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Governing Climate Engineering: Scenarios for Analysis

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Prepared for
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THE HARVARD PROJECT ON CLIMATE AGREEMENTS

The goal of the Harvard Project on Climate Agreements is to help identify and advance scientifically sound, economically rational, and politically pragmatic public policy options for addressing global climate change. Drawing upon leading thinkers in Australia, China, Europe, India, Japan, and the United States, the Project conducts research on policy architecture, key design elements, and institutional dimensions of domestic climate policy and a post-2012 international climate policy regime. The Project is directed by Robert N. Stavins, Albert Pratt Professor of Business and Government, Harvard Kennedy School. For more information, see the Project's website: <http://belfercenter.ksg.harvard.edu/climate>

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How much are we willing to bet that countries will succeed in preventing dangerous climate change by cutting their emissions of carbon dioxide and other greenhouse gases? The Intergovernmental Panel on Climate Change (IPCC) estimates that global emissions would need to go down by 50-85% from 2000 levels by 2050 in order to limit global warming to 2 C° – the goal adopted by states at the Copenhagen conference.¹ But global emissions continue to rise at a rapid rate, and are now 30% higher than in 2000.² Most of the discussions of future warming focus on the effects of doubling carbon dioxide levels from pre-industrial times to 550 parts per million. But the implications of this scenario, although themselves dire, may be far too optimistic, since our current emissions trajectory suggests that CO₂ levels may triple or even quadruple rather than double by the end of the century.³ The resulting climate change would be in the neighbourhood, not of 2-3° C, as most discussions assume, but more than 5° C (or 9° F).⁴ Add to this the possibility of climate

¹ IPCC 2007, Table SPM.5.

² Olivier 2011, Table A1.1 (global emissions 25.3 Gt in 2000 and 33 Gt in 2010).

³ National Research Council 2011, at 60.

⁴ The United Kingdom Met Office warned in 2008 that if no action were taken to reduce emissions, global temperatures could rise by more than 5° C by 2100. A similar MIT study concluded that without emissions controls, median surface warming by the end of the century would be 5.2° C. Sokolov 2009. A recent review concluded that a +4° C warming

“surprises,” in which the climate system crosses some threshold, resulting in “large, abrupt, and unwelcome” changes,⁵ and our current predicament becomes even scarier.

Thus far, the major international response to the climate change problem has been to negotiate international limits on national greenhouse gas emissions. But the results, to date, have been meagre. Global emissions have increased by 45% since 1990, when negotiations on an international climate change regime began. The Kyoto Protocol's initial commitment period covers less than 30% of global emissions for a five-year period ending in 2012, and has not stopped global emissions from continuing to grow due to increased emissions in the United States, China, and other countries that don't have Kyoto targets. Unless the Kyoto Protocol can be either dramatically increased in scope or replaced by a new, more comprehensive agreement, global emissions will continue to rise as China and other major developing countries continue to industrialize. Indeed, even if Western developed countries were to phase out their net emissions of carbon dioxide altogether over the next twenty years – a huge task in itself – global emissions in 2030 would still be higher than today, owing to the projected increase in developing country emissions over the next two decades.⁶

This grim outlook has led many to take a second look at geoengineering solutions to climate change. In the last two years alone, the Royal Society,⁷ the General Accounting Office,⁸ and the National Academy of Sciences⁹ have all issued reports addressing geoengineering; two books and

could result in the collapse of farming in sub-Saharan Africa and displace more than 180 million people due to sea-level rise. New et al. 2011.

⁵ National Research Council 2002, at 1.

⁶ Blanford 2010.

⁷ Royal Society 2009.

⁸ General Accounting Office 2010

⁹ National Research Council 2010, ch. 15.

countless articles have appeared in the popular press;¹⁰ and numerous conferences and workshops have been organized.

Geoengineering is a broad concept that encompasses a variety of approaches to counteract the effects of greenhouse gas emissions, including both techniques to limit how much sunlight reaches the earth (usually referred to as "solar radiation management" or SRM) as well techniques to remove carbon dioxide from the atmosphere ("carbon dioxide removal" or CDR).¹¹ Although specifying a precise definition of geoengineering is difficult, the various geoengineering approaches under consideration have several common threads, identified more than a decade ago by Thomas Schelling.¹² They are all:

- Large scale, capable of affecting the global temperature, as compared to more limited local weather modification techniques such as cloud seeding.
- Intentional, as opposed to the climate modification we are already engaged in as a result of our greenhouse gas emissions.
- "Unnatural" and novel, as opposed to natural, familiar processes such as growing more trees or practicing no-till agriculture.

Geoengineering is of interest to groups across the political spectrum. On the one hand, it is attractive to climate sceptics, since it reduces the need to take action now. If geoengineering were possible, then even if climate change predictions turned out to be true (which sceptics think unlikely), we could still respond through geoengineering. On the other

¹⁰ Goodell 2010a; Kintisch 2010; Wood 2009.

¹¹ Because the term "geoengineering" is controversial and imprecise, the recent Bipartisan Policy Center Task Force report chose to use the term "climate remediation" instead. Bipartisan Policy Center Task Force 2011, at 3.

¹² Schelling 1996, at 303 (geoengineering "seems to imply something global, intentional, and unnatural").

hand, geoengineering is also of interest to environmentalists, as a means of averting catastrophic climate change, should efforts to reduce emissions fall short. Geoengineering could also prove attractive to politicians (although few have shown much interest thus far), because it allows them to avoid making difficult decisions now. And geoengineering is seductive to economists, because some geoengineering technologies appear astonishingly cheap – in particular, injecting sulfur aerosols into the atmosphere to block incoming sunlight.¹³ If geoengineering in fact proves to be effective in reducing the global temperature, then it might well be the most efficient way to address climate change – much cheaper than reducing emissions.

Geoengineering has an additional allure: its low costs and global effects give individual countries the ability – and potentially the incentive – to "solve" the climate change problem unilaterally. As David Victor notes, this "turns the politics of climate protection upside down."¹⁴ Reducing greenhouse gas emissions is an example of what economists call an "aggregate effort" public good. It depends on collective action by the world's big emitters, a prisoners' dilemma problem that has thus far proved impossible to solve. In contrast, geoengineering is a "best shot" collective good – it could be supplied by an individual country.¹⁵ Thomas Schelling once observed that geoengineering "transforms the greenhouse issue from an exceedingly complicated regulatory regime to a simple ... problem in international cost sharing."¹⁶ But even this may overstate the problem of international governance, since if the costs of geoengineering prove sufficiently cheap, international cost sharing might not be necessary.

¹³ Barrett 2008.

¹⁴ Victor 2008, at 323. See also Virgoe 2009, at 115 ("Deployment of geoengineering by one country alone is technically feasible -- it does not require global action, unlike mitigation. One country *could* do it alone.").

¹⁵ Barrett 2007 (elaborating typology of global public goods).

¹⁶ Schelling 1996, at 305.

Of course, the features of geoengineering that make it alluring also make it scary. The prospect of individual countries taking unilateral action to remake the planet brings to mind, for some, images of technology gone awry – of climate scientists acting like Dr. Frankenstein or Dr. Strangelove.¹⁷ The hope is that the geoengineering would be purely positive. But geoengineering also poses risks. Some are known – such as the potential effects on the ozone layer or regional weather patterns. But the unknown, "impossible-to-predict surprises" are what worry many people most.¹⁸

For environmentalists and most scientists, geoengineering is definitely Plan B – a last resort, if efforts to mitigate climate change fail and we face a catastrophe or tipping point calling for rapid remedial action.¹⁹ For them, reducing greenhouse gas emissions should be the primary policy, and geoengineering is suspect to the extent it detracts from emissions mitigation.²⁰ But for climate sceptics and some economists, geoengineering may represent Plan A – that is, the preferred international approach.²¹

Whether seen as Plan A or B, geoengineering raises major political and ethical issues²² – and hence major governance challenges. Who should decide whether and how to engage in geoengineering? Should individual countries be allowed to weigh the potential benefits and risks on their own, or should geoengineering require collective decisions and, if the

¹⁷ Hamilton 2010.

¹⁸ Rand 2011, at 2.

¹⁹ Scott Barrett, for example, describes geoengineering as a "stopgap measure, a quick fix, a Band-Aid." Barrett 2008, at 47. Lee Lane compares this attitude to views about chemotherapy: "No one wants to have it, but everyone wants the option should the need arise." Lane 2010.

²⁰ Many scientists are reluctant to investigate geoengineering, for exactly this reason. They fear that it would create a "moral hazard" that undercuts efforts to reduce greenhouse gas emissions. Cicerone 2006.

²¹ See, e.g., Teller et al. 2002.

²² On the ethical issues, see Gardiner 2010.

latter, what international body should have this responsibility? What limitations, if any, should be placed on individuals to prevent them from undertaking geoengineering? And how should the international community address attempts by individual states to engage in geoengineering?

For many, the default assumption is that issues with global impacts, like geoengineering, should be addressed multilaterally, with significant public participation and transparency, through the United Nations system.²³ But each aspect of this conventional wisdom requires scrutiny.

To begin with, why does geoengineering require multilateral decision-making? Is this because we trust multilateral decision-making processes more than national decision-making? Are multilateral decision-making procedures more likely to yield the correct decision about whether or not to use geoengineering? Or is multilateral decision-making preferable, even if less reliable, because it will have greater public acceptability or because, as a moral matter, everyone affected by a decision should have the right to participate in the decision-making process?

Similarly, consider the need for public participation. Certainly, public participation and transparency may help to prevent a kneejerk reaction against geoengineering research. But once geoengineering moves from the research to the deployment stage, it is unclear how the public might meaningfully continue to participate in the decision-making process.

Finally, consider the assumption that geoengineering should be governed by the United Nations. What exactly does this mean? Does it mean decision-making by the General Assembly, where every state has an equal vote? Or should decisions be made by an institution with more limited membership, such as the Security Council? Many view institutions with universal membership as more “legitimate.” But institutions with more limited membership, such as the Antarctic Treaty System, can be

²³ See, e.g., Banerjee 2011 (need to create a decision-making process involving a diverse group of citizens and experts); Lin 2009; Virgoe 2009.

more effective. So there are likely to be tradeoffs in the design of geoengineering institutions.

What Is Geoengineering?

A wide variety of approaches fall under the rubric of geoengineering, which pose different risks and different governance challenges. In general, there are two ways to address global warming: (1) reduce the amount of solar radiation that reaches the earth, or (2) reduce the concentrations of gases that trap heat in the atmosphere.²⁴ Conventional climate change policy has focused on the second alternative, through limits on emissions of CO₂ and other greenhouse gases. Geoengineering proposals, in contrast, encompass both methods of reducing temperature. Moreover, insofar as geoengineering involves reducing atmospheric concentrations of greenhouse gases, it does so by taking more carbon out of the atmosphere rather than by limiting what we put in.

Solar Radiation Management (SRM)

Solar radiation management involves reflecting more sunlight away from the earth so that it does not warm the earth's surface. Offsetting the warming caused by a doubling of CO₂ would require reducing the amount of incoming solar radiation by about 2%.²⁵ This could be done in a variety of ways:

²⁴ Some discussions of geoengineering define it to include only solar radiation management techniques. See, e.g., Barrett 2008.

²⁵ Royal Society 2009, at 23.

Cloud whitening – Clouds reflect sunlight already, so one possibility would be to make clouds whiter, in order to increase their reflectivity. Potentially, this could be accomplished by injecting small particles of sea salt into the marine atmosphere, which would serve as cloud-condensation nuclei. According to some estimates, a fleet of as few as 1500 vessels spraying micro-droplets into the atmosphere could whiten clouds enough to offset the global warming that has already occurred since the beginning of the industrial revolution.²⁶

Stratospheric aerosols injection (SAI) – Sulfur aerosols produced by volcanoes and industrial activities reflect sunlight from the earth and partially offset the greenhouse effect. The 1991 eruption of Mt. Pinatubo alone is estimated to have injected 20 million tons of sulfur dioxide into the atmosphere and cooled the earth by 0.5° C. And the sulfur dioxide pollution that contributes to acid rain has offset a significant amount of greenhouse warming over the last half century, dampening the effects of CO₂ emissions. Some prominent scientists – including Nobel Prize winner Paul Crutzen – have suggested that sulfur aerosols could be injected into the stratosphere by cannons or airplanes, mimicking the effects of a volcano in cooling the earth. Reducing incoming solar radiation by 2% would require injecting 1-5 million tons of sulfur per year at an altitude of about 20 miles. According to some estimates, this could be done at an extremely low cost – in the range of tens of billions of dollars – making it potentially within the reach of individual states or even very rich individuals.²⁷

Space-based mirrors – Finally, at the science fiction end of the spectrum, mirrors or other reflective material could be positioned in space to reflect incoming sunlight, creating a space sunshade. Although these technologies are still far off and raise major uncertainties, the Royal Society report concludes that they could “offer a cheaper and less risky

²⁶ *Id.* at 27.

²⁷ Barrett 2008.

approach to SRM than any of the stratospheric or near-Earth techniques.”²⁸

Carbon Dioxide Removal (CDR)

In contrast to SRM techniques, which clearly differ from conventional climate change policy, CDR technologies are part of a continuum that encompasses existing policies such as reforestation. Drawing a sharp dividing line between geoengineering and conventional policies to enhance carbon sinks is difficult. The difference lies in a subtle judgment about which processes are “unnatural.” Reforestation is “natural,” so it does not count as geoengineering. In contrast, seeding the oceans with iron to enhance biological production is novel and unnatural, and hence a type of geoengineering.

Possible CDR techniques include:

Enhanced weathering – The natural carbon cycle involves the removal of carbon from the atmosphere through the weathering of rocks. This natural process of carbon removal could be artificially enhanced through the addition of minerals to agricultural soils or ocean waters, or through a variety of chemical techniques that accelerate the rate of weathering.

Mechanical trees – Carbon could be directly captured from the air through chemical reactions by mechanical “trees.” According to a report by the Institution of Mechanical Engineers, a single artificial tree could potentially capture as much as 10 tons of carbon per day.²⁹ Currently, direct air-capture technology is very expensive. But if it could be deployed at an affordable price, it would offer an easily scalable means of addressing climate change.

²⁸ Royal Society 2009, at 33.

²⁹ Institute of Mechanical Engineers 2009, at 10.

Ocean fertilization – Roughly a quarter of the CO₂ released into the atmosphere eventually finds its way into the deep ocean, by means of a “biological pump” that fixes carbon at the surface through plant growth and then draws it into deeper waters as dead organisms and waste materials sink. One of the most publicized geoengineering proposals is to enhance the ocean’s biological pump by adding nutrients to surface waters to stimulate an algal bloom. The first ocean fertilization proposal focused on adding iron, in the belief that it was the limiting nutrient in algae growth. More recently proposals have focused on nitrogen and phosphates as the limiting nutrients. Although proponents of ocean fertilization initially suggested that it could completely reverse anthropogenic climate change, more recent studies have cast doubt on its efficacy, and the 2009 Royal Society report concludes that ocean fertilization can “play at best only a modest role” on “a similar scale to what might be gained by re-forestation of the [earth’s] land surface.”³⁰

Evaluating the Benefits and Costs of Different Geoengineering Approaches

Geoengineering techniques operate very differently and raise different technical, ethical, and political questions. How should we evaluate and compare different geoengineering options? Given the high levels of uncertainty about both benefits and costs, quantitative cost-benefit analysis seems impossible. Instead, a more qualitative evaluation is needed. The Royal Society report proposed four criteria: (1) environmental effectiveness; (2) speed; (3) safety; and (4) cost.³¹ (See Figure 1) Environmental effectiveness includes “confidence in the scientific and technological basis, technological feasibility, and the

³⁰ Royal Society 2009, at 17.

³¹ Id. at 6. Boyd 2008 identifies similar evaluative criteria, but ranks the proposals differently.

magnitude, spatial scale and uniformity of the effects achievable." Speed includes the state of readiness and the speed of the intended effect. Safety includes both known risks and the potential for unpredictable and large-scale harms. Finally, cost involves both the initial costs of deployment and the ongoing costs of operation.³²

Figure 1: Evaluation of Geoengineering Techniques

	Effectiveness	Speed	Safety	Cost
<u>Solar Radiation Management</u>				
Cloud whitening	Low to Medium	Medium	Low	Medium
Sulphur aerosol injection	High	High	Low	High*
Space-based methods	High	Very Low	Medium	Very Low to Low*
<u>Carbon Dioxide Removal</u>				
Enhanced weathering	High	Low	Medium or High	Low
Direct air capture	High	Low	Very High	Low
Ocean fertilization	Low	Low/Very Low	Very Low	Medium

* "High" is a positive score; "low" a negative score. Thus, a score of "high" for costs means low cost, and vice versa. *Source:* Royal Society 2009.

In general, carbon dioxide management has the benefit over solar radiation management of keeping carbon dioxide concentrations stable and thus fully addressing the environmental impacts of emissions. In contrast, solar radiation management addresses the effect of emissions on temperature. But it does not address the other adverse effects of higher carbon dioxide concentrations – in particular ocean acidification, which threatens the continued existence of coral reefs.³³

³² Id.

³³ Sometimes this difference is characterized in terms of CDR addressing the cause of climate change and SRM addressing the effects or symptoms. Lin 2009, at 13. But solar radiation is as much a root cause of climate change as carbon dioxide.

Geoengineering approaches also vary widely in their degree of “leverage” – that is, the potential magnitude of the effects resulting from a given level of effort.³⁴ Sulfur aerosol injection is a “high leverage” technique: a relatively modest amount of sulfur aerosols injected into the stratosphere could have potentially huge and very rapid climatic effects.³⁵ In contrast, adding silicon to agriculture soils is a low leverage technique: it would increase the amount of carbon removed from the atmosphere by only a modest amount over a long period of time. To some degree, the distinction between high and low leverage techniques corresponds to the difference between SRM and CDR. But some CDR techniques such as ocean fertilization involve relatively high leverage, while some SRM techniques involve low leverage.

In general, high leverage approaches are attractive from a climate change perspective because they could produce large, rapid decreases in temperature at a low cost. So they could be “especially important if climate remediation were needed on an emergency basis – that is, if it looked as if climate change were going to cause imminent severe, or even catastrophic, impacts.”³⁶ That is why sulfur aerosol injection has received considerable attention.

But changing the chemical composition of the atmosphere through the addition of sulfur aerosols poses big risks as well, both globally and to regional climate patterns.³⁷ The risks identified thus far include ozone depletion³⁸ and changes to regional precipitation patterns.³⁹ But there is considerable uncertainty, and some believe that the biggest dangers might

³⁴ House of Commons 2010, at 17; *see also* Bipartisan Policy Center Task Force 2011, at 3.

³⁵ Crutzen estimates that the climate effects of SRM could take only a few months. Crutzen 2006.

³⁶ Bipartisan Policy Center Task Force 2011, at 11.

³⁷ For a list of 20 reasons why geoengineering may be a bad idea, see Robock 2008.

³⁸ *Compare* Wigley 2006 (effects on the ozone layer “likely to be small”) *with* Tilmes et al. 2008 (predicting more significant effects).

³⁹ Hegerl and Solomon (2009).

be what Donald Rumsfeld once called the “unknown unknowns” – that is, “the ones we don’t know we don’t know.”⁴⁰

In contrast, low leverage approaches such as mechanical trees pose fewer risks but also require much greater scale in order to produce a given level of cooling. Mechanical trees essentially mimic natural trees and do not pose new dangers. Each additional tree has only a modest impact, so one could easily control the effects by adding fewer trees. But, as a result, one would need to deploy a large number of trees to get a significant response.

Is Geoengineering Permissible under International Law?

What does existing international law have to say about geoengineering? The short answer is, not much. Existing international environmental regimes were not designed with geoengineering in mind, and tend not to address it directly.

General norms

UN Framework Convention on Climate Change – The 1992 United Nations Framework Convention on Climate Change (UNFCCC) was intended to establish an overall governance structure for climate change, and its broad definition of “climate change” – in terms of human activities that “alter the composition of the global atmosphere”⁴¹ – would seem to

⁴⁰ Bunzl 2009.

⁴¹ UNFCCC article 1.2 defines climate change as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global

encompass many forms of geoengineering, including not only CDR but also sulfur aerosols injection. A number of the Convention's provisions are relevant to geoengineering. For example, Article 4 requires states to "promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs ..., including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems."⁴² Furthermore, states are required to employ "appropriate methods" to minimize the adverse effects of mitigation measures on public health and environmental quality," including through environmental assessments,⁴³ and to "cooperate in the full, open and prompt exchange of relevant scientific, technological, technical, ... information related to ... the economic and social consequences of various response strategies."⁴⁴ But although these provisions are relevant to geoengineering – the first by supporting CDR techniques, the last two by imposing disciplines on using geoengineering as a response measure – they do not impose any specific commitments either to undertake geoengineering or to refrain from doing so. And nothing in the Convention addresses geoengineering specifically.

ENMOD – Some writers suggest that the 1976 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD Convention)⁴⁵ limits geoengineering activities.⁴⁶ But although ENMOD's definition of environmental modification techniques includes deliberate changes in the climate,⁴⁷ the Convention is limited to the use of environmental modification techniques for military or other hostile purposes, and explicitly states that it "shall not

atmosphere and which is in addition to natural climate variability observed over comparable time periods."

⁴² Id. art. 4.1(d).

⁴³ Id. art. 4.1(f)

⁴⁴ Id. art. 4.1(h).

⁴⁵ Adopted Dec. 10, 1976.

⁴⁶ See, e.g., Banerjee (2010).

⁴⁷ An understanding to Article II's definition of environmental modification techniques includes in its illustrative list of environmental modification techniques "changes in climate patterns."

hinder the use of environmental modification techniques for peaceful purposes.⁴⁸ Consequently, it would not apply to most scenarios involving the use of geoengineering.

General Principles – Also relevant to geoengineering are general principles of international environmental law such as the precautionary principle and the duty not to cause significant transboundary harm. The precautionary principle admonishes countries to be cautious in the face of scientific uncertainty. When an action has the potential for irreversible and catastrophic harm, the burden should be placed on those proposing the action. The problem is that, in the case of geoengineering, failure to take action could also result in irreversible and catastrophic harm due to global warming, so it is unclear which way the principle cuts. The dilemma brings to mind a cartoon showing one politician confessing to another: "I'm inclined to do the cowardly thing. I just don't know what it is."

Similarly, the duty to prevent significant transboundary harm requires states to exercise due diligence to minimize the risk of transboundary harm,⁴⁹ including harm to the global commons. But exactly how this duty applies to geoengineering activities would likely be the subject of considerable debate, since geoengineering is intended to prevent rather than cause environmental harm.⁵⁰ The same is true of other principles of potential relevance to geoengineering, including the principle of intergenerational equity, which posits a duty to protect the environment for the benefit of future generations, the duty to undertake environmental assessments of activities likely to have significant adverse transboundary effects, and the duties to notify and consult.

⁴⁸ ENMOD art. III(1).

⁴⁹ See International Law Commission, Draft Articles on the Prevention of Transboundary Harm from Hazardous Activities, *Yearbook of the International Law Commission*, 2001, vol. II, part two.

⁵⁰ See ETC Group 2009, at 34 (claiming geoengineering would violate the duty to prevent transboundary harm).

Specialized Norms

Specialized international law regimes relating to specific geoengineering activities have the potential to exercise greater influence than general norms of international environmental law. For example, the Conference of the Parties (COP) to the Convention on Biological Diversity (CBD) adopted a decision in 2010 concerning geoengineering that has received considerable attention.⁵¹ The decision “invites” parties to “consider” “guidance” that they:

ensure ... that no climate-related geoengineering activities that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity.⁵²

This decision is sometimes described as imposing a moratorium on ocean fertilization activities, but this is an overstatement. First, the CBD COP lacks the authority to make legally-binding decisions; that would require an amendment to the CBD. So the CBD COP decision is more akin to a “sense of Congress” resolution than to a legal requirement. Second, the decision itself uses non-mandatory language (“invites,” “consider,” “guidance”). Third, decisions under the CBD apply only to parties, a group that does not include the United States. Finally, the CBD COP decision makes an exception for “small scale scientific research studies,” so it does not prevent all research from continuing.

Similarly, in 2008, the parties to the London Convention and Protocol – which regulate the dumping of wastes in the ocean – adopted a non-

⁵¹ Conference of the Parties to the Convention on Biological Diversity, “Biodiversity and Climate Change,” Dec. X/33, UNEP/CBD/COP/DEC/X/33, Oct. 29, 2010. See Sugiyama and Sugiyama 2010.

⁵² Dec. X/33, para. 8(w).

binding resolution on the ocean fertilization that (1) finds ocean fertilization to be within the scope of the London Convention and Protocol, (2) directs their scientific groups to develop an assessment framework, (3) “urges” parties to “use utmost caution and the best available guidance” until more specific guidance is available, and (4) agrees that, “given the present state of knowledge, ocean fertilization activities other than legitimate scientific research should not be allowed.”⁵³ Notably, the resolution does not amend the London Convention to include ocean fertilization activities in the agreement’s regulatory annexes. Nor does the resolution find that ocean fertilization constitutes “dumping” – a precondition for legally-binding regulation.⁵⁴ Instead, the resolution’s finding that ocean fertilization is within the scope of the Convention and Protocol seems to have been based on the agreements’ general objective of protecting and preserving the marine environment from all sources of pollution.⁵⁵

With respect to solar radiation management techniques, the two agreements of most direct relevance are the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer and the 1979 Convention on Long-Range Transboundary Air Pollution (CLRTAP). The Montreal Protocol

⁵³ Resolution LC-LP.1 on the Regulation of Ocean Fertilization, 13th Meeting of the Contracting Parties to the London Convention, LC/30/16/Annex 6, Oct. 31, 2008.

⁵⁴ Vivian (2010). Rayfuse et al. 2008 argue that ocean fertilization constitutes “dumping,” which the London Convention defines as “any deliberate disposal at sea of wastes or other matter.” London Convention art III(1)(a)(i). But, arguably, ocean fertilization constitutes the “placement of matter for a purpose other than the mere disposal thereof,” which the Convention specifically excludes from the definition of “dumping,” so long as the “placement is not contrary to the aims of th[e] Convention.” Id. art. III(1)(b)(ii). Whether ocean fertilization constitutes dumping would thus depend on whether it is contrary to the Convention’s aim, namely to “improve the protection of the marine environment” and to “assur[e] that it is so managed that its quality and resources are not impaired.” Id. preamble.

⁵⁵ In addition to the London Convention, the United Nations Convention on the Law of the Sea (UNCLOS) sets forth general obligations that are relevant to ocean fertilization, including the duty to protect and preserve the marine environment and to prevent, reduce and control marine pollution from any source. UNCLOS arts. 192, 194.

regulates only *specified* ozone-depleting substances, so it would not apply automatically to sulfur aerosols, even if they have an adverse effect on the ozone layer. But the Montreal Protocol's parent agreement, the Vienna Convention on the Protection of the Ozone Layer, contains a general commitment by states to take "appropriate measures ... to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer."⁵⁶ Since research to date suggests that sulfur aerosols are likely to modify the ozone layer, they fall within the ambit of the ozone regime and could potentially be regulated by the Montreal Protocol.

Similarly, the Convention on Long-Range Transboundary Air Pollution – a regional agreement addressing Europe and North America – sets forth the "general principle" that the parties "shall endeavor to limit and, as far as possible, gradually reduce and prevent air pollution, including long-range transboundary air pollution."⁵⁷ Although, in contrast to the Montreal Protocol, CLRTAP already imposes binding limits on emissions of sulfur dioxide, which arguably would apply to sulfur aerosol injections, the amount of sulfur aerosols that would need to be injected would be very low compared to the permitted emissions levels.

Does Legality Matter and, If So, How?

Apart from the question of what international law says, there is the question, does international law matter and, if so, how? In thinking about this question, it is useful to distinguish three roles that international norms could play.

⁵⁶ Vienna Convention on the Protection of the Ozone Layer, art. 2(1).

⁵⁷ CLRTAP art. 2.

First, international norms could directly constrain behavior. This is the role that most people associate with law – in the first instance domestic law, but also, by extension, international law. For an international lawyer like myself, the faith that non-specialists, and in particular scientists, show in international law is touching. Scientists who write about geoengineering seem to assume that if the parties to the Convention on Biodiversity adopt a resolution imposing a moratorium on ocean fertilization, this means that ocean fertilization cannot be done. Never mind that the resolution applies to states, not to individual scientists; that it is merely a recommendation not a binding decision; and that, in any event, the CBD lacks any enforcement powers.

Certainly, it might be possible, eventually, to develop a legal regime that significantly constrained geoengineering activities. But existing international law does not do so. This is true of both treaty norms, like those contained in the UNFCCC and the United Nations Convention on the Law of the Sea (UNCLOS), as well as general principles such as the precautionary principle and the duty to prevent transboundary harm. To the extent that these norms apply to geoengineering at all, they are so general that they provide little guidance, much less impose any meaningful constraint, on geoengineering activities. Nor is it clear that they should do so. Consider a thought experiment in which an international judiciary existed that could apply existing international law to geoengineering. Would we want decisions about geoengineering to be made by judges, particularly on the basis of general norms and principles that were not developed with geoengineering in mind?

Second, international norms could help structure international and national discussions about geoengineering. This is both a more realistic and a more attractive role for international law. Ultimately, decisions about geoengineering will require complex and highly uncertain tradeoffs among different values – tradeoffs that are appropriately made through a political rather than a legal process. But general norms like the duty to prevent transboundary harm and the precautionary principle could play an important role in that political decision-making process, by providing

principles that help structure the terms of the debate and inform the decision-making process.⁵⁸

Third, international norms could help direct geoengineering governance to particular institutions—a key role of international law, often under-appreciated relative to that of dictating a particular result. Several commentators, for example, have suggested that the UNFCCC is the appropriate forum to consider geoengineering, since it has a universal membership and could consider geoengineering in conjunction with emissions mitigation.⁵⁹ The decision by the parties to the London Convention and Protocol that ocean fertilization falls within the ambit of these agreements means that the London Convention/Protocol regime will likely play a major role in international governance of ocean fertilization. Similarly, the Montreal Protocol regime would be a likely forum for discussions about sulfur aerosol injection.

Scenarios

In thinking about possible governance arrangements, it is useful at the outset to consider the types of scenarios that we are concerned about, for which governance might be needed. The following four scenarios are not an exhaustive list. Rather, they are intended to highlight some of the salient possibilities.

⁵⁸ Bodansky 1996, at 313.

⁵⁹ Barrett 2008; Lin 2009.

Scenario 1: Premature Rejection

One scenario concerning geoengineering – at least in the near term – is that the prospect of geoengineering raises public alarm, leading to a moratorium or ban on geoengineering activities.⁶⁰ Moratoriums or bans have the attraction of simplicity. They create a bright-line rule, and thus avoid the need for complex, ongoing decision-making, which may be beyond the institutional capacity of the international community, particularly in cases of significant uncertainty. Examples of moratoriums or bans in international law include the moratorium on commercial whaling, adopted by the International Whaling Commission in 1982, the moratorium on Antarctic mineral activity imposed by the Antarctic Environment Protocol, and the bans on genetically-engineered foods imposed by European countries in the 1990s. As the whaling case illustrates, unless moratoriums are time limited, they can be very difficult to lift, even after scientific uncertainties are resolved and management is feasible. The CBD decision discussed earlier, imposing a non-binding moratorium on most geoengineering activities, suggests that fears of a moratorium are not unfounded.⁶¹

The prospect of a moratorium is problematic because, if there were no research on geoengineering, we wouldn't know which geoengineering approaches are more or less effective and more or less dangerous. So if and when it became necessary to use geoengineering to respond to catastrophic climate change, there would be a greater chance that efforts would fail or cause serious collateral damage. As Virgoe notes, "ignoring geoengineering today, and only considering it when all else has failed, is a recipe for bad, politics-led decision-making."⁶² What we need instead is a

⁶⁰ Victor 2008.

⁶¹ CBD Dec. X/33, UNEP/CBD/COP/DEC/X/33, Oct. 29, 2010. See Sugiyama and Sugiyama 2010.

⁶² Virgoe 2009, at 117.

research program that assesses the efficacy, risks and costs of different geoengineering approaches, in order to allow better decisions to be made about “whether, when and how to use” geoengineering technologies.⁶³

Under the premature rejection scenario, the problem is not under-regulation but rather over-regulation. A moratorium or ban on geoengineering adopted by an international institution such as the CBD or the London Convention would not directly bind scientists; instead, it would apply to states. But it could nevertheless chill scientific research by influencing government research funding decisions, prompting government to impose domestic restrictions on research, or encouraging professional attitudes hostile to geoengineering research. Making matters worse, a moratorium would likely have the biggest effect on countries that tend to be risk averse and that would have pursued geoengineering research most responsibly, helping to establish sound research norms. A moratorium could thus have the perverse effect of leaving the field of geoengineering research to less responsible countries that ignore the moratorium and engage in riskier activities.

Here, the governance challenge is to forestall drastic regulation through more moderate regulation that promotes transparency, public participation, and independent assessments. In essence, the role of governance is to bolster public confidence that geoengineering will be pursued in a responsible manner, in order to prevent a backlash against it. Guidelines or regulations on geoengineering research could be adopted by an international organization such as the World Meteorological Organization or the Intergovernmental Oceanographic Commission of UNESCO. But getting agreement among states may be difficult, so self-regulation by scientists – for example, through the development of research codes of conduct – may be more feasible, at least initially. Already, this process of self-regulation has begun, with the development of the Oxford Principles on Regulation of Geoengineering by a group at the

⁶³ Bipartisan Policy Center Task Force 2011, at 29.

University of Oxford,⁶⁴ and the organization of the Asilomar Conference on Climate Intervention Technologies in March 2010.⁶⁵ Informal norms developed by scientists, social scientists, philosophers and lawyers could help inform national geoengineering programs⁶⁶ and eventually became the basis for an inter-governmental code of conduct or formal agreement on responsible geoengineering research.

Scenario 2: Inadequate Funding

A second scenario also focuses on the problem of inadequate research, but in this case the cause is inadequate funding rather than over-regulation. Under this scenario, the rationale for international governance is very different than in the first scenario, where governance was needed to build public confidence in order to prevent premature rejection of geoengineering. If the problem, instead, were inadequate public or private funding, the function of international governance would be to encourage national spending, develop cost-sharing arrangements, and incentivize private investment.

Currently, geoengineering research funding is very low. Although cost might not be an issue if a country were facing a climate emergency, this is

⁶⁴ The Oxford principles emphasize public participation in decision-making, disclosure of research results, and independent assessments of impacts.

⁶⁵ The Asilomar Conference was sponsored by the Climate Institute, and brought together scientists, social scientists, lawyers and philosophers from fifteen countries. ASOC 2010. It was self-consciously modeled on the 1975 Asilomar Conference on Recombinant DNA, which is credited with developing voluntary guidelines to ensure the safety of DNA research. For a critical assessment of Asilomar, see Goodell 2010b.

⁶⁶ In urging the establishment of a federal research program on geoengineering, the Bipartisan Policy Center Task Force on Climate Remediation recommended a number of guidelines, which emphasize the importance of outside oversight, transparency and international coordination. Bipartisan Policy Center Task Force 2011, at 13-14.

not the perception now, when geoengineering is still seen as, at best, a second or third choice option. The 2009 Royal Society report found that “little research has yet been done on most of the geoengineering methods considered, and there have been no major directed programmes of research on the subject.”⁶⁷ A 2010 GAO report found that U.S. government agencies were spending \$100.9 million in geoengineering-related funding, but only about \$1.9 million involved direct investigations of a particular geoengineering approach,⁶⁸ a miniscule sum. Government funding of geoengineering research is so low that a significant part of the research funding to date has come for a private gift by Bill Gates of \$4.5 million.

What role might international institutions play in promoting geoengineering research? In some cases, where the costs of geoengineering technologies are high, an international burden-sharing arrangement might be helpful, like those to develop the space station or the Large Hadron Collider at CERN.⁶⁹ But the bigger problem, at the moment, is the lack of significant focus on geoengineering as a serious policy option, both among the political establishment and scientists. International institutions could thus play a more important role in raising awareness than in raising money – in calling attention to geoengineering and helping to legitimate it as a policy option, particularly among scientists.

Finally, the climate change regime could give private actors an incentive to engage in scientific research on mechanical trees, ocean fertilization and other carbon dioxide removal techniques, by making it clear that these activities would be eligible for carbon credits. The prospect of receiving carbon credits for ocean fertilization activities has already prompted the creation of several companies.⁷⁰ A number of

⁶⁷ Royal Society 2009, at xii.

⁶⁸ GAO 2010, at 18.

⁶⁹ Barrett 2007, ch. 4.

⁷⁰ Inman 2010.

commercial ventures have also been undertaken to develop mechanical trees. But uncertainty about whether such activities will be eligible for carbon credits, and about the future of the carbon market more generally, has limited investments thus far. Providing carbon credits for geoengineering activities would convert geoengineering from a public to a private good, and thus provide an incentive to private actors to supply the good. Moreover, the need for international approval to receive credits would help ensure that geoengineering activities were pursued safely, in contrast to the “Greenfinger” scenario that we consider next.

Scenario 3: Greenfinger

A third scenario is what David Victor has dubbed the “Greenfinger” scenario, in which a rich private actor goes ahead with geoengineering on his or her own.⁷¹ The allusion to the villain in James Bond's *Goldfinger* suggests that geoengineering is being seen here as a global public bad rather than a global public good. Accordingly, the governance challenge is not to enable or encourage geoengineering to proceed, as in the first two scenarios, but rather to prevent private actors from engaging in geoengineering on their own.

In many respects, this problem is similar in structure to combating terrorism. In both cases, individuals have the capacity to do things with huge, and potentially damaging, effects for the global community. The international governance challenge is hence to control private conduct. In significant part, this is a problem of international law enforcement cooperation. In the case of terrorism, law enforcement cooperation has been effectuated through various treaties and Security Council resolutions that require states to criminalize terrorist acts, investigate and punish terrorists, and cut off their access to financing. Similarly, states could

⁷¹ Victor 2009.

develop an international regime for geoengineering that requires parties to control geoengineering activities within their jurisdiction, and that clarifies which states have jurisdiction over activities outside of national territory (for example, on the high seas or in outer space).

The example of terrorism also illustrates that, if the threat of private geoengineering seemed sufficiently grave, states might take military action rather than limiting themselves to a law enforcement approach. In this respect, geoengineering is in some ways an easier problem to address than terrorism, since the harms from geoengineering wouldn't be inflicted by a single, difficult-to-prevent act, but rather by ongoing activity that could be stopped, if necessary, through military force. If an extremely rich individual, for example, were to build a fleet of ships to engage in cloud whitening, this would presumably be easy to detect and stop, if necessary by seizing the ships.

Scenario 4: Unilateral state action

A final, more troubling scenario involves an individual country, or small group of countries, undertaking geoengineering – for example, Russia or China or the United States. Because some types of geoengineering appear astonishingly cheap – in particular, injection of aerosols into the stratosphere to reflect sunlight – unilateral geoengineering is likely to be within the capacity of some states, and perhaps many states.⁷² As noted earlier, it would be an example of what economists call a "best shot" global public good, which can be supplied by a single country acting alone.

This characteristic of geoengineering is simultaneously its most comforting and its most troubling feature – comforting because it means

⁷² The Bipartisan Policy Center Task Force on Climate Remediation estimates that perhaps a dozen states have the technological and economic capacity to deploy SRM technologies. Bipartisan Policy Center Task Force 2011, at 29.

that global warming could be solved without the need for international cooperation; troubling because a single country might conceivably have the capacity to wreak havoc on the entire globe climate. For this reason, unilateral geoengineering by states has attracted probably more attention than any other geoengineering scenario.⁷³

Under what conditions might a state decide to undertake unilateral geoengineering? Since doing so would likely provoke a strong reaction by other states, most commentators assume that a state would undertake geoengineering unilaterally only *in extremis*⁷⁴ – and some believe that a state would never do so.⁷⁵ But denying the political possibility of unilateral geoengineering seems unwarranted, given the propensity of states to act unilaterally in other arenas where their survival is at stake, even at the risk of international conflict. Moreover, while it seems plausible that a state would be willing to undertake geoengineering only as a last resort, there is no bright line between normal and extreme situations.⁷⁶ In the movies, climate catastrophes may be so extreme as to leave no doubt, but in the real world catastrophes are usually less obvious. Given the difficulty of attributing particular weather events to global warming, people are likely to disagree about whether it is time to press the panic button and resort to geoengineering. So there is likely to be considerable squishiness about the circumstances that warrant geoengineering. Indeed, it is possible that some states might decide that geoengineering presents a more desirable option than emissions cuts and decide to undertake geoengineering without any triggering, catastrophic event.⁷⁷

⁷³ See, e.g., Horton 2011, Victor 2009.

⁷⁴ Rand 2011. For example, Virgoe states that "unilateral action is really only conceivable in a situation where severe climate disruption was already being experienced, leading to strong domestic pressure to take rapid action." Virgoe 2009, at 115.

⁷⁵ Horton 2011.

⁷⁶ The same is true of decisions about the use of military force, as the lead-up to the Iraq war illustrates.

⁷⁷ Rand 2011.

The unilateral-state-action scenario is more troubling than the Greenfinger scenario, because it would be considerably more problematic to stop a state from acting than an individual. The problem is akin to preventing states from using military force unilaterally, which international law has not been very successful in doing. Plus, if one state proceeded with climate engineering, other states might take retaliatory measures – including measures to warm the climate back up. So there is a significant potential for inter-state conflict.

How might an international regime address the problem of unilateral state geoengineering? One possibility would be to internationalize decision-making about whether to deploy geoengineering, in what amounts, and by whom.⁷⁸ This is the approach that the United Nations Charter takes with respect to the use of force: it takes decision-making authority away from individual states (except in cases of self-defense) and gives it to the United Nations Security Council. Similarly, decisions about geoengineering could be delegated to an existing institution like the UNFCCC or to a newly-created one.

Proposals to create an international geoengineering organization with decision-making authority face two difficulties. First, there seems little prospect that states would turn over decision-making about geoengineering to an international body. Certainly this is true of the United States, where it is almost impossible to imagine 67 Senators agreeing to give an international organization control over United States' decisions about geoengineering. Second, even if such an organization could be established, it is hard to see how it would be able to enforce its decisions. In the parallel case of the Security Council, the Security Council lacks the power in most cases to prevent states from using force

⁷⁸ Virgoe 2009, at 114 (need to establish an inclusive and high-level governing body to make decisions about whether to engage in geoengineering and how much to do). See also Barrett 2008, at 53 (proposing negotiation of a new agreement that would specify whether and under what conditions geoengineering should be allowed); Lin 2009 (suggesting establishment of a non-consensus process under the UNFCCC to address geoengineering).

unilaterally, so states continue to do so when they have a sufficient national interest. There is no reason to think that an International Geoengineering Authority would be any more successful in curbing unilateral action when countries feel that their vital national interests are at stake – that is, in exactly the type of catastrophic situations in which people envision that geoengineering might be used.

A more promising alternative might be to establish an international regime that seeks to cabin rather than prevent unilateral state action. For example, an international instrument could create a scientific advisory body like the IPCC that assesses geoengineering techniques in order to promote science-based decisions.⁷⁹ It could also establish a consultative mechanism that encourages states to notify and consult with one another about planned geoengineering activities. States would have an incentive to do so in order to avoid uncoordinated geoengineering initiatives that might undermine one another—and that might even generate interstate conflict.⁸⁰ An international regime might also address some of the subsidiary issues raised by geoengineering, such as liability for damage resulting from geoengineering activities, although this would be considerably more difficult.

Conclusion

Different scenarios for geoengineering raise very different kinds of governance challenges. In some cases, the problem is too little geoengineering, in others too much. So in some cases, the international governance challenge is to enable and facilitate geoengineering, in others to limit or prohibit it.

⁷⁹ Benedick 2011.

⁸⁰ Horton 2011, at 60 (example of conflicting efforts by equatorial island states and Arctic states).

Different scenarios also involve different “regulatory targets.” Some involve scientists, who are relatively easy to regulate; others involve more difficult regulatory targets, such as rogue individuals or states.

Thus, governance of geoengineering is not a one-dimensional challenge. It could involve many different tasks: developing norms to guide scientific research, allocating jurisdiction among states to regulate individuals, elaborating rules that constrain state behavior, establishing procedures to limit conflict among states, and so on.

Some of these governance tasks seem more do-able than others. Developing a minimal governance structure to guide geoengineering research seems comparatively easy, as does providing some modest research funding. In contrast, limiting geoengineering deployment would be more difficult. The problem posed by individuals could potentially be addressed in the same way as terrorism: through treaties that address jurisdictional issues and require states to proceed against individuals subject to their jurisdiction. But developing a governance structure that limits geoengineering by states will be very difficult.

When we think about geoengineering governance, we are, of course, in a highly speculative area. The kinds of governance that might emerge will depend on a wide range of often unpredictable factors. But let me venture a few tentative predictions:

- The international community is more likely to adopt a simple prohibition on geoengineering than a complex multilateral decision-making process.
- Governance of geoengineering is more likely to develop through the extension of existing treaty regimes to cover various types of geoengineering than through the development of a single comprehensive regime – for example, through the application of the London Convention to ocean fertilization, or the Montreal Protocol to stratospheric aerosol injections. This makes sense, partly because different types of geoengineering raise very different kinds of issues. But the dispersion of

authority to different institutions will make it more difficult to consider geoengineering in an integrated manner.

- A geoengineering regime is unlikely to be adopted under the UNFCCC, as some have suggested,⁸¹ since the UNFCCC is seen as dysfunctional by many countries, and few trust its ability to make decisions.

Geoengineering raises understandable fears about human hubris. Virtually everyone who studies geoengineering hopes that it will not prove necessary. But with global emissions continuing to rise, and little prospect of reversing that trend anytime soon, we are not living in a world where we can assume the best. We are living in a world where we must prepare for the worst.

⁸¹ Barrett 2008; Lin 2009.

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