they had opportunities to influence decision-making, as well as on whether they agreed that decision-making on complex scientific or technical subjects should only be made by experts. Levels of agreement on these issues did not show a statistically significant shift by the end of the forum.

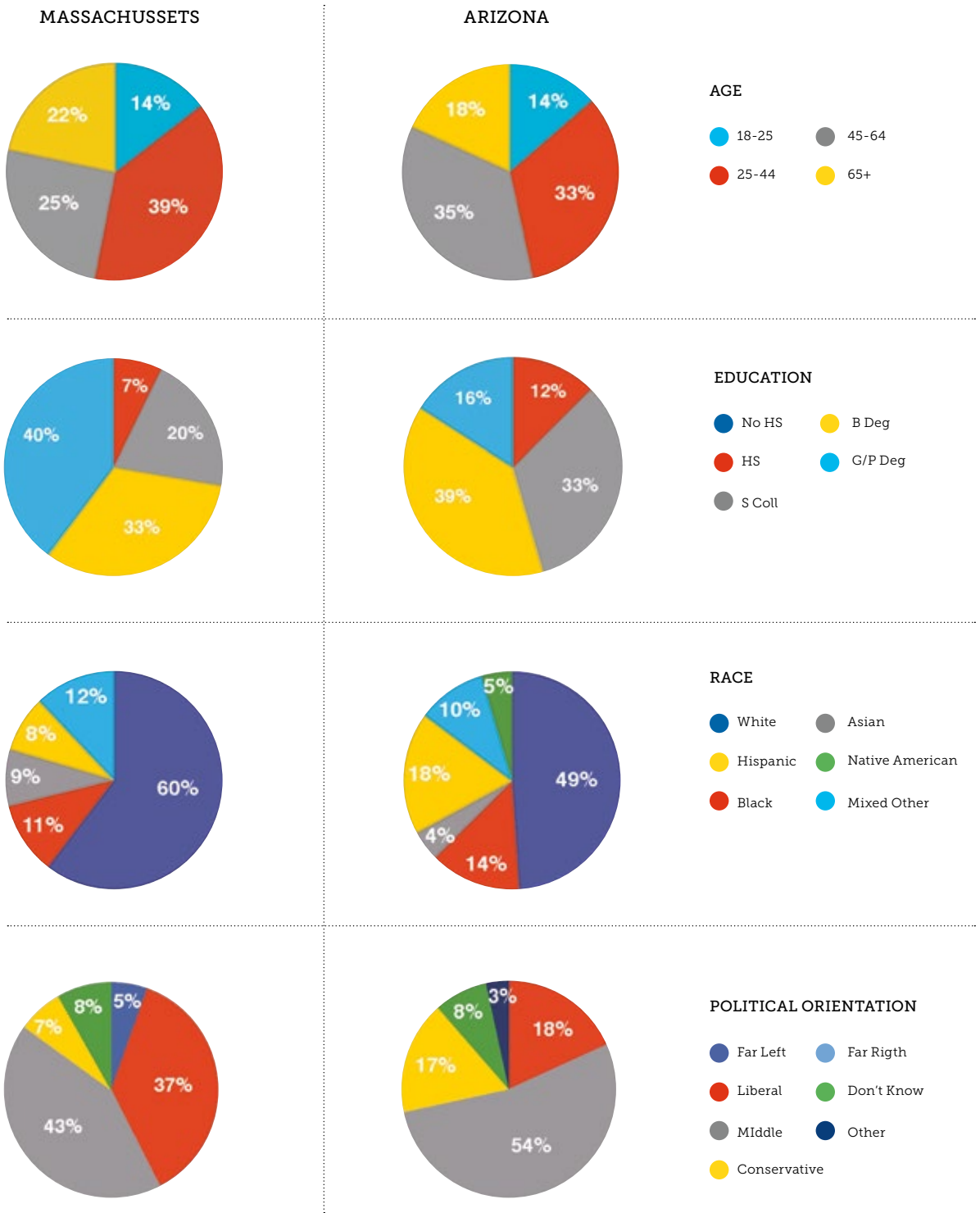
Participant perceptions of forum organization and outcomes have important bearing on how one should view the results of the SRM forum. If participants perceive that the outcomes of deliberations are compromised as a result of, for example, poor event organization, biases in the materials, or not having their views represented fairly in the results, then the quality of the results should be called into question.[17] According to the post-forum survey (see Appendix 2.6), participants in general were highly satisfied with their experience at both sites. One area where participants were less satisfied was related to the prompt "It's clear to me how the dialogue results will be used." It is not surprising that people were unsure about how the forum results would be used; no immediate decisions about SRM research are currently taking place in the United States. Participants were told that expert scientific and policy stakeholders would see the results, potentially informing future decision-making around SRM research, but it was probably difficult for participants to envision how the results might influence future decision making.

Participant Perceived Knowledge and Attitude Change

Another way to gauge the success of a pTA forum is to determine how much participants learned during the event and to what extent the event challenged people to reconsider how technology relates to their personal values. A successful deliberation provides an environment where people have the opportunity to become more knowledgeable about a subject, but also to use that newly acquired knowledge to reconsider previously held beliefs or inform their opinions about issues they have not previously considered.[18]

We measured participant learning and attitude change by providing participants the same prompts on both the pre- and post-forum surveys, which participants rated on a scale from 1 (absolutely agree) to 7 (absolutely disagree). Overall, participant responses on the pre-and post-surveys demonstrate that the SRM forum had a highly significant impact on participant learning and, to a lesser extent, changed participant attitudes toward climate change research, and SRM research in particular (see Appendix 2.6 for details). The following three categories highlight types of prompts on the pre- and post-surveys.

Figure 2.5.1 Demographics of Participants in Massachusetts and Arizona.
State-level comparison data from the US 2012 Census is available in Appendix 2.5.



Participant Perceived Knowledge and Attitude Change

Interest and Knowledge

Goal: Ascertain changes in interest and knowledge.

Sample statement: "I am familiar with the topic of SRM research" (Pre-survey mean response: 4.4, post survey mean response: 2.0 – shift toward higher agreement)

These data show that people did not come into the forum with significant knowledge about SRM research, and that they learned from the forum process.

Climate Change Research

Goal: Ascertain changes in attitude toward climate change research.

Example: "Experts and science in general will help solve most climate change problems" (Pre-survey mean response: 3.4, Post survey mean response: 2.9 – shift toward higher agreement)

Overall, 5 of 18 prompts showed a significant mean change from before and after the event. This suggests that people's views shifted in a statistically significant way toward agreeing that support for climate research, and SRM research (to some degree), is desirable. Participants also significantly shifted their opinions toward agreeing that it is important collect data on the public's ethical concerns and decisions about SRM research.

Influence of Participation

Goal: Ascertain perceived influence of the forum on participants' personal knowledge and behaviors related to climate change and SRM research. (Only on post-survey.)

Example: the forum "significantly increased my knowledge about climate change" (AZ mean response: 1.6, MA mean response: 2.6 – between absolutely agree and somewhat agree)

In general, participants rated that the SRM forum had a positive influence on their knowledge about and desire to take action on climate change. Interestingly, participants in Arizona showed significantly more perceived influence than those in Massachusetts in 8 of 12 statement categories. These results deserve more attention because they suggest that people in some geographic regions might have more to gain from capacity-building experiences like pTA forums.

While we recognize that providing "more scientific information" generally does not lead people to change their views about science-related issues, our results may suggest that public engagement exercises such as pTA do build capacity for informed decision making through the deliberative process.[19]

TABLE VIGNETTE, *part 1:*

The quantitative results give insight into overall group preferences about SRM research and how those opinions evolve over the course of the deliberative activities. The type and extent of learning, reasoning, and group dynamics that occurred during the forum, which are not easily apparent from other analyses, can be illustrated by narrative descriptions of group interactions at one table. Here we present one table observer's narrative analysis of the deliberations at the table he observed for the day. It is informed by his observation notes, an audio recording of the deliberation, and the preferences and justifications recorded by individual participants and by the group as a whole as they participated in the activities.

My table was composed of four women and three men, plus the facilitator and a non-participating table observer. Participants included a freelance author and environmental activist, an advocate for homeless veterans who himself had served in the armed forces, an indigenous man who works in the environmental office of his tribal government, and several students. The age spread covered twenty-somethings up to participants who appeared to be in their sixties. Several ethnicities were represented. As might be expected in a diverse group such as this, no two people at the table came to the day with similar perspectives. Even when superficial agreement was present, it occasionally masked divergent motivations. For example, most participants made it clear that they distrusted the US federal government, but what that meant varied from person to person. One person made several statements early on that suggested he believed that the government was already conducting secret manipulation of solar radiation. Others clearly had no such belief but asserted at various points that they distrusted government for reasons ranging from a perceived tendency for government to overreach, to the exact opposite—that the recent election of Donald Trump as president undermined the federal government's ability to shape society.

3. Forum Results Analysis

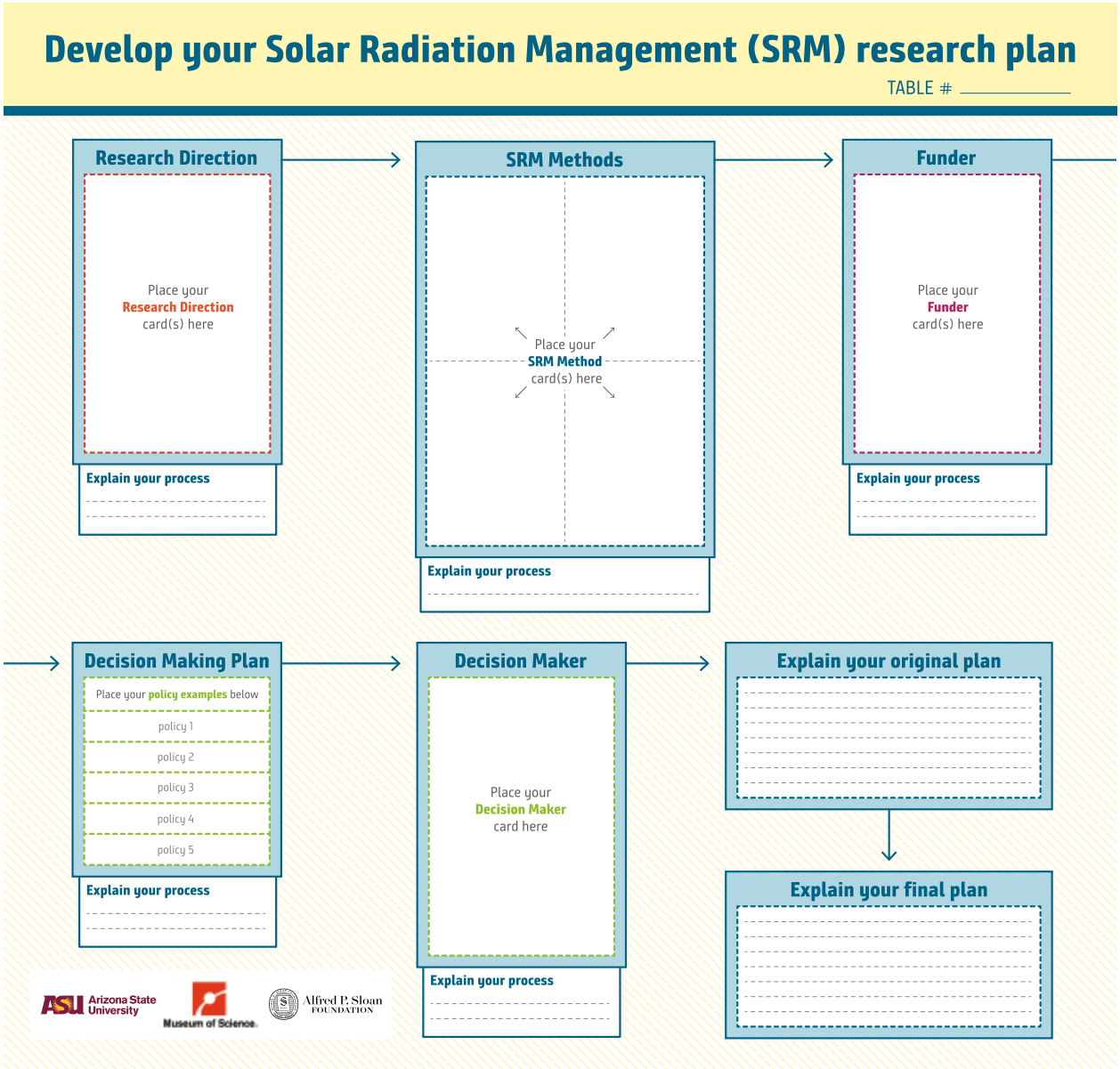
3.1 Session 1 - Research Directions

Session 1 Summary

In the day's first session, we introduced forum participants to the idea of solar radiation management (SRM) and to its environmental, technical, and social contexts. An introductory video reiterated key points of background material and the major themes of the deliberation materials. The video summarized the current state of climate science and society's response to climate change. It explained why SRM has been proposed and described six SRM methods that researchers have proposed. The video outlined five SRM research directions, designed to illustrate the different scales and methods by which SRM research could be pursued, and described six considerations potentially relevant to selecting among them. We developed the SRM methods presented to participants based on our review of formal and informal literature, and through discussions with experts in the SRM field. Participants articulated their preferences regarding the future direction of SRM research and groups formulated "research plans" for SRM research (Figure 3.1.1). This format was designed to maintain participant enthusiasm through a sense of progression and collective effort throughout the forum. During the first session, groups selected from among five pre-created "research directions," modified them if desired, and determined which, if any, of the six proposed SRM methods should be researched. Participants also individually rated their support for the different research directions, selected their two most-preferred and two least-preferred research directions, and provided written rationales for their choices.

Rather than attempt to provide an exhaustive catalog of possible SRM research pathways or directions, we designed the research directions to emphasize differences between possible research trajectories (e.g., in scale, organization, and regulation). Groups were encouraged to select and/or modify multiple directions if different research directions better represented their desired research trajectories.

Figure 3.1.1: Group deliberation board and SRM Method, Research Direction, and Research Consideration cards.



Cirrus Cloud Thinning

Release of solid particulates in the high troposphere might thin cirrus clouds, allowing more heat to escape.

- **Large in scale**
- **Potentially low deployment costs**
- **Excessive seeding could thicken clouds, reversing the effect**
- **Climate effects are uncertain**

Photo credit: Simon Eugster https://commons.wikimedia.org/wiki/File:Cirrus_fibratus_and_Cirrocumulus.jpg

Cool Infrastructure

Painting roads, roofs, and other infrastructure in reflective colors and increasing reflective plant cover could help reflect incoming sunlight and reduce local temperatures.

- **Easily targeted**
- **Few unpredictable impacts**
- **Effects are small on a global scale**

Stratospheric Aerosols

Release of sulfate aerosols into the stratosphere could reflect a small amount of sunlight, colling the planet.

- **Inherently global in scale**
- **Potentially low deployment costs**
- **Climate effects only partially understood**
- **May impact rainfall patterns**

Marine cloud brightening

Spraying salt water into the air above Earth's ocean could stimulate additional cloud formations, reflecting more sunlight away before it reaches the ocean surface.

- **Easily targeted**
- **Potentially significant local impacts**
- **May impact rainfall patterns**

Ocean Surface Microbubbling

Fleets of dedicated ships could disperse reflective microbubbles across the ocean surface, reflecting away incoming solar radiation.

- **Easily terminated**
- **May affect marine ecosystems**
- **Potentially high energy costs**

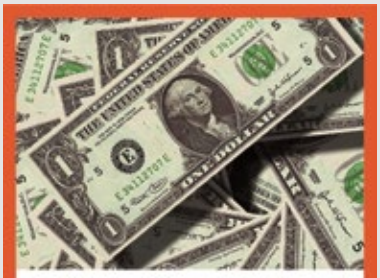
Sea Ice Thickening

Pumping seawater to the Arctic ice surface can allow it to freeze more easily. Increased ice cover could reflect much more sunlight than open water.

- **Potentially resource-intensive**
- **Requires a large number of pumping devices**
- **May help conserve Active ecosystems**

Continued

Figure 3.1.1: Group deliberation board and SRM Method, Research Direction, and Research Consideration cards.



Monetary investment

Research costs money: in researcher and support staff salaries, space usage, materials, electricity and more. Research projects vary widely in scale, but larger ones can involve amounts of money well outside most persons' everyday experience. For example, The National Institutes of Health spent $37.3 billion on research in 2017.

Improved climate system understanding

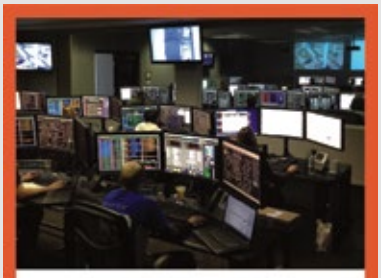
The global climate system is extremely complex. SRM research could provide an opportunity for additional study of the atmosphere and climate systems, especially under conditions induced by SRM methods. Improved understanding of the climate system could inform the design of and discussion around SRM methods and influence more general climate discussion and policy choice.

SRM knowledge development

SRM research would be designed to improve the understanding of how SRM methods function, their potential impacts and potential efficacy. It could also help develop and refine SRM infrastructure and implementation procedures. This would provide a better idea of how SRM could work, what it could accomplish, and what undesired impacts it might have if implemented.

Direct risks

Direct risks include threats which research could pose to humans, wildlife, or the local environment through release of substances, equipment malfunction or crash, or unexpected weather influence.



Technological lock-in

Research on SRM methods could make their use more likely. The line between large-scale experimentation and actual deployment is blurry. Technological development tends to attract financial support, political constituencies, and physical infrastructure, so it can be easier to justify continued commitment to options with high prior investment. This could distract from other climate action options or exclude affected publics from the decision-making process.

Moral hazard

SRM research may develop the capability to limit global temperature increases relatively quickly and inexpensively. But, SRM methods treat the symptoms of, not the causes, of climate change. The proposed SRM methods don't reduce emissions of greenhouse gases or remove them from the atmosphere. Some observers fear that SRM investment may remove incentives to or distract from efforts to reduce fossil fuel use and adapt to the changes climate change is already producing in the environment. Because of the complexity of human political choice, though, it is unclear how accurate such fears may be.

Session 1 Results

SRM Methods

Groups in Arizona and Massachusetts had similar preferences for SRM methods, with cool infrastructure and sea ice thickening as the most common choices (Figure 3.1.2). Groups were allowed to select between 1 and 4 preferred SRM methods. All groups selected cool infrastructure and 89% of groups chose sea ice thickening. Marine cloud brightening (65%) and ocean micro-bubbling (46%) were also relatively common choices. However, stratospheric aerosol injection (15%) and cirrus cloud thinning (8%) garnered very little support.

In making their choices, group rationales tended to focus on technologies perceived as having low environmental risk. The three top choices (cool infrastructure, sea ice thickening, and marine cloud brightening) are focused on reflecting sunlight in a manner that participants perceived as being more "natural" than stratospheric aerosol injection and cirrus cloud thinning, which many groups viewed as introducing chemicals into the atmosphere that might cause pollution. For example, one group from Arizona chose "methods that focus on reflection, not on altering the atmosphere." Another group said, "We prefer SRM methods that don't vastly chemically alter the environment." Groups also noted low cost, feasibility, and reversibility of research effects as common reasons for choosing cool infrastructure and sea ice thickening.

SRM Research Directions

Group considerations about environmental risk, cost, feasibility, and reversibility of SRM technologies played into how groups chose research directions. Again, there were not large differences between Arizona and Massachusetts on group preferences for research directions, especially with regard to the high investment research directions (Figure 3.1.3). Both sites chose *Computer Modeling* and *Small-Scale Field Trials* at a much higher frequency than high-investment *Decentralized* or *National Coordinated* efforts. However, groups in Arizona chose *Computer Modeling* and *Small-Scale Field Trials* at a lower frequency than in Massachusetts. Only one group chose *No SRM Research*, though that group also paired the selection with *Computer Modeling* and *Small-Scale Field Trials*.

Patterns were similar for individual measures of participant preferences for research directions, with *Computer Modeling* and *Small-Scale Field Trials* scoring the highest ratings (see Appendix 3.1). Participants

Figure 3.1.2: Group choices for preferred SRM methods in Arizona, Massachusetts, and combined.

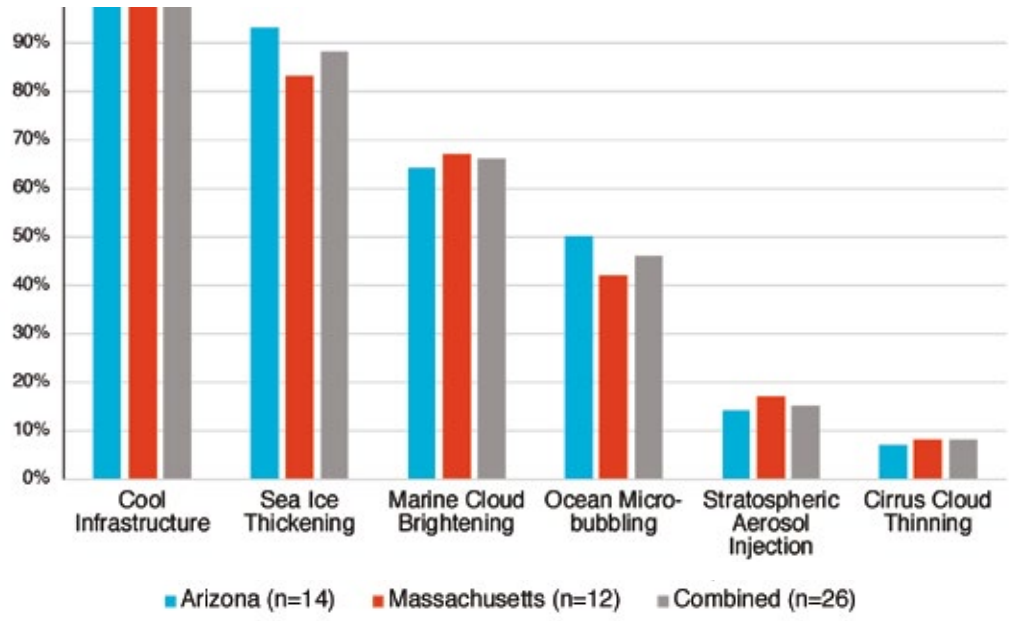


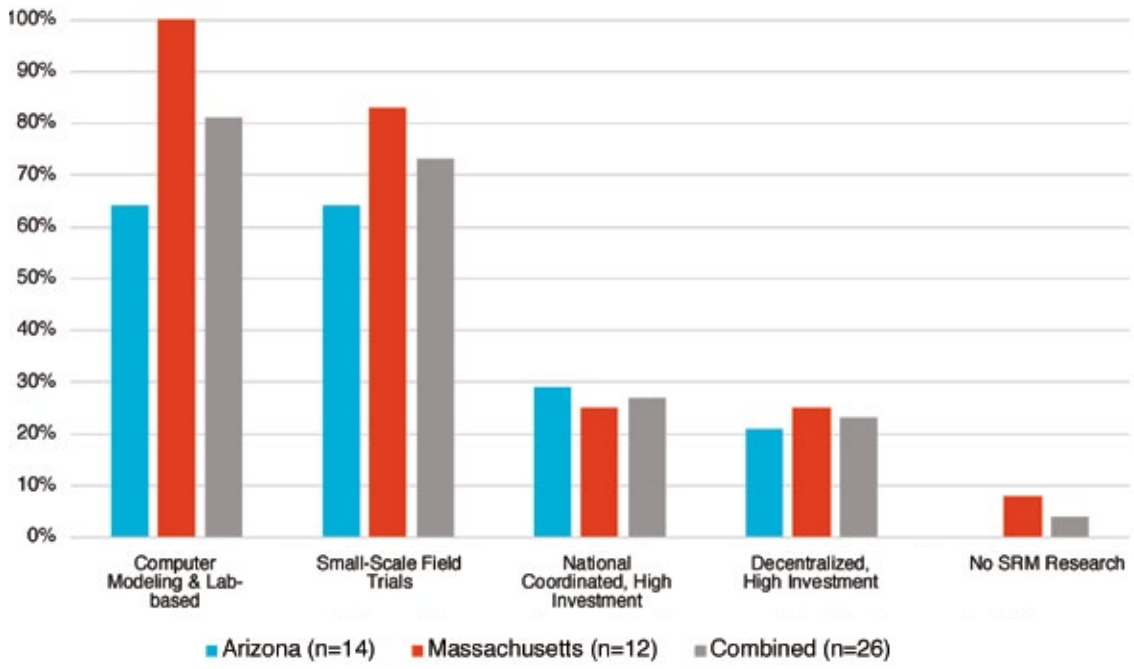
TABLE VIGNETTE, *part 2:*

The group was civil and respectful of each other's perspectives once voiced, but the conversation was far from frictionless. One participant at several points elicited obvious discomfort from several others, including when she made a statement impugning the motives of the military as an institution and when she asserted that the government should restrict population growth as a climate change policy. Both of these comments caused another participant to sink in his chair and become notably quieter. These moments of tension and self-censorship did not last long, however, as another participant who seemed to be particularly attuned the group dynamic reliably intervened to validate aspects of both participants' perspectives and redirect the conversation to the assigned tasks. The participants clearly came to appreciate each other over the course of the day despite their differences. During breaks, they had conversations about their professions and interests and shared laughs and chuckles. People were eager and able to connect their personal experiences and prior knowledge to the task at hand and respected each other's beliefs, even when there was disagreement.

Despite occasional moments of tension and the participants' heterogeneous backgrounds, prior notions, and value sets, the group was able to have a productive dialogue about SRM research. No participants rejected the forum premise, the instructions, or the activities they were asked to complete. The only notable discomfort with the proceedings was that several people stated that they were concerned their deliberations of SRM could be misconstrued as implying that they did not feel that carbon emissions reductions were necessary. The opportunity to record their rationales and logic on the individual scoring sheets, as well as on the group results board, seemed to alleviate these concerns.

Most participants at the table did not have a substantial prior knowledge of climate change and few knew much about SRM. Some participants had trouble pronouncing some of the words as they were reading materials for the group. A lack of prior knowledge did not impede thoughtful deliberation about SRM research. The group had plenty of questions and quickly resorted to asking each other and/or consulting the provided materials when they were unsure about an issue. Participants also referenced the material to settle disagreements amongst themselves when one person's understanding of a method or stakeholder did not match the understanding of another participant. Through collaborative learning, the group seemed to grasp all the technical information in the provided materials. The only notable misconceptions that persisted through the deliberation were around the scale of financial resources that universities and nongovernmental organizations typically have for use at their own discretion, and the formal accountability of philanthropies and nongovernmental organizations to the public will.

Figure 3.1.3: Group choices for research directions in Arizona, Massachusetts, and combined.



perceived that the large-scale research projects were environmentally, socially, and politically riskier than the small-scale research. However, while both *Decentralized* and *National Coordinated* research directions had low preference on a group level, on the individual level, *National Coordinated* scored much higher (71% of participants supporting it "somewhat" or "very much") than *Decentralized* (55% of participants supporting it "somewhat" or "very much"). Reasons for these patterns can be explained by participant statements of conditional acceptance, further explored in our coding analysis below.

At the individual level, slightly more people appeared to support *No SRM Research* than at the group level, with 12% of individuals rating support for *No SRM* as "somewhat" or "very much" as compared to one group's selecting *No SRM.* This finding stresses the importance of assessing both group- and individual-level reporting, as group choices can mask individual preferences.

While ambivalence about SRM research pervaded discussions, many participants seemed to adopt the position that this participant took: "Eliminating the option of SRM research vastly limits our options to combat climate change.... No research is not an option, because we could not know it is a viable option to the climate change problem; doing no research at this point is a missed opportunity."

Participants provided rationales for their research direction choices. In order to understand why participants preferred, disliked, or were ambivalent about a particular research direction, we open-coded all participant rationales. The open-coding process entails reading through participant rationales and searching for common themes. Through this analysis, we show the diverse ways people were thinking about the research directions. Later in this section, we focus on why people focused their desires so much on computer-based and small-scale field trials.

Rationales were dense with people's ideas about SRM research. We identified 7 primary categories of rationales (Table 3.1.4), which included 609 separate references. A person could express more than one type of category within their rationales. In other words, each participant had multiple views about SRM research. Participants' rationales in this session focused heavily on the research process and its outcomes, which is not surprising, since the session

mainly focused on SRM methods and research directions. Nonetheless, participants also discussed issues of governance, cost, feasibility, and risk (Figure 3.1.5). There was also much discussion about the efficacy of SRM to address climate change.

Many participants advocated an incremental approach that did not waste time and was efficient. For instance, one participant wrote, "Computer modeling is a safe way to test without messing things up and a good way to see potential pitfalls. Small scale trials are the next logical step so real world pitfalls can be observed that didn't happen in the lab." Incrementalism was sometimes associated with the need for reversibility; as one participant put it, "I think that small scale field trials is important due to the fact that if it doesn't work or something needs to be adjusted you have not risked doing harm on a large scale." In contrast, some participants felt that large-scale efforts are "vital" and the only way that would give researchers any usable results: "National-scale research could lead to rapid advancements and better understanding of the various impacts SRM methods."

It was also important to some participants that researchers "make sure to get many different and important points of views." This sentiment was often associated with calls for collaboration or the necessity of international involvement. It was also associated with the notion that testing a combination of the methods would yield better results.

Participants focused on the nature of the data generated by the research process (Figure 3.1.5). They questioned how scientists would know about the accuracy of data. There was some concern that the organizational agenda of those conducting research "would skew the results." Collecting "real world" data was also frequently emphasized. Most participants identified a need for some way to test SRM methods in small-scale field trials.

The governance of research directions was the second-most frequent category of rationale, even though it was not the specific focus for this session. We will discuss participant perspectives on governance elicited in a subsequent session, but even in this earlier session, people expressed a desire for accountability, transparency, protection against political influence,

Table 3.1.4: Definitions of categories for individual rationale statements derived through open-coding.

CATEGORY	DEFINITION
Research Process	Considerations of research outcomes, the level of collaboration, and quality of research, which includes references about data accuracy, bias, and usability.
Governance	References to decision making, political influences on research, accountability, research transparency, public engagement, and the role of experts in governance.
Risk & Uncertainty	Statements that express concerns about environmental, public health, technological, and/or social risks and/or uncertainty.
What we should do	Proclamations of how we should proceed with SRM research and/or dealing with climate change in general. These statements are assertive affirmations of one's position.
Economics	Statements that refer to the cost of doing research.
Long-term Consequences	References that discuss issues that go beyond the immediate outcomes of SRM research, which include the moral hazard and slippery slope arguments, effects on climate change and adaptation, the consequences of doing no research, and sociopolitical challenges.
Feasibility	Statements that refer to how difficult or easy it would be to pursue a particular research direction.

and public engagement. A noticeable tension existed between participant rationales with some participants stating that large-scale efforts would necessitate "top-down mandates" and others emphasizing the likelihood that "high investment [efforts] will become a political issue."

Many participants spoke in terms of "what we should do" (11%), invoking a normative judgement about how we should proceed with SRM research. These kinds of references ranged from positively supporting SRM research ("I do feel strongly that some SRM research should take place") to expressing serious doubt about its utility ("Still not convinced we need SRM research").

Frustration about the inability of the US government to do anything about climate change pervaded people's considerations about SRM research. While a common sentiment was that small-scale efforts are currently more feasible, participants also typically felt that large-scale efforts, if demonstrated to be viable after performing small-scale research, would be hard to execute due to the "current political polarization on the issue of climate change." People were also concerned about the "siloed" nature of scientific research as a barrier to progress; as one participant claimed, "Climate change is advancing at such an extraordinary pace that we need coordinated approaches—[we need] a community working together, instead of institutional silos."

Rationale statements also invoked economic issues, long-term consequences, and the feasibility of SRM research. These rationales were generally expressed as concerns about the nature of SRM research, which speak to conditions that participants were setting for the acceptance of these technologies,[20] discussed in more detail below.

Issues to Consider for SRM Research

After the initial discussion about SRM methods and potential research directions, groups discussed six research considerations and then ranked them according to their perceived importance. Among groups in both Arizona and Massachusetts, improved understanding of climate, direct risks, and SRM knowledge development were clearly clustered together as relatively more important than moral

Figure 3.1.5: The percentage of participant references (n = 609) about their research direction choice in each rationale category. A participant rationale could include more than one category. See Table 3.4.1 for category definitions.

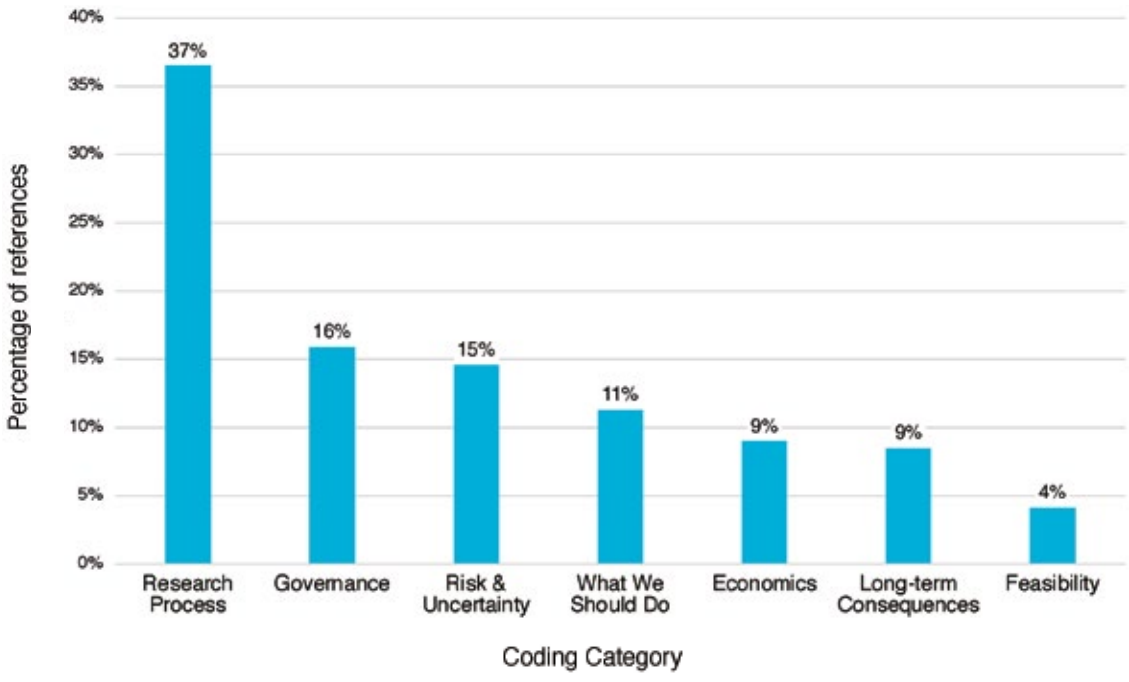
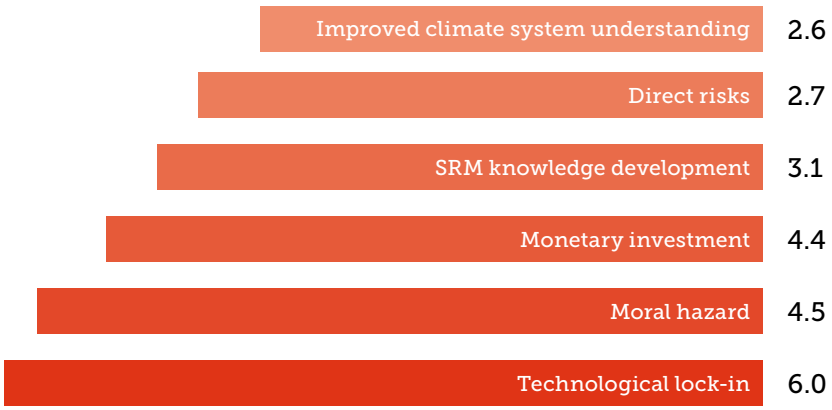


Figure 3.1.6: Average ranking for the six research considerations.
Considerations were ranked from 1 (most important) to 6 (least important).



hazard, monetary investment, and slippery slope/technological lock-in (Figure 3.1.6). The relatively high rankings of improved understanding of climate, direct risks, and SRM knowledge development match well with the relatively high frequency of references about research process, data, and risk & uncertainty that occurred in the earlier discussion.

The relatively low ranking of monetary investment also is not surprising. As part of the background materials, participants were given information about the cost of SRM research in relation to typical expenditures on scientific research; they saw that the cost was low compared with public and private research budgets. Presumably they felt comfortable with potential investment in SRM research. Groups also had the opportunity to write in their own considerations to be ranked. Many of these write-ins fall into purview of governance and included public education; sociopolitical issues such a public resistance to SRM; risks at deployment scale; public involvement; SRM as backup to climate mitigation and adaptation; and concerns that the behavior of the climate could be commodified in some way.

Conditional Acceptance of SRM Research

Much of the seemingly broad support for computer-based, lab-based, and small-scale field research was conditional: participants felt that SRM research held promise, but should only be pursued under environmentally, politically, socially, and economically constrained circumstances. The conditionality of support became clearer as participants explored the specifics of funding and governance later in the day. The findings here are similar to results from research conducted on small focus groups discussing the prospects of geoengineering in Europe.[21]

Three-quarters of the SRM forum participants set some sort of conditions on the SRM research (see Appendix 3.1). While generally supportive, people wanted assurances that SRM research will be governed in a certain way for it to be acceptable.

To better understand participant conditions, we open-coded all participant rationales concerning SRM research direction choice a second time, with a frame for identifying under what circumstances SRM research was acceptable or not acceptable. We identified five primary themes, of which four were similar to the original coding scheme from the initial analysis in this section. The theme of *Cooperation,* which entails statements expressing the need for or the difficulty of obtaining cooperation among researchers and various stakeholders at the national and/or international level, emerged as a fifth important category that was different from the earlier analysis. Participant statements most frequently contained conditions related to *Research*

Table 3.1.7: Numbers of statements associated with secondary conditional acceptance themes for each of the primary themes identified by open coding (n = 130 participant statements). Definitions of major themes are presented below.

PRIMARY/SECONDARY THEME	# of Statements	PRIMARY/SECONDARY THEME	# of Statements
Research Process – *conditions related to research methods, data collection, outcomes, and approaches.*		**Risk & Uncertainty** – *concerns about risk associated with the conductance and outcomes of research.*	
Data accuracy and reliability	53	Unspecified risk	35
Computer and lab research first	33	Environmental risk	24
Small-scale research first	17	Moral hazard	14
Context-specific research	6	Reversibility of research	8
Many approaches strategy	6	Social impact	3
National-scale research first	3	Energy consumption of research	2
Economic Cost – *concerns about the cost of SRM, including political implications.*		**Governance** – *conditions related to governing the research process.*	
Large-scale research expensive	17	Appropriate governance necessary	35
Small-scale research cost effective	17	Public engagement necessary	11
Funding is political	6	Oversight and accountability	8
General statements about cost	6	Researcher autonomy	2
Private funding preferred	5	Transparency	1
Cost isn't a factor	1	Property rights	1
Cooperation – *assertions that cooperation is necessary or difficult to achieve.*			
Leads to agreement	12		
International cooperation necessary	9		
Agreement is difficult	8		
Leads to diverse ideas	5		

Process (51%) and *Risk & Uncertainty* (44%), with issues of *Governance* (29%), *Economic Cost* (28%), and *Cooperation* (19%) also garnering significant attention.

We broke these primary themes down into secondary themes that show the diversity of ways people expressed conditions (Table 3.1.7). The 130 participants who set conditions articulated, on average, 2.7 conditions, which suggests that people were viewing the SRM research landscape in complex ways.

The most common secondary theme was related to data accuracy and reliability (53 statements). Participants seemed keenly concerned with what the outcomes of research would really tell them. For instance, would the results truly reveal the long-term environmental risks of SRM research (59 statements for environmental and unspecified risk combined)? One participant asserted that "there is a lot unknown and computer-simulation might confuse or misrepresent real world questions." Another participant saw value in computer modeling but believed that it "sometimes fails to capture many real-world aspects that can interfere with safety." A common sentiment was that "small-scale SRM field trials do have a risk but [it] is not high."

Because many people saw limitations to computer modeling, they felt that small-scale field trials were necessary to paint a more complete picture of the risks before deciding to scale up. However, a fair number of participants preferred starting with

computer modeling and lab research in order to determine if small-scale field trials would produce meaningful results. This participant captured the nature of these conversations: "I somewhat agree with this [national scale research], but only if computer modeling & small SRM experiments have already been done & show to help significantly reduce climate change."

A minority of participants felt that small-scale field trials "will not show true results due to limitations" and that we would only learn how well SRM technology would work at larger-scale research efforts. There was a fair amount of concern about SRM research leading to a moral hazard (14 statements). For example, the following participant spelled out his or her concerns about pursuing SRM research through an analogy with Western medicine:

> I feel this research should be conducted in tandem as parallel to mitigation / adaptation that should still be the primary focus otherwise it becomes like modern Western medicine where you try to treat the side effects of drug treatment with yet another prescription (drug) instead of ... eliminating the cause of the illness itself.

In this analogy, SRM technology is like the prescription drug treating the symptoms of an illness; one can get caught up in a cycle of technological fixes without actually ever addressing the root cause of the problem. Overall, though, many participants seemed to support SRM research moving forward as long as it began in the lab or on a small scale in order to identify the technology's risks and its efficacy in curtailing climate change.

Public engagement also was important to some. One participant pointed out, "Research that affects specific communities must take them into consideration." Concerns about cooperation manifested itself in two ways in participant rationales. First, many participants felt that to get anything done requires "[g]etting ideas from different types of people [which can be] eye-opening to new concerns. People need to work together to bring a global change. If we do not cooperate on this or any matter, no or little change will occur." This first way of seeing cooperation is about working together to get things done. Others saw cooperation as a difficult thing to achieve: "I have little faith in the ability of world governments to cooperate enough to make a difference in time." There was tension between optimistic and pessimistic views toward cooperation among participants.

Considerations of governance and funding also arose during this session; we defer analyses of these issues to their corresponding sections below.

3.2 Session 2 - Funding

Session 2 Summary
In Session 2, participants articulated their preferences regarding SRM research funding among six possible categories of SRM research funder: corporations, civilian federal government, military, non-governmental organizations, philanthropies, and universities. Military was included as a funder category distinct from the federal government because of its large budget and distinctive role as a technology catalyst. Universities were included because they can provide seed funding for projects pursued by their faculty. Information

TABLE VIGNETTE, *part 3:* SRM research methods and research implementation

During the proceedings, the group easily achieved consensus around prioritizing researching SRM methods that they deemed to be of lower risk of unintended impacts and those with impacts that they saw as more reversible should problems emerge. Drawing on their prior knowledge of stratospheric ozone depletion, they shared a distrust of what they deemed to be chemical interventions in the stratosphere. The research directions conversation quickly converged on a scaled approach that they felt would allow for ongoing learning and revision of the research approaches. These topics yielded easy consensus across the group. As soon as someone voiced any of the aforementioned aspects of research as being desirable, the others quickly nodded in agreement and built upon those arguments.

Figure 3.2.1: SRM funder cards. If selected to fund the group's research plan, the card(s) would be placed in the "Funder" slot on the group deliberation board (Figure 3.1.1).

Federal Government

Who are they?
Federal agencies like the National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), and National Aeronautics and Space Administration (NASA). These agencies could fund SRM research at universities or undertake the work themselves. Government agencies are funded by tax dollars and their budgets are subject to congressional approval. Financial support for SRM research could vary over time depending on the current political leadership.

What types of projects do they fund?
Projects that benefit the public. This can include health, education, and economic benefits.

How much oversight do they provide?
Federal research projects must comply with state and federal laws and any relevant institutional requirements. Research proposals must also go through a comprehensive application and review process.

How will they use the research?
Research may be published or presented to increase public understanding of an issue. Research findings may also be used to develop new technologies.

Military

Who are they?
The US Department of Defense funds large amounts of research through each wing of the military and through initiatives like the Defense Advanced Research Projects Agency (DARPA). Military research is responsible for some things we use every day, such as airplanes, the internet, and GPS. Military research tends to be more shielded from politics than federal government research, although it is also tax funded and subject to congressional approval.

What types of projects do they fund?
Research to enable or improve the nation's military capabilities or to support national security.

How much oversight do they provide?
Military grant recipients must comply with federal and state laws and researchers must submit progress reports to show they are on track with the project's objectives.

How will they use the research?
Military research is used to enhance the United States' military capabilities. Research may be used to improve offensive or defensive military capabilities or meet other strategic, mission-oriented needs.

Corporations

Who are they?
For-profit corporations could invest in SRM research in the hope that the technology becomes profitable in the future. Typically, corporations invest significant amounts of money to fund research that promotes their objectives. For example, pharmaceutical companies fund research at universities or within their own R&D departments to support drug development.

What types of projects do they fund?
Research that will eventually translate into profits for the company. If research costs exceed potential profits or if the company's priorities shift, research on a topic may no longer be supported.

How much oversight do they provide?
This varies based on the company, as well as whether the project is conducted within or outside of the organization. If the company provides funding to a university research group, it may require progress reports.

How will they use the research?
Corporations will eventually monetize the research by translating it into a technology or service for sale.

Philanthropies

Who are they?
Philanthropic organizations typically fund a wide variety of projects that support research relevant to their foundation's mission. Sometimes philanthropies partner together to fund larger-scale programs.

What types of projects do they fund?
Philanthropies often award grants for research that is relevant to the foundation's mission through a proposal and review system. Philanthropies can directly solicit an organization or researcher to complete a project, which limits the diversity of proposals. Philanthropies can be narrow in focus. For example, they might exclude nuclear energy when funding research on sustainable energy sources.

How much oversight do they provide?
Each philanthropy has different processes for tracking project progress and providing oversight. Some organizations provide templates for tracking results, which include progress narratives, fiscal reports, and a final report. Others may only require a final report.

How will they use the research?
Philanthropies may discuss the research projects as evidence of their commitment to their stated mission, but are unlikely to further develop the research on their own. The outcome could encourage or discourage further research funding for the same method.

Nongovernmental Organizations (NGOs)

Who are they?
Nonprofit nongovernmental organizations (NGOs) are similar to philanthropies but tend to be more focused on a specific issue or cause. NGOs can be organized on the local, national, or international scale and can collaborate on a specific issue.

What types of projects do they fund?
NGOs fund research that supports their organizational mission and objectives and may also be narrow in focus. NGOs receive their funding from government grants or philanthropies. NGOs might not always be able to acquire large amounts of funding, which can make it difficult for to fund long-term research projects.

How much oversight do they provide?
NGO's periodically collect project reports from researchers and conduct project reviews.

How will they use the research?
NGOs use research as an informational tool for the public or for key stakeholders involved with their mission.

Universities

Who are they?
SRM researchers can also receive financial support directly from their university. When universities receive funding through private donors or large grants, they can direct some of that funding towards specific research projects.

What types of projects do they fund?
Because universities receive their funding from donors, the size of projects they can fund is directly related to their own ability to get funding. This might make it difficult for them to fund long-term or large-scale research projects.

How much oversight do they provide?
Universities typically evaluate research programs based on scholarly productivity.

How will they use the research?
Universities fund research for a variety of reasons, including the intent to produce publications, patents, and prestige for the institution.

provided to forum participants included background materials, a pre-deliberation informational video, and deliberation materials (Figure 3.2.1) describing the identities, usual funding domains, oversight capabilities, annual budget, and potential interests in SRM research of each funder.

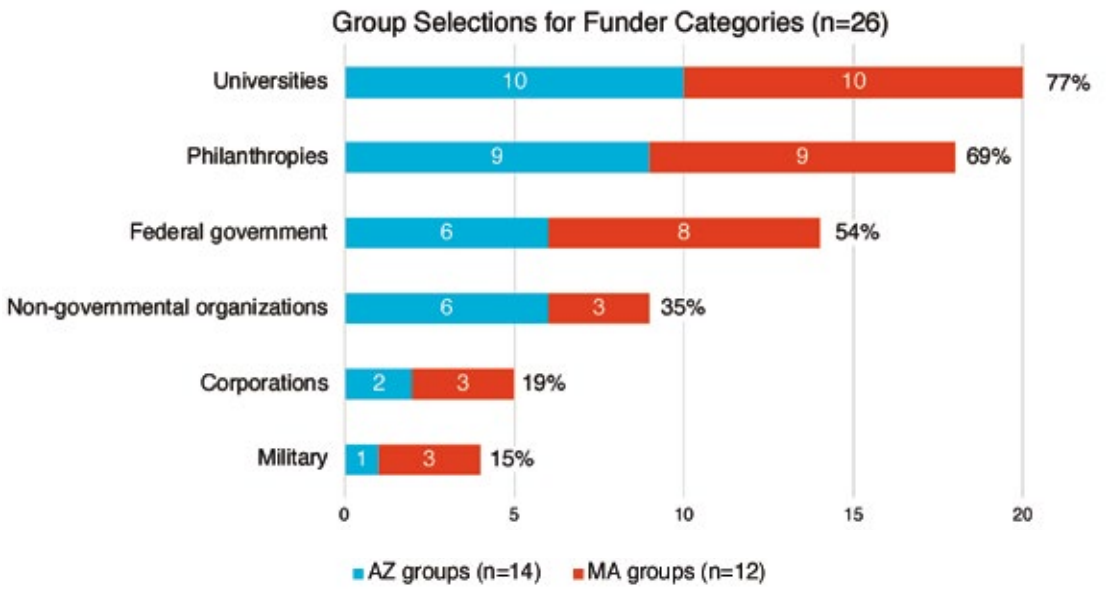
In discussion, each deliberation group selected one or more categories of actor to fund the research plan it developed in Session 1. They provided a brief, textual explanation of the group's choice(s). Groups which had chosen not to pursue SRM research in Session 1 would have been asked who they would want to fund a medium-investment research plan consisting of computer modeling, indoor research, and small-scale field trials. However, since all groups chose to pursue some form of SRM research (the single group that selected *No SRM Research* also selected *Computer Modeling* and *Small-Scale Field Trials)*, this contingency was not used. Following group discussion, participants indicated their individual support (noting if they wanted the funder to fund SRM research "very much," "somewhat," "not really," "not at all," or "not sure") for each funder category's involvement in SRM research via individual response sheets and provided written rationales explaining their evaluations.

Session 2 Results

The results here represent the first detailed analysis of public attitudes toward potential SRM research funding. While some studies that focused on governance revealed public concerns about funder motivations and trustworthiness, these studies weren't specifically designed to assess public perceptions and preferences of funders.[22] Of 26 total forum deliberation groups (14 in Phoenix, 12 in Boston), 20 (77%) selected university funding for research; 18 (69%) selected philanthropy funding; 14 (54%) selected civilian federal funding; 9 (35%) selected non-governmental organization funding; 5 (19%) selected corporate funding; and 4 (15%) selected military funding (Figure 3.2.2). Groups were allowed to choose more than one funder, so percentages sum to over 100%.

In individual funding support ratings, universities also enjoyed the highest level of support (89% of individuals rating support at "very much" or "somewhat"), slightly above philanthropies (86%)

Figure 3.2.2: Numbers of groups selecting each funder category. Groups could select multiple funders for their SRM research plans. Percentages reflect proportions of all groups selecting each funder category.



and followed more distantly by NGOs (72%), federal government (71%), corporations (51%), and the military (40%) (see Appendix 3.2.1). Corporate and military funding received both strongly positive and strongly negative ratings: 56% of participants rated support for military as a funder as "not really" or "not at all"; for corporations this percentage was 46%.

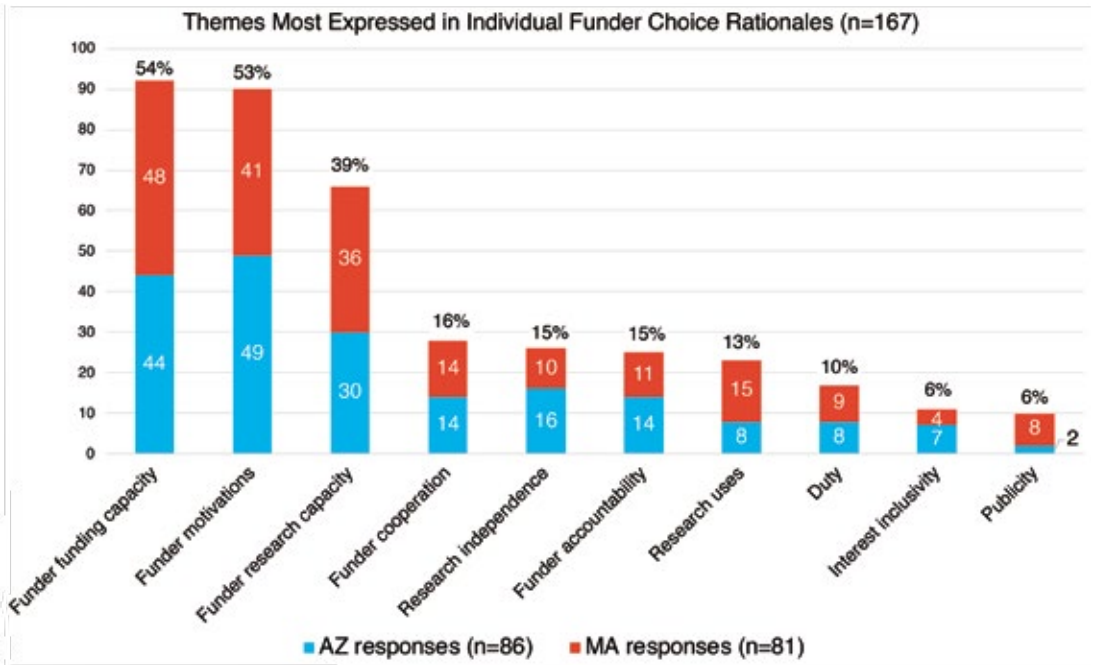
We open-coded both group and individual funder decision rationales into thematic categories (category definitions are described in Appendix 3.2) for insight into participant funder preference patterns (Figure 3.2.3). Both group and individual statements most frequently invoked the availability, scale, and reliability—coded as *Funder Funding Capacity*—of prospective funding to explain their funder selections and evaluations. Individual statements discussed the motivations and trustworthiness of funders (23% of groups, 53% of individuals), as well as funders' likely competence in funding management or in research itself (8% of groups, 39% of individuals), more frequently than did group funder choice rationales. While the number of group rationales is small, these results are nonetheless notable, considering that the same set of participants produced both the group and the individual statements.

Participants' focus on funder capacity and motivations in Session 2 aligns with the high ranking of improved climate understanding from Session 1. Setting knowledge attainment as the highest priority, participants evaluated funders on their ability to fund research and on their likelihood to misuse or "bias" the results. That is, many participants justified their funder choice by appealing to the funder's perceived ability—or lack thereof—to produce knowledge about the climate and SRM.

Participants' written rationales did not always align with their quantitative evaluations. For example, they paired negative statements about universities with very positive ratings for university funding of SRM research. Some participants may have simply used the written response section to voice misgivings about their own evaluations. Often participants articulated both potential benefits and drawbacks of SRM research support by a given funder, displaying mixed or nuanced attitudes.

Their statements provide insights into common perceptions and evaluations of the proffered funder categories. To further investigate these perceptions, we open-coded participant responses, looking at

Figure 3.2.3: Numbers of individual funder category evaluation rationales expressing 10 most frequently expressed coded themes. Percentages reflect the proportion of all 171 forum participants who expressed each theme in their written funder evaluation rationales.



each funder category individually (see Appendix 3.2.2). Not all participants commented on all funders, let alone all possible considerations. The following sections highlight some of the most frequent themes associated with each funder.

Universities

Statements in favor of university funding tended to stress universities' "affinity" for research, attributing to universities both learning-oriented, "unbiased," or beneficent agendas, and strong preexisting research infrastructures and cultures. Some participants felt that universities have significant financial resources, with one participant opining that "large universities are among the best-funded institutions of our time." We recognize that presenting the total research expenditures for Arizona State University may have overstated the funding capabilities of universities. Participants likely were not aware of the distinction between universities' discretionary research budgets and external funding from grants that supports specific projects. In the future, we will amend our materials to more accurately reflect the amount of funding that a university might be able to dedicate to SRM research.

In contrast, statements against university funding tended to emphasize universities' dependence on other funders and the limitations or unreliability of their own resources. For example, one participant felt that "universities have too limited resources to do anything beyond initial research." In aggregate, participants tended to view universities as genuinely interested in and capable of both knowledge generation and pursuit of the public good, although respondents gave varied accounts of the scale of resources universities could devote to these ends.

Philanthropies

Philanthropies were the second-least frequently commented-on funding category. Nonetheless, more participants attributed beneficent motives or trustworthiness to philanthropies than to any other funder. Those participants asserted, for example, that "philanthropies provide money without the potential for extreme ulterior motives and thus are less susceptible to greed." Alongside attributions like this, statements in favor of philanthropic funding tended to emphasize its perceived large scale and easy accessibility.

Philanthropy-favoring participants also occasionally portrayed philanthropies as friendly to cooperation, open to diverse ideas, and capable of agile research choices in response to project feedback. Statements against philanthropic funding expressed concerns that philanthropies would not "follow through" with the research (i.e., make use of it) and that philanthropies could not provide funding at sufficient scale or consistency for SRM research projects to have meaningful impacts.

Federal Government

The federal government was the funder category most discussed in participants' written rationales. Statements in favor of federal government funding for SRM research tended to invoke the government's large reach and budget; a few statements held that only the federal government has the requisite resources to meaningfully invest in SRM research and/or address climate change. Other favorable statements referenced preexisting federal accountability and oversight mechanisms, the federal government's history of successful research, and preexisting research infrastructure. Some participants felt that the federal government's "public good" mission would help to produce broadly beneficial research outcomes; others felt that the federal government has a responsibility to address climate change.

Statements against federal government funding for SRM research tended to express a lack of trust in the government, voicing concerns about cynical motivations and "biased" interference with research. Such sentiments were often articulated as a mistrust of "politics" or of "political processes," although no participant explained what that meant in detail. One participant simply asserted that he or she "d[id] not trust the federal government to use money wisely due to [the government's] political nature." Other rationales asserted that the government was wasteful, cumbersome, or inefficient, or that "red tape" or strict regulations would hinder the research process. Concerns arose about federal SRM research funding as politically contingent and hence unreliable.

Non-governmental Organizations

NGOs were the funder category least commented on in participants' rationales. Those participants who did comment did not seem to have a clear

understanding of NGOs and their work. In written and in quantitative responses, Massachusetts participants displayed a more evenly distributed and less positive range of views on NGOs than did Arizona participants. Arizonan participants often treated NGOs and philanthropies as equivalent. As one participant wrote, "Philanthropies and NGOs have limited financial contribution but are important contributors to setting priorities." Statements in favor of NGO funding referenced public good–oriented motives, international reach, institutional agility, and ability to passionately focus on research topics. Statements against NGOs tended to portray NGOs as lacking in resources, inappropriately motivated, or overly narrow in focus. Overall, NGOs were sometimes portrayed as passionate but poorly funded; occasionally as unaccountable and with questionable motivations; and sometimes as organizations with strong international reach and potential for collaboration.

Corporations

Though support for corporate SRM research funding was polarized, participants who addressed corporate funding in their written responses tended to express concerns rather than confidence, and focused on how corporate profit motives could lead either to funding inconsistency or the development of an industry around SRM that may not align with public priorities. Statements against corporate involvement tended to express concerns that corporations would misuse, skew, or abandon research depending upon what choices were most profitable. One participant, for example, found corporate funding "iffy" because "[corporations'] objectives are always revolving [around] money rather than the greater good."

Statements in favor of corporate funding tended to envision corporations in a technology development role, saving public funds by using private money for SRM research. As one participant put it, "Corporations could participate in the later (engineering) phases of SRM. If they see a way to make money, they could provide efficient cost-effective solutions."

Military

Statements in favor of military funding, like those in favor of federal funding, tended to reference the military's significant financial and organizational resources. A few participants expressed satisfaction with the military's prior research outputs or a belief in its efficacy and efficiency. Some participants felt that the military could provide funding for SRM research at a smaller scale than civilian federal agencies, but with greater stability, because they perceived it as more insulated from political variability.

Statements against military funding for SRM research tended to express a lack of trust in the military or a feeling that its motives were inappropriate for broadly beneficial research outcomes. Several rationales expressed concern that military investment would "create sides" around SRM internationally, hindering cooperation and potentially ignoring other nations' interests in SRM research and prospective deployment. Others expressed fears that SRM would be militarized. Some participants felt that SRM was irrelevant to the military's missions.

Many participants coupled the military with the federal government in responses, particularly when referencing the military's significant resources and

trustworthiness (or lack thereof). One participant declared that "neither the government nor the military could be considered appropriate funders due to current & previous lack of public trust & transparency." In aggregate, participants portrayed the military as a well-funded and effective organization, but one which might misuse research outputs or disregard important stakeholder interests in the research process. Capturing many of these themes, one participant asserted that a "military agenda could be a great danger to the science … or use … the power to test trial on other countries. Funding could be large but the risks of Congressional approval leave the doors open for climate change deniers and individuals who don't believe in science to make choices."

Mapping of Funders to Research Directions

Here we discuss patterns of agreement among participant groups for linking funders to research directions. By tracing funder selections to research direction selections, we found that the scale of a group's research direction influenced its selection of funders. Many groups that chose smaller-scale research directions that required less funding discussed small-scale pilot funders as sufficient in their rationales. These pilot funders included combinations of funding from universities, philanthropies, and non-governmental organizations (see Appendix 3.2.3). Just as groups mentioned the potential to scale-up research in the future, they explained that additional funding sources could be included as funding demands increase.

Though some groups that chose only small-scale research methods included small-scale funders, the majority selected a combination of small funders (universities, NGOs, and philanthropies) with the federal government. In the rationale section, groups highlighted existing partnerships between the federal government and the small funders. Their rationales focused on including the federal government in the funding mix as a source of financial resources, while also providing both national and international funding resources, and funding transparency.

For the higher-investment research directions such as *Decentralized* or *Centralized Research*, participants sought to diversify their funding sources and included the military and corporations as funders more frequently. Corporations specifically appealed to groups that favored "voluntary funding" and the creation of competition. Beyond garnering more funds, some groups viewed the inclusion of multiple funders as a mechanism for ensuring broader stakeholder inclusion in decision making.

3.3 Session 3 - Decision Making

Session 3 Summary

In Session 3, participants articulated their preferences about the governance of SRM research. We framed governance in terms of a) the entities that make decisions about SRM research and b) the priorities those entities use to make decisions. At the beginning

TABLE VIGNETTE, *part 4:* **Research funding and governance**

Participants implicitly linked funding sources with questions of governance, funder motivations, and accountability to the public will. Conversation about these topics was notably more superficial than discussions about research methods and research implementation. Whereas during the earlier sessions participants were eager to explore where differences existed and worked to understand each other's perspectives, in these latter sessions they tended to find approaches about which they more-or-less agreed and called it "good enough." This seemed to result both from fatigue at the end of the day and from a recognition that governance more directly related to political ideologies that clearly varied within the group and were more deeply personal.

Balancing concerns and interests of other nations came up as an important topic early in the morning's discussion but did not play a central role after that, likely because the materials and activities were largely oriented around domestic actors.

of this session, participants watched an introductory video that reviewed five decision-making priorities (these had also been explained in the pre-forum briefing materials). After the video, facilitators asked participants to consider the five priorities and their corresponding policy examples (Figure 3.3.1). We designed this activity to familiarize participants with various aspects of SRM governance. Groups selected five of the 15 policy examples for inclusion in their SRM research plan by cutting out these examples and taping them to their group deliberation boards. Participants then individually ranked the decision-making priorities on individual worksheets.

In the session's second half, participants selected among 5 SRM research decision-makers. Groups chose one or more decision-makers that they wanted to be involved in the governance of their research plan. Following this selection, groups wrote a brief explanation of the research plan they had constructed over the previous three sessions, in the "Explain your original plan" section on the group deliberation board.

Session 3 Results

Researcher presence in policymaking was the most common policy example selected (by 16 groups); most groups did not seem concerned with intellectual property rights (selected by 2 groups) (see Appendix 3.3 for more details). While there were large differences between dimensions of governance in this exercise, groups prioritized transparency and flexibility in SRM research practices over public involvement, enforcement, and researcher interests. This same pattern played out with individual ranking of decision-making priorities and accompanying participant rationales, with flexibility and transparency receiving the highest percentage of positive references in these rationales. Open-coding of rationales revealed sub-categories of priorities (Table 3.3.2) that influenced participant perceptions and selections of overall decision-making priorities.

People viewed transparency in diverse ways. Notably, all of the decision-making priority categories were reflected in statements about transparency, suggesting that many people were seeing transparency as a linchpin for all the decision-making priorities. The following participant statement tied together three other decision-making priorities (public involvement, enforcement, and researcher interests) with transparency: "Transparency is important and fundamental for everything from public involvement and support, to governance and enforcement, to good research and science."

The most common sub-category of transparency was "Openness to the public" (62 statements), which links transparency to public involvement: "[The] public should be involved so transparency is needed to have [the] public make informed decisions." Another sub-category related to public involvement was "Creates public support" (13). A number of participants believed that transparency promotes enforcement (30). For instance, one participant characterized the process like this: "Enforcement and transparency are important because it holds researchers accountable and helps the public understand where researchers are in their processes." Some also saw transparency subtly influencing enforcement, in that "transparency involves clarity of purpose and gives incentive to researchers to collaborate and adhere to objectives." To a lesser degree, participants linked flexibility of research process with transparency (11). One way that people viewed this process was that transparency of research results would allow decision-makers to see all options before proceeding: "I would like the process to be (reasonably) open so that there can be input from (knowledgeable, hopefully) members of the public, but I would also like it to be responsive and able to make changes quickly when appropriate."

Enforcement emerged as the most straightforward decision-making priority category (Table 3.3.2), with most participants simply stating that enforcement is necessary for public accountability (72). Very rarely did participants delve into the mechanisms of enforcement, but 14 participants stated that good science would lead to de facto enforcement, and one participant saw a similar role for the market. However, some people mentioned financial penalties, independent inspections, and unspecified rules and regulations as mechanisms of enforcement. Linked to the notion of transparency, many participants stated that constant monitoring was necessary to make sure experiments remained safe. Monitoring was also essential to some people in order to promote "common standards and acceptability. Research cannot be conducted to its fullest potential if there is chaos and non-uniformity."

Figure 3.3.1: Decision-making priorities and decision-maker cards.

Flexibility

Ongoing research and technological development can often lead to unexpected problems or discovering new avenues of research. A flexible system that can adapt and respond to these issues quickly will help the research move forward, or not, depending on the situation.

A flexible system requires significant resources and fast decision-making may mean that not every stakeholder can be included in the decision-making process.

Policy Examples:

Constant monitoring of ongoing research projects

Anticipatory expert advice to decision-makers

Frequent review and revision of standards, regulations, and procedural requirements

Enforcement

Many researchers follow a set of general principles that guide their research to make sure they are following safe procedures and working toward project goals. It is important to have consequences for any actions that could compromise the project or risk safety. Consequences can range from formal or informal reprimands, to the withdrawal of funding or support, to legal action, depending on the situation.

The monitoring and action required for enforcement require workforce and financial resources—the more intensive the monitoring, the greater the costs.

Policy Examples:

Penalties for deviation from standards

Regular inspections to ensure compliance

Independent review processes to validate adherence to standards and principles

Transparency

The public should be informed about what local, state, and federal policy decisions are being made in a clear and accessible way. Many policy-makers, researchers and community leaders are unsure of where to strike the balance between transparency and other important goals, such as efficiency or intellectual property rights.

Having a transparent process means anyone can be aware of the decisions being made. This may slow down the process, disincentivize research with commercial potential, or make it difficult to make tough decisions.

Policy Examples:

Openly available documentation on all policy proposals and policymaker discussion

Regular "state of SRM research" reports for general audiences

Public research proposal review and approval process

Public Involvement

Public involvement in the policymaking process helps to ensure that the community's needs and values are considered throughout the process.

However, Public involvement in decision-making can be time- and resource-intensive. With so many different interests involved, it could mean that no decision is made due to too many conflicting opinions.

Policy Examples:

Public impact reports for proposed research

Public comment periods on policy and open community for engagement with decision-makers

Democratically selected decision-makers or policy options

Responsiveness to Researcher Interests

SRM research potentially involves many stakeholders and interests. But it's unlikely to happen if researchers and funders don't feel the system will help them accomplish their goals, whether those are increasing knowledge or the development of a profitable product. Having decision makers who respond to researcher interests could ease and incentivize research.

It is possible to overrepresent researcher and funder interests at the expense of the public. This could be detrimental to providing a public good or even to public safety.

Policy Examples:

Strong intellectual property protection

Explicit researcher presence in policy making process

Regulators set broad rules that are left to the researcher's interpretation and application

Table 3.3.2 Numbers of participant statements for each sub-category of governance priorities identified through open-coding (n = 171 statements). Positive and negative categories are included below (negative sub-categories are italicized). Only combined analysis for Arizona and Massachusetts is shown.

GOVERNANCE PRIORITY MAIN CATEGORY/SUB-CATEGORY	# of Statements	PRIMARY/SECONDARY THEME	# of Statements
ENFORCEMENT		FLEXIBILITY	
For public accountability	72	Governance process	51
Through good rules of science	14	Vetting new and untested	32
As transparency	7	Researcher decision-making	23
On a global scale	2	Generates diverse ideas	8
Through the free market	1	Undefined	8
Hinders progress	4	*Creates bias*	2
TRANSPARENCY		PUBLIC ENGAGEMENT	
Openness to the public	62	People should have a say	51
Promotes enforcement	30	Create awareness/education	31
Fundamental to governance	27	Encourages enforcement of rules	8
Good science	17	To save the environment	6
Creates public support	13	*Public shouldn't interfere*	13
Next research steps are flexible	11	*Hinders progress*	17
Undefined	9	RESEARCHER INTEREST	
Trust	8	Scientists know best/bring legitimacy	36
Aids cooperation	6	Helps motivate scientists	23
Generates clear facts	4	Promotes value free autonomy	11
Hinders progress	1	Inclusive/serves others	3
		Detrimental to the public	9
		Not a priority	7

For many participants, flexibility was essential to governance (51, Table 3.3.2). Participants believed that the newness and experimental nature of SRM research creates a lot of uncertainty. This participant's statement sums up this sentiment: "This is a wholly new approach. Chance must be easily accommodated." Another fairly common sentiment was the idea that researchers should have the flexibility to adjust research projects as new data becomes available (23). One participant characterized the need to give researchers a fair amount of autonomy in the early stages of research: "At the level of basic research, the most important factors revolve around getting the maximum number of ideas and opportunities in order to fully understand the next steps and direction." This idea relates well to how a fair number of participants saw the role of experts, as most positive statements about research interest expressed the need for researcher autonomy (11) and trusting scientists to make decisions about research (36). Interestingly, research interests garnered the second most negative statements ("Detrimental to the public" = 9; "Not a priority" = 7) and generated the least number of statements of all of the governance priorities, suggesting that researcher autonomy was not a high priority for participants.

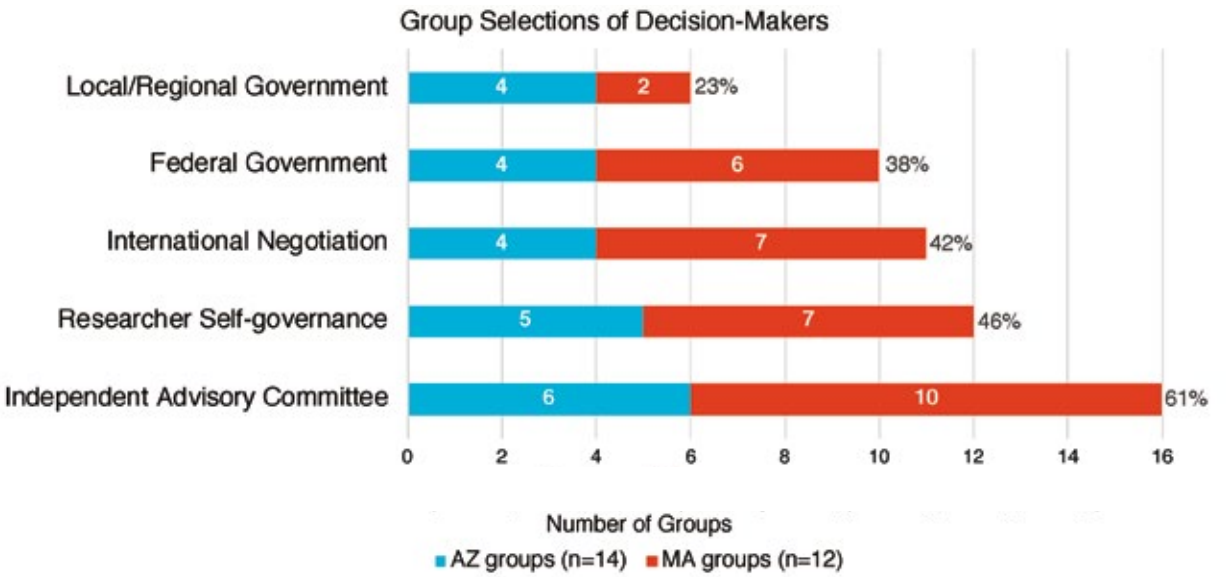
Participants were divided about the role of the public in SRM research (Table 3.3.2). While most statements about public engagement were positive, a number of

participants felt that public engagement could hinder progress (17) or felt that the "public shouldn't interfere" with research (13). Most participants who commented on public engagement saw it as a vital tool for educating citizens about the issue (31) or providing input into decision making (51). For example, one participant claimed, "We need solutions quickly, so optimizing speed should be a priority. However, the public should be informed and educated, and even have some input into project priorities." So on the one hand, this person describes the situation with climate change as urgent, but on the other hand, believes public participation is vital to good governance. Based on the open-coding analysis of participant rationales, "transparency"—considered in a number of ways, including public involvement, flexibility, good science, encouraging cooperation, promoting public support, and public accountability—seems key to the conditional acceptance of SRM research centered on computer modeling and small-scale field trials.

However, we found considerable disagreement on who should be in charge of ensuring proper governance of SRM research (Figure 3.3.3). In Arizona, there was very little agreement on decision-makers, with the *Independent Advisory Committee* receiving the highest preference level and *Researcher Self-Governance* the second-highest. In Massachusetts, most groups chose the *Independent Advisory Committee; International Negotiation*, *Federal Government*, and *Researcher Self-Governance* were each selected by at least half of the groups.[23]

The discrepancy between Arizona and Massachusetts can probably be explained by demographic differences in the region (Arizona is more conservative, ethnically diverse, and has lower education levels). But it is important to remember that most people did conditionally accept SRM research as a fruitful endeavor. Past studies have likewise identified areas of agreement on the conditions of governance,[24] but have done little exploration of what institutions the public would trust to govern SRM research. The results of this study suggest that finding an institutional decision maker that everyone can trust might be challenging. Regardless of the governance plan, the public perception of the governing institution will matter when it comes to whether people trust it.[25]

Figure 3.3.3: Group decision-maker preferences from Arizona and Massachusetts. Percentage of groups is noted in parentheses. Percentages add up to great than 100% because groups could choose up to three decision-makers.



Mapping of Decision Makers to Research Directions

A group's preference about scale of research activity also factored into its selection of decision makers (Table 3.3.4). Specifically, groups that chose smaller-scale research activities excluded certain decision makers such as the military and corporations. For small-scale research (computer modeling/lab-based research, small-scale field trials), a combination of *Researcher Self-Governance, Independent Advisory Committees*, and *Federal Government* was one of the most popular groupings (4 groups). These groupings excluded *International Negotiation*, which some groups viewed as unnecessary for small-scale SRM research in their rationales.

The other most frequently selected decision-maker group for small-scale research directions focused solely on expert governance (4 groups). Participants felt that beyond governance by either the researchers themselves, an independent advisory committee, or a combination of the two, there was "no need to have more [decision makers] at this scale." Many groups incorporated formal governance along with expert knowledge, selecting *Researcher Self-Governance* and *Independent Advisory Committees* with combinations of *Local/Regional Government, Federal Government*, and *International Negotiation*. Nonetheless, for small-scale research, there was a tendency for groups to accept less oversight and less consideration of international input.

For larger-scale research directions, groups opted for broad-based decision making, typically including two to three different decision makers. At both scales, many groups discussed the global nature of the problem and subsequent need to include international negotiation. This may indicate a perceived blurring of the boundary between research and deployment associated with larger-scale research efforts, hinting at a presumption that with larger-scale research efforts, deployment may inevitably follow SRM research. Groups also strongly emphasized the inclusion of certain decision makers to ensure representation of impacted communities; in some cases, this referred to regional government and local communities while other times it referenced the global community.

Overall, no singular pathway linked groups' selections of research directions to both a particular funder *and* a specific decision maker. At most, three groups shared the same selection pathway of similar funders and decision-makers. This pathway involved small-scale research, funded by small-scale funders and government, and governed by experts only. The lack of a singular dominant pathway suggests the possibility of multiple acceptable governance strategies for geoengineering research.

Session 4 - Hypotheticals

Session 4 Summary

In the forum's final session, we introduced participants to several possible future developments in climate change, climate change research, and the geopolitics of SRM in the form of hypothetical scenarios (Figure 3.4.1). These scenarios were designed to provide a sense of the large and multi-sectoral uncertainties with which the design of any research plan must grapple.

Groups were intended to consider two climate change scenarios, one projecting significant sea level rise and one projecting limited warming with less severe climate impacts. Additionally, they were assigned one other scenario to consider from the following: 1) technical developments lower the cost of solar power below that of fossil fuels; 2) technical developments lower the cost of stratospheric aerosol injection methods below the cost of mitigation strategies; 3) China unilaterally announces intent to pursue SRM research; or 4) an international body passes a resolution calling for a moratorium on SRM research. After considering each scenario, we asked groups to note how the scenario would affect their research plans.

Not all groups, however, strictly followed instructions; some groups wrote considerations for all of the scenarios on their response sheets while others did not complete the response sheet at all. At the session's end, groups were invited to revise their original research plans in the "Explain your final plan" space on the group deliberation board, considering the possibilities or risks highlighted by their reviewed scenarios.

Responses to presented scenarios were somewhat sparse, with only 13 groups (of 23 responding and 26 in total) suggesting any changes to their research plans in response to any of the scenarios they re-

Table 3.3.4: Opening-coding of five types of Research Direction Groupings. The percentages indicate the number of groups that relate to that category. Groups are assigned to only one category.

CATEGORY	DESCRIPTION	Percentage of Group Selection (n = 26 groups)
No SRM	No SRM research or conditional acceptance of small-scale research **Cards Combinations:** • No SRM and Computer modeling / lab-based research and Small-scale field trials	4% (1)
Small-scale research	Pursue small-scale, low investment research **Card Combinations:** • Computer modeling / lab-based research and Small-scale field trials • Small-scale field trials	58% (15)
Decentralized research	Explore many SRM research projects via decentralized, high-investment research **Card Combinations:** • Computer modeling / lab-based research and Small-scale field trials and Decentralized, high-investment research	11% (3)
Coordinated research	Support a strong SRM research push with coordinated, high-investment research **Card Combinations:** • Computer modeling / lab-based research and Small-scale field trials and Coordinated national effort • Small-scale field trials and Coordinated national effort • Computer modeling / lab-based research and Coordinated national effort • Coordinated national effort	19% (5)
Both centralized and decentralized research	Maximize potential for research success with both decentralized and coordinated high-investment research. **Card Combinations:** • Decentralized, high investment research and Coordinated national effort	8% (2)

viewed (Appendix 3.4). For no single scenario did more than 40% of groups adjust their plans. No group carried over the changes suggested in their discrete hypothetical scenario responses to their final group plan.

We suspect that groups' limited responses to the hypothetical scenarios relates to several factors. First, table observers noted that groups worked hard to arrive at their shared plans over the course of the deliberation and may have been reluctant to revisit or alter their hard-won consensus positions. Second, based on written responses, we believe that participants may not have appreciated the significance of the difference between scenarios outlined in the cards and current climate projections. Third, Session 4 was the last session of the day, and table observers reported

that many participants appeared fatigued or disengaged during this portion of the deliberation. Any or all of these factor (or others we haven't thought of) may have affected the apparent reluctance of groups to further modify their research plans in Session 4.

3.5 Research vs. Deployment Analysis

The forums were intended to elicit public opinion on the governance of SRM research. Prior work indicates that the public can and does distinguish between geoengineering research and geoengineering deployment.[26] Here, we analyze participants' individual written statements to determine whether this held true in our forums. We also assess how participants related to or invoked ideas of SRM research and potential or actual SRM deployment in making and justifying their choices for research directions, funders, and decision makers.

A binary coding scheme of "research" or "deployment" proved ineffectual for handling the ambiguity of participants' statements. Instead, we conducted an open-coding analysis to develop three large categories of statements capturing the relationship of research to deployment (see Appendix 3.5). The first category captures statements that clearly focus solely on SRM research. An example: "Computer modeling is a good starting point and could provide an idea of real world results."

Statements discussing the consequences of research, including potential movement toward future SRM deployment, were coded into the second category. These statements include discussions about the pressing need to address climate change, as one participant puts it, "Because of climate change we need to do something." Other statements express concerns about potential positive or negative physical or environmental effects. One participant explains, "Small-scale trials seem like the best option due to actually testing in real world conditions just in a smaller area so there [are] less global effects if trials are producing undesirable consequences." Some rationales discuss implementation of SRM research on a large scale: "It may be better to start small, determining the presence of beneficial and adverse events, weighing those results, and deciding whether to move to large scale efforts if benefits outweigh risks." In this rationale, it is difficult to determine whether "large scale efforts" refers to further research efforts or a progression to deployment. Complicating this distinction is the recognition that the line between large-scale field trials and deployment is in any case difficult or impossible to specify for some SRM methods, such as stratospheric aerosol injection.[27] Overall, however, statements in this category appear to recognize the distinction between research and deployment, even with considering potential future deployment when making research governance selections.

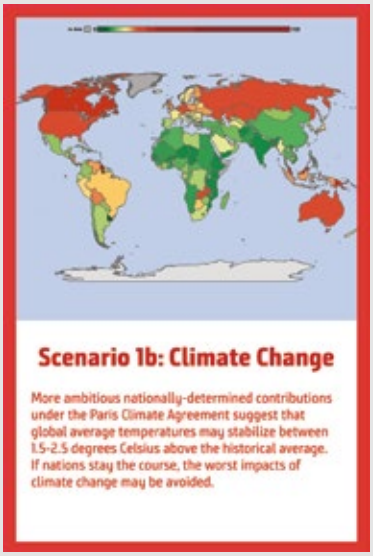
Statements discussing SRM deployment by either researchers or by others were coded into the third category. Some sample responses include: "[Military:] They are currently weaponizing weather and are the global leader in pollution" and "Given the scope of the problem, there is no possibility of significant advances or implementation w/out federal-government involvement & funding." In these rationales, participants viewed deployment as already under way, or are making decisions under the assumption that the current end goal of research must be deployment.

The results of the coding analysis revealed that participants did mostly restrict their thinking to SRM research (Appendix 3.5). Only three percent of participants' statements referenced deployment occurring in the present, while the remaining 97% of rationales corresponded to the first two coding categories. To more clearly determine whether participants have difficulty separating considerations of research and deployment, especially for open-ended issues such as environmental effects and scaling, the research team would need to conduct a different forum specifically looking at this distinction. However, our results suggest that people are capable of understanding the distinction between research and deployment, and exercised that understanding during our deliberations.

Figure 3.4.1 Hypothetical scenario cards.

Scenario 1a: Climate Change

New predictions suggest that the average sea level rise due to climate change is likely to be higher than expected—more than 3 feet in some places by 2100. this amount of sea level rise could significantly impact coastal cities like New York, New Orleans, and Miami, and may have a severe impact on low-lying islands, cities, and countries around the world.

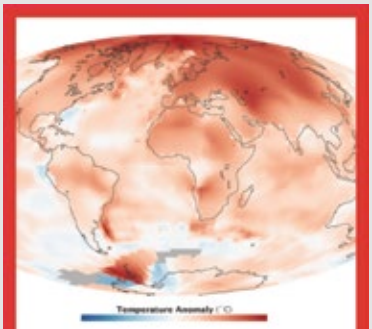


Scenario 1b: Climate Change

More ambitious nationally-determined contributions under the Paris Climate Agreement suggest that global average temperatures may stabilize between 1.5-2.5 degrees Celsius above the historical average. If nations stay the course, the worst impacts of climate change may be avoided.

Scenario 2a: Technical Developments

Major investments in solar panel production drives the commercial cost of solar power below that of fossil fuels. Solar power providers begin to significantly compete with fossil fuel utilities across the United States.



Scenario 2b: Technical Developments

Preliminary trials suggest that stratospheric aerosol injection could reduce global average temperature by 1 degree Celsius at a cost of about $100 billion dollars a year, which is relatively inexpensive compared to other mitigation strategies. However, the risks of SRM implementation remain uncertain.

Scenario 3a: Geopolitical Developments

China announces its intent to pursue SRM research regardless of other nations' actions.

Scenario 3b: Geopolitical Developments

An international governing body passes a resolution calling for a moratorium on SRM research, similar to the Paris Agreement.

4. Synthesis of Analysis

This project sought to learn how a diverse set of lay citizens, armed with basic background knowledge but not (for the most part) otherwise having a direct stake in the issue, would deliberate among themselves to develop guidance and principles for the governance of research on emerging solar radiation management technologies in the context of global climate change.

In a political era that seems to be characterized by deep polarization, we begin by emphasizing that our effort demonstrates that highly diverse groups of citizens will enthusiastically participate in civil, serious-minded, and productive deliberation on contentious issues if given the opportunity. This is perhaps the most robust conclusion arising from this and other, similar deliberations conducted over the past five years.[28]

Our many deliberative exercises—on topics including geoengineering, asteroid research, and autonomous vehicles—also demonstrate that citizens who lack area expertise are highly capable of productive deliberation about the societal aspects of scientifically and technologically complex matters. The basic background materials that we developed and provided to our deliberators gave them the foundation they needed to apply their own knowledge, experience, values, and common sense to the collective reasoning process.

The results of this project, then, provide a perspective that does not and cannot easily emerge from politics as usual—that, in fact, is suppressed by politics as usual. Standard political discourse gives voice to interested stakeholder groups and experts, but not to everyday people whose lives may nonetheless be profoundly and materially affected by decisions being made. Our 171 participants represented a broad political and demographic cross-section of America. We emphasize that our results are not (and not intended to be) statistically meaningful. Nor are they analogous to a focus group approach. Rather, they tell us how citizens may reason together to map out diverse perspectives about the matter at hand.

Our forums demonstrate that diverse groups of citizens can indeed deliberate productively on the matter of SRM research governance; that is, lay citizens can acquire both new knowledge and, through collective reasoning, new perspectives on the subject. Importantly, in this regard, the results of our deliberations do not simply mirror the priorities and concerns of experts and engaged stakeholders. Our citizens were not, for example, stymied by some areas of disagreement that at times block productive discussions among experts and interest groups. Moreover, at the level of both individual participants and small deliberative groups, our forums yielded new insights about how people view the difficulties and the opportunities of governing SRM research. Our results challenge some assumptions held by experts and interest groups, while expanding the range of ideas, opportunities, and options available in developing governance regimes. We would not claim that our results can or should be directly applied to the specific design of such regimes, but we do think they provide some quite concrete constraints and perspectives to inform such design efforts.

The overriding point that emerges from our forums is that citizens hold in dynamic tension two ideas about SRM research. First, the great majority of our participants feel that some sort of SRM research is a good idea simply because acquiring more knowledge is a good idea. Second, again for most participants, SRM research approval is nonetheless conditional; they are not offering a carte blanche acceptance of SRM research or technology. Our citizens recognize the difficulty of acquiring reliable knowledge; and they recognize that there is no obvious optimal research path to pursue or research governance model to adopt.

Despite this tension and ambiguity, as we've noted, our participants did not find some of the points of major controversy among experts to be roadblocks to deliberation or even to achieving a degree of consensus. In particular, some experts have portrayed the fuzzy boundary between SRM research and deployment as a slippery slope leading inevitably to geoengineering. Our citizens did not, for the most part, buy into this concern. Rather, they were able to discuss research on its own merits, even as they were clearly aware of the difficulty of drawing a sharp line between research and deployment. This awareness led to a general preference for small-scale experiments and modeling work, and an emphasis on incremental approaches to research. And while some of our citizens were sensitive to the moral hazard argument, on the whole they did not

find it a compelling reason to bar research, even as they made clear that SRM should not be seen as a substitute for mitigation and adaptation.

Rather than further summarize the specific results presented above, we want to highlight three broad areas of concern that emerged from these deliberations, and that may help to inform future research governance efforts. The first two concerns reflect sensibilities widely shared among our forum participants; the third reflects an important source of disagreement.

1. *Naturalness is preferred*. Citizens strongly prefer research on SRM approaches that seem to them more "natural" over those that add new chemicals and materials to the atmosphere. The collective intuition here is a concern for unintended environmental risks created by the introduction of unnatural substances into the climate system. This appears to be a robustly held sentiment among our participants, and pushes against current expert assumptions. Stratospheric aerosol injection, which is probably the approach most widely discussed by scientists, was favored by less than 20% of our deliberative groups.

2. *Transparency is required*. The governance principle most strongly articulated and shared in our forums is transparency, although the meaning of the term is not sharply delineated. Yet the sentiment being expressed by our citizens seems quite clear: they expect that SRM research be sponsored by trusted institutions, conducted openly and in a publicly accountable manner, and protected from capture by biased or interested parties.

3. *Who shall govern?* That SRM research does indeed require good governance was also a shared sensibility among our participants, as we have emphasized. But when it comes to institutional choices about where funding, governance responsibilities, and decision making should be located, disagreement emerges. This disagreement may in part reflect the different political environments of our forum locations, Phoenix and Boston. It may also reflect a lack of strong criteria for choosing among the options that we presented in the background material. Yet results do reflect some general sense that "independent" and "self-governing" approaches to governance are preferred to those of formal government bodies at either the national or local level. Given the lack of consensus on these matters, we want to flag these questions of institutional choice as an important area for future research on public concerns and how best to meet them.

The role of geoengineering approaches like SRM in meeting the challenge of climate change is at this point entirely unpredictable. A decade or more of attention to the need for developing appropriate governance mechanisms for SRM and other geoengineering approaches is especially notable given the non-existence of any concerted scientific or engineering research on SRM options, let alone the technical capacity to implement such options.

Yet this anticipatory attention to governance is appropriate and encouraging. It is furthermore an opportunity to draw on the "intelligence of democracy" by involving lay publics in the discussion. The stakes couldn't be higher, the uncertainties enormous, and the values implicated in making choices highly diverse and to some extent incommensurable. Under such conditions, the special value of expertise for guiding decisions is quite reduced because the matters under consideration are only loosely determined by agreed-upon expert knowledge. Different experts are aligned with different sets of stakeholder interests. The questions, for the moment, remain largely political and value-based.

Yet the sharp disagreement that characterizes expert and stakeholder debates about SRM and geoengineering is not reflected in the findings from our participatory technology assessment deliberations. Our diverse group of citizens have mostly ended up on the same page here, and we see this as the most interesting and possibly most valuable finding of our project. If the message from our citizens is not entirely coherent, it is nonetheless quite clear: keep things small; govern transparently, flexibly, and inclusively; learn from past mistakes and be prepared to reverse course. Proceed—but with caution.

Moving Forward

Climate change is, of course, a global challenge. Effective responses to it must be at a commensurate global scale. If SRM is to one day be considered a viable approach to avoiding the worst effects of climate change, research into potential deployment, along with the governance of that research, should be a worldwide effort. There is value, therefore, in understanding public perceptions of SRM research in countries where research might occur and in neighboring countries where the effects of such research could be experienced.

These forums show that citizens take an interest in discussing SRM research, reflect about it in a nuanced way, and have opinions about it that differ to some extent from those of experts and other stakeholders. For these reasons, the organization of more public forums is highly recommended, both in additional countries and as transnational citizen forums. The following are a few reflections on the rationale for doing so; with which governance structures and decision-making procedures this project should connect; and what adjustments to the forum format might be useful.

Forums in more countries promote public engagement in SRM research agenda-setting, such as what SRM research agendas should include (e.g., risks, reversibility options). They contribute new inputs (citizens' views) to discussions about SRM governance frameworks.

International-level researchers, funders, and policymakers would be the primary target groups with which to share these forum results, but stakeholder and civil society groups would be important to include as well. In countries with SRM research agendas in place or in the making, citizen forums on SRM are highly recommended.

Transborder citizen forums engage citizens in neighboring countries to countries with SRM research activities, potentially bringing new and different insights. These forums could make citizens, experts, and policymakers more aware of potential transnational consequences of SRM research and deployment, and potential conflicts of interest between countries and stakeholder groups. Such forums would be multilingual and could be conducted with the help of translation services.

Global citizen consultations with forums discussing identical sets of questions are increasingly relevant as the United Nations intensifies discussions about the governance of SRM. In this case, the deliberation format should be revised to focus on policy options more closely connected to those being discussed at the UN level.

From method to manual

If this forum were to scale to other countries and be used for national and transborder citizen dialogues, it would help to turn the method into a manual that local stakeholders could use without requiring expertise in SRM or public engagement. Turning the method into a manual would involve explaining:

- How to engage researchers, funders and policymakers in the national forums.
- How to analyze and present results at the national level in an accessible format.
- Making videos, deliberation cards, background materials, etc. available in a format that allows for translation into multiple national languages.
- Simplifying the forum method as much as possible; suggesting a simple framework for analyzing results and making conclusions about the citizens' views on SRM.

Next steps

The US forum results should be of considerable interest to a number of different target groups, such as researchers, funders, journalists, and policymakers in other countries and at the UN level. We recommend developing and implementing a communication strategy for presenting and disseminating our results to these groups.

Bjørn Bedsted, Global Coordinator of World Wide Views and Head of DBT International at the Danish Board of Technology Foundation

Endnotes

[1] National Research Council. (2015b). Climate Intervention: Reflecting Sunlight to Cool Earth. Washington, DC: National Academies Press.

[2] NRC 2015; United States Global Change Research Program. (2017). *The National Global Change Research Plan 2012-2012: A Triennial Update*. Washington, DC: USGCRP.

[3] Dykema, J. A., Keith, D. W., Anderson, J. G., and Weisenstein, D. (2014). Stratospheric controlled perturbation experiment: a small-scale experiment to improve understanding of the risks of solar geoengineering. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *372*(2031).

[4] Keith, D. W., Duren, R., and MacMartin, D. G. (2014). Field experiments on solar geoengineering: report of a workshop exploring a representative research portfolio. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 372*(2031).

[5] Pierrehumbert, R. T. (2017). The trouble with geoengineers "hacking the planet." *Bulletin of the Atomic Scientists*. Retrieved from http://thebulletin.org/trouble-geoengineers-"hacking-planet"10858

[6] Lin, A. C. (2013). Does Geoengineering Present a Moral Hazard? *Ecology Law Quarterly, 40*, 673-712; **Corner, A., and Pidgeon, N. (2014).** Geoengineering, climate change skepticism, and the "moral hazard" argument: an experimental study of UK public perceptions. Philosophical Transactions of the Royal Society A, 372, 20140063. dx.doi.org/10.1098/rsta.2014.0063

[7] Cairns, R. (2017). Solar Geoengineering Research and the Social Sciences. In *Forum on U.S. Geoengineering Research*. Washington, DC: Carnegie Endowment for International Peace.

[8] Szerszynski, B., Kearnes, M., Macnaghten, P., Owen, R., and Stilgoe, J. (2013). Why solar radiation management geoengineering and democracy won't mix. *Environment and Planning A, 45*, 2809-2816.

[9] Corner, A., Pidgeon, N., and Parkhill, K. (2012). Perceptions of geoengineering: public attitudes, stakeholder perspectives, and the challenge of "upstream" engagement. *Wiley Interdisciplinary Reviews: Climate Change*, *3*(5), 451–466. doi:10.1002/wcc.176; **Cairns, R. (2013).** Geoengineering: issues of path-dependence and socio-technical lock-in. Background briefing for The Climate Geoengineering Governance Project. Retrieved from http://geoengineering-governance-research.org/perch/resources/background-briefing.pdf

[10] Burns, E. T., Flegal, J. A., Keith, D. W., Mahajan, A., Tingley, D., and Wagner, G. (2016). What do people think when they think about solar geoengineering? A review of empirical social science literature, and prospects for future research. *Earth's Future*, *4*(11), 536–542. doi:10.1002/2016EF000461

[11] Bellamy, R., Palmer, J., and Lezaun, J. (2015). *Report on Public Engagement in the Climate Geoengineering Governance Project*. Retreived from http://geoengineering-governance-research.org/perch/resources/a-report-on-cgg-public-engagement.pdf

[12] Bellamy, R., Chilvers, J., and Vaughan, N. E. (2016). Deliberative Mapping of options for tackling climate change: Citizens and specialists "open up" appraisal of geoengineering. *Public Understanding of Science*, *25*(3), 269–286. doi:10.1177/0963662514548628

[13] Rourke, B. (2014). *Developing Materials for Deliberative Forums*. Kettering Foundation. 200 Commons Road, Dayton, OH 45459.

[14] E.g., Burns, E. T., Flegal, J. A., Keith, D. W., Mahajan, A., Tingley, D., and Wagner, G. (2016). What do people think when they think about solar geoengineering? A review of empirical social science literature, and prospects for future research. *Earth's Future*, *4*(11), 536–542. doi:10.1002/2016EF000461

[15] Kerr, A., Cunningham-Burley, S., & Tutton, R. (2007). Shifting subject positions: Experts and lay people in public dialogue. *Social studies of science*, *37*(3), 385-411.

[16] E.g., Tomblin, D., Worthington, R., Gano, G., Farooque, M., Sittenfeld, D., Guston, D., ... & Kaminski, A. (2015). Participatory technology assessment of NASA's asteroid redirect mission. In *66th International Astronautical Congress 2015: Space-The Gateway for Mankind's Future, IAC 2015* (pp. 10307-10319). International Astronautical Federation, IAF.

[17] Van Oudheusden, M. (2011). Questioning 'participation': a critical appraisal of its conceptualization in a Flemish participatory technology assessment. *Science and Engineering Ethics*, *17*(4), 673-690.

[18] Tomblin et al. 2015. (Full citation above)

[19] Guston, D. H. (2011). Participating despite questions: toward a more confident participatory technology assessment. *Science and Engineering Ethics*, *17*(4), 691-697.

[20] Bellamy, R., Lezaun, J., & Palmer, J. (2017). Public perceptions of geoengineering research governance: An experimental deliberative approach. Global Environmental Change 45, 194-202. https://doi.org/10.1016/j.gloenvcha.2017.06.004.

[21] See Bellamy, Lezaun, and Palmer 2017; Macnaghten, P., and Szerszynski, B. (2013). Living the global social experiment: An analysis of public discourse on solar radiation management and its implications for governance. *Global Environmental Change*, *23*(2), 465–474. doi:10.1016/j.gloenvcha.2012.12.008; Wibeck, V., **Hansson, A., and Anshelm, J. (2015).** Questioning the technological fix to climate change – Lay sense-making of geoengineering in Sweden. *Energy Research & Social Science*, *7*, 23–30. doi:10.1016/j.erss.2015.03.001; and Burns, Flegal, Keith, Mahajan, Tingley, and Wagner 2016.

[22] See Wibeck, V., Hansson, A., Anshelm, J., Asayama, S., Dilling, L., Feetham, P.M., Hauser, R., Ishii, A., & Sugiyama, M. (2017). Making sense of climate engineering: a focus group study of lay publics in four countries. Climatic Change 145, pp. 1-14.; **United States Government Accountability Office (2011).** '5. Potential responses to climate engineering research', in *Climate Engineering: Technical Status, Future Directions, and Potential Responses* (GAO-11-71), USGAO, Washington, DC, pp. 61-70.; **Pidgeon, N., Parkhill, K., Corner, A., and Vaughan, N. (2013).** Deliberating stratospheric aerosols for climate geoengineering and the SPICE project. *Nature Climate Change*, *3*(5), 451–457. doi:10.1038/nclimate1807; **Parkhill, K., N. Pidgeon, A. Corner, & N. Vaughan (2013).** "Deliberation and Responsible Innovation: a Geoengineering Case Study." In R. Owen, J. Bessant, & M. Heintz (eds.), Responsible Innovation (First Edition) (pp. 219-239). Hoboken, NJ: John Wiley and Sons.

[23] Data for individual decision-maker choices and rationales is not available. The forum designers made the decision to limit the amount of data collected at the end of the day, as it is common for people to have deliberation fatigue. Future studies should dig deeper on who people would trust to govern SRM research.

[24] E.g., Bellamy, R., Lezaun, J., & Palmer, J. (2017). Public perceptions of geoengineering research governance: An experimental deliberative approach. Global Environmental Change 45, pp. 194-202.; Parkhill et al. 2013.

[25] Pidgeon et al. 2013.

[26] Corner et al. 2012; Burns et al. 2016.

[27] Hulme, M. (2012). Climate change: climate engineering through stratospheric aerosol injection. *Progress in Physical Geography*, *36*(5), 697.; **Frumhoff, P. C., & Stephens, J. C. (2018).** Towards legitimacy of the solar geoengineering research enterprise. *Philosophical transactions of the royal society A: mathematical, Physical and Engineering Sciences*, *376*(2119), 20160459.

[28] E.g. Tomblin, David, Worthington, Richard, Gano, Gretchen L., Farooque, Mahmud, Sittenfeld, David and Lloyd, Jason. (2015). Informing NASA's Asteroid Initiative: A Citizen's Forum (Full Report). *Consortium for Science, Policy & Outcomes*.; **World Wide Views on Biodiversity (Results Report). (2012).** ***The Danish Board of Technology.***; **and World Wide Views on Climate and Energy (Results Report). (2015).** ***The Danish Board of Technology.***