

# The Limitations of Geoengineering Governance In A World of Uncertainty

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## Abstract

This Article evaluates several leading proposals for geoengineering governance with respect to Jasanoff’s “technologies of humility” rubric, which is anchored in four key questions: “What is the purpose; who will be hurt; who benefits; and how can we know?”<sup>1</sup> It draws on historical examples (such as the 1978 Environmental Modification Treaty, the 1972 Asilomar conference on recombinant DNA, and the emergence of the International Atomic Energy Agency) to examine the limitations of voluntary codes of conduct and treaties, the most popular approaches to governing geoengineering. Next, the Article examines the relevance of environmental assurance bonds, which would require geoengineers or their funders to post a guarantee price-equivalent to the worst-case threats posited by a particular deployment scheme. Finally, the Article envisions how critically engaging with Jasanoff’s framework could enrich leading approaches to geoengineering governance while diminishing the risk of moral hazard.

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<sup>1</sup> Sheila Jasanoff, *Technologies of Humility: Citizen Participation in Governing Science*, 41 MINERVA 223, 240 (2003) [hereinafter Jasanoff (2003)]; see also Sheila Jasanoff, *Technologies of Humility*, 450 NATURE 33 (2007) [hereinafter Jasanoff (2007)].

## I. FRAMEWORK

*A. Introduction to the Geoengineering Conversation*

Geoengineering is a catch-all term for an array of technological approaches to the deliberate manipulation of the earth's climate in response to climate change. These approaches include: fertilizing the ocean with iron filings in hopes of inducing enough algae-growth to offset carbon dioxide (CO<sub>2</sub>) emissions; building artificial trees that will capture CO<sub>2</sub> directly from the air; and repeatedly shooting sulfate aerosols into the stratosphere in order to deflect the sun's light and heat. Over the last year, as it became clear that the Copenhagen climate talks would not result in meaningful emissions reductions,<sup>2</sup> a disparate but increasingly strident band of voices ranging from respected scientists and environmentalists to former anthropogenic global warming deniers began to call for amplified research into geoengineering.<sup>3</sup>

Proponents claim that geoengineering could provide a high-leverage method of staving off catastrophic climate change; they also suggest that some geoengineering technologies (for example, shooting sulfate aerosol particles into the stratosphere) are so cheap and feasible that unilateral action by a state or private entity in the near future is not unthinkable.<sup>4</sup> Blackstock et al.'s ten-year road-map of geoengineering research and development suggests field tests with aerosol dispersal could commence by year five.<sup>5</sup> Moreover, Russia recently conducted field tests of the sulfate aerosol method, and Planktos, a private company, briefly fertilized the Pacific Ocean with iron until environmental groups successfully pressured the EPA to intervene.<sup>6</sup>

A September 2009 Royal Society report divides geoengineering into two main categories, a distinction which many subsequent discussions retain: Solar Radiation Management (SRM) and Carbon Dioxide Removal (CDR). The Royal Society claims that SRM is fast, cheap, uncertain, and prone to unintended side effects, while CDR could take up to a thousand years, is considerably more expensive, and has fewer associated uncertainties. The Royal Society further claims that CDR is preferable to SRM. But, since CDR is costly and cannot respond to abrupt climate change, both the Royal Society and the Novim Group announced that two SRM techniques—shooting sulfate aerosols into the stratosphere and increasing the albedo, or reflectivity, of marine clouds by wafting ocean-mist into them—were the most promising avenues for research.<sup>7</sup>

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<sup>2</sup> A 2009 analysis jointly conducted by MIT's Sloan School of Management, the Sustainability Institute, and Ventana Systems estimates that the Copenhagen Accord puts the world on track to 3.9 degrees Celsius of warming by 2100. The likelihood of abrupt and catastrophic climate change increases once global average temperature rises above 1.5 degrees Celsius.

<sup>3</sup> See James R. Fleming, *The Climate Engineers*, WILSON Q. 46, 57 (Spring 2007) (pointing out that a 1965 President's Science Advisory Commission report, often considered the U.S. government's first position paper recognizing anthropogenic climate change, called for a suite of geoengineering responses to the problem, such as albedo modification via reflective particles scattered over tropical oceans, and that the report did not suggest curbing fossil-fuel use).

<sup>4</sup> See JASON BLACKSTOCK ET AL., CLIMATE ENGINEERING RESPONSES TO CLIMATE EMERGENCIES 3 (Novim 2009), available at <http://arxiv.org/ftp/arxiv/papers/0907/0907.5140.pdf>.

<sup>5</sup> See *id.* at 41.

<sup>6</sup> DIANA BRONSON ET AL., SWEDISH SOC'Y FOR NATURE CONSERVATION, RETOOLING THE PLANET: CLIMATE CHAOS IN THE GEOENGINEERING AGE 26 (2009); David Keith et al., *Research on Global Sunblock Needed Now*, 463 NATURE 426, 426 (2010).

<sup>7</sup> In one of the most rigorous assessments of the different geoengineering schemes at hand, Lenton and Vaughan claim that "[s]trong mitigation, combined with global-scale air capture and storage, afforestation, and bio-char production, i.e. enhanced CO<sub>2</sub> sinks, might be able to bring CO<sub>2</sub> back to its pre-industrial level by 2100, thus removing the need for other geoengineering." T. M. Lenton & N. E. Vaughan, *The Radiative Forcing Potential of*

Some scientists question this approach because firing sulfate aerosol particles into the stratosphere could further damage the ozone layer, interfere with Asian and African monsoon patterns, and affect the food and water supplies of up to two billion people.<sup>8</sup> Despite the possibility of such grim consequences, many proponents of the aerosol dispersion method are calling for field tests within the next decade even though there are major outstanding uncertainties with deploying geoengineering. Some scientists suggest that SRM field tests will not yield meaningful results unless the tests are conducted at scale—in other words, the difference between testing and deployment would be minimal. Moreover, it may be impossible to determine unintended consequences without testing at scale.<sup>9</sup>

Despite these potential adverse effects, a September 2009 Royal Society report suggests that the UK government should allocate up to 10 million pounds for geoengineering research over the next decade, and that the Royal Society, in conjunction with scientists around the world, should develop a “voluntary research governance framework.”<sup>10</sup> A day before the Royal Society issued its report, the British Institution of Mechanical Engineers released its own report calling for additional funding and claiming that geoengineering could “buy us some time” to decarbonize the British economy and create a million jobs by 2050.<sup>11</sup> Around the same time, in the United States, the Novim Group, a privately funded organization modeled after a defense advisory project called JASON, issued its own report advocating further research into sulfate aerosol dispersion that could be deployed in the face of “climate emergencies.”<sup>12</sup> Moreover, between 2009 and 2010, Congress held two hearings on geoengineering, and President Obama’s science advisor, John Holdren, indicated that geoengineering should not be ruled out.<sup>13</sup> Since geoengineering research and even trials are picking up speed, increased scrutiny of geoengineering governance has become critical.

The first part of Section I provides an overview of the current geoengineering discourse. The second part classifies the major proponents of geoengineering according to their preferred method of governance. The third part introduces Jasanoff’s “technologies of humility” rubric, which is anchored in four key questions: “What is the purpose; who will be hurt; who benefits; and how can we know?”<sup>14</sup> The fourth part examines two popular approaches to geoengineering governance—code-based and treaty-based—and evaluates both through the “technologies of

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*Different Climate Geoengineering Options*, ATMOSPHERIC CHEMISTRY & PHYSICS 5539, 5539 (2009). They go on to suggest an alternative scenario, where atmospheric CO<sub>2</sub> has stabilized at 500 parts per million (for comparison, pre-industrial levels were 280 parts per million) due to mitigation plus either SRM or air capture of carbon. They acknowledge that stratospheric aerosol injections could offset the warming expected by 2100, but note that these techniques hold “a heavy burden of risk because they have to be continually replenished and if deployment is suddenly stopped, extremely rapid warming could ensue.” *Id.* at 5556. Currently, air capture and storage of CO<sub>2</sub> is cost prohibitive; investing in this technology could divert government investments in renewable energy. However, air capture does not have the same accompanying governance concerns that SRM does.

<sup>8</sup> *Geoengineering: Assessing the Implications of Large-Scale Climate Intervention: Hearing Before the H. Comm. on Sci. and Tech.*, 111th Cong. 1-11 (2009) (statement of Alan Robock, Rutgers University Professor).

<sup>9</sup> *E.g.*, BLACKSTOCK ET AL., *supra* note 4, at 38 (emphasizing stratospheric aerosol loading, “[T]he wide range of temporal and spatial delays and nonlinearities in the climate parameter response functions, along with the natural variability of these parameters, severely limit the utility of short-term tests for many parameters.”).

<sup>10</sup> THE ROYAL SOCIETY, GEOENGINEERING THE CLIMATE: SCIENCE, GOVERNANCE, AND UNCERTAINTY 61 (2009), available at <http://royalsociety.org/geoengineering-the-climate/>.

<sup>11</sup> TIM FOX ET AL., INSTITUTION OF MECHANICAL ENGINEERS, GEOENGINEERING: GIVING US THE TIME TO ACT 1, 5 (2009).

<sup>12</sup> BLACKSTOCK ET AL., *supra* note 4, at vi.

<sup>13</sup> BRONSON ET AL., *supra* note 6, at 12.

<sup>14</sup> Jasanoff (2003), *supra* note 1, at 240; *see also* Jasanoff (2007), *supra* note 1.

humility” rubric. The fifth part evaluates geoengineering schemes using the technologies of humility rubric. And the sixth part underscores the limitations of cost-benefit analysis because of the uncertainties and indeterminacies prominent in the geoengineering discourse.

In the Second Section, the first part draws on historical accounts of the 1972-75 Asilomar Conferences on recombinant DNA research in order to grapple with the recent Asilomar conference’s attempt to draft voluntary scientific codes of conduct. This Section also reflects on the Asilomar conference’s outcome in light of Jasanoff’s theoretical framework. The second part examines the treaty-based approach to governance. This approach is grounded in the history of U.S. weather modification attempts during the Vietnam War and the political response to these attempts, which resulted in the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD). This part also distills lessons from both ENMOD and the International Atomic Energy Association. The third part takes the precautionary position that neither treaties nor voluntary codes of conduct are satisfactory methods of governing geoengineering. This part critically examines the relevance of environmental assurance bonding as a potentially promising regulatory tool. Finally, the Conclusion outlines the implications of applying the technologies of humility framework to geoengineering governance.

### *B. Leading Geoengineering Governance Proposals*

As the geoengineering discussion has taken on increased legitimacy, governance questions have loomed large. Several innovative attempts to grapple with climate change governance exist;<sup>15</sup> to date, however, the scant numbers of scholars who have wrestled with geoengineering governance have come to wildly different sets of conclusions.

There are at least two very distinct approaches to geoengineering governance. The first approach favors using the United Nations Framework Convention on Climate Change (UNFCCC) and other existing treaties like the London Convention on Dumping, and the Convention on Biological Diversity.<sup>16</sup> The second approach insists that existing treaties and scientific assessment bodies cannot evaluate geoengineering; instead, scientists should govern geoengineering research via voluntary codes of conduct.<sup>17</sup> In support of this position, in late March 2010, 150 scientists gathered in Asilomar, California to determine a set of principles for governing geoengineering research.

Before looking at case studies which can help us evaluate code and treaty-based approaches, it may be useful to situate these approaches within the context of their proponents’ heterogeneous backgrounds.<sup>18</sup>

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<sup>15</sup> Scott Barrett, *Climate Treaties and the Imperative of Enforcement*, 24 OXFORD REV. ECON. POL’Y 239 (2008); Richard Lazarus, *Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future*, 94 CORNELL L. REV. 1153 (2009).

<sup>16</sup> Albert Lin, *Balancing the Risks: Managing Technology and Dangerous Climate Change*, 8 ISSUES IN LEGAL SCHOLARSHIP 1, 15-16 (2009).

<sup>17</sup> Keith et al., *supra* note 6, at 427; see David Victor et al., *The Geoengineering Option: A Last Resort Against Global Warming?*, FOREIGN AFF. (2009).

<sup>18</sup> Table 1 is by no means exhaustive. It has two major drawbacks. First, it addresses neither the risks and uncertainties associated with each technology nor the major barriers associated with implementation. Second, the table accepts the Royal Society’s SRM versus CDR (air capture) distinction. In reality, several different geoengineering techniques exist; a very different classification system—one in which risk and uncertainty are the starting points—might foreground a different palette of geoengineering techniques. See Section II.

Table 1. Major positions on geoengineering governance taken by proponents of geoengineering.

Proponent	Favored Technology	Favored Form of Governance	How the Underlying Justification is Framed	Source of Funding
1. Royal Society (John Shepherd, David Keith, Peter Cox, Ken Caldeira)	SRM	Code of Conduct and treaties	Returning atmospheric concentration of carbon to 350 parts per million (ppm)	U.K. Government
2. Institution of Mechanical Engineers (Peter Cox)	Air capture of CO <sub>2</sub> via artificial trees	N/A	“Buying time” to reduce emissions; job creation	U.K. Government
3. American Enterprise Institute	SRM	Potential alternative to EPA regulation of greenhouse gases (GHGs)	Cost; lack of threat to “economic opportunity”	N/A
4. Copenhagen Consensus Center (founded by contrarian Bjorn Lomborg)	Cloud brightening.	Unknown	No need to address underlying cause of climate change	N/A
5. Novim Group (modeled after JASON, a military advisory group comprised of physicists; headed by Stephen Koonin, former Chief Scientist of BP and current Under Secretary of Energy; David Keith, and Ken Caldeira are participants)	SRM	Some group members support code of conduct; others support treaties	Need to prepare for “climate emergency”	U.S. Government
6. Climate Response Fund (non-profit started by Margaret Leinen, the former CSO of Climos, a for-profit company that sought CDM funding for ocean iron fertilization; Climos continues to be run by Leinen’s son.)	SRM/Ocean Fertilization	Code of Conduct via Asilomar Expert Town Hall in late March; the conference brings together all of the major players mentioned here	“Buy time” to transform the energy infrastructure	U.S. Government; private entities
7. Alvin Lin (legal academic)	SRM	Existing Treaties	Either emergency or non-emergency option	N/A

8. Scott Barrett (economist)	SRM	IPCC review, followed by UNFCCC review, followed by new protocol under UNFCCC	Band-aid against abrupt climate change	N/A
9. David Victor (legal academic)	“Cocktail” of techniques	Code of Conduct	Alternative to international deadlock	N/A
10. Russia	Expertise in SRM but could do cloud seeding	N/A	Carrying on long tradition of scientific research in Russia	Russian government
11. China	Expertise in cloud seeding but could do SRM	N/A	Carrying on recently established tradition of weather modification in China; potential military force multiplier	Chinese government
12. Pentagon	Dispersal of Hydrochlorofluorocarbons (HFCs) in atmosphere	N/A	Potential military force multiplier	U.S. Government
13. Private entities like Climos, Planktos, Bill Gates (who is advised by David Keith)	Ocean iron fertilization	N/A	Profit motive (selling CDM offsets via Kyoto)	Privately funded
14. Environmentalists/scientists weary of political deadlock (Stewart Brand, James Lovelock, Mike MacCracken)	A range of options— MacCracken suggests directing the sulfate emissions from the coal plants being built in India and China and deploying limited, strategic aerosol geoengineering over the Arctic	Modifying ENMOD to allow geoengineering	Returning the atmospheric concentration of CO <sub>2</sub> to pre-industrial levels; protecting Arctic sea-ice; buying “insurance” against climate emergencies	Unclear

By identifying the major proponents of geoengineering and the various frames within which they justify deployment, the above table begins to suggest the limitations of geoengineering governance. Additionally, the table underscores both the heterogeneity of geoengineering proponents and the fact that a small, core group of proponents (comprising of David Keith, John Shepherd, and Ken Caldeira) is involved in several of these initiatives. Notably, all three proponents have emphasized the need for a robust interdisciplinary debate linked to public deliberation on geoengineering. Moreover, Caldeira and Keith have acknowledged that even discussing geoengineering opens up the possibility that policy-makers and publics will be less likely to move towards mitigation and adaptation if they feel that

geoengineering could provide a higher-leverage solution.<sup>19</sup> Jasanoff's "technologies of humility" framework, discussed at length in the next part, provides a few core principles that could encourage richer public deliberation on geoengineering. As I will address in the concluding section of this Article, Jasanoff's framework may even hold a possible resolution to the moral hazard dilemma—i.e., the possibility that the perceived availability of "cheap" geoengineering solutions could sap political will to mitigate greenhouse gas emissions and adapt to the predicted effects of climate change.

### *C. Technologies of Humility*

Jasanoff's technologies<sup>20</sup> of humility<sup>21</sup> framework consists of "disciplined methods to accommodate the partiality of scientific knowledge and to act under irredeemable uncertainty."<sup>22</sup> Jasanoff emphasizes that the vast majority of science policy has focused on predictive approaches such as cost-benefit analysis and climate modeling. She argues that strengthening deliberative processes that complement these predictive processes will result in more democratic engagement with the frontiers of policy-relevant science.<sup>23</sup> Jasanoff suggests that technologies of humility arise from four focal points—framing, vulnerability, distribution, and learning. I will briefly outline Jasanoff's explication of these points.

Jasanoff notes that policy scholars agree that the quality of a solution to any problem is only as good as the frame out of which that solution is generated.<sup>24</sup> She goes on to emphasize that risk analysis often classifies human populations into groups determined by "physical and biological indicators"<sup>25</sup> without accounting for variability across individuals. Statistical, population-centered risk-assessments, Jasanoff writes, can "leave out of the calculus of vulnerability such factors as history, place, and social connectedness, all of which may play crucial roles in determining human resilience."<sup>26</sup> Calling these factors the "social foundations of vulnerability," Jasanoff commends qualitative, individual-centered assessments that go beyond statistical, population-centered risk-assessment.<sup>27</sup> Next, she notes that policy-processes have had limited success in capturing the socio-economic impacts of technological change—particularly across global boundaries; she suggests that "sustained interactions between decision-makers, experts, and citizens, starting at the upstream end of research and development, could yield significant dividends in exposing the distributive implications of innovation."<sup>28</sup> Finally, Jasanoff notes the connection between framing, and the lessons learned from a particular experience. She

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<sup>19</sup> See Ken Caldeira & Lowell Wood, *Global and Arctic Climate Engineering: Numerical Model Studies*, 366 PHIL. TRANSACTIONS OF THE ROYAL SOC'Y 4039, 4053 (2008); Keith et al., *supra* note 6, at 427.

<sup>20</sup> Jasanoff uses the word "technologies" interchangeably with the phrase "social technologies." In both cases, she is referring to the practical application of knowledge. See Jasanoff (2003), *supra* note 1.

<sup>21</sup> Jasanoff's conception of humility has an implicit link with theories of social justice—a link that is worth further elaboration. She writes, "Humility instructs us to think harder about how to reframe problems so that their ethical dimensions are brought to light, which new facts to seek and when to resist asking science for clarification. Humility directs us to alleviate known causes of people's vulnerability to harm, to pay attention to the distribution of risks and benefits, and to reflect on the social factors that promote or discourage learning." Jasanoff (2007), *supra* note 1, at 33.

<sup>22</sup> *Id.*

<sup>23</sup> Jasanoff (2003), *supra* note 1, at 240.

<sup>24</sup> *Id.*

<sup>25</sup> *Id.* at 241.

<sup>26</sup> *Id.*

<sup>27</sup> *Id.*

<sup>28</sup> *Id.* at 242.

points out that different stakeholders can walk away with varying (and sometimes diametrically opposed) interpretations of the same problem, its origins, and its solution.<sup>29</sup>

Jasanoff encourages greater public participation in frame-analysis and greater participation of vulnerable individuals in vulnerability assessments. She calls for better upstream engagement between policymakers, citizens, and scientists in assessing the distributive impacts of a particular intervention.<sup>30</sup> And finally, she urges, “[I]t would be fruitful to design avenues through which societies can collectively reflect on the ambiguity of their experiences, and to assess the strengths and weaknesses of alternative explanations.”<sup>31</sup>

Jasanoff’s four focal points give rise to the questions “what is the purpose; who will be hurt; who benefits; and how can we know?”<sup>32</sup> In the next section, I will apply these questions to the assumptions built into code and treaty-based approaches in order to reveal the limitations of the current conversation about geoengineering governance. In the final section of this Article, I will suggest how the “technologies of humility” framework could potentially suggest a way out of the moral hazard dilemma.

#### *D. Applying the Technologies of Humility Rubric to Code-Based and Treaty-based Geoengineering Governance*

**Framing.** As Table 1 reveals, the first, and most obvious, limitation of both code- and treaty-based approaches to geoengineering governance is that disparate proponents frame the underlying justification for geoengineering in very different ways. For scientists and environmentalists who are weary of the international deadlock on climate change, returning the atmospheric concentration of CO<sub>2</sub> to pre-industrial levels by 2100 is frequently the primary motivation. Others, like climate skeptics and national militaries, may have a much higher threshold. Private entities or guilds seeking to reap a profit from geoengineering patents or from selling offsets may see their interest in geoengineering independent of any particular target for future atmospheric concentration of CO<sub>2</sub>. As Jasanoff notes, it is a truism among policy scholars that the solution to a problem will only be as good as the framing of that problem.<sup>33</sup> The heterogeneity revealed by Table 1 complicates the possibility of agreement, even among proponents. Notably, all proponents of geoengineering agree that a geoengineering technology can provide a “solution.” However, the technologies of humility rubric implicitly prioritize solutions grounded in improved deliberation rather than in technological change.

**Vulnerability.** Just as climate change will disproportionately affect socioeconomically marginalized individuals, so will any adverse consequences of geoengineering. Yet, individuals who may be particularly vulnerable to the impacts of geoengineering due to their socioeconomic status are notably absent from Table 1. The “technologies of humility” framework reveals that the current conversation about geoengineering governance lacks input from those who may be most affected. At the same time, geoengineering aims for regional-scale impact; Jasanoff’s framework suggests the importance of engaging vulnerable individuals within regions that might be impacted by geoengineering.<sup>34</sup>

**Distribution.** While vulnerability and distribution are closely related, I have chosen to read “vulnerability” primarily as a socioeconomic index, and “distribution” as a geographic

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<sup>29</sup> *Id.*

<sup>30</sup> *Id.*

<sup>31</sup> *Id.*

<sup>32</sup> *Id.*

<sup>33</sup> *Id.* at 240.

<sup>34</sup> *Id.* at 241.

index. Table 1 reveals that the proponents of geoengineering governance, at present, hail from the U.S., Canada, Europe, the U.K., and Australia. Additionally, a handful of elite developing country scientists from the Academy of Sciences for the Developing World are involved in an SRM governance initiative with the Royal Society; a public report is forthcoming in Spring 2011.<sup>35</sup> The technologies of humility rubric, which emphasizes both vulnerability and distribution, would suggest that there is a need to create processes that can fruitfully involve developing-world citizens in deliberative dialogue with policy-makers and scientists early in the process of designing region-scale geoengineering interventions.

**Learning.** I will discuss learning in the second part of this Article, where I apply the “technologies of humility” framework to case studies involving code and treaty-based approaches to geoengineering governance.

### *1. Evaluating Geoengineering Schemes Through the Technologies of Humility Rubric*

Using Jasanoff’s technologies of humility approach, let us ask of each leading geoengineering scheme, “what is the purpose; who will be hurt; who benefits; and how can we know?” In the table below, I rely on Wynne’s definition of “uncertainty” as “unknowns solely within the parameters of science” and indeterminacy as “the open-ended question of whether knowledge is adapted to fit the mismatched realities of application situations, or whether those (technical and social) situations are reshaped to validate the knowledge.”<sup>36</sup>

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<sup>35</sup> The Royal Soc’y, SRM Governance Initiative, <http://royalsociety.org/SRM-governance-initiative/> (last visited May 8, 2011).

<sup>36</sup> Brian Wynne, *Uncertainty and Environmental Learning: Reconceiving Science and Policy in the Preventative Paradigm*, GLOBAL ENVTL. CHANGE 111, 115 (1992).

Table 2. A “Technologies of Humility” approach to geoengineering strategies.

	<b>Purpose?</b>	<b>Who Will be Hurt?</b>	<b>Who Benefits?</b>	<b>How Can We Know?</b>
<b>Solar Radiation Management (SRM)</b>	Mask the warming effects of increased carbon in the atmosphere; it could potentially be used as a hostile climate modification strategy	Monsoon-dependent developing countries; taxpayers in countries whose governments fund research; future generations (in part because it is difficult to estimate how much they might value a non-engineered atmosphere); any entity engaged in mitigation efforts that might lose funding or business opportunities	The fame and individual funding prospects of a geoengineering researcher are distortionary benefits worth considering; private and governmental entities interested in maintaining the carbon status quo	Bala; Roebock; <sup>37</sup> however, much uncertainty and indeterminacy remain
<b>Air Capture</b>	Remove CO <sub>2</sub> directly from atmosphere and bury it underground	Taxpayers; any entity engaged in mitigation efforts might lose funding or business opportunities; if the carbon leaks, workers and neighbors could be affected	Companies and innovators if they can bring down costs; the carbon status quo benefits if air capture’s sunk costs are incompatible with boosting renewable technologies	Keith; <sup>38</sup> however, much uncertainty remains.

<sup>37</sup> See e.g., G. Bala et al., Impact of Geoengineering Schemes on the Global Hydrological Cycle, 105(22) PNAS 7664 (2008); Alan Robock et al., *Benefits, Risks, and Costs of Stratospheric Geoengineering*, 36 GEOPHYSICAL RES. LETTERS (2009).

<sup>38</sup> See Keith et al., *Climate Strategy with CO<sub>2</sub> Capture from the Air*, 74 CLIMATIC CHANGE 17 (2006).

<b>Afforestation</b>	Increase the carbon sink; receive additional ecosystem services	Farmers; loggers; other competing land users	Forest-dependent and forest ecosystem-service-dependent communities; future generations.	The Economics of Ecosystems & Biodiversity (TEEB), <sup>39</sup> uncertainty about calculating baselines and the permanence of carbon sequestration remain
<b>Biochar made from sustainable sources of biomass</b>	Permanently sequester carbon; improve soil fertility; reduce fossil-fuel fertilizer use potentially reduce strain on irrigation resources.	Farmers and biodiversity will lose out if perverse incentives exist for sourcing the feedstock unsustainably (i.e., by maintaining biomass plantations).	Farmers; anyone who values productive soil; future generations.	Lehmann, <sup>40</sup> uncertainties remain.
<b>Directing sulfate aerosols emitted from power plants in Global South countries over to the stratosphere above the Arctic</b>	Slowing down Arctic ice melt	MacCracken <sup>41</sup> speculates that if the aerosols were only directed towards the Arctic in the winter, no damage to the ozone layer or disruption in monsoons would result; however, countries that expect economic benefits from an ice-free Arctic could conceivably say they have been hurt	Current and future generations	MacCracken; Caldeira and Wood, <sup>42</sup> much uncertainty and indeterminacy remain.

In Table 2, the technologies of humility rubric suggests that each geoengineering scheme may produce different sets of winners and losers (though Jasanoff would probably dislike the reductive binarism in that assumption). Table 2 also reveals that uncertainty and indeterminacy loom large in each of these schemes. This begs the question: what efforts would be required to reduce the uncertainty and indeterminacy, and to what extent can we be confident that these efforts would actually produce greater clarity?

As Battisti points out, the climate models used by would-be geoengineers have to rely upon unrealistically simplified climate models that leave out key factors. These factors include sea ice dynamism and dynamic ocean feedback (both of which affect the temperature response in the northern latitudes) along with atmosphere-ocean dynamics in the tropics, cloud dynamics,

<sup>39</sup> See TEEB, THE ECONOMICS OF ECOSYSTEMS AND BIODIVERSITY IN NATIONAL AND INTERNATIONAL POLICY MAKING – SUMMARY: RESPONDING TO THE VALUE OF NATURE (2009), available at <http://www.teebweb.org/LinkClick.aspx?fileticket=dYhOxrQWffs%3d&tabid=1019&mid=1931>.

<sup>40</sup> See Johannes Lehman, *A Handful of Carbon*, 447 NATURE 143 (2007).

<sup>41</sup> See Michael MacCracken, *Beyond Mitigation: Potential Options for Counter-Balancing the Climatic and Environmental Consequences of the Rising Concentrations of Greenhouse Gases* (World Bank Pol’y Res., Working Paper No. 4938, 2009)

<sup>42</sup> See *id.*; Caldeira & Wood, *supra* note 19.

and complex, cyclical phenomena like El Niño.<sup>43</sup> Battisti notes that if we were planning to do regional-scale geoengineering twenty years from now, the current limitations of our models would put us at “plus or minus two or three degrees and plus or minus 20% precipitation.”<sup>44</sup>

Battisti critiques a leading aerosol injection model by Rasch et al.,<sup>45</sup> which is generally interpreted to indicate promising results for SRM by pointing out that the Rasch model doesn’t take sea-ice or ocean dynamics into account.<sup>46</sup> Battisti’s model uses the same parameters as Rasch’s, but adds sea-ice and ocean dynamics—and finds differences in precipitation as large as 40% between the two runs, and differences in temperature as large as two to three degrees C.<sup>47</sup> Battisti suggests that it will take a few decades until we understand sea-ice, ocean, and cloud dynamics well enough to model them adequately.<sup>48</sup>

The five leading geoengineering strategies fall into two distinct categories—the first set focuses on a discrete technology (e.g., injecting sulfate aerosols) while the second set manages a linked social and biophysical system (e.g., afforestation, biochar in farming).<sup>49</sup> In this context, Wynne’s observation that in cases where risk intersects with unknowns about biophysical systems, “limitations of available knowledge are potentially more serious because the system in question, not being a technological artifact, cannot be designed, manipulated, and reduced to within the boundaries of existing analytical knowledge.”<sup>50</sup>

Notably, Lenton and Vaughan find that both biochar and afforestation can only play a supportive but minor role in maintaining global temperatures at or below 1.5 or 2 degrees Celsius (degrees C) by 2100.<sup>51</sup> Moreover, some critics question whether large-scale use of biochar and afforestation could stymie food production on arable land. Lenton and Vaughn conclude that air capture in combination with strong mitigation strategies plus biochar and afforestation hold the greatest promise for returning the global atmospheric carbon dioxide concentration to pre-industrial levels.<sup>52</sup>

Nonetheless, the Royal Society’s 2009 report, which suggests that SRM is the most promising geoengineering option, was based on Lenton and Vaughan’s 2009 evaluation.<sup>53</sup> In other words, the same data can lead to very different conclusions—which is why the “technologies of humility” rubric’s emphasis on framing matters. This point is best illustrated by

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<sup>43</sup> Video: David Battisti, *Climate Engineering with Aerosols—Predictable Consequences?*, MIT EARTH SYSTEM INITIATIVE – CLIMATE ENGINEERING SYMPOSIUM (Dec. 2, 2009), <http://techtv.mit.edu/genres/32-science/videos/4636-climate-engineering-with-aerosolspredictable-consequences>.

<sup>44</sup> *Id.* at 5:33.

<sup>45</sup> *Id.* at 3:20; see Philip J. Rasch et al., *Exploring the Geoengineerings of Climate Using Stratospheric Sulfate Aerosols: The Role of Particle Size*, 35 GEOPHYSICAL RES. LETTERS 1 (2008).

<sup>46</sup> Battisti, *supra* note 43, at 4:33.

<sup>47</sup> *Id.* at 5:00.

<sup>48</sup> *Id.* at 21:40.

<sup>49</sup> Friends of the Earth U.K. performs a similar analysis and comes out in favor of air capture of CO<sub>2</sub>. It suggests that research into bringing down costs and safely storing the carbon is an urgent priority. However, Friends of the Earth does not acknowledge the liability and safety issues that surround the storage of carbon. FRIENDS OF THE EARTH, BRIEFING NOTE: CARBON CAPTURE AND STORAGE (2005), *available at* [http://www.foe.co.uk/resource/briefing\\_notes/carbon\\_capture.pdf](http://www.foe.co.uk/resource/briefing_notes/carbon_capture.pdf). In an evaluation of the public health issues surrounding carbon capture and sequestration, Fogarty and McCally note that the “risks are substantial” and “have not been considered.” John Fogarty & Michael McCally, *Health and Safety Risks of Carbon Capture and Storage*, J. AM. MED. ASS’N 67, 67 (2010).

<sup>50</sup> Wynne, *supra* note 36, at 113.

<sup>51</sup> Lenton & Vaughn, *supra* note 7, at 5550.

<sup>52</sup> *Id.* at 5556.

<sup>53</sup> The Royal Soc’y, *supra* note 10, at 6.

a closer look at a diagram featured in the Royal Society report (Figure 1 *infra*). Note that the diagram contains a mistake—the lower right hand corner should read “high effectiveness: high affordability.” Dot-size is intended to represent “timeliness,” and dot color, ranging from green to red, is intended to represent safety. The Royal Society’s explanation of the diagram is striking and underscores the de-emphasis of uncertainty even amongst scientists: “Indicative error bars have been added to avoid any suggestion that the size of the symbols reflects their precision (but note that the error bars are not really as large as they should be, just to avoid confusing the diagram).”<sup>54</sup>

### *E. Cost-Benefit Tests Are Inappropriate in Face of the Scientific Uncertainties Associated with Geoengineering*

Questions of cost have dominated the geoengineering discourse even more than concerns of risk and uncertainty. However, the premise that geoengineering would cost considerably less than de-carbonizing the global economy is based on a false definition of cost and an inadequate understanding of compensation.<sup>55</sup> One set of proponents, for example, suggests that aerosol geoengineering is essentially costless in proportion to the benefits it could provide.<sup>56</sup> In contrast, Goes et al. demonstrate that aerosol geoengineering fails a cost-benefit test because if aerosol loading were stopped, abrupt climate change with grave associated monetary damages would result.<sup>57</sup>

Hopefully, Goes et al.’s study will elicit many other studies along similar lines. At present, however, some proponents of geoengineering emphasize cost as one of the key underlying justifications for funding geoengineering research and development.

## II. CASE STUDIES

### *A. Can Expert Town Halls Govern Geoengineering?*

A risk-based approach to geoengineering that internalizes any potential social costs might rule out geoengineering altogether. A strongly precautionary approach to geoengineering would ban all research, or impose a moratorium.<sup>58</sup> Indeed, Victor argues that most countries would push for a ban if a treaty process were initiated today.<sup>59</sup> He also argues that the Intergovernmental Panel on Climate Change (IPCC) is not well-equipped to assess

<sup>54</sup> *Id.* at 49.

<sup>55</sup> See, e.g., BLACKSTOCK ET AL., *supra* note 4, at 46 (estimating that stratospheric sulfate loading would cost \$8 billion annually, but noting that “costs would go up dramatically” if it turned out that aerosols need to be delivered significantly higher up than the 20 kilometers that is currently assumed). Further, David Victor writes, “In short, the claim that geoengineering is remarkably cheap is based on simple assessments of silver-bullet geoengineering. In practice, however, the geoengineering cocktails that are likely to be deployed will not be cheap.” David G. Victor, *On the Regulation of Geoengineering*, 24 OXFORD REV. ECON. POL’Y, 322, 327 (2008). Both the Novim group and Victor examine only the cost of deploying the technology—not the cost of dealing with unintended consequences or compensating injured parties.

<sup>56</sup> Scott Barrett, *The Incredible Economics of Geoengineering*, 39 ENVTL. RESOURCE ECON. 45, 49 (2008).

<sup>57</sup> Marlos Goes, et al., *The Economics (Or Lack Thereof) of Aerosol Geoengineering*, in review at CLIMATIC CHANGE 1, 14 (2010); see also MacCracken, *supra* note 41 (citing Brovkin and Roebock’s suggestion that aerosol geoengineering would have to continue unabated for at least 200 years).

<sup>58</sup> Douglas Kysar, *Ecologic: Nanotechnology, Environmental Assurance Bonding, and Symmetric Humility* 1, 46 (Yale L. & Econ. Res., Working Paper No. 391, 2009), available at [http://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=1464913](http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1464913) (citing Mandel’s description of a moratorium on nanotechnology research).

<sup>59</sup> Victor, *supra* note 55, at 331.

geoengineering schemes because it is not accustomed to making trade-offs or to commissioning new, speculative research; neither are its consensus-oriented assessments equipped to evaluate the complexities of a sub-field as relatively under-studied and complicated as geoengineering.<sup>60</sup> David Keith, one of the scientists at the heart of the push for additional geoengineering research, has also spoken against treaty-based regulation. Keith supports building “international cooperation and norms from the bottom up” via the work of several independent teams.<sup>61</sup>

Victor and Keith emphasize the need for “bottom-up” governance, which, for Keith, includes informal consultations between governments and civil society.<sup>62</sup> For, Victor writes, “a dedicated international entity overseen by the leading academies” is key.<sup>63</sup> Keith and Victor both participated in the Asilomar International Conference on Climate Intervention Technologies,<sup>64</sup> which self-consciously styled itself after the Asilomar conferences on establishing guidelines for recombinant DNA research.<sup>65</sup> Given some experts’ clear preference for the expert town hall governance structure, the next section explores whether Asilomar I is a relevant point-of-departure for geoengineering governance.

### 1. Reflections on Asilomar I

The Asilomar I conference on recombinant DNA research guidelines emphasized hazard (rather than cost-benefit analyses).<sup>66</sup> These conferences were funded by the federal government and convened by scientists who had already imposed a moratorium on additional research. The guidelines established at Asilomar ended the moratorium, were immediately picked up by federal agencies, and continue to provide the backbone of agencies’ perspective on recombinant DNA research.<sup>67</sup> While a group called Science for the People comprised of scientists who opposed such research was invited, Frederickson notes that members chose not to attend. The group distributed a letter at Asilomar asking for a moratorium on such research until the public could be involved in drafting research guidelines.<sup>68</sup>

In a vivid reflection that is alternately querulous and eloquent, Roger Dworkin, a legal scholar who attended the second Asilomar conference on recombinant DNA, recollects the scientists’ minimal engagement with public policy questions.<sup>69</sup> He also emphasizes that the scientists who were present frequently repeated how important it was “to avoid outside control.”<sup>70</sup> Dworkin notes, “Calling the researchers’ attention to their potential liability induced a fear in them akin to a layperson’s fear of virulent bugs crawling out of a laboratory.”<sup>71</sup>

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<sup>60</sup> *Id.* at 329.

<sup>61</sup> Keith et al, *supra* note 6, at 427.

<sup>62</sup> *Id.*

<sup>63</sup> Victor et al., *supra* note 17, at 4.

<sup>64</sup> ASILOMAR SCI. ORGANIZING COMM., THE ASILOMAR CONFERENCE RECOMMENDATIONS ON PRINCIPLES FOR RESEARCH INTO CLIMATE ENGINEERING TECHNIQUES: CONFERENCE REPORT 32-35 (2010), available at <http://www.climateactionfund.org/images/Conference/finalfinalreport.pdf>.

<sup>65</sup> *Id.* at 4.

<sup>66</sup> See Donald S. Frederickson, *Asilomar and Recombinant DNA: The End of the Beginning*, in BIOMEDICAL POLITICS 258, 273, 282 (Kathi E. Hanna ed., 1991).

<sup>67</sup> *Id.* at 283-84.

<sup>68</sup> *Id.* at 279.

<sup>69</sup> Roger Dworkin, *Science, Society, and the Expert Town Meeting: Some Comments on Asilomar Symposium: Biotechnology and the Law: Recombinant DNA and the Control of Scientific Research: VI. Regulatory Aspects*, 51 S. CAL. L. REV. 1471, 1476 (1977-1978).

<sup>70</sup> *Id.* at 1473.

<sup>71</sup> *Id.* at 1474.

Dworkin further notes that, by the time of Asilomar I, recombinant DNA research had far outpaced policy: “The expert town meeting may be useful for backing and filling and for moderating foregone conclusions, but *our greatest need is for an institution that can anticipate problems* before options are foreclosed. The expert town meeting cannot fulfill that need.”<sup>72</sup> Dworkin emphasizes the need for an institution that has oversight over governmental decisions about science. He also describes how rapidly the statement that emerged on the final day was rammed through as a consensus declaration, even though only a small group had been involved in drafting it, and notes that the campground setting of Asilomar forced the 150 scientists in attendance to rub shoulders every day for a week; according to Dworkin, this created conditions similar to a traditional New England town-meeting, where constant proximity makes quarrelling with one’s neighbors all the more difficult.<sup>73</sup> Too, Briggie (2005) notes that the scientists chose not to focus on ethical issues.<sup>74</sup> “Defining the problem in technical terms legitimated the model of self-government by scientists, because they were the only group that could solve such problems.”<sup>75</sup>

I will refer to the Asilomar Climate Intervention conference as Asilomar II. Here are some interesting contrasts between Asilomar I and Asilomar II: while Asilomar I was funded by the U.S. government,<sup>76</sup> Asilomar II (which featured working groups on all major categories of geoengineering) was funded by several private foundations and by the Australian state of Victoria, which also served as a strategic organizational partner and convened by two non-profits: the Climate Response Fund and the Climate Institute.<sup>77</sup> Certain civil society organizations like the Action Group on Erosion, Technology and Concentration (ETC Group) criticized the conference in an open letter.<sup>78</sup> The ETC Group’s Diana Bronson told journalist Eli Kintisch that, although she had been invited to Asilomar, she had declined to attend in part because her group opposed the creation of voluntary guidelines proposed by scientists.<sup>79</sup>

Another interesting contrast between the recombinant DNA conference and the upcoming geoengineering conference is that geoengineering includes a much greater diversity of schemes. As the geoengineering community matures, perhaps more focused conferences on each technological approach will enable a more coherent conversation about governance to emerge. Despite these distinctions, Asilomar II was an important first step in creating a community of interdisciplinary scholars and members of civil society who could think through the challenges of geoengineering together. At Asilomar II, some discussion centered on the fact that geoengineering schemes may hold limited—and possibly exceptional—promise because of their heightened attention to strategically significant aspects of global material-flow balance.

For example, MacCracken points out that there was a small reduction in warming over the Northern Hemisphere during the middle of the Twentieth Century due to the aerosol

<sup>72</sup> *Id.* at 1481 (emphasis added).

<sup>73</sup> *Id.* at 1478.

<sup>74</sup> Adam Briggie, *Asilomar Conference*, in *ENCYCLOPEDIA OF SCIENCE, TECHNOLOGY, AND ETHICS* 118-121 (Carl Mitcham ed., 2005).

<sup>75</sup> *Id.*

<sup>76</sup> Frederickson, *supra* note 66, at 268.

<sup>77</sup> The Climate Response Fund, Donors,

[http://www.climateresponsefund.org/index.php?option=com\\_content&view=article&id=79&Itemid=75&phpMyAdmin=cug23OhjKGQC374EoLnU0y3xkXd](http://www.climateresponsefund.org/index.php?option=com_content&view=article&id=79&Itemid=75&phpMyAdmin=cug23OhjKGQC374EoLnU0y3xkXd) (last visited May 8, 2011).

<sup>78</sup> ETC Group, Open Letter Opposing Asilomar Geoengineering Conference, <http://www.etcgroup.org/en/node/5080> (last visited May 8, 2011).

<sup>79</sup> Chris Mooney, *Enviros Split on Geoengineering Conference*, *DISCOVER*, Mar. 15, 2010, available at <http://blogs.discovermagazine.com/intersection/2010/03/15/enviros-split-on-geoengineering-conference/>.

emissions from coal plants.<sup>80</sup> (Air pollution regulations to clean up these emissions would then have the side effect of increasing local warming.) Taking a material-flow-analysis perspective, MacCracken suggests directing the sulfate aerosols captured by newly installed scrubbers towards the stratosphere above the Arctic in order to minimize Arctic warming.<sup>81</sup> He cites Caldeira and Wood (2008) to the effect that reducing solar radiation in the Arctic could offset anthropogenic global warming in that location, thereby limiting sea-level rise.<sup>82</sup> MacCracken also suggests that “[t]he injection altitude could be chosen to ensure that the aerosols would stay aloft only during the sunlit months, thereby limiting their contribution to intensification of springtime ozone depletion.”<sup>83</sup> However, climate modeler, Alan Robock has raised the question of whether a geographically limited intervention would in fact remain confined.<sup>84</sup>

Limited interventions like this are, perhaps, worth more investigation. However, they are based on the same models that are plagued by deep uncertainties at present; such interventions also maintain the current epistemological disjunction between the realms of science and policy. Clearly, such interventions could deliver enormous benefits, but because of the scale of the uncertainties, neither a traditional cost-benefit analysis, nor an outright ban on more research fits perfectly.

## 2. Asilomar I and II from a “Technologies of Humility” Framework

From a “technologies of humility” framework, Asilomar II was an improvement on Asilomar I because the second Asilomar attempted to bring together social and natural scientists, and to engage citizens in deliberation about geoengineering governance. That said, attention to framing, vulnerability, distribution, and learning was not made explicit at Asilomar II. Any future expert town hall on geoengineering governance would do well to incorporate the “technologies of humility” framework in an upstream attempt to engage citizens in deliberation.

### *B. Can Treaties Govern Geoengineering?*

Since so many proponents have framed geoengineering as a way out of the deadlocked international climate negotiations, it is perhaps unsurprising that there are very few voices calling for treaty-based regulation. Ironically, in a treaty-based approach, the unfettered enthusiasm of the geoengineer may suffer from the same “super-wicked” issues that have bogged down the climate negotiations—equity between the global north and global south countries, access to technology, and a compensation fund for countries which suffer adverse consequences from geoengineering.<sup>85</sup> It turns out that the same murky questions of intellectual property, international funding structures, and capacity building that have dogged the climate negotiations do not lurk far under the surface of any comprehensive treaty-based approach to geoengineering governance. Redgwell suggests that governance must, of necessity, be fragmented into a patchwork of local, regional, national, and international laws.<sup>86 87</sup>

<sup>80</sup> MacCracken, *supra* note 41, at 3.

<sup>81</sup> *Id.* at 24.

<sup>82</sup> *Id.*

<sup>83</sup> *Id.* at 23.

<sup>84</sup> See Alan Robock, *Twenty Reasons Why Geoengineering May Be A Bad Idea*, 64 BULL. OF THE ATOMIC SCIENTISTS 14, 15 (2008).

<sup>85</sup> See Lazarus, *supra* note 15, at 1153.

<sup>86</sup> See Video: Catherine Redgwell, *Geoengineering Governance: Rendering the Possible Impossible*, MIT EARTH SYSTEM INITIATIVE'S CLIMATE ENGINEERING SYMPOSIUM (Dec. 2 2009), <http://techtv.mit.edu/genres/32-science/videos/4627-geoengineering-governance-rendering-the-possible-impossible>.

In other words, geoengineering governance, demystified, does not look too different from the current, patchy approach to regulating CO<sub>2</sub> emissions—with one caveat. Geoengineering could make intentional, hostile climate modification even more of a possibility than it currently is. Our current relationship with greenhouse gasses constitutes cumulative, inadvertent, climate modification. But, deploying sulfate aerosols—or hydrofluorocarbons, as a study prepared for the Department of Defense suggests<sup>88</sup>—could explicitly constitute hostile weather modification.<sup>89</sup> Victor estimates that the United States, European Union, Russia, China, India, and Japan are the only nations capable of deploying sulfate aerosol schemes in the immediate future.<sup>90</sup> (Jasanoff would likely recommend attention to the nuances of the dominant frames that would be used to view geoengineering within these imagined communities.) Except for China, all of these countries are parties to ENMOD, which came into force in 1978 in response to U.S. deployment of cloud-seeding during the Vietnam War.<sup>91</sup>

The problems posed by geoengineering governance are not entirely unprecedented and require better understanding of the circumstances that led to the creation of ENMOD. The United States attempted to use cloud-seeding against North Vietnam between 1967-1972 in order to worsen the regional monsoon and “reduce trafficability” along the Ho Chi Minh Trail in an operation code-named POPEYE.<sup>92</sup> Until the WASHINGTON POST reported the story in 1971, the U.S. public, and even the Deputy Assistant Secretary of Defense for East Asia at the time, remained unaware that the U.S. Air Weather Service had scattered silver iodide, which

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<sup>87</sup> Potentially applicable international treaties include: The Montreal Protocol, the Convention on Biodiversity, the London Convention on Dumping, and the Convention on Long Range Transboundary Air Pollution.

<sup>88</sup> Peter Schwartz and Doug Randall, *An Abrupt Climate Change Scenario and its Implications for United States National Security*, GLOBAL BUS. NETWORK 22 (2003), available at <http://www.gbn.com/articles/pdfs/Abrupt%20Climate%20Change%20February%202004.pdf> (recommending that the United States “[e]xplore geo-engineering options that control the climate . . . . Today, it is easier to warm than to cool the climate, so it might be possible to add various gases, such as hydrofluorocarbons, to the atmosphere to offset the affects of cooling. Such actions, of course, would be studied carefully, as they have the potential to exacerbate conflicts among nations.”).

<sup>89</sup> Barrett provides a useful summary of additional governance issues with geoengineering. He points out that some countries (like Russia, China, and Canada) are expected to benefit from climate change and asks whether they would need to be compensated if geoengineering schemes cool the climate. He summons the possibility of geoengineering wars and asks, “Would countries be allowed to engineer any temperature, or would they only be permitted to limit change from the recent historical average?” Barrett, *supra* note 56, at 51. He recommends IPCC review, followed by UNFCCC review, followed by a new protocol under UNFCCC.

However, Barrett’s review of SRM is surprisingly imprecise and lacks any perspective on unintended consequences. He does not mention the adverse effects accompanying the Pinatubo eruption; neither does he mention SRM’s spatially heterogeneous effects, such as its potentially severe consequences for precipitation in some parts of the world. His “Incredible Economics of Geoengineering” essay assigns geoengineers an incredibly credulous amount of control and agency over the climate system; it simultaneously assigns treaty negotiators an unrealistically high ability to create a new protocol given the long-standing deadlock in the climate negotiations. Barrett is not the only scholar who exhibits symmetrical hubris. Another one of the few voices crying out in favor of treaty-based governance belongs to legal scholar, Albert Lin. Lin also advocates addressing geoengineering through the UNFCCC and emphasizes “adaptive governance,” or frequent review of the geoengineering processes. Lin, *supra* note 16. However, he does not adequately address the fact that abruptly stopping a climate intervention could magnify damages. Goes et al., *supra* note 57. Like Barrett, he fails to acknowledge the deadlocks within the UNFCCC process that might prevent the creation of a new geoengineering protocol.

<sup>90</sup> Victor et al., *supra* note 17.

<sup>91</sup> Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, Dec. 10, 1976, 31 U.S.T. 333, 1108 U.N.T.S. 151 [hereinafter ENMOD Treaty].

<sup>92</sup> Fleming, *supra* note 3, at 55.

accelerates the formation of rain-clouds, throughout Southeast Asian airspace during 2600 plane flights funded by U.S. citizens.<sup>93</sup>

Outcry within the United States and internationally prompted the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, which 70 nations signed in 1979.<sup>94</sup> This treaty, better known as ENMOD, has never been invoked, although some scholars point to several applicable instances.<sup>95</sup> ENMOD prohibits “military or other hostile” intervention into “the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space.”<sup>96</sup> Notably, ENMOD does permit modification of the weather for “peaceful purposes,” and some attendants of Asilomar II called for revamping ENMOD so that would-be geoengineers could bind themselves with its “peaceful purposes” language.<sup>97</sup> However, it would be extremely difficult to know for sure if one nation decided to covertly manipulate another nation’s climate with hostile intent.<sup>98</sup>

Although ENMOD prohibits intentionally hostile weather modification, it has never been invoked to censure a state and does not even address liability. Chamorro and Hammond (2001) characterize ENMOD as a “non-use arms control treaty,” noting that an environmental modification has to be either “wide-spread,” “long-lasting,” or “severe” in order to fall within ENMOD’s purview. While ENMOD’s compliance mechanism is hypothetically strong (it calls on the U.N. Security Council to resolve disputes, and, in theory, the Security Council could use the threat of trade sanctions), Chamorro and Hammond list ENMOD’s many additional weaknesses.<sup>99</sup> Strengthening ENMOD’s compliance mechanisms could go a long way towards staving off international concerns about hostile geoengineering—but this process would be difficult due to the same justice, equity, and competitive advantage concerns that plague the climate negotiations.

### 1. The International Atomic Energy Agency

Perhaps the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), which is generally hailed as one of the most successful international arms control efforts to date, can provide additional guidance to anyone interested in curtailing potentially hostile uses of geoengineering.<sup>100</sup> The International Atomic Energy Agency (IAEA) is entrusted with key roles and responsibilities under the NPT, including inspecting international safeguards inspectorate and transferring peaceful applications of nuclear technology.<sup>101</sup> The IAEA was started after World War II based on Eisenhower’s concept of “Atoms for Peace,” which distinguished

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<sup>93</sup> *Id.*

<sup>94</sup> ENMOD Treaty, *supra* note 91.

<sup>95</sup> See Bidisha Banerjee, *ENMOD Squad*, SLATE, Sept. 23, 2010, <http://www.slate.com/id/2268123/>.

<sup>96</sup> ENMOD Treaty, *supra* note 92, art. I.

<sup>97</sup> *Id.* art. III.

<sup>98</sup> Victor et al., *supra* note 17.

<sup>99</sup> Susana P. Chamorro & Edward Hammond, *Addressing Environmental Modification in Post-Cold War Conflict: The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) and Related Agreements*, in OCCASIONAL PAPERS OF THE EDMONDS INSTITUTE (2001), available at <http://www.edmonds-institute.org/pimiento.html>.

<sup>100</sup> Treaty on the Non-Proliferation of Nuclear Weapons, Mar. 5, 1970, 21 U.S.T. 483, 729 U.N.T.S. 161 [hereinafter NPT].

<sup>101</sup> *Id.* arts. III & V.

between peaceful and hostile uses of nuclear technology.<sup>102</sup> The IAEA is the product of numerous compromises between national sovereignty and U.N. authority.

Imber cites remote surveillance as a key reason why the NPT has been successful.<sup>103</sup> The NPT is built around the concept of safeguards: the Agency's Inspectors keep tabs on the materials being used by member countries, and conduct inspections—especially at strategic points of the fuel refining cycle, where hostile uses of the technology could exist. Inspectors also have the ability to apply leaded seals in order to contain particular batches of material.<sup>104</sup> Moreover, the Inspectors' power has gradually increased over several decades.<sup>105</sup>

Scale and intention are the biggest differentiators between geoengineering technology and nuclear technology. Geoengineering, by definition, attempts to evoke large-scale changes in the global atmosphere; these changes could have both hostile and beneficial consequences. Meanwhile, the fallout from nuclear technology is somewhat more contained; a brighter line separates peaceful and hostile uses.<sup>106</sup> Nonetheless, this Article's abbreviated account of the IAEA's success can provide some guidelines for geoengineering research.

Once in place, a governance framework can be strengthened over time. This would argue for bolstering ENMOD and other existing treaties rather than creating new ones. (At the same time, the NPT's biggest weakness is its failure to bind *all* countries.) Remote surveillance and the ability to inspect strategically important aspects of the fuel cycle are key reasons for the NPT's success; these approaches minimally intrude on national sovereignty. Geoengineering researchers could focus on improving remote surveillance of international carbon emissions and on improving their climate models. Those interested in deploying geoengineering in case of climate emergency could focus on improving our still very limited understanding of climate tipping points and the possibility of geographically limited geoengineering interventions.<sup>107</sup> Research along these lines would also benefit international climate negotiations, which suggests a valuable test for geoengineering research: would this research explicitly synergize with existing research into mitigation/adaptation?

## 2. Environmental Assurance Bonding: A Relevant Alternative?

Given the existence of a few, limited situations where geoengineering may hold exceptional promise for responding to the climate crisis, a strongly precautionary approach may not be appropriate. Kysar argues that environmental assurance bonding (EAB) offers a middle-of-the-road regulatory perspective in cases where both risks and benefits are poorly understood.<sup>108</sup> Noting that such bonds would be price-equivalent to the worst-case threats

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<sup>102</sup> Dwight D. Eisenhower, President of the United States, Speech to the 470th Plenary Meeting of the United National General Assembly: Atoms for Peace (Dec. 8, 1953), *available at* [http://www.iaea.org/About/history\\_speech.html](http://www.iaea.org/About/history_speech.html).

<sup>103</sup> Mark F. Imber, *NPT Safeguards: The Limits of Credibility*, 1 CONTEMP. SECURITY POL'Y 177, 179 (1980).

<sup>104</sup> *Id.*

<sup>105</sup> *Id.*

<sup>106</sup> *But see* Brian Wynne, *Uncertainty and Environmental Learning*, 2 GLOBAL ENVTL. CHANGE 111-127 (1992) (explicating a case-study of sheep-farming after Chernobyl, which traces how the limits of scientific analysis led to unanticipated negative interactions on a wide-scale when radioactive caesium was blown from Chernobyl to sheep-pastures in the UK).

<sup>107</sup> David Keith, *Photophoretic Levitation of Engineered Aerosols for Geoengineering*, 107(38) PNAS 16428-16431 (2010).

<sup>108</sup> Douglas Kysar, *Ecologic: Nanotechnology, Environmental Assurance Bonding, and Symmetric Humility*, 28 UCLA ENVTL. L. & POL'Y J. (forthcoming) (manuscript at 6, *available at* <http://www.cnsi.ucla.edu/NanoRegulatoryPolicy/pdfs/kysar.pdf>.)

posited by the scheme, Kysar claims that this approach exhibits an equal degree of humility towards both sociolegal and biophysical systems.<sup>109</sup> Unlike an outright ban, which would preclude any possible benefits of the research, a bond could incentivize researchers to move from uncertainty (which has no standard measure) to risk (which does).<sup>110</sup> However, Kysar does note that environmental assurance bonds have not worked effectively thus far, primarily because regulators have been unwilling to demand the full value of the bonds.<sup>111</sup> Moreover, Gerard and Wilson note, “Being able to estimate remediation costs is a crucial component for setting the bond amount.”<sup>112</sup> Without a more comprehensive epistemic shift in the regulatory framework, it is difficult to see how this problem could be circumvented.

Furthermore, the particular characteristics of geoengineering may make assurance bonding prohibitively difficult to implement, at least in the case of SRM attempts. Environmental assurance bonding would require a geoengineering project to post a bond “equal to the current best estimate of the largest potential future environmental damages.”<sup>113</sup> This is ideally suited to, say, a mining project, where the surety company’s exposure can be calculated based on local effects and knowledge accumulated over hundreds of years.<sup>114</sup> In the SRM case, the vastness of the worst-case harms and the degree of uncertainty makes it hard to imagine who would put up a bond. Depending on the level of certainty required and the method by which numerous non-economic harms (the loss of small island nations or cultures, for example) were valued, EAB can, to some extent, degenerate into two familiar limit cases: a prohibitive precautionary approach or a permissive cost-benefit analysis. Environmental assurance bonding may be easier to implement in the CDR and sequestration contexts, however. Even in the SRM case, its conceptual features and incentive shifts should be studied closely. If governments, and not private firms, were engaging in SRM, perhaps more comprehensive assurances (of relocation assistance, foreign aid, and so on) could substitute for the strictly economic nature of a bond.

If these challenges could be overcome, civil society groups could embrace the idea of EABs for specific geoengineering research projects. This could have the additional benefit of resolving the tension between scientific erasure of socio-political realities and context-specific, place-based meaning-making that Jasanoff highlights in her technologies of humility rubric. Demanding environmental assurance bonding would sharpen civil society engagement with geoengineering and elevate the dialogue beyond the broad allegations of groups like Geoengineering Watch, which are easy for scientists to dismiss. Egede-Nissen and Venema additionally suggest a role for the Arctic Council in encouraging more public participation in and construction of a dialogue about geoengineering interventions in the Arctic.<sup>115</sup> Even if EAB simply shifts the battle between precaution and prohibition to a new territory, that territory may

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<sup>109</sup> *Id.* at 8.

<sup>110</sup> *Id.* at 9. Kysar further points out that “the assurance bonding approach still would represent a lower burden of proof for regulators than the risk-assessment/CBA approach typified by cases such as *Corrosion Proof Fittings v. EPA*, 947 F.2d 1201 (5th Cir. 1991).” *Id.* at 48.

<sup>111</sup> *Id.* at 51.

<sup>112</sup> David Gerard & Elizabeth J. Wilson, *Environmental Bonds and the Challenge of Long-Term Carbon Sequestration*, J. ENVTL. MGMT. 1097, 1100 (2008).

<sup>113</sup> Kysar, *supra* note 108, at 45 (quoting Robert Costanza & Laura Cornwell, *The 4P Approach to Dealing with Scientific Uncertainty*, 34 ENV’T 12 (1992)).

<sup>114</sup> *Id.*

<sup>115</sup> BJORNAR EGEDE-NISSEN & HENRY DAVID VENEMA, INT’L INST. FOR SUSTAINABLE DEV., DESPERATE TIMES, DESPERATE MEASURES: ADVANCING THE GEOENGINEERING DEBATE AT THE ARCTIC COUNCIL (2009), available at [http://www.iisd.org/pdf/2009/desperate\\_times\\_desperate\\_measures.pdf](http://www.iisd.org/pdf/2009/desperate_times_desperate_measures.pdf).

be less intellectually and politically deadlocked than the one in which we find ourselves at present.

### III. CONCLUSION

Jasanoff's "technologies of humility" framework suggests the importance of creating a deliberative sequence with a protocol for recognizing when to stop turning to technological refinement to resolve a problem that ethical reasoning suggests should be resolved socially. By highlighting the limitations of pure technological approaches, this deliberative sequence could diminish the risk of a moral hazard, insofar as that risk results from reflexive overconfidence in technological solutions. For example, the framework's emphasis on social learning could lead to workshops in which a diverse group of citizens and experts conduct frame-analysis, evaluate the distribution of vulnerability, and extensively deliberate over case studies and speculative scenarios that incorporate systems failures and scientific uncertainties. An emphasis on creating new deliberative sequences could also have clear implications for funding geoengineering proposals; funders could stipulate that any research program which tries to improve our understanding of relevant predictive phenomena should also try to improve our understanding of relevant deliberative phenomena—how a range of stake-holders across the world would view proposed geoengineering schemes, how they would evaluate risks and benefits, and which alternatives they would bring to the table. The creation of a rich deliberation process could have significant intrinsic value and yield important insights for allied fields. Finally, the framework's emphasis on confronting uncertainty and indeterminacy could encourage regulators to reassess the value of environmental assurance bonding.

Figures

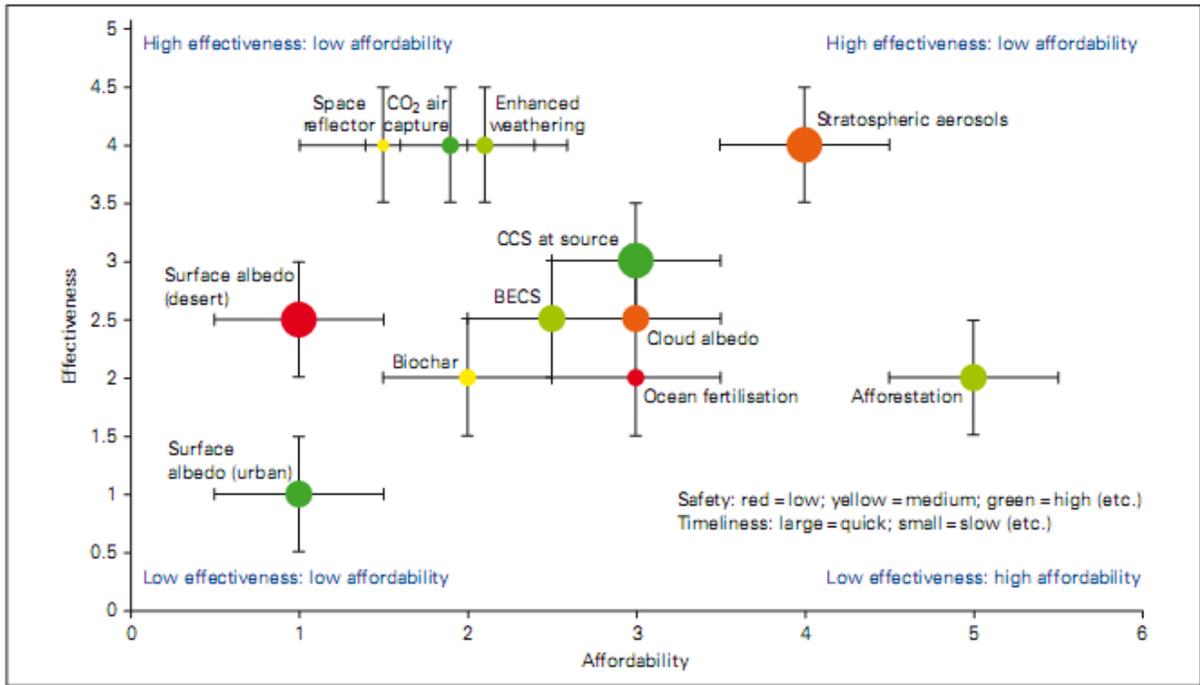


Figure 1. Unrealistically and unquantifiably small error bars in the Royal Society evaluation of geoengineering techniques.<sup>116</sup>

<sup>116</sup> The Royal Soc’y, *supra* note 10, at 6, fig.5.1.