

Climate Geoengineering Governance²

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“An emergency ‘Plan B’ using the latest technology is needed to save the world from dangerous climate change, according to a poll of leading scientists carried out by *The Independent*”.

O’Connor & Green 2009

Climate change geoengineering, defined by Britain’s Royal Society as “the deliberate large-scale manipulation of the planet’s environment to counteract climate change” (Shepherd et al 2009:1) is receiving growing attention from both scientists and policy makers concerned with the slow progress of international negotiations to reduce emissions of greenhouse gases, especially after the Copenhagen climate conference. However, scientists and climate activists seem sharply divided over the wisdom and practicality of geoengineering (O’Connor & Green 2009). We shall begin this paper by considering the reasons why humanity might seek to geoengineer the climate. We assess the potential opportunities and limitations associated with various generic options for geoengineering and the implications of these for governance of research, development, demonstration and deployment of the various technologies. Finally we propose some high level principles for the governance of the field of geoengineering and a structure for the development of specific guidelines or “protocols” for different kinds of technology that might be developed.

1. Why might we geoengineer the climate?

Climate geoengineering is not a new idea². Weather modification dates back at least to the 1860s when the proposals of James Pollard Espy to stimulate rain by controlled forest burning led to his being dubbed the “Storm King” (Meyer 2000). More recently, the US “Project Stormfury” sought for two decades to modify the path of hurricanes by seeding them with silver iodide. Cloud seeding to stimulate rain is practiced routinely in various parts of the world with, it must be said, inconclusive

¹ I am grateful to Catherine Redgwell, Professor of International Environmental Law at University College London for her advice in preparing this paper.

² To be published in German in JAHRBUCH ÖKOLOGIE 2011.

² For more detailed histories of geoengineering see Keith (2000) and Fleming (2010).

results (Fleming 2010). Geoengineering proposals to modify the climate specifically to counteract the greenhouse effect date from at least 1965 (President's Science Advisory Committee 1965). Preliminary studies were conducted throughout the 1970s to 1990s (Budyko 1977, 1982; Marchetti 1977; US National Academy of Sciences 1992) and was the subject of a workshop convened by the Tyndall Centre and MIT in 2004. However, the emphasis of climate research and policy throughout the 1980s and 1990s focused clearly on mitigation and, for much of that period, discussion even of adaptation, let alone geoengineering, was seen as a potentially dangerous distraction from the task of emissions reduction. The issue of "moral hazard" – the idea that even considering additional policies will result in diminished efforts at conventional mitigation – has not turned out to be justified in regard to adaptation, which remains very much the poor cousin of mitigation and the Royal Society could find no extant empirical evidence to justify the concern in respect of geoengineering.

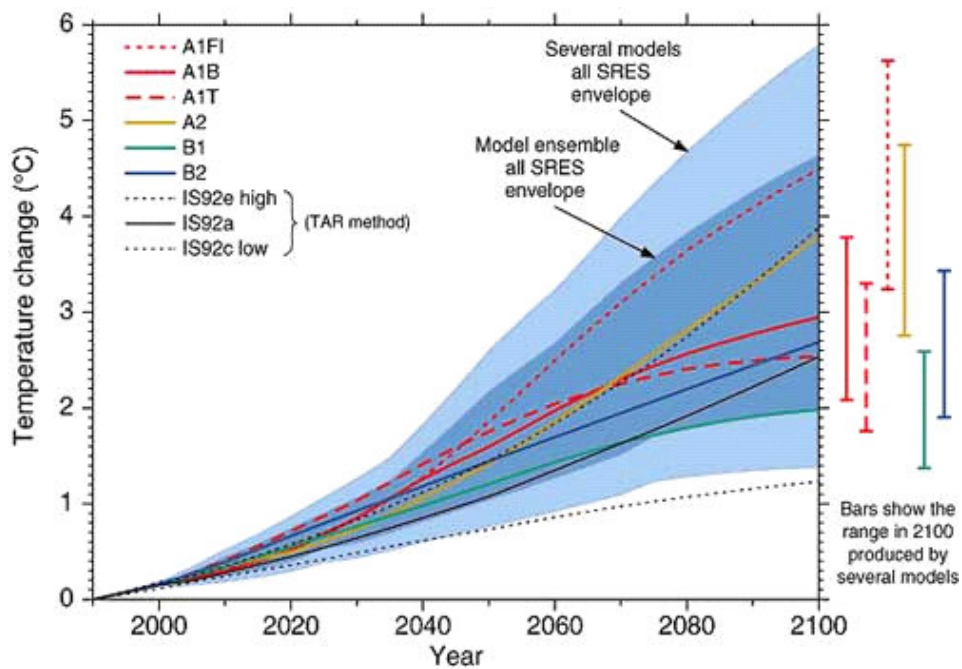
However, sparked by a controversial article in *Climatic Change* by Paul J. Crutzen (2006), the Dutch chemist who won the Nobel Prize for identifying the damage caused to the stratosphere by chlorofluorocarbons, leading scientists have increasingly expressed concerns about lack of progress in international negotiations to reduce global greenhouse gas emissions and have begun talking publicly about the need for a "Plan B" - geoengineering the climate (e.g. Kunzig & Broecker 2008; Walker & King 2008). There are at least four compelling reasons why humanity might want to explore the capacity to geoengineer the climate.

The *first* of these is that the world seems to be locked in to the highest emissions trajectory envisaged by the Intergovernmental Panel on Climate Change. *Figure 1* shows the projections of what the IPCC considers a plausible range of global average temperature increases over the course of the 21st Century, based on various assumptions about global economic development and technological change. At the time of writing, global emissions are increasing at about 3 % per annum, which places the world on the topmost of the curves shown in the figure, that is to say we appear to be headed inexorably towards an increase of 2°C by the year 2040 and 4° by 2100. The IPCC has recommended that the global average temperature increase be limited to a maximum of 2°C. Given the long lag time between changes in atmospheric CO₂

concentrations and predicted climatic response, it seems inevitable, even if radical cuts in emissions were to be introduced in the next decade, that this recommendation will be exceeded.

Figure 1:

IPCC EMISSIONS SCENARIOS

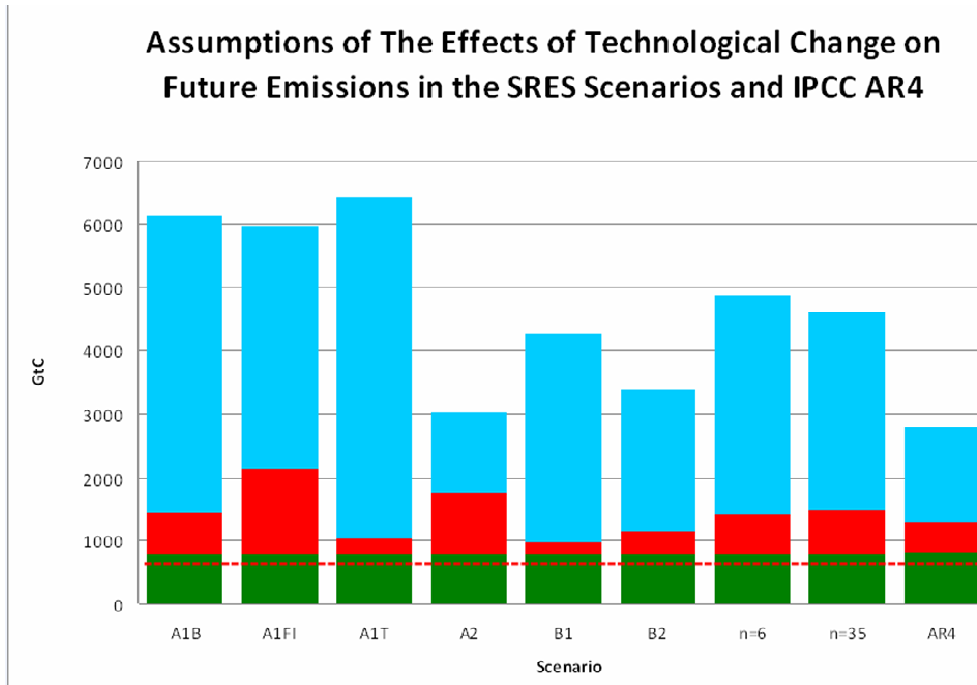


Source: IPCC 2007.

Second, it seems altogether possible that the IPCC has significantly underestimated the extent of emissions cuts that would be required to stabilize atmospheric CO₂ concentrations at any point on *Figure 1*. This is because in devising all of its emissions scenarios, the IPCC made highly optimistic assumptions about future energy and carbon intensity of the global economy. Both the amounts of energy and of carbon needed to create each new unit of global wealth (GDP) have fallen steadily for about a century. The IPCC assumed that this would continue and at a rate considerably faster than anything that has been observed historically. Not only was this over optimistic, but a couple of years ago

these declining trends went into reverse, largely due to rapid expansion in the emerging economies of China and India.

Figure 2:



Source: Pielke et al. 2008.

Note: The blue portions indicate the assumed autonomous decline in carbon and energy intensity in each scenario. Red indicates the IPCC estimates of required additional mitigation to reach allowable emissions shown in green.

Figure 2 shows an estimate of the total avoided emissions that would be necessary over the course of the 21st Century if the IPCC assumptions turn out to be incorrect, as they almost certainly are. In this event, the emissions reduction challenge may prove to be as much as three times what the IPCC has estimated.

A *third* concern is that current CO₂ emissions are accompanied by emissions of sulphate aerosols that reflect sunlight back into space and so partially offset the warming effects of CO₂. If humanity is successful in reducing carbon emissions then it will also reduce the production of these aerosols, which have a much shorter residence time in the atmosphere than the CO₂. The elimination of these aerosols may therefore exacerbate the warming effect of greenhouse gases already in the atmosphere by more than a degree (IPCC 2007).

Finally there is concern that temperature rises over the next century may exceed irreversible “tipping points” in the climate system or in ecosystems leading to abrupt, potentially catastrophic impacts on human and natural systems. For example, it is possible that melting tundra could release large quantities of methane, a more potent gas than CO₂, into the atmosphere, accelerating the warming process. Although the US National Academy of Sciences (2002) has described abrupt climate change as a very low probability but very high consequence event, some geoengineering measures appear to offer humanity the ability to shave the peaks off CO₂ driven emissions and avoid such tipping points. This possibility raises numerous governance issues, not least who would determine when a planetary emergency is imminent and who would actually control the “global thermostat”.

Any one of these *four* considerations would suggest that a safe, effective, and affordable means to ameliorate atmospheric warming and/or to achieve negative carbon emissions would be a highly desirable addition to the existing portfolio of climate policies consisting of conventional greenhouse gas mitigation and adaptation.

In Britain, the topic has been the subject of the Royal Society report and the House of Commons has conducted two inquiries respectively recommending both funding for research and the development of governance principles for geoengineering (UK House of Commons 2009, 2010). In the US Congress, the House Science and Technology Committee has also been holding hearings on the governance of geoengineering research and possible deployment. So what exactly is under consideration?

2. How might we geoengineer the climate?

The first thing to emphasize is that geoengineering technologies do not yet exist, although some of the components that might go into them are already available or are under development for other reasons, for example carbon sequestration in geological formations, which is already being explored for conventional carbon capture and storage from power stations,³ would be an integral part of a programme to capture carbon dioxide from the ambient air by artificial means. However the front end

³ Where governance issues are already being addressed through, for example the EU CCS directive.

of the system – CO₂ removal from ambient air – is currently only available on a very small scale for use in submarines, where the very high cost of the current technology is justified. It is all too easy, in discussing geoengineering, to fall victim to Whitehead's (1919) fallacy of misplaced concreteness and to talk about the comparative merits and drawbacks of geoengineering technologies as if they were already well developed and known.

Second, it is essential to recognize that the term geoengineering currently encompasses a wide variety of concepts exhibiting diverse technical characteristics with very different implications for their governance. There is a tendency in some circles to seek to exempt favoured technological concepts from the category of geoengineering, leaving the term to apply only to big scary or impractical options. This paper resists that impulse precisely because, as has just been argued, the technologies are really just ideas at this stage and it is important not to close in prematurely on which technologies require specific levels of governance.

However, the very variety of technologies suggests the need for a preliminary taxonomy of technology concepts that identifies salient characteristics for both research and governance considerations.

The Royal Society distinguishes two principal mechanisms for moderating the climate by geoengineering. One is by reflecting some of the sun's energy back into space to reduce the warming effect of increasing levels of greenhouse gases in the atmosphere. This is described as *Solar Radiation Management* or SRM. The other approach is to find ways to remove some of the carbon dioxide from the atmosphere and sequester it in the ground or in the oceans. This is called *Carbon Dioxide Removal* or CDR. (The Royal Society report recognized, but gave less prominence to another way of discriminating between geoengineering technologies, which cuts across the distinction between SRM and CDR). Both goals can be achieved by one of two different means.

One is to put something into the air or water or on the land's surface to stimulate or enhance natural processes. For example, injecting sulphate aerosols into the upper atmosphere imitates the action of volcanoes, which we know to be quite effective at reducing the sun's energy

reaching the earth's surface; hence this is one candidate SRM technique. Similarly, we know that lack of iron constrains plankton growth in some parts of the ocean. So adding iron to these waters would enhance plankton growth, taking up atmospheric CO₂ in the process. This would be a potential CDR technique also achieved by imitating nature.

The *second* approach to both SRM and CDR is through more traditional “black-box” engineering. Mirrors (either large or more likely myriad small ones) in space, either in orbit or at the so-called Lagrange point between the earth and the sun, would be a way of reflecting sunlight (SRM), while a potential CDR technique would be to build machines to remove CO₂ from ambient air and inject it into old oil and gas wells and saline aquifers in the same way that is currently proposed for carbon capture and storage (CCS) technology.

Combining these two means (natural systems enhancement and black-box engineering) with the two goals described above (SRM and CDR) creates a serviceable typology for discussing the range of options being considered under the general rubric of geoengineering (see Table 1).

Tab. 1:

GEOENGINEERING FOR CLIMATE CHANGE

	CARBON DIOXIDE REMOVAL	SOLAR RADIATION MANAGEMENT
ECOSYSTEMS ENHANCEMENT	OCEAN IRON FERTILIZATION	STRATOSPHERIC AEROSOLS
BLACK-BOX ENGINEERING	AIR CAPTURE (ARTIFICIAL TREES)	SPACE REFLECTORS

Source: Royal Society 2009.

3. Opportunities and limitations of different approaches

At first sight, it might seem that the different goals and means represented in geoengineering are alternatives. Some commentators have suggested that geoengineering is itself an alternative to mitigation (e.g. Barrett 2008) although the Royal Society report emphatically rejected this idea. However, closer scrutiny suggests that different techniques may be suited to very different tasks and time perspectives. Currently, there is much interest in SRM using sulphate aerosols. This is because we know from volcanic eruptions that such tiny particles in the atmosphere can effectively cool the earth, the technique is relatively straightforward, the programme costs involved appear to be relatively modest and they could be implemented quickly. Hence many commentators see aerosols as a Band Aid to stop the earth from getting too hot and triggering a runaway greenhouse effect or other possible climatic emergency (so-called *tipping points*).

At the other extreme, air capture of carbon “using artificial trees” and sequestration in spent oil and gas wells or saline aquifers seems a relatively distant and costly prospect compared to aerosols. In any case, as with conventional emissions mitigation, the climate benefits of removing carbon from the air will take longer to realize because changes in the global average temperature lag behind changes in greenhouse gas concentrations by [umpteens] years. However, in principle, all of the carbon that came out of the ground could be put back there, so, in theory at least, air capture holds out the prospect of restoring atmospheric carbon concentrations to pre-industrial levels over the very long term.

Sulphate aerosols have at least two well-recognized drawbacks. One is that the effects on the earth’s climate may be uneven, possibly causing disruption of the Asian Monsoon upon which billions rely for agriculture. Another is that stopping a sulphate aerosol programme in the event of unforeseen negative outcomes would result in a sudden temperature spike, unless drastic compensating emission reductions have been simultaneously achieved. That is to say, the full environmental and social costs of aerosols may be very much higher than the programme implementation costs and there is likely to be a high level of technological lock-in. These drawbacks strongly suggest that SRM using aerosols would be controversial. Also, public opinion is

likely to be wary of “tinkering with earth systems”, especially through what could be described as deliberate air pollution. And, furthermore, the transborder implications suggest that aerosols would require international agreement for their deployment and, as we know, international agreement on climate actions has proven to be highly elusive.

On the other hand, except where the geological formations used for storage cross national boundaries, regulation of air-capture technology would seem to be almost entirely a matter for the governments of the countries in which it is located.⁴ Furthermore, in the event that the technology did have unforeseen negative consequences, there would be no technical barrier to switching the black-box machines off, although it is arguable that the sunk costs in the technology would create vested commercial interests in keeping it running.

This is the geoengineering paradox (Rayner 2010). The technology that seems to be nearest to maturity and could technically be used to shave a few degrees off a future peak in anthropogenic temperature rise is likely to be the most difficult to implement from a social and political standpoint, while the technology that might be easiest to implement from a social perspective and has the potential to deliver a durable solution to the problem of atmospheric carbon concentrations is the most distant from being technically realized. These appear to be the “bounding cases” and other geoengineering technologies fall somewhere in between.

This brief example of the specificity of geoengineering applications helps to emphasise the Royal Society findings that geoengineering cannot be considered as an alternative to mitigation nor can its merits be evaluated *sui generis* because they “vary greatly in their technical aspects, scope in space and time, potential environmental impacts timescales of operation, and the governance and legal issues that they pose” (Shepherd et al. 2009: 47).

Furthermore, the Royal Society concluded that “The acceptability of geoengineering will be determined as much by social, legal, and

⁴ Additional international implications would arise should such capture and sequestration qualify as mitigation, and/or as a CDM qualifying activity, under the Kyoto Protocol and any successor regime.

political issues as by scientific and technical factors. There are serious and complex governance issues that need to be resolved” (Shepherd et al. 2009: ix).

4. Geoengineering governance

The key challenge of geoengineering governance is that articulated by the British sociologist David Collingridge (1980) as the “technology control dilemma.” Briefly the dilemma consists of the fact that it would be ideal to be able to put appropriate governance arrangements in place upstream of the development of a technology to ensure that all of the stages from research and development through demonstration and full deployment are all appropriately organized and adequately regulated to safeguard against unwanted health, environmental and social consequences. However, experience repeatedly teaches us that it is all but impossible, in the early stages of development of a technology, to know how it will turn out in its final form. Mature technologies rarely, if ever, bear close resemblance to the initial ideas of their originators. By the time technologies are widely deployed, it is often too late to build in desirable characteristics without major disruptions. The control dilemma has led to calls for a moratorium on certain emerging technologies and, in some cases, on field experiments with geoengineering.⁵ This would make it almost impossible to accumulate the information necessary to make informed judgements about the feasibility or desirability of the proposed technology.

However, Collingridge did not intend identification of the control dilemma to be a counsel of despair. He and his successors in the field identify various characteristics of technologies that contribute to inflexibility and irreversibility and which are therefore to be avoided where more flexible alternatives are available. These undesirable characteristics include high levels of capital intensity, hubristic claims about performance, and long lead times from conception to realization, to which Britain’s Royal Commission on Environmental Pollution recently added, in the context of nanoparticles, “uncontrolled release into the environment” (RCEP 2008). Consideration of the control dilemma suggests that it would be sensible to favour technologies that are encapsulated rather than involving dispersal of materials into the

⁵ See e.g. the resolution by parties to the Convention on Biological Diversity ‘prohibiting’ ocean iron fertilisation apart from small-scale scientific research in ‘coastal waters’.

environment and those that are easily reversible over those that imply a high level of economic or technological lock-in.

The other key challenge for geoengineering governance lies in the varying degrees of international agreement and coordination that would seem to be required for the different technologies involved. At least upon first examination, carbon air capture with geological sequestration would not seem to require much in the way of international agreement, except where the geological formations chosen for storage crossed national boundaries and possibly where facilities were located close to national borders, or where sequestration is to occur offshore.⁶ National planning regulations, rules governing environmental impact assessment, and health and safety laws would seem to provide, at least in principle, an adequate framework for ensuring the responsible management of the technology where there is little prospect of transborder damage occurring to people or the environment. Existing national legislation for the governance of CCS from fixed point sources (e.g. coal fired power plants), without an overarching global governance framework, underscores this point.

However, the situation seems to be very different with CDR involving iron fertilization because it involves modification of natural processes that cannot be territorially contained. Similarly, any kind of SRM, whether involving space mirrors (black-box engineering), cloud whitening or sulphate aerosols (modification of natural processes), would seem to require international agreement even for field trials, let alone deployment.

The Royal Society suggests that many issues of international coordination and control could be resolved through the application, modification and extension of existing treaties and institutions governing the atmosphere, the ocean, space and national territories, rather than by the creation of specific new international institutions. All geoengineering methods fall under provisions of the 1992 UN Framework Convention on Climate Change (UNFCCC) and the 1997 Kyoto Protocol which impose a general obligation to “use appropriate methods, e.g. environmental impact assessment...with a view to

⁶ Subseabed sequestration is subject to regulation by global and regional dumping conventions, which have been adjusted to permit it under the London Convention and OSPAR Convention.

minimising adverse effects...on the quality of the environment of projects or measures undertaken to mitigate or adapt to climate change.” Additionally, there are several customary law and general principles that would apply to such activities. The duty not to cause significant transboundary harm is recognized in many treaty instruments⁷ and at customary international law. As the Royal Society observes, “States are not permitted to conduct or permit activities within their territory, or in common spaces such as the high seas or outer space, without regard to the interests of other states or for the protection of the global environment” (Shepherd et al. 2009).

The use of sulphate aerosols for SRM may fall under the jurisdiction of the Montreal Protocol for Protection of the Ozone Layer as they may have ozone depleting properties. Ocean fertilization has already caught the attention of the London Dumping Convention and London Protocol, which has adopted a cautious approach to permitting carefully controlled scientific research through a 2008 resolution agreeing that the technology is governed by the treaty but exempting legitimate scientific research from its definition of dumping. The Convention on Biological Diversity has also sought to intervene to prevent ocean fertilization experiments except for small scale experiments in coastal waters.⁸

Potentially lengthy negotiations would be necessary before sulphate aerosols could be deployed by any country or other agent within an agreed international governance framework⁹; without such framework such activities would likely attract the condemnation of the international community. Overall, the international legal framework within which geoengineering will be conducted remains as under-specified as the technologies themselves. Furthermore, the control dilemma means that it is almost impossible to determine governance requirements until the shape of any of the technologies under consideration is better known. This dilemma led the Royal Society to recommend establishing an international scientific collaboration to “develop a code of practice for geoengineering research and provide recommendations to the

⁷ Examples include the UNFCCC, the Convention on Biodiversity (CBD), the UN Law of the Sea Convention (UNCLOS), and the UN Convention to Combat Desertification.

⁸ The expression “coastal waters” has no fixed international legal definition and small near-shore studies are largely meaningless for evaluating iron fertilization technology, which has led to contestation of the CBD language and the scientific assumptions underpinning it.

⁹ ENMOD already prohibits environmental modification techniques by States for military or hostile purposes; the presumption here is the peaceful use of climate intervention techniques.

international scientific community for a voluntary research governance framework” (Shepherd et al. 2009: 61).

5. Governance principles from research to deployment

Following publication of the Royal Society report, the UK House of Commons Select Committee on Science and Technology initiated an inquiry on the topic of how geoengineering should be governed. An ad hoc group of academics submitted a list of five high-level principles (Rayner et al. 2009) for research, development and deployment of geoengineering technologies.

“The ‘Oxford Principles’, as they are known, hold that geoengineering should be regulated as a public good, in that, since people cannot opt out, the whole proceeding has to be in a well-defined public interest; that decisions defining the extent of that interest should be made with public participation; that all attempts at geoengineering research should be made public and their results disseminated openly; that there should be an independent assessment of the impacts of any geoengineering research proposal; and that governing arrangements be made clear prior to the use of any actual use of the technologies” (*The Economist* 2010: 75).

The idea behind these principles is that they should provide real assurance that the entire process from initial research through development, field trials, and eventual deployment are conducted openly and in the public interest of all affected countries, while also allowing for the development of more flexible technology-specific protocols for the governance of individual geoengineering approaches as their technical contours and socioeconomic implications become clearer through the R&D process.

The Final Report of the Parliamentary Select Committee welcomed the principles saying that “While some aspects of the suggested five key principles need further development, they provide a sound foundation for developing future regulation. *We endorse the five key principles to guide geoengineering research*” (House of Commons 2010: 35). Although they were not specifically included in the final communiqué of the 2010 Asilomar Conference convened to explore the governance issue facing geoengineering researchers, it was reported that they were

“generally endorsed” by the research community (The Economist 2010: 75).

At the time of writing, it is unclear how governance of climate geoengineering will be taken forward. The House Science and Technology Committee of the US Congress is due to report shortly on the topic and the Royal Society has announced a project to explore research governance guidelines for SRM to be conducted in collaboration with the US National Academy of Sciences, the Third World Academy, and the Environmental Defense Fund. There seems little doubt there is scientific momentum building behind efforts to develop geoengineering options and that legislators are eager for guidance on both how that research should be conducted and how decisions about deploying any resulting technology should be made.

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