

Advancing Solar Radiation Modification Governance and Research

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Giving Green

Table of Contents

Table of Contents **1**
Summary **2**
Introduction **5**
Refining Our Research Scope 8
Stratospheric Aerosol Injection 9
Cloud-Based Interventions 12
Pathways to Reduce Climate Damages Through Advancing SRM Governance and Research **16**
Legitimizing SRM Research and Policy Engagement 17
Developing Governance and Coordination Infrastructure 17
Expanding and Diversifying Research Capacity 18
Advancing Research 18
Assessment of Philanthropic Sub-Strategies **19**
Theory of Change for Philanthropic Engagement **24**
Evaluating Key Assumptions 26
Cost-Effectiveness of Advancing SRM Governance and Research **30**
Is There Room for More Funding? **30**
Key Uncertainties and Open Questions **35**
Bottom Line and Next Steps **37**
Acknowledgments **37**

Appendices for this report can be found here.

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Summary

- **What is solar radiation modification (SRM) research and governance, and why is it important?**

  Solar radiation modification (SRM) refers to a range of hypothetical approaches that would cool the planet by reflecting sunlight and reducing the energy the Earth absorbs. The best-known proposed method is stratospheric aerosol injection (SAI), which would disperse reflective aerosols in the stratosphere. In principle, SAI could be scaled up to cool the Earth by 2-5°C, though each additional increment of aerosol produces diminishing returns and its cooling effects are impermanent.

  SRM is the only known approach that could reduce temperatures within a few years of deployment, but it has real limits. For example, it would mask warming rather than remove greenhouse gases, would not reverse problems like ocean acidification, and would involve risks such as ozone depletion in the case of SAI.

  SRM research is the scientific work needed to better understand SRM's potential, limitations, downstream effects, and uncertainties. SRM governance refers to the frameworks and norms that guide this research as well as any decision-making around deployment. Both matter because SRM uncertainty is costly. Over- or underconfidence about its potential could lead to tens of trillions of dollars in avoidable climate damage. Yet SRM remains controversial and underdeveloped, and lacks the governance infrastructure needed to ensure transparent, just decisions.

- **How could efforts to advance SRM governance and research reduce climate damages?**

  SRM governance and research serve multiple purposes. Governance guards against moral hazard—the risk that interest in SRM research weakens the push to cut emissions—by keeping SRM and mitigation linked. Research reduces the risk of physical harm by building the evidence base needed to understand its effects. Studies suggest that more intensive SRM deployment corresponds to a higher risk of adverse effects, including disrupted precipitation patterns, ozone depletion, and termination shock if deployment were abruptly halted. SRM also carries geopolitical risk, especially with unilateral deployment. Without research and governance, decisions about (non-)deployment would be made without understanding the consequences. Together, governance and research can help ensure decisions about development and (non-)deployment are responsible, just, and transparent.

  None of these arguments presume that SRM should be deployed. The aim is to ensure that if a decision is eventually taken, it is taken openly, deliberately, and on the basis of evidence assembled well in advance. Laying the groundwork now

would allow resources to be directed toward the questions that matter most and guard against rushed decisions made under crisis conditions and weak oversight.

- **What do our findings suggest are the most promising philanthropic sub-strategies for advancing SRM governance and research?**

  Based on our evaluation of scale, feasibility, and funding need, we think the most promising philanthropic sub-strategies to advance SRM governance and research center on opening political pathways for SRM research by engaging key stakeholders, building research governance and coordination infrastructure, and strengthening low- and middle-income countries' (LMICs) capacity to shape SRM research and governance.

  Because SRM carries political risk today, opening political pathways means making SRM research a legitimate, discussable topic. Opening these pathways would create the conditions needed to build the research governance infrastructure SRM currently lacks. Broader global participation would better reflect diverse geographic perspectives and the reality that LMICs are likely to shape future governance and deployment decisions.

- **Is there room for more funding?**

  We estimate that efforts to advance SRM research and governance receive approximately $31 million USD in philanthropic funding per year, based on the 2024-2025 average. Total SRM funding from the public sector over the same period averaged around $11.3 million per year. Private sector funding has historically been low but spiked in 2025 with $60 million flowing to a single company. Private funding of SRM is problematic without a governance structure that can ensure SRM serves the public good.

  The National Academies of Sciences, Engineering, and Medicine has called for $100 million to $200 million over five years for a national research program in the U.S. alone, suggesting the true global need may be in the hundreds of millions. However, this figure has not been independently corroborated, and we are uncertain whether the field could productively absorb funding at that scale. We base the case for additional funding on three points:

  1. The scientific and governance uncertainties around SRM are large enough that they merit continued, well-resourced research.
  2. Since SRM research carries real risk, that research needs to be well-governed to ensure it serves the public interest.
  3. Current funding has largely neglected LMICs.

  Based on this funding data and reasoning, we think some efforts to advance SRM governance and research are likely underfunded.

- **What are the key uncertainties and open questions?**

  It is unclear whether advancing SRM governance and research could inadvertently open the door to unregulated or unilateral deployment, and no consensus yet

exists on what would count as sufficient agreement to move toward deployment or halt research altogether. The relationship between governance and research pace is also uncertain, since governance could either accelerate well-governed research by attracting funding, or slow it through added bureaucracy.

- **What is the bottom line and what are the next steps?**

  Our central concern is a scenario in which a decision on SRM development and (non-)deployment is made without the research and governance infrastructure needed to prevent adverse outcomes. Funding that enables well-governed research and ensures meaningful participation from LMICs addresses that risk directly. That said, philanthropy should not fill the entire funding gap. SRM research should ultimately function as a public good, led by governments building transparent, cross-disciplinary programs.

  We also believe that philanthropic and public portfolios should focus overwhelmingly on mitigation and adaptation. To align our actions with this belief, we

  1. Focus our grantmaking portfolio on mitigation, with SRM composing a small fraction of grants
  2. Require grantees applying for funding under this strategy to describe how they minimize moral hazard risks

  The findings in this report will inform the grantmaking strategy for the Giving Green Fund and our list of Top Climate Nonprofits. Therefore, donors interested in progressing this work can choose to donate directly to the Giving Green Fund.

Introduction

Solar radiation modification (SRM)—also known as solar geoengineering or solar radiation management—is a set of hypothetical interventions that would reflect a portion of sunlight into space or allow more infrared radiation to escape into space.[1] SRM includes both global and regional interventions. The best-known approach is stratospheric aerosol injection (SAI), which would disperse reflective aerosols in the stratosphere to scatter a fraction of incoming sunlight and lower global temperatures (**Figure 1**).

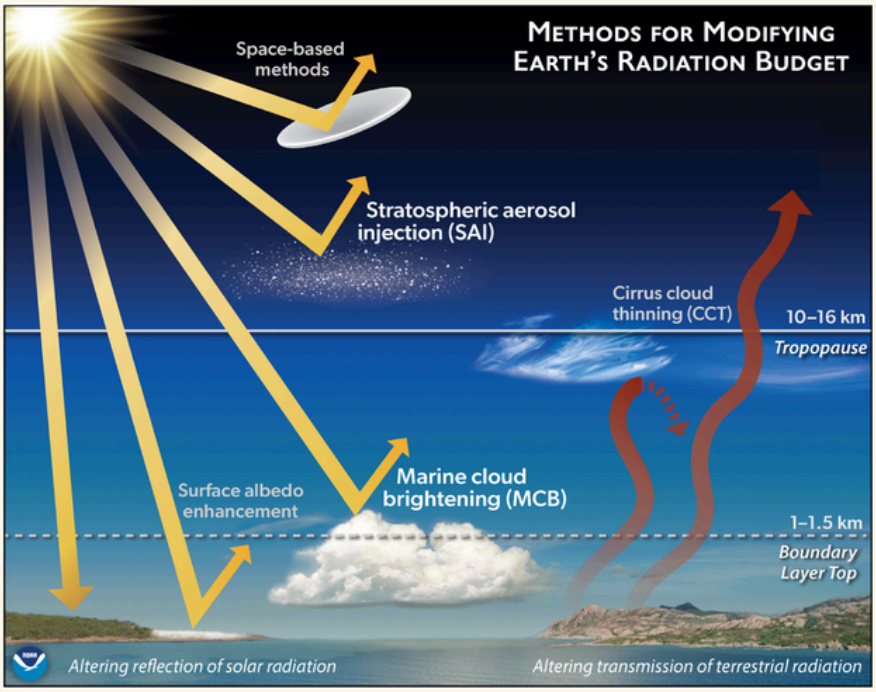


Figure 1: Proposed methods for modifying the Earth's radiation budget[2]

SRM is considered the only known approach that could reduce global temperatures or limit temperature increases within a few years of deployment, assuming inadequate mitigation continues.[3] Most researchers in this space see SRM as a possible "last resort" in case emissions reductions fail to avoid the most dangerous climate scenarios. At the

[1] "In most proposed SRM approaches, a small additional amount of sunlight is reflected to space, or more of Earth's infrared radiation is allowed to escape to space (...)." United Nations Environment Programme (UNEP), 2023

[2] Figure 1. Proposed methods for modifying Earth's radiation budget, including SRM methods and cirrus cloud thinning. National Oceanic and Atmospheric Administration (NOAA), 2024

[3] "SRM deployment is the only known approach that can (i) cool the planet within a few years, or (ii) limit rates or amounts of temperature increase (i.e. to meet the Paris Agreement target of well below 2°C, preferably 1.5°C), if insufficient mitigation continues (emission reduction and GHG removal)." UNEP, 2023

same time, meaningful deployment of SRM would require substantial lead time and is not a "break glass in case of emergency" option.[4]

Critically, SRM would mask warming rather than address its root cause: greenhouse gas (GHG) emissions. SRM would not address effects of rising CO_2, such as ocean acidification, and would have unintended consequences, such as effects on ozone.[5] SRM would not reliably address tipping points, given the large uncertainties in the effects of SRM on the drivers of different Earth system tipping elements.[6] Temporarily reducing warming to 1.5°C or 2°C through SRM in a warmer future world would result in different levels and types of climate damage from a world in which temperature targets are met via GHG mitigation.[7] Therefore, we still need to drive down emissions regardless of any potential future SRM (non-)deployment decision.

SRM should not substitute for deep decarbonization. Instead, we think that if SRM were deployed safely, responsibly, and justly, it could help reduce near-term warming while slower-acting emissions cuts and carbon dioxide removal take effect.[8] However, this "buying time" logic carries risks. On cost-effectiveness grounds, SRM could substitute for the most expensive and difficult mitigation measures rather than supplementing them. Governance that prevents this kind of mitigation deterrence is therefore essential, not optional, to any responsible case for SRM.

Significant uncertainty about SRM's effects carries high costs. According to Harding, Belaia, & Keith (2022), overconfidence in SRM's potential could lead to insufficient emissions reductions and climate damages of up to $115 trillion USD. Meanwhile, underconfidence forgoes opportunities to mitigate climate damage cost-effectively using SRM, with costs reaching $95 trillion.[9] Because both overconfidence and underconfidence carry substantial risks and costs, the authors argue that research to

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[4] "An intervention resulting in 0.5 or 1°C of cooling would require hundreds of aircraft, and this fleet build-out itself would span another decade or more." Smith, 2024

[5] Acidification: "SRM is not a substitute for mitigation. Impacts from excess carbon dioxide (CO_2), such as ocean acidification and ecological degradation, would continue." UNEP, 2023
Ozone: "Based on the observed cooling after large volcanic eruptions and various model studies, stratospheric aerosol injection (SAI) has the potential to reduce global mean temperatures. However, SAI cannot fully offset the wide-spread effects of global warming and produces unintended consequences, including effects on ozone." NOAA, 2022

[6] See Table 1 in Futerman et al., 2025

[7] "Because of these differences in climate forcing and response patterns, the regional and seasonal climates of a world with a global mean warming of 1.5°C or 2°C achieved via SRM would be different from a world with similar global mean warming but achieved through mitigation (MacMartin et al. 2018)." Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report, 2022

[8] "Our results thus suggest that deploying SRM alongside emissions cuts and CDR would substantially accelerate the end of temperature overshoot." Boselius, Duffy, & Irvine, 2025

[9] "Comparing across the unbiased diagonal, we find that over-optimistic bias about SG – believing SG is more efficacious than reality – can be more costly than over-pessimistic bias. However, both directions of bias can have large costs. For example, the cost of over-optimistically believing SG efficacy is 0° when it is really 45° is around $115 trillion and the cost of over-pessimistically believing SG efficacy is 45° when it is really 0° is lower but still large at around $95 trillion." Harding et al., 2021

reduce this uncertainty is itself highly valuable. They estimate the value of this information at up to $10 trillion.[10] These estimates rely on a simplified model with a single global decision-maker and are sensitive to key assumptions. Although the authors caution that these estimates could be off by a factor of three or more, they argue the core conclusion is robust to this uncertainty: bias is costly in both directions.[11]

We chose to investigate the role of philanthropy in advancing SRM governance and research based on an assessment of scale (high), feasibility (medium), and funding need (high), as described in our *Climate Risk Management* sector report**. Our work on SRM targets the quality of decision-making around it, not any particular decision.** We do not advocate for deployment, since the risks of it going badly are real and impossible to eliminate, and the evidence base is far too thin. But we also do not want a premature ban to foreclose the field and prevent the research needed to make good judgments later.

Good governance matters for three reasons. First, it guards against moral hazard—the risk that pursuing SRM could weaken the incentive to cut emissions—by keeping mitigation and SRM discussions institutionally linked so that interest in SRM does not translate into reduced pressure for emissions cuts. It also keeps mitigation the priority by framing SRM as a last-resort supplement rather than a substitute. Second, it lowers the risk of physical harm from SRM itself, since poorly designed, unilateral, or abruptly halted deployment could lead to climate harms that governance is meant to anticipate and prevent. Third, it builds toward a more just process. SRM research today is fragmented and dominated by a small set of well-resourced actors in high-income countries (HICs), so investing in more inclusive, transparent governance now means that any eventual decision is made deliberately and with broader legitimacy.[12] Timing matters because governance takes years to build, while interest in SRM is growing quickly.

Because SRM remains controversial and poorly understood, we believe philanthropy's clearest role is to open political pathways for research and governance—by engaging the institutions, funders, and individuals who can legitimize the research field. This groundwork can help build the research governance infrastructure SRM currently lacks, increasing the likelihood that future decisions are transparent, just, and well-informed. We also see value in strengthening low- and middle-income countries' (LMICs) capacity to shape SRM research and governance, since LMICs will likely shape future governance and deployment.

The rest of this report describes our assessment of the field and where we think philanthropy can improve how future decisions are made.

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[10] "We estimate the value of information that eliminates uncertainty about SG efficacy is up to roughly $10 trillion, comparable to the value of eliminating uncertainty about climate sensitivity." Harding et al., 2021

[11] "Our model has many potential order-unity uncertainties, so our estimates could be uncertain by a factor of three or more. But, even with this uncertainty, and even if research reduces uncertainty by only one-fifth, the value of reduced uncertainty about SG is about a thousand-fold larger than the cost of a SG research programme." Harding et al., 2021

[12] See Figure 1 in Biermann & Möller (2019)

Refining Our Research Scope

We categorized SRM interventions into four approaches: space-based, stratospheric, cloud-based, and surface-based.[13]

- **Space-based** approaches, such as space mirrors, would involve placing reflective surfaces in space between Earth and the Sun to block some incoming sunlight.
- **Stratospheric** approaches center on stratospheric aerosol injection (SAI), which would increase the number of small reflective particles in the stratosphere to boost the reflection of incoming sunlight.
- **Cloud-based** approaches take three proposed forms. Marine cloud brightening would add particles to the lower atmosphere to increase the reflectivity of low-lying clouds over particular regions of the ocean. Mixed-phase cloud thinning would target clouds containing both ice crystals and water droplets, thinning them to reduce the amount of heat they trap. Cirrus cloud thinning would modify the properties of high-altitude ice clouds to increase the atmosphere's transparency to outgoing thermal radiation.
- **Surface-based approaches** would take four broad forms: urban, agricultural, desert, and ocean. Reflective roofs and crops would increase surface albedo, an approach that is global in theory but produces only modest cooling even at scale.[14] Increasing desert albedo with reflective materials would cool the areas where it is applied, but modeling suggests it would severely disrupt rainfall across the tropics and subtropics.[15] Ocean albedo change would increase the surface's reflectivity using microbubbles or reflective foam, with effects confined to particular regions.

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[13] Unless indicated otherwise, we use definitions from "BOX S.1 Solar Geoengineering Strategies Considered in This Study." National Academies of Sciences, Engineering, and Medicine (NASEM), 2021
Mixed-phase cloud thinning: "After a few cloud droplets freeze, the resulting ice particles grow quickly due to the Wegener–Bergeron–Findeisen process (Heymsfield et al 2011, Findeisen et al 2015) and scatter less solar radiation compared to cloud droplets. These large ice particles fall faster than droplets, forming ice virgae or precipitation, which depletes the total water content (TWC) of the cloud. This cloud depletion results in a weaker cloud's heat-trapping, but also a weaker solar reflectivity. Thus, we are interested in identifying MPRCs with a net positive radiative effect dominated by heat-trapping, for which glaciogenic seeding could produce a net cooling effect. We refer to this geoengineering concept as mixed-phase regime cloud thinning (MCT)." Villanueva et al., 2022
Ocean albedo change: "Increase surface albedo of the ocean (e.g., by creating microbubbles or placing reflective foam on the surface)" IPCC Sixth Assessment Report, 2022
[14] "To date, studies indicate limited potential for such approaches, and the efficacy and environmental consequences of these approaches have yet to be carefully studied." NASEM, 2010
[15] "Although global desert geoengineering has the potential to generate the largest global average cooling effect, this average masks the fact that most of the 1.12°C cooling is highly concentrated over the desert regions where the albedo increase is applied... For both urban and crop albedo geoengineering, only minimal shifts in precipitation occur, with the exception of equatorial Pacific regions (Figures 3b and 3c), whereas desert geoengineering induces quite extreme changes in precipitation patterns throughout the tropics and subtropics (Figure 3d)." Irvine, Ridgwell, & Lunt, 2011

We ruled out space-based interventions on feasibility grounds and surface-based interventions on scale grounds.[16] **We therefore focus our assessment on stratospheric and cloud-based approaches.** In general, stratospheric and cloud-based approaches differ in mechanism, geographic extent, longevity, and technological readiness. Theoretically, a deployment scenario could combine SRM approaches to leverage their distinct benefits. However, little to no research has examined their benefits, risks, or optimal mix of combined approaches.[17]

Stratospheric Aerosol Injection

How SAI would work: In a hypothetical global deployment, an actor would inject highly reflective aerosols or their precursors at an altitude of at least 20 kilometers, or about 12 miles, above the subtropics in both hemispheres.[18]

Materials: Sulfate is the most studied option, since large volcanic eruptions inject sulfur dioxide (SO_2) gas into the stratosphere, giving researchers a real-world precedent to study.[19] However, sulfate aerosols carry known risks, such as contributing to ozone depletion, which allows more harmful ultraviolet radiation to reach the Earth. Researchers have therefore considered other substances such as calcite (calcium carbonate), titanium dioxide, and alumina in hopes of reducing those risks.[20]

Cooling effects: Climate models suggest that, hypothetically, well-designed and incremental SAI deployment could fully or partially offset the mean increase in Earth's temperature, though the actual effect would depend heavily on the deployment scenario and injection strategy.[21] Factors that affect cooling include the type of injected material,

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[16] Space-based interventions: "Due to the magnitude of space-based deployment required for such an undertaking, and the enormous cost of putting objects into orbit, these options appear impractical for addressing threats posed by climate change this century." NASEM, 2021

[17] "It should be noted that applying combinations of SAI, MCB, and CCT strategies could offer possible ways to leverage the benefits and reduce the negative consequences of each approach individually. But there has to date been little to no focused study of these combined strategies." NASEM, 2021

[18] "SAI involves injecting highly reflective sub-micron-size particles into the stratosphere, possibly through releases from aircraft that will need to reach altitudes of 20–25 km (lower stratosphere)" UNEP, 2023. For more information on injecting SAI at multiple different latitudes, we recommend MacMartin et al., 2017.
For information on SAI and latitude, see Henry, Bednarz, Haywood, 2024

[19] "Sulfate is the most well-studied stratospheric aerosol due to its enhancement after volcanic eruptions. As a result, many SAI scenarios have been modelled using sulfate to offset different GHG trajectories set out by the IPCC." Huynh and McNeill, 2024

[20] "For instance, simulations suggest that stratospheric injection of solid materials such as alumina, calcite, or rutile (TiO2) as an alternative to sulfate would enhance shortwave RF while minimizing stratospheric ozone loss and heating." NASEM, 2021

[21] Climate model: "Climate model results indicate that an operational SRM deployment could fully or partially offset the global mean warming caused by anthropogenic GHG emissions" UNEP, 2023
Actual effect: "As indicated by climate model results, a well-designed SRM deployment that ramps in over time may reduce rates or amounts of surface temperature increase, and reduce some changes to the hydrological cycle associated with climate change across most regions." UNEP, 2023

the pace at which the material converts to sulfate aerosols, and where and when the material is added.[22] These sensitivities affect cooling in two ways: the choice of aerosol determines how effectively it scatters sunlight and how long it persists in the stratosphere, while the timing and location of injection determine how stratospheric circulation patterns transport and disperse the aerosols. Because these variables interact, it is hard to say precisely how much material is needed to achieve a given amount of cooling. In principle, SAI might be scaled up to cool the Earth by 2-5°C, but each additional increment of aerosol produces diminishing cooling returns.[23]

Duration and reversibility: Once injected, aerosols are expected to remain in the stratosphere for one to three years, and SAI could measurably reduce warming within one year of deployment.[24] However, SAI's cooling is impermanent. Without continued injection, its cooling effects would fade, and global temperatures would revert to previous levels, as if SAI had never been deployed.[25] SAI would therefore have to be maintained until GHG emissions reach safe levels. One study modeling 355 emissions reduction scenarios found that SAI deployment, alongside emissions cuts, might need to be maintained for over 100 years to limit global warming to 1.5°C.[26]

Real-world evidence: SAI is the most studied and best-understood SRM approach.[27] However, no scientific outdoor experiments have been undertaken to understand SAI's effects.[28] Instead, researchers have relied on natural events as a proxy, with the 1991

For examples of different types of cooling scenarios, we recommend the section, "Implementation of SAI" and Figure 2 from Zarnetske et al., 2021.

[22] "As illustrated in several studies, simulations of the relationship between RF and the amount of sulfur added (i.e., the resulting sulfur burden and the ratio of surface area to volume produced) are sensitive to several factors, including: how the sulfur is added (H2S versus SO2 versus sulfate); the oxidation rate of the SO2; the microphysical description of the gas to particle conversion, particle coagulation, and sedimentation; changes in the large-scale dynamics of the stratosphere (Kleinschmitt et al., 2018; Marshall et al., 2019); and the altitude (Dai et al., 2017; Tilmes et al., 2018b), latitude (Dai et al., 2017; Tilmes et al., 2017), and season of addition (Visioni et al., 2019)." NASEM, 2021

[23] "An operational SAI deployment could be scaled up to produce global cooling of 2–5°C, albeit with diminishing returns at higher rates of injections." UNEP, 2023

[24] "The aerosols released by SRM deployments would persist in the stratosphere for 1–3 years for SAI." UNEP, 2023

"In contrast to the longer timescales of mitigation, an SRM deployment could produce a substantial reduction in radiative forcing in as little as one year." UNEP, 2023

[25] "The cooling effects of proposed SRM options would start to diminish as soon as the SRM deployment is halted." UNEP, 2023

[26] "In all pathways consistent with extrapolated current ambition, SRM deployment would exceed 100 years even under the most optimistic assumptions regarding climate response." Baur et al., 2023

[27] "SAI is the most studied and best understood of the SG approaches proposed to date." NASEM, 2021

[28] We do not consider previous SAI outdoor experiments to have been scientific. Actual outdoor experiments explicitly aimed at studying SRM have been (1) low-altitude and only loosely analogous to stratospheric conditions (Yuri Izrael), (2) commercial rather than scientific (Make Sunsets), (3) without active materials (SCoPEx), or (4) conducted without producing peer-reviewed scientific output (SATAN).

Mount Pinatubo eruption as the most frequently cited case study. This eruption injected about 17 million metric tons of SO_2 into the lower stratosphere and is estimated to have cooled global temperatures by up to 0.5-0.6°C for three years.[29] Volcanic analogies suggest SAI's effects would likely be uneven and particularly harmful if injections were hemispherically asymmetric.[30]

Cost: According to Smith (2020), a hypothetical SAI program beginning in 2035 and running through 2100 would cost between $250 billion and $2.5 trillion in aggregate, depending on the Representative Concentration Pathway (RCP) and the cooling target.[31] By 2100, annual costs would range from about $7 billion (halving warming under RCP4.5) to about $72 billion (reversing to 2020 levels under RCP8.5).[32] Across all nine scenarios, the annual cost to suppress 1°C of warming is within 10% of $18 billion.[33] We consider these figures lower-bound estimates because they exclude indirect costs like monitoring and measuring the impacts of SAI.[34] Bronsther & Xu (2025) argue that the true "price" of SRM would likely be much higher than its technical cost given SRM's political and social challenges; they estimate that damages from SAI's side effects would fall between $0 and $809 billion annually.[35]

As a point of comparison, Liu et al. (2023), a separate study with its own assumptions, estimates that an SAI program starting in 2045 in a world with moderate emissions would avoid $169 trillion—or about $7 trillion annually—in expected climate damage by 2069.[36]

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[29] Tons of SO_2: "Eruption columns reached 40 kilometers in altitude and emplaced a giant umbrella cloud in the middle to lower stratosphere that injected about 17 megatons of SO_2 (...)" Self et al., 1993
Cooling: "Effects on climate were an observed surface cooling in the Northern Hemisphere of up to 0.5 to 0.6°C (...). The optically dense Pinatubo aerosol cloud caused marked changes in the amount of radiation reaching the Earth's surface; in turn, these changes affected weather and climate over the past 3 years following the eruption." Self et al., 1993
[30] "Thus, our results indicate that much like the response to volcanoes, asymmetrically loading one hemisphere with stratospheric aerosols could induce drought or increased rainfall in the Sahel in subsequent years." Jacobson et al., 2020
[31] "Depending upon the scenario analyzed, aggregate costs for SAI through the remainder of the century can range from roughly $250 billion to nearly $2.5 trillion, with an annual budget in the year 2100 of $7 to $72 billion (all in 2020 USD)." Smith, 2020
[32] See Table 6. Cost impact of scenario choices. Smith, 2020
[33] "What remains remarkably constant however is the annual cost to suppress 1 °C of warming, which remains within 10% of $18 billion irrespective of the scenario chosen." Smith, 2020
[34] "Moreover, this analysis also excludes any indirect costs for damages that might accrue either from SAI or from climate change itself. Those could be orders of magnitude larger than the aggregate program budget." Smith, 2020
[35] "However, SRM comes with at least four political and social challenges that are not accounted for in such calculations. First, best estimates from Irvine et al. indicate that SAI will harm 0% to 7% of the world's population as a side-effect12, such that those people would demand compensation from the technology's winners. Using existing (and conservative) metrics to calculate the amount of side-effect harm for SAI, we estimate that such harms would fall between $0 and $809 billion annually." Bronsther & Xu, 2025
[36] We calculated the total avoided climate damage by subtracting climate damage under scenario "SAI-1.5-2045" from that under scenario "SSP2-4.5." We divided the total by the number of years

This estimate combines SAI with a fixed emissions trajectory representing pledged mitigation, and does not model any feedback between SRM and mitigation ambition. As a result, it captures neither the risk of moral hazard nor the possibility that mitigation could instead be accelerated beyond current pledges, either of which would change SRM's estimated value.

Who would deploy SAI: According to Horton, Smith, and Keith (2025), the high technical requirements of a "Planetary, Large-scale, Uninterrupted, and Speedy" (PLUS) deployment limit potential actors to around 10 states.[37] Narrowing further to account for geopolitical requirements, the same analysis concluded that only the U.S. and China have the capabilities needed to overcome external opposition and implement a PLUS deployment unilaterally.[38] The barrier to entry is much lower at a small scale, however. A single state or small coalition could likely deploy SAI at a small scale within a few years using only current technology, well short of the PLUS threshold described above.[39]

Cloud-Based Interventions

Researchers have proposed several techniques that modify clouds to reduce net radiative forcing (**Appendix**). These methods are generally earlier-stage than SAI, with most confined to modeling studies or small-scale field experiments. Cloud-based approaches were originally proposed, and remain most commonly discussed in the literature, as a method for global cooling.[40] A smaller, more recent strand of research has explored localized, temporary cooling, such as using marine cloud brightening to shade coral reefs during heat waves and weaken El Niño's effects.[41] The feasibility of marine cloud brightening for global cooling remains disputed.

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of deployment to annualize the avoided damage. See Table 1: NPVs of climate damages, adaptation, and mitigation costs, and total economic effects. Liu et al., 2023

[37] "Thus, only a few states—including the US, France, Germany, the UK, Japan, Canada, Russia, China, India, and Brazil—appear capable of developing the fleet of aircraft numbering in the hundreds that would be required to reduce global temperatures by 1°C by midcentury." Horton, Smith, & Keith, 2025

[38] "The fact of bipolarity means that the US and China alone will be sufficiently powerful across multiple domains to both successfully implement a PLUS deployment on a unilateral basis and prevent other non-rival but technically capable states from doing so." Horton, Smith, & Keith, 2025

[39] "Provocative unilateral action could also take the form of a deployment much smaller than the one in this full-scale scenario, placing on order one-tenth as much sulfur or less. Such subscale deployment, using current technology, would be within reach of many more actors and could be started within a few years... The change in climate achievable in this way would not be detectable above natural variability at national scale, so deployers could argue that this was consistent with avoiding trans-boundary harm under customary international law." Parson and Keith, 2024

[40] The concept of marine cloud brightening was introduced in Latham, 1990, which framed it as a tool for controlling global warming.

[41] The Australian Reef Restoration and Adaptation Program's work on marine cloud brightening is representative of newer, more localized applications.
El Niño: "By exploiting a unique opportunistic experiment provided by the 2019–2020 Australian wildfires, we show that both the modeled cloud brightening and ensuing La Niña–like response can be reproduced by simulating MCB in the SESP." Wan et al., 2026

Deployment Risks

Across SRM approaches, the effects of deployment are largely unknown and could pose major risks to human and natural ecosystems.[42] Because Earth's systems are complex and connected, our ability to predict or control SRM's effects is limited.[43] Research on SRM's effects, their regional variability, and the appropriate methods to assess tradeoffs associated with their development and deployment remains nascent.[44] Some deployment risks include:

- **Effects on ecosystems, agriculture, health, and water:** Evidence is limited and conflicting on the effects of SRM on natural and human ecosystems, agriculture, health, or water resources.[45] For example, one study suggests that SAI may increase some crop yields when compared with a business-as-usual scenario due to scattered sunlight reaching more plants in dense areas.[46] Other studies indicate that SAI could negatively affect crop productivity and nutritional value by altering precipitation patterns and reducing sunlight.[47] Confidence around SAI's effects on agricultural yields remains low.[48]
- **Regional tradeoffs:** Existing assessments suggest both localized and global interventions would affect regions unevenly.[49] SRM's regional effects are still

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[42] Unknown effects: "The extent to which these adverse consequences might manifest and to which they might be mitigated or avoided is largely unknown." UNEP, 2023
Risks: "SRM would be a new and intentional interference in the climate system with potentially dangerous side-effects and risks to human society and ecosystems." UNEP, 2023

[43] "These damages would likely be unevenly distributed across nations. The extent to which these adverse consequences might manifest and to which they might be mitigated or avoided is largely unknown." UNEP, 2023

[44] "A final reason for caution is that for most of these impact areas, there have been very few published studies (only one or two in some cases), and even the methodologies of how to study some of these impact areas are in nascent states." NASEM, 2021

[45] "Despite a growing literature on the climate response to solar geoengineering—proposals to cool the planet by increasing the planetary albedo— there has been little published on the impacts of solar geoengineering on natural and human systems such as agriculture, health, water resources, and ecosystems." Irvine et al., 2017

[46] "Under SAI, the positive effect of increased diffuse radiation on yields largely compensates for the loss caused by reduced direct sunlight, and in some cases contributes to increased yields." Fan et al., 2021

[47] Precipitation: "Crop productivity is also projected to be reduced where SAI reduces rainfall relative to the scenario without SRM, including a case where reduced Asian summer monsoon rainfall causes a reduction in groundnut yields (Xia et al. 2014; Yang et al. 2016)." IPCC Sixth Assessment Report, 2022
Nutritional value: "Compared to SSP2-4.5, the reduced surface temperatures under SAI tend to decrease protein in maize and rice, with milder impacts on wheat and soybean." Clark et al., 2025
Reduced sunlight: "SAI will increase the fraction of diffuse sunlight, which is projected to increase photosynthesis in forested canopy, but will reduce the direct and total available sunlight, which tends to reduce photosynthesis." IPCC Sixth Assessment Report, 2022

[48] "Because of the divergence in results from the studies, including change in crop yields and plant productivity, overall confidence is low." UNEP, 2023

[49] "Regional disparities in climate hazards may result from both regionally-deployed SRM options such as GBAM, and more globally uniform SRM such as SAI (Jones et al. 2018; Seneviratne et al. 2018)." IPCC Sixth Assessment Report, 2022

largely uncertain.[50] Studies suggest SAI would reduce the magnitude of climate change in most locations, while altering hydrological patterns in a few.[51] These uneven effects could create regional winners and losers, raising concerns about social welfare, equity, and justice.[52] Because these effects could be traced back to a deploying actor's choices, they also risk complicating international cooperation by giving states new grounds for interstate blame and conflict.[53]

- **Suitability to address climate tipping points:** Little is known about how SRM would interact with tipping point drivers.[54] There is early consensus that SRM would be ineffective as an emergency response to tipping points, but SRM's possible role in preventing tipping points remains uncertain.[55]
- **Termination shock:** If SRM were abruptly halted—removing SRM's masking effect on warming—temperatures could rise far faster than they would under climate change alone (termination shock). This rapid warming could severely affect biodiversity hotspots.[56] One modeling study found that most of the cooling from SRM would be lost within a decade of an abrupt halt, and that a phase-out would need to last roughly 30 years to avoid a rapid rebound.[57] Because ongoing

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[50] "These damages would likely be unevenly distributed across nations. The extent to which these adverse consequences might manifest and to which they might be mitigated or avoided is largely unknown" UNEP, 2023

[51] "We found that stratospheric aerosol geoengineering deployed to halve warming might substantially reduce the overall magnitude of climate change, while exacerbating hydrological change in only a small fraction of places." Irvine & Keith, 2020

[52] "Like climate change, SG interventions would impose heterogeneous impacts across the world and over time, which would have important social welfare, equity and justice, social, and political implications." Aldy et al., 2021

[53] "Effective climate mitigation could be made more difficult by high-leverage climate engineering technologies that introduce intentionality and shorter chains of causation to climate politics…This could complicate ongoing efforts to mitigate and adapt, not least by promoting adversarial friend–enemy logics that sour international relations and make collective action on mitigation (and other collective global problems) more difficult, as well as making climate engineering solutions themselves more costly and difficult to implement." Corry, 2017

[54] "The linkages between different kinds of solar geoengineering and the drivers of tipping points are understudied and uncertain." Global Tipping Points Report, 2023

[55] "There is already early consensus that geoengineering techniques would not offer an emergency response to anticipated tipping events (Horton, 2015; Lenton, 2018). However, assessment over whether they might provide pre-emptive measures to support prevention is ongoing, and heavily contested (Gupta et al., 2020)." Global Tipping Points Report, 2023

[56] "Sudden termination of SG was found to cause extremely rapid temperature velocities for both land and ocean environments (far exceeding the values predicted for future climate change without SG)—thus placing much greater migration pressure on most species—with particularly acute effects seen in "hotspots" for biodiversity including the tropical oceans, the Amazon basin, Africa, Eurasia, and the polar regions." NASEM, 2021

[57] Lost cooling: "First, as shown in figure 1, the termination of SAI causes around 75% of its cooling to be lost within a decade. However, this percentage is not a fixed number. If SAI is deployed for a long time, as it is in figure 4(h), SAI is slower to lose its cooling in a termination. The most-sustained cooling emulated (320 years) loses only 50% of its cooling in a decade, rather than 75%." Farley et al., 2024

Phase-out length: "For a phase-out beginning in 2055 under our scenario to meet these safety criteria, it would be approximately 30 years long."

emissions-driven warming makes phase-outs longer and impacts emerge faster, the study highlights emissions mitigation as key to managing this risk.[58] Uncertainties and risks include how much warming SRM deployment would actually be masking by the time of any halt and the potential to prevent or slow the cessation of an SRM program.

- **Unilateral or unauthorized deployment:** Much of the literature assumes a state facing severe climate harms would weigh the benefits of unilateral SRM deployment against globally shared risks.[59] However, political scientists argue this framing is too narrow. Deployment could just as plausibly be driven by motives unrelated to climate vulnerability, including geopolitical competition.[60] This wider set of self-interested, competitive, or security deployment scenarios remains under-examined relative to more idealized climate modeling literature.[61] We think the implications of unilateral deployment grow substantially in a large-scale deployment scenario, where the climate effects would be significant enough to draw international scrutiny. Whether this leads to conflict or to cooperation may depend more on how other countries react than on the original actor's motive.[62]
- **Regional rivalry and attribution disputes:** SAI has little ability to target specific regions. The main exception is that deploying more in one hemisphere than the other shifts tropical rainfall patterns, which could favor some regions over others. Cloud-based approaches are inherently more regional, but even these smaller-scale interventions may have effects that reach beyond their target areas.[63] Since scientists likely will be unable to prove exactly how much any single deployment affected a given region's weather, we think disputes over blame and harm could persist for decades without a clear resolution.

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[58] "Since the risks of potential inconsistencies in SAI deployment are linked to the size and duration of an inconsistency, mitigation of GHG emissions is an important factor of risk management during SAI deployment." Farley et al., 2024

[59] "Current literature focuses on actors that are heavily impacted by climate change as the most likely contenders to develop and use the technology…" Young, 2023

[60] "In climate-oriented governance parlance, SRM engenders a 'free-driver' logic because any capable actor could in theory attempt to engineer a preferred climatic state. For security-related actors, drivers of unilateral development (or use) resided much more in distrust towards (and competition with) other countries than climate risks." Corry, McLaren, Kornbech, 2024

[61] "As a foundation for negotiating governance—whether to enable or constrain the development and deployment of such technologies—such projections are dangerously incomplete and potentially misleading. They tell us little about climatic responses to nonideal—self-interested, malicious, or competing—deployments, and even less about political or cultural responses outside of the climate system." McLaren, 2025

[62] "The main threat from unilateral intervention is the provocation it presents to other states and the resultant risks of destabilization or conflict. Other states will surely object, for various reasons and with varying intensity, ranging from pro forma objection to firm determination to resist. The severity of geopolitical threat from this narrative will mainly depend on these responses by other states, especially major powers." Parson & Keith, 2024

[63] "For any given average cooling, spatially uneven changes to radiative forcing, either by strong north–south imbalance of SAI or by patchy use of MCB or CCT, would likely exacerbate climate changes over larger areas than an even distribution with the same average cooling." Parson & Keith, 2024

Pathways to Reduce Climate Damages Through Advancing SRM Governance and Research

Summary of key pathways to reduce climate damages

- **Legitimizing SRM research and policy engagement:** SRM is still largely treated as politically untouchable. This pathway builds the public, governmental, and civil-society support needed to study SRM openly, aiming for formal governments research programs and conditional engagement from key skeptical institutions.
- **Developing governance and coordination infrastructure:** This pathway creates structures that keep SRM research accountable and in the public interest. It starts with lightweight voluntary mechanisms and builds toward independent review bodies and international authorization frameworks.
- **Expanding and diversifying research capacity:** SRM research has been concentrated in HICs, sidelining the LMICs most exposed to climate risk. This pathway builds research capacity in those regions so they have their own evidence, expertise, and voice in decision-making.
- **Advancing research:** This pathway moves SRM from modeling and lab work toward bounded, real-world testing and builds the physical and social science base needed to reach a responsible (non-)deployment decision. It excludes technical development toward deployment.

We prioritize all four pathways in our philanthropic strategy.

Given SRM's risks, we see a clear need for more and better research into SRM, along with governance structures that keep pace with that research and constrain moral hazard. We categorized opportunities that would advance SRM governance and research into four pathways:

- Legitimizing SRM research and policy engagement
- Developing governance and coordination infrastructure
- Expanding and diversifying research capacity
- Advancing research

We think these four pathways reinforce one another, and together, are intended to produce a world where a (non-)deployment decision, if it is ever made, is made transparently, inclusively, and with good evidence, rather than in secrecy, by a narrow set of powerful actors, or under crisis pressure. Transparent and inclusive decision-making, in turn, would lead to better outcomes regardless of which way the decision goes. A well-governed research process would also keep emission cuts on track regardless of a (non-)deployment decision.

Legitimizing SRM Research and Policy Engagement

Because SRM research and discussion carry political risk right now, this pathway is about making SRM a legitimate, discussable topic. It centers on engaging the decision-makers, institutions, and civil society groups who currently treat SRM as untouchable, and on building the public and governmental support needed to fund and conduct well-governed SRM research openly. We think legitimizing SRM research can also help protect it from premature research bans. As legitimacy grows, we would expect governments to begin building formal, publicly funded research programs, and skeptical organizations to shift toward conditional engagement.

Near-term (1-2 years) goals could include at least one major government publicly committing to funding a dedicated research line or at least one influential environmental nonprofit shifting from blanket opposition against SRM to conditional engagement. Longer-term (5+ years) goals could include multiple publicly funded SRM research programs. We think the location and multi-disciplinarity of SRM research programs matter. Currently, most SRM research is concentrated within natural science departments in HICs. We define our goals for expanding geographic diversity in our “Expanding and Diversifying Research Capacity” section.

Developing Governance and Coordination Infrastructure

This pathway covers the structures needed to keep SRM research accountable and internationally aligned as it scales. We include both informal, voluntary mechanisms institutions can adopt now and more formal international governance frameworks that may be adopted over the next one to two decades. Because formal international agreements tend to be slow or prone to stalling, near-term efforts will likely focus on lighter-weight coordination that institutions can adopt without waiting on treaty-level consensus. Over time, this kind of infrastructure would make SRM research more reflective of and accountable to the public good. We expect this type of work to help build trust in the research process itself.

A near-term goal could include getting a critical mass of research institutions to adopt a voluntary code of conduct or research registry (e.g., self-reporting of experiments, funding sources, and results), building on existing efforts like the American Geophysical Union’s Ethical Framework for Climate Intervention Research and the Solar Geoengineering Research Governance Platform. However, these voluntary, institution-led approaches still face real legitimacy challenges from civil society and LMIC stakeholders, who have historically been excluded from shaping SRM governance. Overcoming this challenge will require deliberately building in public engagement beyond the research

institutions and funders that have driven governance efforts thus far. Longer-term goals could include developing an independent, cross-institutional scientific and ethical review body to evaluate field trials against agreed criteria before they proceed and, eventually, a formal international framework to authorize and monitor SRM field research.

Expanding and Diversifying Research Capacity

SRM discussions have so far been shaped largely by institutions and actors based in HICs. This asymmetry has left LMICs and their publics, which are generally more exposed to climate risks, with little say in setting research priorities or steering policy conversations.[64] This pathway is about growing the base of researchers and institutions producing evidence on SRM's risks and impacts. It includes broadening who participates in SRM research globally, so the research is not produced solely by wealthy countries or in line with HICs' cultural beliefs and epistemology. Done well, this gives a wider range of countries and institutions their own evidence, their own experts, and a genuine and informed voice in decisions that will shape their futures, rather than leaving those decisions to be made elsewhere on their behalf.

A near-term goal could include increased funding or fellowships open specifically to researchers and institutions in LMICs. A longer-term goal could be SRM modeling and field capacity in multiple regions beyond HICs, with independent research budgets.

Advancing Research

This pathway covers work that moves SRM approaches beyond modeling and lab-based study toward bounded, real-world experiments. It also includes building the physical and social science evidence base for SRM needed to make an eventual (non-)deployment decision responsibly. Examples under this pathway include directly funding and conducting physical and social science research. It excludes technical development toward deployment, which we see as both premature and unnecessary for advancing the knowledge needed to judge (non-)deployment.

A near-term milestone could include establishing staged research pathways, or a pre-defined sequence of studies, experiments, and go/no-go review points that should precede an eventual, evidence-based (non-)deployment decision. This roadmap would ideally integrate physical and social science research, embed community engagement, connect with governance efforts, and include exit ramps so funding is not renewed year after year without meaningful progress. A long-term milestone could be at least one SRM approach completing its staged pathway end-to-end and reaching a (non-)deployment decision point, regardless of which way the decision goes.

[64] "To date, however, SRM debates have been dominated by institutions and actors from the GN, while countries and communities in the GS, many of which face the greatest climate vulnerability, have had limited influence in shaping research agendas or policy discussions (Talberg et al., 2018; Jinnah & Dove, 2025)." Ramos, Schmidt and Santos, 2026

Assessment of Philanthropic Sub-Strategies

We identified nine promising philanthropic sub-strategies and evaluated each sub-strategy's scale, feasibility, and funding need (see **Table 2**). For more information on these metrics and our research process, see Giving Green's Research Overview.

Table 2: Scale, feasibility, and funding need of approaches nonprofits use to advance SRM governance and research

Sub-strategy	Scale	Feasibility	Funding Need
Opening political pathways for SRM research by engaging key stakeholders	High	Medium	High
Strengthening low- and middle-income countries' (LMICs) capacity to shape SRM research and governance	High	Medium	High
Building research governance and coordination infrastructure	High	High	Medium
Advocating for public research funding and government-led research frameworks	High	Medium	Medium
Engaging and mobilizing civil society	Medium	Medium	High
Funding and conducting SRM physical science research	Medium	Medium	High
Funding and conducting SRM social science and risk research	Medium	Medium	High
Developing international governance frameworks	High	Low	Low
Researching regional and reversible SRM approaches	Medium	Medium	Medium
Building public understanding of SRM	High	Low	Low

We prioritized sub-strategies rated high on at least two criteria. While we believe SRM research has significant unmet needs, we have chosen not to fund it directly for three reasons. First, we think direct funding offers less scale and leverage than advocating for policy that would unlock research funding. Second, at the scale Giving Green operates, direct funding would make only a marginal contribution to a vast research agenda. Third, philanthropy is not well positioned to ensure the research it funds is well governed. We believe SRM research is best served when governments fund and govern it, with philanthropy playing a complementary role. Given this, **we focus our funding on opening political pathways for SRM research, building the governance and coordination infrastructure the field currently lacks, and strengthening LMIC capacity to shape SRM research and governance**—work we see as critical to ensure that research is legitimate, accountable, and less concentrated among a handful of wealthy-country institutions.

We expand on our reasoning for prioritizing these sub-strategies below. Further information on our reasoning for deprioritizing the remaining sub-strategies is available on Giving Green's research dashboard.

Opening Political Pathways for SRM Research by Engaging Key Stakeholders

Scale	🟢🟢🟢 High
Feasibility	🟡🟡⚪ Medium
Funding need	🟢🟢🟢 High

Scale: High. Public awareness of SRM remains very low: across a 30-country, 19-language survey of over 30,000 people, SRM technologies were among the least familiar of all climate interventions tested.[65] Additionally, SRM has typically been treated as too sensitive and controversial to address directly within the climate movement.[66] This lack of familiarity creates both a challenge and an opportunity: policymakers are unlikely to support research they do not understand, but early, well-framed engagement could shape how SRM is perceived before opposition movements harden. We think this work could be a force multiplier for other sub-strategies. Its downstream effects could include attracting organizations that previously avoided SRM for fear of controversy and providing policymakers with the cover they need to authorize further research. This sub-strategy could also help prevent bans on SRM. Several institutions have already moved toward opposing SRM: the European Parliament, Germany's Federal Environment Agency, and a coalition of African countries have all called for an international agreement to prohibit its use, while Mexico proposed a ban on SRM experiments.[67] Without active efforts to open political pathways, these bans could spread and create a patchwork of restrictions that constrain where and how research can be conducted.

Feasibility: Medium. Feasibility varies significantly by approach and actors involved. For relationship-driven political engagement, this work is inherently fragile; a few key political reversals could significantly set back progress. We think this type of work can be more resilient if it targets sub-political actors such as career civil servants who remain in place across electoral cycles. For mainstream institutional engagement—such as normalizing SRM conversations among Big Green nonprofits—academic workshops, convenings, and policy publications are well-understood, executable activities. However, we think

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[65] "This study presents the findings of a large-scale, cross-country, set of nationally representative surveys (n = 30,284 participants, with at least 1000 in each country) of the public perceptions of CDR and SRM technologies in 30 countries and conducted in 19 languages... The technologies deemed the least familiar included SRM options and enhanced weathering, while greater familiarity is expressed with the ecosystem-based CDR approaches." Baum et al., 2024

[66] Controversial nature of SRM in the climate movement: "But until recently, many U.S. civil society organizations working on climate, justice, health, and science didn't have the opportunity to engage in this conversation in earnest. Whether too technical, too fringe, or too fraught, the issue is often treated as too sensitive and taboo to address directly." Chesapeake Climate Action Network, 2025

[67] "Indeed, the European Parliament, the German Federal Environment Agency, and a group of African nations are now calling for a global SRM non-use agreement—and Mexico has outright banned SRM experiments." Bronsther & Xu, 2025

mainstream organizations face a couple of meaningful failure modes. First, reputational backlash from their membership or donor base for engaging with SRM could damage their broader advocacy work and undermine their credibility. Second, philanthropic funding could put too much pressure on these organizations to shape their work in ways that erode their credibility. In both cases, the causal chain from building political permission structures to making informed, responsible, and just decisions about SRM (non-)deployment is long and uncertain.

Funding Need: High. We think opening political pathways for SRM research is likely underfunded relative to its importance and potential leverage. Most philanthropic funding for SRM has gone to research, so funders often overlook this type of policy and advocacy work. Based on 2026 budget information from all major organizations working on SRM, we estimate that roughly 9% of their combined funding, including some government funding, goes toward this sub-strategy.[68] We arrived at this figure by estimating the share of each organization's budget allocated to this sub-strategy and summing across organizations. We do not have a precise field-wide funding target for this sub-strategy, but organizations in this space report significant funding needs relative to their aspirational budgets. These self-reported funding gaps are on the order of magnitude of $10 million per year, but we would encourage readers to treat these claims with some caution given that organizations have an inherent incentive to overstate their funding needs. We have medium certainty that additional funding could be deployed effectively at this stage. We think this sub-strategy could eventually be constrained by access, relationships, and timing rather than funding, but that we have not yet reached this point. We note that governments will not fund this type of work, and no private-sector constituency exists for it.

Strengthening LMIC Capacity to Shape SRM Research and Governance

Scale	🟢🟢🟢 High
Feasibility	🟡🟡⚪ Medium
Funding need	🟢🟢🟢 High

Scale: High. We think that SRM governance frameworks are more likely to center global perspectives and well-being if LMIC researchers participate meaningfully in the science. This sub-strategy likely enhances both the legitimacy and inclusivity of governance frameworks. Building a more geographically diverse research community also produces better science by incorporating local knowledge and regional priorities.[69] Therefore, we think this sub-strategy has implications for several other sub-strategies, such as funding

[68] Percentages reflect our estimates of how 2026 budgets are allocated across sub-strategies. We collected 2026 budget information from all major SRM organizations, estimated the share of each organization's funding going to each sub-strategy, and summed it across organizations. Some budgets include government funding (e.g., ARIA funding to research universities). Because these are estimates based on budget information rather than reported spending, figures should be read as approximate.

[69] "For example, climate and social scientists from throughout the world could bring valuable region-specific knowledge and perspectives relevant to identifying priority research questions, developing and refining models, and assessing possible impacts." NASEM, 2021

and conducting SRM research. We think the work is inherently global in scope but operates through a slow, institution-building pathway.

Feasibility: Medium. Building research capacity through training, fellowships, data access, and funding is well-understood work that organizations execute routinely. We think the main constraints include the slow pace of institution-building and the challenge of ensuring that capacity built in LMICs translates into meaningful participation in global research and governance conversations.

Funding Need: High. The funding gap in this space is stark and well-documented. According to a 2025 article, SRM-related research activities take place in more countries in the Global South—a term used by this source, though we use LMICs in our own work—than in the Global North.[70] Yet cumulative funding tells a different story. According to the same source, Global South countries have received roughly $7.8 million in total SRM funding, compared to $259 million in the Global North.[71] One nonprofit has provided more than half of all funding received by Global South countries for SRM work, illustrating how concentrated this funding is.[72] We think philanthropic funding could be highly catalytic for this sub-strategy, given how little government funding flows into this space and how foundational geographic diversity is to governance legitimacy. Based on our estimates of 2026 organizational budgets, this sub-strategy accounts for roughly 8% of combined SRM funding across the major organizations we reviewed.

Building Research Governance and Coordination Infrastructure

Scale	●●● High
Feasibility	●●● High
Funding need	●●○ Medium

Scale: High. We believe this sub-strategy has high systemic leverage. It enables research and development (R&D) by sharing templates, establishing best practices, and ensuring research builds cumulatively rather than in isolation, reflecting the National Academies of Sciences, Engineering, and Medicine's (NASEM) finding that "coordination is essential for integrating perspectives from research, from those involved in supporting and guiding this research enterprise, and from those exploring governance strategies for any potential

[70] "SRM-related activities are taking place in more countries in the Global South than the Global North, but this masks extreme differences in the amounts of funding received. SRM researchers and organisations in the Global North have received more than 50 times more funding to date, with $188.2m received through 2024, compared to $3.5m in Global South countries." SRM360, 2025
[71] We calculated the amount received by the Global North based on the total amount of funding and the 97% reported to be received by the Global North. "More than 99% of the funds provided came from countries in the Global North – about $265 million versus $1.8 million. The Global North also received 97% of the total. Still, $7.8 million in funding has flowed to 22 countries in the Global South, in large part from the non-profit Degrees Initiative." SRM360, 2026
[72] "While the Global South receives only a small fraction of total funding, they represent 22 of 34 countries receiving funding to work on SRM. This is in large part thanks to a single NGO, The Degrees Initiative, which provided more than half of the total funding for those countries' work on this topic..." SRM360, 2025

future deployment."[73] Critically, NASEM also argues that "if these technologies are ever seriously considered for deployment, the perceived legitimacy of the research program will be as important as the specific findings."[74] Therefore, we think research governance infrastructure is not just a technical necessity but a prerequisite for public and political acceptance. We think failure under this sub-strategy could undermine the field's legitimacy, while poorly designed infrastructure could entrench the wrong research directions or create accessibility barriers that exclude LMIC researchers. We are unsure whether increased bureaucracy would slow down R&D or enable and accelerate well-governed research.

Feasibility: High. Building platforms, establishing transparency standards, and convening researchers are well-defined activities. We believe the main constraints are the slow pace of institutional adoption and the challenge of ensuring infrastructure built by HIC-based organizations is accessible and relevant to LMIC researchers and policymakers.

Funding Need: Medium. Based on our review of 2026 budgets for a sample of major organizations conducting SRM research and governance, we estimate that roughly 6% of their combined funding goes toward this sub-strategy, including a small amount of government funding. To benchmark against need, the NASEM report recommended funding governance and engagement work at about 20% of total research program support—implying $4 million to $8 million per year for the U.S. alone based on its recommended research budget of $100 million to $200 million over five years.[75] Current philanthropic funding and small amounts from the Advanced Research and Invention Agency (ARIA)—the U.K.'s "invention agency" similar to the Defense Advanced Research Projects Agency in the U.S.—fall well short of that benchmark. We think philanthropic funding is most catalytic for lower-cost infrastructure components where modest investments can shift the whole field. For expensive monitoring infrastructure, we think philanthropic money is better used on advocacy and scoping that makes the case for government investment, rather than paying for it directly.

[73] "Specifically, coordination is essential for integrating perspectives from research, from those involved in supporting and guiding this research enterprise, and from those exploring governance strategies for any potential future deployment." NASEM, 2021

[74] "If these technologies are ever seriously considered for deployment, the perceived legitimacy of the research program will be as important as the specific findings. Thus, a key challenge is to develop and coordinate a research program that is informing decisions without committing to further development of that technology or creating research communities that are invested in its ultimate deployment." NASEM, 2021

[75] "The committee suggests that a reasonable initial investment in SG research is in the range of $100–200 million total over 5 years... The committee suggests as a general rule of thumb that these governance and engagement efforts be supported at approximately 20 percent of the level of the total research program support—an investment that would scale with the overall size of the research program." NASEM, 2021

Theory of Change for Philanthropic Engagement

Based on the current state of SRM research and governance, we developed a high-level theory of change for how philanthropic actors can help guide the field toward just, responsible, and transparent decision-making (**Figure 2**). Theories of change help us better understand pathways of influence, the likelihood of each pathway, and the avenues of greatest impact for philanthropic and civil society efforts.

We evaluate the main assumptions underlying the theory of change and rate our certainty in each as **low**, **medium**, or **high**.[76] Our assessment is based on both primary and secondary evidence, as well as our general impression of the assumption's plausibility.

[76] We describe our certainty as low/medium/high to increase readability and avoid false precision. Since these terms can be interpreted differently, we use rough heuristics to define them as percentage likelihoods the assumption is, on average, correct. Low = 0-60%, medium = 60-80%, high = 80-100%

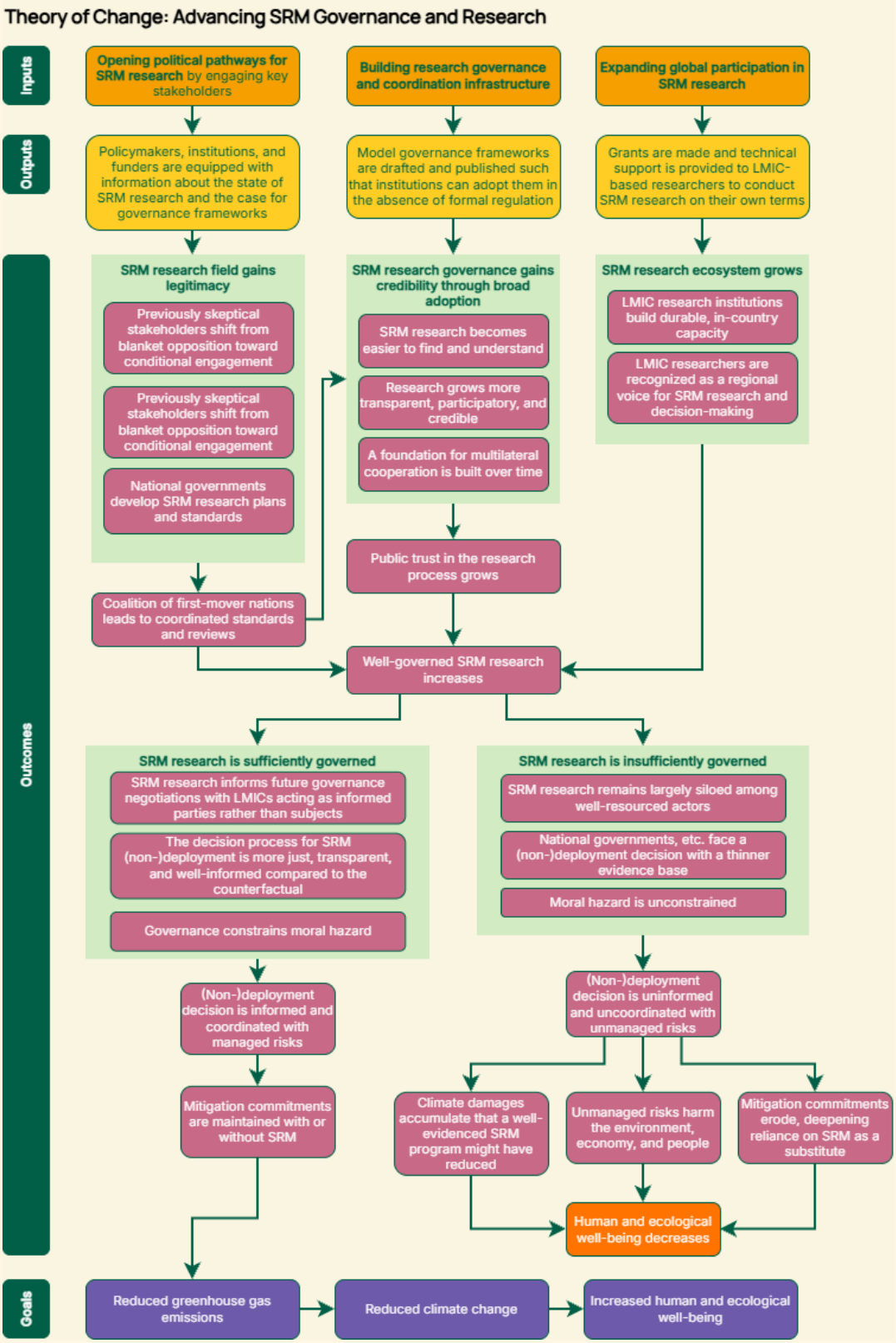


Figure 2: Theory of change diagram for advancing SRM research and governance

Evaluating Key Assumptions

1. Good research governance could help reduce the risk that SRM R&D might delay or deter mitigation efforts (high certainty)

We assume that good SRM governance can meaningfully reduce the risk of moral hazard. Getting there requires both well-designed governance measures and political mobilization to support them. Reynolds (2022) proposes several forms of governance linkages between SRM and mitigation. They include conditioning participation in SRM R&D on states' mitigation performance and—in the linkage he sees as most promising—having one or more states assert a right to deploy only if they meet their mitigation goals while other states fail to meet theirs.[77] He presents these ideas as speculative and warns that linking mitigation and SRM could still entrench the very perception that mitigation and SRM are substitutes.[78]

Some of that speculativeness is unavoidable because moral hazard is inherently hard to measure empirically. Precisely quantifying mitigation deterrence would require comparison to a counterfactual baseline (i.e., how much mitigation would have occurred in the absence of SRM research), which is not practically available.[79] Existing evidence is mixed and does not clearly support or refute concerns about moral hazard. Some social science research has found that individuals may increase their commitment to mitigation when introduced to the prospect of geoengineering, but we do not think laypeople's survey responses predict how policymakers will behave.[80] Because moral hazard is so

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[77] Linkage to research and development: "I propose that linkers offer targets the opportunity to participate in solar geoengineering research and development. Such participation could include (preferential) access to financial resources, expertise, intellectual property, discussions, plans, and results, as well as input into design, management, and decision-making regarding priorities and programmes." Reynolds, 2020
Preferred linkage: "Of the linkages considered here, I believe that Authority to Act has substantial potential to increase mitigation while being consistent with states' apparent interests to join, comply, and enforce any agreement. In this, linker(s) proclaim their right to deploy solar geoengineering only if they meet their own mitigation goals and the rest of the world's countries have failed to meet theirs." Reynolds, 2020

[78] Limitations: "Like most discussions of solar geoengineering's governance challenges and possible responses, the exploration and assessment here are necessarily speculative... As another limitation, the proposed linkages rest on the assumption that states' preferences regarding the two response options are related, which might not be the case. Some states—which could be superpowers—might simply resist or undertake solar geoengineering independently of mitigation and climate change impacts... Third, targets and other observers may have reservations because most of the linkages discussed here, including those that appear to have the greatest potential, are noncooperative." Reynolds, 2020
Perception of substitutes: "Steps toward linking international policies for mitigation and solar geoengineering could create and reinforce beliefs that the two responses to climate change are mutual substitutes, perhaps furthering mitigation obstruction." Reynolds, 2020

[79] "A major problem, especially for demonstrating social and political forms of moral hazard, is the absence of a counterfactual." McLaren, 2016

[80] For more information on individual, social, and political moral hazard, see "3 Disaggregating and Detecting Moral Hazard" in McLaren, 2016

hard to measure directly, we think the more productive question is not whether moral hazard exists, but whether we can shape the conditions that make it less likely.[81] We assume that governance design is more tractable to influence than the underlying psychological or political dynamics driving moral hazard, which is why governance is central to our theory of change.

We think moral hazard is more likely to be constrained if countries and institutions treat SRM as an open question rather than an available option. Our funding reflects that stance: we support governance and research work precisely because we do not have clear answers to key questions—such as whether SRM should be developed at all, and if developed, whether it should ever be deployed. Given how consequential those answers are, we believe we should pursue them equitably and responsibly. We also believe that philanthropic and public portfolios should focus overwhelmingly on mitigation and adaptation. To align our actions with this belief, we (1) focus our grantmaking portfolio on mitigation, with SRM composing a small fraction of grants, and (2) require applicants for our funding under this strategy to describe how they minimize moral hazard risks.

2. Increased understanding of SRM's benefits and risks will lead to more engagement from policymakers (medium certainty)

In the current U.S. political environment, we think it is unlikely that increased understanding of SRM among policymakers would lead to the establishment of an SRM research program of the kind recommended by NASEM in 2021.[82] Under the second Trump administration, funding cuts and firings at agencies such as the National Oceanic and Atmospheric Administration have set back the study of both climate change and climate intervention generally.[83] Because broad political priorities have driven these changes, we think better information on SRM alone is unlikely to shift federal policy under the current administration.

We are similarly skeptical that this assumption applies at the U.S. state level. Dozens of U.S. states have introduced or passed bans on SRM research and experimentation since 2023, several of which conflate legitimate SRM research with unrelated "chemtrail" conspiracy theories.[84] Indeed, Buck et al. (2025) found that roughly one in five

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[81] "The next decade of research will need to turn from trying to prove or disprove the phenomenon of moral hazard, to much more nuanced efforts to understand when, where, and how it might appear; the extent of the likely negative impacts on climate policy and its goals, including that of climate justice; and the effectiveness of different mechanisms to limit or even reverse those impacts." McLaren, 2016

[82] For more information, see Recommendation 4.1 in NASEM, 2021

[83] Funding cuts: "The breakdown sheds fresh light on one of the most endlessly repeated pledges of Trump's second term: his vow to unravel the nearly $1.6 trillion in spending and tax breaks that Biden had set in motion for a sprawling array of climate, clean energy and infrastructure programs." Politico, 2026

Agency firings: "The Trump administration has fired hundreds of workers at the National Oceanic and Atmospheric Administration (Noaa), the US's pre-eminent climate research agency housed within the Department of Commerce, the Guardian has learned." The Guardian, 2025

[84] Number of state bans: "Thirty-seven US states and the federal government have proposed banning solar geoengineering since 2023." SRM360, 2025

respondents believed it at least partly true that the U.S. government is already running a program to inject chemicals into the atmosphere to fight warming, with nearly half unsure either way.[85] Notably, belief in such a program was itself associated with lower support for SRM research.[86] We think this association suggests that conspiracy-adjacent beliefs feeding state-level bans are not fringe but a mainstream driver of public (and likely legislative) sentiment. We suspect that successful engagement here would require more than sharing information.

We think such engagement may be more feasible outside the U.S. The U.K.'s ARIA program offers useful evidence. ARIA's £56.8 million GBP (around $75.1 million USD) solar geoengineering program came under serious public pressure when a petition to outlaw geoengineering gathered over 160,000 signatures and forced a parliamentary debate.[87] Anecdotally, we have heard that individuals with a strong understanding of SRM's benefits and risks engaged directly with key policymakers to help protect ARIA's funding from being cut. If accurate, this outcome suggests that informed engagement at moments of political pressure can make a real difference to policy outcomes, even when the underlying backlash is strong.

We think the greatest near-term potential may be in LMICs, where domestic researchers—who can communicate in relevant national languages and co-produce research questions—lead engagement efforts. Cross-country evidence supports this underlying premise. For example, a large-scale representative survey across 30 countries found that LMIC publics are considerably more favorable toward the potential benefits of climate intervention technologies than HIC publics.[88] A companion cross-country focus-group study found that LMIC participants expressed both greater hope and a richer

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Chemtrails: “Louisiana is the latest state taking inspiration from a wide-ranging conspiratorial narrative, mixing it with facts, to create legislation. Tennessee Gov. Bill Lee signed a similar measure into law last year and one in Florida has passed both the House and the Senate. More than a dozen other states, from New York to Arizona, have introduced their own legislation.” AP News, 2025

[85] “Twenty percent of respondents believed it is partly or completely true that the US government is currently putting chemicals into the atmosphere to counteract global warming, and nearly half of respondents are unsure.” Buck et al., 2025

[86] “Conservatives were less likely to support research, as well as people reporting greater interest in political news, people who indicated they believed chemtrails to be true, and those who indicated they believed airborne interventions were already happening.” Buck et al., 2025

[87] Budget size: “This £56.8m programme aims to build a robust evidence base to explore – with independent oversight – if climate cooling approaches could ever be feasible, scalable, safe, and governable.” ARIA, n.d.

Signatures and debate: “On Monday 23 June, MPs will debate a petition relating to geo-engineering and the environment... The petition, which has received more than 159,000 signatures, stated: "We want all forms of geo-engineering to be illegal in the UK. We do not want any use of technologies to intervene in the Earth's natural systems."” U.K. Parliament, 2025

[88] “Surprisingly, our survey provides evidence that Global South countries are more supportive of SRM technologies than Global North countries, viewed more benefits to research and deployment, and express stronger interest in policies that would facilitate continuing research, development, and oversight.” Baum, Fritz, Low, & Sovacool, 2024

set of concerns about SRM than their HIC counterparts.[89] Beyond public receptivity, researchers have made the case that LMICs need the capacity to lead this research on their own terms rather than being cast as passive recipients of outside expertise.[90]

3. Public support or backlash will influence decision-making (high certainty)

We believe public support will strongly influence policymakers' decisions around SRM research and governance in their respective jurisdictions. The need for public support likely varies by research type. We think public support likely declines as the scale and perceived risk of research increases. For example, climate modeling is perceived as relatively uncontroversial, while large-scale outdoor experimentation tends to be widely opposed.[91]

Several outdoor SRM experiments have been halted or canceled due to public pushback. For example, the for-profit company Make Sunsets' sulfur-containing balloon launches in Mexico led to a proposed national ban on SRM experiments in 2023.[92] In 2024, Harvard ended its SCoPEX after its planned launch in Sweden was suspended in 2021, while the University of Washington's Marine Cloud Brightening Project in Alameda, California, was canceled.[93] After the canceled SCoPEx experiment, its researchers concluded that early engagement is essential for future SRM research efforts.[94] Because public opposition has already shaped SRM research, we are highly certain it will remain a key factor.

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[89] "Our results nuance these insights: global South focus groups exhibit greater hope but an arguably richer range of concerns for solar geoengineering, in the context of observable inequities in climate action and potential geopolitical conflict." Low, Fritz, Baum, & Sovacool, 2024

[90] See Rahman et al., 2018 and Mutiso, 2024

[91] "Support for research generally declines in proportion to the scale of physical intervention proposed: indoor research is relatively uncontroversial, but support drops for small-scale outdoor experiments, and large scale experiments are widely opposed." Horton, 2024

[92] "But on January 13, Mexico's Ministry of Environment and Natural Resources announced that the government will prohibit and, where appropriate, halt any solar geoengineering experiments within the country. The agency noted that Make Sunset's launches were done without notice or consent." MIT Technology Review, 2023

[93] SCoPEx: "Most recently, the team hoped to launch a balloon to test out the aircraft's hardware from the Esrange Space Center in Kiruna, Sweden in the summer of 2021. But those plans were canceled on the recommendation of the project's advisory committee, which determined the researchers should hold discussions with the public ahead of any flights. The effort was also heavily criticized by the Saami Council, which represents the indigenous Saami peoples' groups in Sweden and neighboring regions, as well as environmental groups and other organizations, who argued it's too dangerous a tool to use." MIT Technology Review, 2024
University of Washington: "The five-member Alameda City Council voted unanimously to reject University of Washington researchers' aerial spraying of liquefied salt from the deck of a retired aircraft carrier in San Francisco Bay, two months after the experiment began." Politico, 2024

[94] SCoPEx conclusion: "The AC also agreed on four core principles for societal engagement, when conducted, which reflect insights from the academic literature but we deem as sufficiently important to future solar geoengineering research efforts as to amplify them here: 1. Start engagement efforts as early as possible; 2. Include social scientists with engagement expertise on research teams during the research design process; 3. Don't presuppose what communities will be concerned about; 4. Develop a plan to be responsive to community concern." SCoPEx Advisory Committee, 2024

Cost-Effectiveness of Advancing SRM Governance and Research

We chose not to evaluate the cost-effectiveness of advancing SRM governance and research. Typical Giving Green cost-effectiveness analyses (CEAs) are built around a specific question: how much a given amount of funding to an organization reduces or removes CO_2 emissions. That framing does not map well onto this strategy. First, our goal is not to decide whether to pursue SRM but to determine how philanthropy can help ensure that any eventual decision-making is transparent, inclusive, and grounded in good evidence. Second, and relatedly, this work is not about reducing or removing CO_2 at all; it is about improving the process around a potential future decision. A standard CEA denominated in dollars-per-metric-ton is not a natural fit for that kind of outcome. While well-governed SRM research can limit moral hazard, which could be denominated in tons of CO_2, quantifying that benefit would require estimating how much mitigation would have been displaced without governance. We do not think we can credibly estimate this counterfactual.

Is There Room for More Funding?

Cumulative funding for SRM reached $267 million through 2025, and annual funding in the 2021-2025 period averaged roughly $44 million per year, 11 times the 2011-2015 average (**Figure 3**).[95] Between 2005 and 2025, philanthropy contributed roughly $102 million (38%) of total SRM funding, followed by government funding at $87.5 million (33%).[96] Commercial investment has historically been minimal but is growing ($77.5 million, 29%). Stardust Solutions has now raised a cumulative $75 million in venture capital—its 2023 backing from Awz Ventures ($15 million) followed by a larger 2025

[95] We calculated annual funding based on data provided by SRM360. "Funding for SRM reached a cumulative total of $267 million through 2025 and was 11 times larger in the five years from 2021–2025 ($214 million) compared to ten years earlier in 2011–2015 ($19.1 million). Adjusting for inflation, that is more than 8 times larger ($221 million vs. $26.4 million)." SRM360, 2026

[96] We caution that public SRM funding figures are likely incomplete because some funders have not disclosed full information. "Through 2025, philanthropic funding was the leading source at $102 million, or about 38% of the total. That is followed by governmental sources in second place ($87.5 million, 33%) and commercial sources in third ($77.5 million, 29%)." SRM360, 2026

round—to develop a patented SAI system it hopes governments will eventually deploy.[97] Many SRM researchers consider Stardust's for-profit research to be opaque and inappropriate in this space, in contravention of the governance principles proposed thus far, including the Oxford Principles, Calgary Code, and Asilomar statement.[98]

[97] Funding: "On the commercial side, Awz Ventures, a Canadian-Israeli-US firm with ties to defence agencies, supported Stardust in 2023 with $15.0 million. With additional investors from the US, UK, and across Europe, its 2025 fundraising round brought Stardust's total investment to $75.0 million." SRM360, 2026
Use of technology: "Stardust Solutions, a company led by a team of Israeli physicists, announced on Friday that it has raised $60 million in venture capital to develop technological building blocks that it says will make solar geoengineering possible by the beginning of next decade... It is seeking a patent for aspects of its geoengineering system, including protections for the reflective particles that it hopes governments will eventually disperse in the atmosphere." Heatmap, 2025
[98] Lack of transparency: "Stardust is currently not sharing information about the particles it intends to release into the sky, though it says it plans to do so once it secures a patent, which could happen as soon as next year." Heatmap, 2025
Contravention to governance principles: All three frameworks converge on public disclosure of methods and data. For more information, see Rayner et al., 2013, Hubert, 2020, and Asilomar statement, 2010.

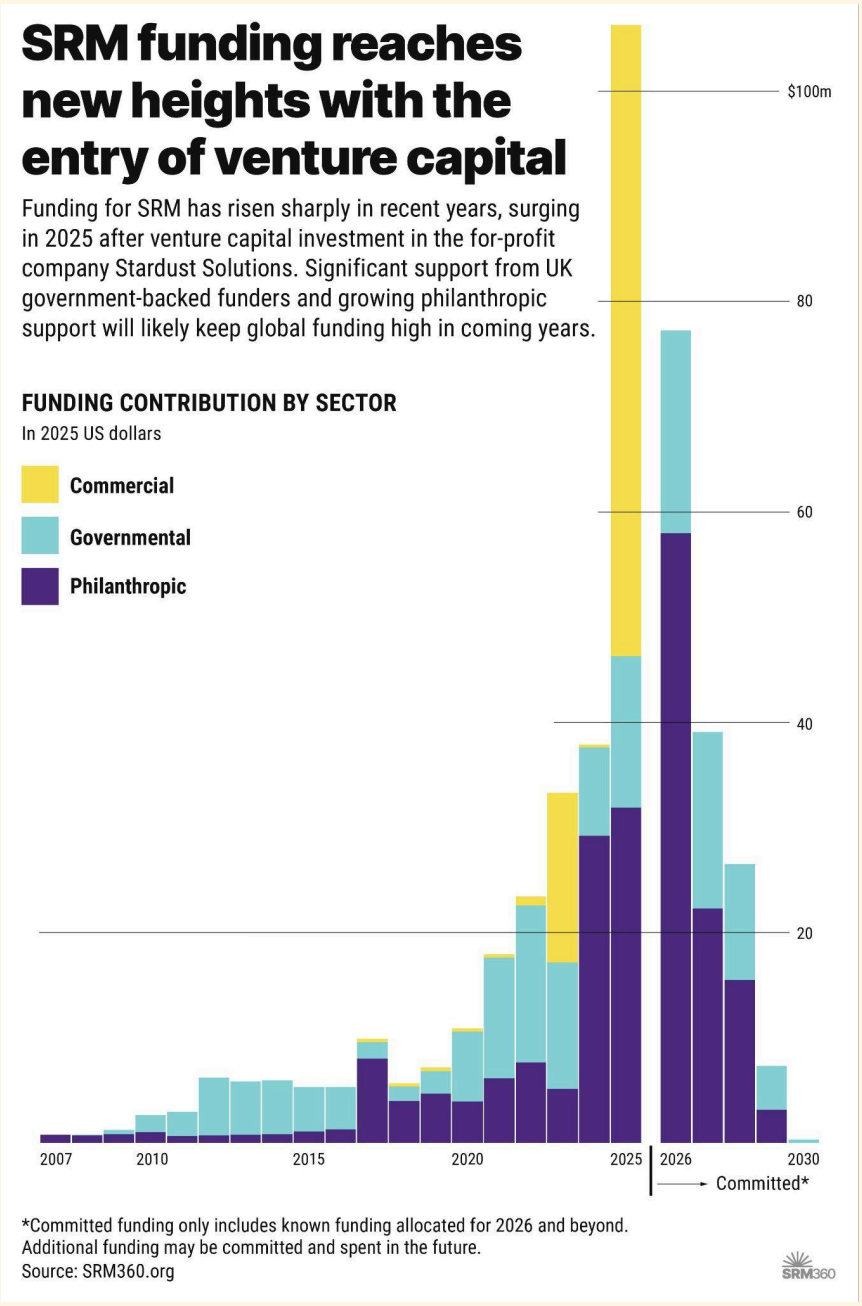


Figure 3: Funding entering the SRM field annually, 2007 - 2030[99]

Despite this growth, funding remains short of what some experts say is needed. NASEM has called for $100 million to $200 million over five years for a national research program in the U.S. alone, suggesting the true global funding gap is likely in the hundreds of millions.[100] We treat this figure with caution rather than as an independent benchmark,

[99] See figure "SRM funding reaches new heights with the entry of venture capital" SRM360, 2026
[100] "The committee suggests that a reasonable initial investment in SG research is in the range of $100–200 million total over 5 years." NASEM, 2021

given that researchers with a direct interest in expanding funding for their field produced it; we are unfamiliar with any independent corroboration of this level of need. We are also uncertain whether the existing research community could absorb funding at this scale even if it were available.[101]

We base the case for additional funding on three points: (1) the scientific and governance uncertainties around SRM are large enough that they merit continued, well-resourced research, (2) because SRM research carries real risk, that research needs to be well-governed to ensure it serves the public interest, and (3) current funding has largely neglected LMICs. In particular, LMICs have received only $7.8 million, or 3% of overall funding, for SRM work.[102]

We do not believe philanthropy should fill the entire funding gap for advancing SRM governance and research. Instead, we think SRM research should ultimately function as a public good, with governments playing the leading role in building transparent, cross-disciplinary research programs. In line with NASEM, we see philanthropic support as a complement to, not a replacement for, government funding.[103]

Philanthropic Funding

Philanthropic interest has increased in recent years, from $28.5 million in 2024 to $34.1 million in 2025.[104] This amount represents less than 1% of total climate philanthropy from foundations that year.[105] When we consider all of SRM's funders, including national governments, half of its top 10 funders are philanthropic. Leading philanthropic funders include Quadrature Climate Foundation, Simons Foundation, Coefficient Giving, LAD Climate Fund, and Bill Gates.[106] Based on the budgets of major nonprofits working on SRM research and governance, as well as government funding that flows to universities and nonprofits in this space, we estimate that at least 40% of philanthropic funding related to this strategy has gone toward physical science research.[107]

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[101] Our uncertainty rests on (1) how few institutions currently have the staff, infrastructure, and disciplinary breadth to responsibly scale up SRM-related research and (2) how long it typically takes a small field to build that capacity even when funding is available.
[102] See "SRM funding for Global North and South." SRM360, 2025
[103] "As a general approach, philanthropic support for SG research and research governance (and related activities such as capacity building and engagement) should complement rather than replace core U.S. federal support for these activities." NASEM, 2021
[104] See Figure "SRM funding reaches new heights with the entry of venture capital" SRM360, 2026
[105] We calculated <1% by annual philanthropic giving to SRM research and governance in 2024 ($28.5 million) by annual foundation giving to climate mitigation that same year ($6 billion). "Climate mitigation funding from foundations has grown significantly in recent years, with annual totals more than doubling from $2.3 billion in 2020 to $6 billion in 2024." ClimateWorks Foundation, 2026
[106] See "Philanthropies and Stardust's investors outspend most nations on SRM" SRM360, 2026
[107] Our estimate is based on a review of the major nonprofit players in SRM research and governance and recipients of ARIA funding for which we estimated 2026 budgets and the share allocated to each sub-strategy. This approach likely misses smaller-scale or harder-to-track nonprofit research activity, though covering these major players should capture most of the funding in this space.

Government Funding

Government funding for SRM has risen and fallen over the past two decades but appears to be on an upswing. In 2024, government funding was around $8.2 million, rising to about $14.4 million in 2025.[108] Most of this government funding is concentrated in a few wealthy countries. The U.K. leads, with $64.2 million spent and committed through 2030. It is followed by the U.S. at $26.5 million, Australia at $22.6 million, and Germany at $10.1 million.[109] Almost all government funding committed to SRM research beyond 2026 comes from the U.K. ($49.3 million, 94% of the total).[110]

Major government funding initiatives include ARIA's £56.8 million (around $75.1 million USD) climate cooling program in the U.K. and U.K. Research and Innovation's (UKRI) £10.5 million (around $13.9 million USD) research program on risk-risk analyses.[111] The Co-CREATE program, which focused on governance principles and guidelines for responsible SRM research, received funding from both the EU's Horizon Europe Program and UKRI.[112]

Private Sector Funding

Private sector funding for SRM was very low for most of the past two decades but has risen sharply in recent years, driven almost entirely by Stardust Solutions, which raised $60 million in 2025, for a total of $75 million raised to date.[113] The only other known for-profit SRM entity, Make Sunsets, raised just over $1.2 million in 2024.[114] We are unsure what future private funding for SRM will look like, and whether Stardust's raise represents a one-off or the start of a broader trend. Private, for-profit SRM funding is problematic without a governance structure that can ensure the technology serves the public good.

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[108] We used data downloaded from SRM360's 2026 funding report. SRM360, 2026

[109] See Figure "Philanthropies and Stardust's investors outspend most nations on SRM" SRM360, 2026

[110] "Looking ahead from 2026, philanthropic sources have committed an additional $101 million, accounting for about 66% of the known total of future funding. Governmental sources account for the other 34% of committed funding, with almost all of that ($49.3 million, or about 94%) coming from one country, the UK, while the EU, France, and the US have committed much smaller amounts." SRM360, 2026

[111] ARIA: "In spring 2025, ARIA announced funding for 22 research projects under the Exploring Climate Cooling programme, backed by £56.8 million." ARIA, 2026
UKRI: "A new £10.5m, five-year research programme will deliver independent risk-risk analyses to inform policymakers in the area of solar radiation management (SRM)." U.K. Research & Innovation, 2024

[112] "This work was funded by UK Research and Innovation (UKRI) under the UK government's Horizon Europe funding guarantee [No. 10123643 – Climate Strategies; No. 10094614 – Trilateral Research Limited; No. 10098060 – University College London]." Co-CREATE, n.d.

[113] "For-Profit Startup Secures $60 Million for Climate Cooling Technology… This funding brings the total investment in this for-profit venture to $75 million, making it the largest single recipient of funds in a field otherwise dominated by non-profits and public research institutions." SRM360, 2025

[114] "But Make Sunsets is attracting significant Silicon Valley investment, and is hoping to have that bigger impact. The company has raised more than $1.2 million from venture capital firms like Boost VC, Pioneer Fund, and Draper Associates." NPR, 2024

For-profit approaches to SRM, such as "cooling credits," could lead to both inadequate mitigation *and* increasingly risky reliance on geoengineering.[115]

Key Uncertainties and Open Questions

- **Risk of unwarranted deployment:** Critically, we are uncertain whether efforts to expand SRM research and governance could open the door to unwarranted and unregulated deployment—for instance, unilateral actors scaling up engagement toward deployment. Governance frameworks can help mitigate this risk by guiding the scale and scope of research (particularly outdoor experimentation) and by clarifying SRM's objective. However, no consensus yet exists on whether that objective should be reducing human suffering, minimizing economic costs, or buying time for adaptation. We are uncertain how the SRM field will evolve, and we recognize the risk of individual stakeholders breaking from community norms.

- **Contested and understudied benefits and potential risks:** While we remain agnostic about deployment, we note potential risks or benefits that could arise if SRM were deployed. Some modeling suggests SRM could reduce damages caused by warming, such as reducing extreme heat events and possibly slowing polar ice sheet melt, though this latter claim is disputed and its proponents themselves caution that the regional impacts of SRM are not yet sufficiently well-understood to justify large-scale deployment.[116] At the same time, SRM

[115] For instance, inadequate mitigation would happen if companies sell "cooling" as a substitute for real emissions cuts, while increased risk would happen if companies race to deploy unproven SRM technologies. "Researching solar geoengineering technologies under these conditions, without more restrictive governance concerning commercial activities and powerful private sector actors, is likely to lead to the advancement of solar geoengineering amidst inadequate mitigation." Surprise et al., 2025

[116] Heat events: "While models suggest that the frequency of many extreme climatic events (eg, heat waves and wildfires) could be reduced under SRM, extreme weather events would still occur." The Royal Society, n.d.
Polar ice sheet melt: "Our simulations suggest that the most effective path to prevent total long-term WAIS collapse is rapid decarbonization or, depending on GHG emissions, the early deployment of planetary SRM. The latter is politically challenging and associated with unintended and potentially damaging side effects. We believe that a robust understanding of the regional impacts of planetary SRM, or any kind of climate intervention, is imperative before considering large-scale employment." Sutter et al., 2023
Negative consequences of SAI on polar regions: "In the polar regions, atmospheric injections would be ineffective in winter owing to the lack of sunlight. Instead, they could lead to residual warming in winter (due to the blanketing effect of cloud cover), potentially altering the high-latitude seasonal cycle, with potential consequences for the water cycle through atmospheric drying. Atmospheric injections could also cause stratospheric heating, which may alter atmospheric

would alter far more than temperature—including precipitation, sunlight quality, sea level rise, and ocean biogeochemistry—with cascading effects on ecosystems, agriculture, and human health that depend heavily on deployment specifics we cannot yet predict.[117] In general, the more intensely SRM is deployed, the greater the risk of adverse effects.[118] A goal of advancing SRM governance and research would be to improve our understanding of these potential effects.

- **Governance and research pace:** The relationship between governance and research is complex and often described as a chicken-and-egg problem: effective governance could accelerate research by attracting more funding and shifting public perception, while the process of establishing governance could also slow research given its bureaucratic nature. The optimal framework for inclusive, transparent governance that advances ethical research remains an open question.
- **Consensus for decision-making:** Global consensus on SRM seems unlikely, which raises several open questions. For example, what constitutes "sufficient consensus" for halting research or pursuing deployment? Should the opinions of climate-vulnerable countries carry more weight? How can we justify deployment without everyone's consent, considering SRM's global, generational impact? We believe pursuing an inclusive, participatory decision-making process early increases the likelihood of broader agreement over time.
- **Technological barriers to deployment:** We have not fully investigated the technological barriers to SRM deployment. For example, commercial aircraft cannot operate at the altitude range assumed necessary for SAI. Timelines for developing the required engineering and aircraft capabilities remain uncertain, with ranges from under 10 years to roughly two decades.[119] We think development could be perceived as deployment-oriented, risking a "socio-technical lock-in" before we determine whether SRM is desirable.
- **Nonprofit influence on the field:** We are uncertain how much influence nonprofits have on the SRM field. They may shape outcomes by advancing research and inclusive decision-making, or by advocating for a moratorium on SRM research. Their influence could prove limited if governments and private actors come to dominate attention on the topic. However, since we began funding SRM research and governance work in 2024, we have found the field remains relatively small in terms of active players, and overall public knowledge of SRM remains low. We

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circulation patterns, leading to wintertime warming over northern Eurasia, among other unintended consequences." Siegert et al., 2025

[117] For more information, see "2.2c Potential Impacts on Critical Human and Environmental Systems." NASEM, 2021

[118] "The more intense the SRM deployment, the larger is the likelihood for the risks of side effects and environmental risks (e.g., Heutel et al., 2018)." IPCC Sixth Assessment Report, 2022

[119] 10 years: "It is viewed by some scientists that SAI deployment technology could be developed in under ten years" UNEP, 2023

20 years: "Nonetheless, the fleet development interval defines a speed limit that would be hard to exceed, and that speed limit suggests that planetary scale SAI is at least two decades away from being realizable." Smith, 2024

therefore think nonprofits are well-positioned to have outsized effects on the field's trajectory.

Bottom Line and Next Steps

Our central concern is a scenario in which a decision on SRM development and (non-)deployment is made without the research and governance infrastructure needed to prevent adverse outcomes. Advancing SRM governance and research addresses that risk directly. SRM research should ultimately function as a public good, led by governments building transparent, cross-disciplinary programs. We also believe public and philanthropic portfolios should focus primarily on mitigation and adaptation. To align our actions with this belief, we (1) focus our grantmaking portfolio on mitigation, with SRM composing a small fraction of grants, and (2) require grantees applying for funding under this strategy to describe how they minimize moral hazard risks.

Based on our research into relevant sub-strategies, we believe the path to responsible, transparent, and just (non-)deployment decisions runs through opening political pathways for SRM research by engaging key stakeholders, building research governance and coordination infrastructure, and strengthening LMIC capacity to shape SRM research and governance.

Because parts of this impact area have received little funding and could reduce climate damage, we plan to consider organizations working on these topics for our Top Climate Nonprofits and as potential grantees from the Giving Green Fund.

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Giving Green

Giving Green was founded to help donors cut through the complexity of climate philanthropy and direct their resources for maximum impact.

Our founder, Dan Stein, Ph.D., spent 15 years developing evidence-based strategies in global philanthropy. He saw people eager to fight climate change but paralyzed by its scale. In 2019, with support from IDinsight, he launched Giving Green to rigorously evaluate solutions and share clear guidance.

What began as a side project is now a team directing tens of millions of dollars to high-impact initiatives. Our success is shared—with donors ranging from kids donating allowances to retirees investing in a better future. We believe anyone can start small and still make a huge difference.

Thank you for joining us on the path to net zero.
Together, we keep moving forward.