Bioenergy and carbon capture with storage (BECCS): the prospects and challenges of an emerging climate policy response

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Wil Burns
American University Washington D.C.

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14 Governing Climate Engineering

Wil Burns and Simon Nicholson

The real revenge ... is the tendency of the world around us to get even, to twist our cleverness against us.
—Edward Tenner

One of the defining features of the New Earth is humanity's rapidly expanding technological reach. The modern world is filled with marvels. Devices that fit in the palms of our hands can connect us with friends and happenings in all corners of the world. Satellites and sensor arrays can deliver pinpoint information about human activities and the state of Earth systems. Looking forward, the positive potentials of near-future technologies are mind-boggling. In particular, extension of the rapid advances already being seen in genetics, robotics, information technology, and nanotechnology—a suite of developments that social commentator and former *Washington Post* journalist Joel Garreau terms the "GRIN" technologies—offers remarkable promise for the betterment of our lives and our world.[1]

At the same time, though, technology's immense promise comes with peril. Technologies are implicated deeply in the most pressing problems of the New Earth. For example, technological churning within industrialized economies produces an array of disruptive social effects, with each new major technological innovation challenging established patterns of livelihood. It is also now widely appreciated that the patterns of technology-driven economic and social development are at the root of much environmental harm, from localized pollution and resource scarcities to ecological distress on a global scale (see chapter 1). At the extreme, it is one of the intrinsic burdens of living on the New Earth that humanity has developed the technological capacity to destroy the preponderance of life, whether by choice or error, in a number of different ways. Nuclear weapons—deployed in the service of either superpower security or megaterrorism—threaten all living things. Many other innovations similarly contribute

to our collective abilities to kill one another, poison ourselves, and, most dramatic, undermine the planet's life-supporting functions. Climate change stands as the most potent example of this reality.

The New Earth, then, is marked by humanity's ability, through the application of technology, to fundamentally shape and reshape all aspects of the world. In a very real sense, the fate of the planet rests on humanity's coming to terms with potent technologies and with effectively steering their development. An important set of questions for scholars and practitioners of global environmental politics then centers around technological governance. Is the shaping of technological development something that is even possible? If it is, by what means can technological development be nudged in productive rather than destructive directions? Other questions follow. Who gets to set the technological agenda, and in pursuit of what ends? What does a realistic and honest conversation about technological futures look like? And so on.

In this chapter, we take on one particular technological governance question: How can the existing tools and techniques of global governance, and in particular the kinds of institutional arrangements that Kate O'Neill and Maria Ivanova explore in, respectively, chapters 7 and 8, to good effect, be used to shape the directions of technological innovation? We examine that question through the emerging technological realm of climate engineering, or geoengineering.

Climate engineering is an umbrella term that encompasses a wide array of speculative technologies and techniques that, proponents contend, could be a bridge to help avoid passing critical temperature thresholds while the global community moves toward the decarbonization of the world economy that Navroz Dubash looks at in chapter 13, or as a response to a climate emergency, such as rapid melting of ice masses or permafrost. A number of climate engineering ideas have been advanced, and the ideas are normally separated into two categories. In the first category are carbon dioxide removal (CDR) proposals, which might draw down carbon (and perhaps other greenhouse gases) from the atmosphere, to be held in long-term storage or put to beneficial use. Examples include seeding the oceans with iron to encourage carbon-inhaling blooms of phytoplankton and the imagined deployment of "artificial draws" that would trap carbon in the open air using a chemical receptor. The second category is known as solar radiation management (SRM), or albedo modification, on the understanding that reflecting some amount of incoming solar radiation back into space before it can warm the earth's atmosphere would suppress global, or perhaps regional, temperatures. The leading SRM proposals include depositing reflective sulfate particles in the upper atmosphere and artificially brightening clouds by spraying saltwater into the cloud layer.

Such ideas have the ring of science fiction, and for many years, they were largely viewed as "a freak show in otherwise serious discussions of climate science and policy."[2] However, climate engineering is rapidly emerging from the fringes of climate policymaking to the realm of serious contemplation.

Both of us have been paying close attention to the scientific, legal, political, and public conversations around climate engineering for many years. We were drawn to an examination of climate engineering initially out of simple intellectual and academic curiosity. Until quite recently, discussions of climate engineering seemed devoid of any practical relevance. Now, though, the push for geoengineering is gathering steam. This is understandable, as we'll explain below, but also potentially troubling.

The Fast-Evolving Climate Engineering Conversation

Many of the ideas we touched on above are not new. In fact, some of them have been floating around for decades. In the United States, the Report of the Environmental Pollution panel of the President's Science Advisory Committee in 1965 included a discussion of the potential impacts of climate change and "the possibilities of deliberately bringing about countervailing climatic changes" by "increasing the albedo of the world's oceans by spreading reflective particles over large portions."[3]

In 1977, the National Academy of Sciences (NAS) released a report, "Energy and Climate," that included in its discussion of "four crucial questions" the issue of "what, if any, countervailing human actions could diminish the climatic changes or mitigate their consequences." Several options were discussed, including ocean fertilization with phosphorus, engineered increases in planetary albedo, and massive afforestation. While the report concluded that mitigation via reliance on renewable energy sources would most likely emerge as a more viable strategy, it also stated that if climate change projections were further substantiated, there might be a need for looking at options under which carbon dioxide can be "controlled" or "compensated" for.

The impulse to control the world around us is hardly a new thing. Our earliest ancestors used the power of mind and muscle, augmented by rudimentary tools, to bend and shape local ecosystems. Since the birth of

agriculture around 10,000 years ago, humanity's efforts to alter the world to fit human needs and desires has taken on a new character and force as human populations have settled and expanded, as capital and knowledge have accumulated, and as ever more powerful technologies have been brought forth. One way to read climate engineering proposals is as the logical (and perhaps culminating) expression of this deep urge to control the world around us.

Still, despite some scattered attention in prior times, it is only in the last handful of years that climate engineering proposals have lost the ring of the impossible and have started to receive serious consideration by scientists and policymakers. Talk of climate engineering is now edging from the fringes of the climate conversation for two closely related reasons.

First, there is a growing sense of widespread disillusionment with international and national responses to climate change. The United Nations Framework Convention on Climate Change (UNFCCC)[4] and its Kyoto Protocol,[5] the primary international instruments to address climate change, have proven to be feckless. Greenhouse gas emissions have grown by a third since the UNFCCC was agreed to in 1992,[6] and its parties have failed to commit to meaningful future reductions in greenhouse gas emissions within the requisite time frames to exceed critical temperature thresholds. Moreover, at the national level, major emitters, including the United States, China, and India, remain committed to fossil fuel–based economies. Indeed, a recent assessment by the International Energy Agency concludes that at current rates of greenhouse gas emissions, the "carbon budget" to avoid exceeding temperature increases of 2°C above preindustrial levels could be exceeded in approximately twenty-five years.[7] The Intergovernmental Panel on Climate Change (IPCC) concludes, in its most recent assessment reports, that temperature increases of this magnitude would substantially increase the likelihood of "severe, pervasive and irreversible impacts for people and ecosystems."[8] By the end of the century, temperatures could increase by 3°C to 4°C or more, with potentially catastrophic implications.[9] Moreover, temperatures would not begin to drop substantially for at least a millennium.[10]

As a consequence, a range of voices has begun to call for serious consideration of what some are calling a "plan B" response to climate change, usually as part of a suite of strategies including mitigation and adaptation approaches.[11] One of the most important endorsements of climate engineering research in the past decade was by Paul Crutzen, a recipient of the Nobel Prize in Chemistry. In a 2006 article, Crutzen bemoaned "the grossly disappointing international political response to the required greenhouse gas emissions." Concluding that "drastic results" could occur from projected temperature increases, Crutzen advocated research on the feasibility of using stratospheric sulfur injections to cool the planet.[12] Crutzen's intervention set the stage for the recent burst of scientific activity around climate engineering by helping to dispel the widely-held taboo associated with it that to that point had been held within the scientific community.

Second, a growing number of credible and respected scientists and scientific bodies around the world are now devoting serious attention to climate engineering. Relevant research programs have been established by individual labs and by groups of scientists at national laboratories and universities in the United States, Canada, several European countries, Japan, and India. In addition to work on atmospheric modeling related to climate engineering science and technological logistics, prominent universities in the United States and Europe have established programs focused on geoengineering policy, ethics, and governance. The Fifth Assessment Report of the IPCC, released in 2013 and 2014, surprised many in the climate world by including a quite extensive analysis of climate engineering approaches. The technical work completed to date as a result of these various efforts indicates that, at least in theory, there appear to be some relatively straightforward and cost-effective ways to intervene in the climate system in order to bring about meaningful levels of change. Some strategies, such as the introduction of sulfates into the stratosphere, build from existing technologies and technical knowledge such that they could conceivably be deployed within a handful of years. Other options exist largely as promising lines of inquiry.

These are recent and quite rapid developments. Tellingly, one study from 2013 notes that at that point, there had been more peer-reviewed articles on climate engineering in the prior three years than were seen in the thirty years before that period.[13]

The heightened levels of academic interest in climate engineering are beginning to be echoed in the policy realm. A notable intervention took place in 2009 when John Holdren, President Obama's chief science advisor, stated in an interview with the Associated Press, "It [climate engineering] has got to be looked at. We don't have the luxury of taking any approach off the table."[14] He subsequently emphasized, however, that the focus of the administration was on decarbonizing the economy. That same year and in 2010, the House Science and Technology Committee of the US House of Representatives, under the chairmanship of Bart Gordon, a Democrat from Tennessee, held hearings on geoengineering that examined the "potential

environmental risks and benefits of various proposals, associated domestic and international governance issues, evaluation mechanisms and criteria, research and development (R&D) needs, and economic rationales supporting the deployment of geoengineering activities."[15] The United Kingdom's House of Commons Science and Technology Committee also held hearings in 2009 and 2010, culminating in a committee report that recommended public funding of climate engineering research and consideration of potential regulatory architecture for climate engineering research.[16]

The year 2010 ended up being a signal year for the climate engineering discussion in the United States. In March of that year, Margaret Leinen of the Climate Response Fund and Michael MacCracken of the Climate Institute organized and facilitated the Asilomar International Conference on Climate Intervention Technologies, which culminated in the release of a report calling for climate engineering research under a set of prescribed guidelines.[17] Also in 2010, the Bipartisan Policy Center, a nonprofit organization established by several former US Senate majority leaders from both parties, launched the Task Force on Geoengineering, consisting of American scientists, academics, and representatives of various policy communities. The task force's work culminated in the release of a report calling for an international research program on climate engineering options and a dialogue on policy issues.[18]

A final notable occurrence in 2010 was the establishment of the Solar Radiation Management Governance Initiative (SRMGI) by the American-based nongovernmental Environmental Defense Fund, in conjunction with the United Kingdom's Royal Society and the World Academy of Sciences.[19] The purpose of this group has been to meet with and encourage conversation among a wide variety of stakeholders, especially those in the developing world and emerging economies, to ensure more robust and global discussions of SRM research and governance.

Since 2010, the pace of public and policy engagement has, if anything, continued to speed up, with a wider variety of actors showing interest in different aspects of the climate engineering conversation. In 2013, for instance, the American Meteorological Society readopted a policy statement on climate engineering that concluded that "it is prudent to consider geoengineering's potential benefits, to understand its limitations, and to avoid ill-considered deployment," and that climate engineering "could contribute to a comprehensive risk management strategy to slow climate change."[20] Some level of ongoing interest on the part of the US Congress has been signaled by two reports on climate engineering being

commissioned from the Congressional Research Service (CRS) in the span of three years, with the second report released in November 2013. The most recent CRS report provided an overview of then-current climate engineering research and funding by government agencies and the current state of international law in the context of climate engineering.[21]

Still, it should be stressed that activity focused on climate engineering within the US government, or public research funded by government agencies, is still very small in scale. Despite a US Department of Energy white paper recommendation in 2001 for a $64 million geoengineering proposal, there was only, by late 2014, approximately $1 million of government money directly funding climate engineering research in the United States, though substantial amounts of research in other areas (e.g., carbon capture and storage and climate modeling) are pertinent. In testimony before the House Committee on Science and Technology, officials from various interagency bodies coordinating the US response to climate change stated that their offices "(1) have not developed a coordinated research strategy [for geoengineering activities], (2) do not have a position on geoengineering, and (3) do not believe it is necessary to coordinate efforts due to the limited federal investment to date."[22]

In retrospect, a potential inflection point may have been the release in early 2015 of a pair of reports by an ad hoc committee on climate engineering established by the National Research Council of the National Academy of Sciences.[23] In the past, reports issued by this body have proven highly influential in guiding national agendas on major technologies.[24] The committee was tasked with both conducting a technical evaluation of climate engineering options and identifying future research needs. The reports' release followed closely on the heels of a meeting in Washington, D.C., convened by dozens of international scientific societies to develop a set of principles for climate engineering research.[25] While expressing caution about these technologies, particularly solar radiation management approaches, the reports called for a federal research initiative on climate geoengineering options.

There are also modest research programs in Europe. This includes the Implications and risks of engineering solar radiation to limit climate change (IMPLICC) project, a collaboration by five European universities to assess the potential effectiveness and risk of SRM climate engineering approaches with numerical earth system models;[26] the Stratospheric Particle Injection for Climate Engineering (SPICE) project in the United Kingdom, an aborted effort to conduct a field test on SRM approaches;[27] EuTRACE, the European

Transdisciplinary Assessment of Climate Engineering,[28] a consortium of fourteen institutions tasked with assessing the potential for deploying climate engineering technologies and policy options; and the Oxford Geoengineering Programme,[29] which advocates climate engineering research and stakeholder engagement.

The drumbeat for a fully funded research program for climate engineering may grow much louder should the parties to the UNFCCC fail in coming years to formulate a transformative long-term agreement to address greenhouse gas emissions. However, should this transpire, it could impose, as Maria Ivanova observes, "the most serious governance concern … in the next couple of decades."[30] In the next section of this chapter, we outline the potential governance architecture for climate engineering should it come to be a reality on a New Earth.

Governing Climate Engineering: The Prospects within Existing Regimes

Climate engineering is a difficult emerging technology with which to wrestle. The upsides are enormous, but the risks run the gamut from intrusive (sulfate aerosol dispersal changing the color of the sky) to catastrophic (sulfate aerosol dispersal shutting down the South Asian monsoons). Besides its purportedly low cost, many proponents argue that one of climate engineering options' most attractive characteristics is that they could be deployed unilaterally. This is often contrasted with "the unprecedented international cooperation" required to effectuate mitigation of greenhouse gas emissions.[31] Unfortunately, this is also one of the most foreboding aspects of the emergence of geoengineering options, because deployment of SRM and CDR technologies could pose serious threats to the interests of many who could be denied a voice in a unilateral or limited multilateral decision-making process. For example, stratospheric sulfur injection approaches would almost invariably reduce rainfall in several vulnerable regions because evaporation is approximately twice as sensitive to sunlight as temperature. The consequent reductions in evaporation could substantially weaken Asian and African monsoons, potentially imperiling the food and water supplies of billions of people.[32]

Moreover, recent studies also indicate that climate engineering schemes that would enhance aerosol loads in the stratosphere could result in global annual mean decreases of the ozone column of 4.5 percent, more than the annual global mean decreases associated with ozone-depleting substances in the early part of this century. This could delay recovery of the ozone layer in the Antarctic by between thirty and seventy years.[33] This would likely have a disproportionate impact on populations in developing countries where medical care, including early diagnosis of disease, is often lacking.

Carbon dioxide removal schemes could also pose threats in a transboundary context or to the global commons. For example, ocean iron fertilization could potentially wreak havoc with ocean ecosystems by reducing surface nutrient inventories; imperiling productivity of downstream plankton communities;[34] inducing hypoxia (oxygen deprivation), which could imperil marine species;[35] and creating changes in the composition of phytoplankton communities that could adversely affect the populations of larger predators, including copepods, krill, salps, jellyfish, and other fish species.[36] Bioenergy capture and carbon sequestration options could substantially increase food prices for the poor, as they could divert substantial amounts of farmland or crops for biofuel production.[37] Moreover, already marginalized populations, including indigenous peoples, could be displaced in land grabs for feedstock.[38]

A failure to engage in a coordinated program of climate engineering research, should such a research program gather significant steam, could also result in a scenario in which a nation panics in the future and deploys a wholly untested technology, with potentially dire results. As John Virgoe notes, "Ignoring geoengineering today, and only considering it when all else has failed, is a recipe for bad, politics-led decision-making."[39]

Thus, it is critical that international governance mechanisms are put in place to ensure that any research on climate geoengineering that may ensue, as well as potential deployment, be structured in a way that protects the interests of the global community and particular populations and landscapes within it. In using the term *governance* in this context, we adopt the expansive definition of the Bipartisan Policy Center, which encompasses "the actions of government agencies, nation states and international institutions, but … also includes formal and informal efforts by scientific organizations, non-governmental organizations and many other non-state actors and networks carrying out purposive acts of steering."[40]

A critical threshold question is determining the optimal forum, or forums, for situating such governance. We initially examine whether two international treaty regimes that have responded to ocean iron fertilization field research experiments, the Convention on Biological Diversity and the London Convention and its Protocol under the International Maritime Organization, are the appropriate venues for climate engineering governance.

At its annual meeting in 2009, the parties to the Convention on Biological Diversity adopted a resolution calling on the parties to not engage in ocean fertilization activities in the absence of "an adequate scientific basis on which to justify such activities," including risk assessment and transparent and effective control and regulatory mechanisms. An exception was carved out for small-scale scientific research studies in coastal waters, if justified for specific scientific purposes and without commercial purpose.[41] The parties essentially affirmed this position in two subsequent resolutions and expanded its scope to all climate engineering activities that may affect biodiversity. [42]

The CBD, however, would be ill equipped to serve as the primary forum to regulate climate engineering. Its remit is limited to threats to biodiversity, while many of the gravest threats posed by climate engineering are to humans. Moreover, the resolutions passed by the parties are not legally binding,[43] and there has been no movement to adopt a binding amendment, protocol, or annex to the convention to address climate engineering. Finally, one of the nations most likely to engage in climate engineering activities, the United States, is not a party to the treaty, and thus not subject to its mandates.

The other regime that has addressed climate engineering in the past few years is the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (London Convention) of the International Maritime Organization.[44] In 2008, the parties to the convention passed a resolution recognizing the treaty's jurisdiction over ocean fertilization activities and limiting such activities to "legitimate scientific research." The resolution also provided that scientific research proposals should be vetted on a case-by-case basis under an assessment framework to be developed by the Scientific Groups of the London Convention and its protocol.[45] In 2010, the parties adopted the Assessment Framework for Scientific Research.[46] Finally, in 2013, the parties adopted an amendment to the 1996 Protocol to the Convention, authorizing ocean fertilization activities under the convention only if they constitute "legitimate scientific research" taking into account any specific placement assessment framework. It also incorporated the Assessment Framework into an annex, and allowed for the London Protocol to consider, include, and regulate other marine geoengineering activities in the future.[47]

The London Convention, however, despite these actions, would also appear to be a problematic institution for climate engineering governance. First, it has only eighty-seven parties, limiting its legitimacy. This is in contrast to almost universal ratification of treaties such as the Convention on Biological Diversity and the UN Framework Convention on Climate Change. Also, like the CBD, the convention suffers from the fact that its resolutions are not legally binding. Finally, the convention's focus on marine activities means that most contemplated geoengineering options would not fall under its regulatory purview. The marine geoengineering amendment to the London Protocol does legally bind its parties.. However, it has been ratified by only forty-five states to date, severely circumscribing its legitimacy, and again, the focus of the convention circumscribes the climate engineering options that could conceivably fall under its rubric.

International governance suitable to the potential deployment of large-scale climate engineering requires, then, a regime with broad reach and legitimacy. Additionally, any formal governance of climate engineering must be explicitly tied to efforts to reduce greenhouse gas emissions. This is because should a nation, or group of nations, choose to deploy an SRM approach, it would be critical to coordinate a scheduled reduction of emissions of sufficient rapidity to avoid the threat of a "termination" effect. The *termination effect* refers to the potential for a huge multidecadal pulse of warming should the use of an SRM scheme be terminated abruptly in the future due to technological failure or a decision by future policymakers (such as under threat of military retaliation by a nation that believes its interests are threatened). This would be a consequence of the buildup of carbon dioxide that had accrued in the atmosphere in the interim, with its suppressed warming effect, as well as the temporary suppression of climate-carbon feedbacks.[48]

The ramifications of the termination effect could be "catastrophic."[49] As one study recently concluded:

> Should the engineered system later fail for technical or policy reasons, the downside is dramatic. .... The climate suppression has only been temporary, and the now CO_2-loaded atmosphere quickly bites back, leading to severe and rapid climate change with rates up to 20 times the current rate of warming of ≈0.2°C per decade.[50]

As a consequence, models suggest that temperatures could increase 6°C to 10°C in the winter in the Arctic region within thirty years of termination of the use of SRM technology, with northern landmasses seeing increases of 6°C in summer.[51] Moreover, temperatures could jump 7°C in the tropics in thirty years.[52] Projected temperature increases after termination would occur more rapidly than during one of the most extreme and abrupt global warming events in history, the Paleocene-Eocene thermal maximum.[53] It is beyond contention that climatic changes of this magnitude "could trigger unimaginable ecological effects."[54] To put this rate of

temperature increase in perspective, a recent study concluded that even a warming rate of greater than 0.1°C per decade could threaten most major ecosystems and decrease their ability to adapt.[55] Should temperatures increase at a rate of 0.3°C per decade, only 30 percent of all affected ecosystems and only 17 percent of all affected forests would be able to adapt.[56] Moreover, temperature increases of this magnitude and rapidity would imperil many human institutions.[57]

Governing via the Existing Climate Change Regime

Ultimately we believe that the most appropriate venue for international oversight of climate engineering research and potential deployment would be the UNFCCC, the primary international instrument to address climate change. This should include assessment of the viability and impacts of response measures.[58] Moreover, the regime's legitimacy to address this issue globally is also enhanced by universal state ratification, with the exception of the Holy See.

Questions remain, however. One potentially serious barrier to tasking the UNFCCC with this role is its questionable jurisdictional authority over SRM climate engineering approaches. The text of the UNFCCC provides that its ultimate objective is "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system,"[59] primarily to be effectuated by "measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of ... greenhouse gases."[60] John Virgoe contends that climate engineering approaches that don't seek to alter the composition of the atmosphere in terms of greenhouse gases would thus be outside the regulatory scope of the UNFCCC.[61] By its terms, this would preclude UNFCCC jurisdiction over all solar radiation management options because they don't seek to alter atmospheric concentrations of greenhouse gases, but rather the amount of incoming solar radiation.

We believe that this interpretation of the UNFCCC is too crabbed. Article 3(1) provides that the parties are to "protect the climate system for the benefit of present and future systems," with the term *climate system* defined as "the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions."[62] Thus, to the extent that SRM approaches could profoundly affect precipitation patterns or the ozone layer, or more basically, alter heat distribution in the stratosphere, it would appear that the UNFCCC would have jurisdiction to address potential climatic threats posed by such

technologies. Furthermore, Article 4(8) mandates that the parties "give full consideration" to the implementation of response measures to climate change on developing countries, which could clearly encompass climate engineering responses.

The UNFCCC regime does not directly engage in research, so one critical question would be how climate engineering research could be conducted under its rubric. We suggest that the UNFCCC has the legal authority to establish a coordinated transnational research program on climate engineering approaches. Article 4(1)(g) requires UNFCCC parties to "cooperate in scientific, technological, technical, socio-economic and other research ... related to the climate system." Furthermore, Article 5(a) provides for support and development of international and intergovernmental programs to facilitate such research.

The convention also authorizes an assessment process by the parties of any research that would grow out of such an initiative. Article 7 provides for the Conference of Parties to assess the effects of measures taken to address climate change and "to seek and utilize ... the services and cooperation of, and information provided by, competent international organizations and intergovernmental and non-governmental bodies." In conducting such assessments, the parties could also draw on the expertise of its Subsidiary Body for Scientific and Technological Advice,[63] which has established a Forum and Work Program on the Impact of the Implementation of Response Measures,[64] as well as the IPCC.

Every effort should be made to establish an international research program with broad representation of the world's scientific community. Potential forums for this program, in coordination with the UNFCCC, could include the Inter Academy Council of the world's scientific academic academies[65] or the World Climate Research Programme.[66] Such research should also be guided by the following principles:

1. *Transparency and public deliberation.* As Craik and Moore observe, "Transparency enables affected parties to understand their interests and effectively participate in case-by-case decisions."[67] Coordinators of research efforts should develop transparency protocols to maximize public access to pertinent information. These protocols should be based on the risk of any specific experiment as well as the risks that could be posed by deployment of the technology in question. Additionally, given the momentous implications of deploying geoengineering technologies in terms of both potential impacts and governance, every effort should be made to engender extensive public deliberation. This should include the use of deliberative

mechanisms such as citizen juries, deliberative mapping, and deliberative polling.[68]

2. *Impact assessments*. The UNFCCC provides for environmental impact assessment by its parties for measures to mitigate and adapt to climate change,[69] and thus should by extension mandate the same to potential climate engineering responses. Moreover, the International Court of Justice has held that there is an obligation under customary international law to conduct transboundary environmental impact assessments for any activity that may impose a risk of a significant adverse transboundary impact.[70] While mandates of environmental impact assessments usually do not result in halting projects, it often results in modification of projects in ways that may reduce their adverse impacts.[71] A good model for formulating such assessments would be the UN Convention on Environmental Impact Assessment in a Transboundary Context[72] (the Espoo Convention) and its associated Protocol on Strategic Environmental Assessment,[73] which could be applicable in the case of climate engineering deployment programs. Beyond the standard components of impact assessments, we would argue that climate engineering protocols should include a consideration of the implications of these technologies for human rights. The parties to the UNFCCC in their Copenhagen Long-Term Cooperative Action (LCA) negotiating text recognized that "parties should, in all climate change-related actions, fully respect human rights."[74] Some of the potential negative impacts of climate engineering technologies could have serious implications for human rights, including the right to life,[75] the right to health,[76], the right to food,[77] and the rights of indigenous people to enjoyment of land and natural resources.[78] The human rights obligations taken on by the parties in the Copenhagen LCA should be operationalized in climate engineering assessments by including a human rights assessment. This approach may help to ensure that the interests of the vulnerable, which might otherwise be overlooked in a strict cost-benefit analysis, are taken into account in the decision-making process.[79]

3. *Establishment of research thresholds*. Research initiatives should be limited initially to small-scale interventions, defined by strict criteria related to project scale and risk, employing metrics such as project area, duration, and potential system responses, such as potential changes in radiative forcing in the case of SRM approaches. Any escalation of research above such thresholds should require express approval by the parties to the UNFCCC.

4. *Coordination with other regimes*. The UNFCCC should seek to coordinate with other treaty bodies that have an interest in climate engineering

options because of their potential impacts. Beyond the Convention on Biological Diversity and the London Convention, this might include, for example, the Convention on the Conservation of Antarctic Living Resources in the context of ocean iron fertilization or the Vienna Convention for the Protection of the Ozone Layer. Every effort should be made, for example, to draw on the specialized expertise of these regimes in proposed research programs.

We are not so naive as to believe that these first steps toward a robust governance proposal would stop a powerful individual nation from proceeding with deployment of climate engineering technologies. However, efforts to create an international forum to scrutinize such options may, as Daniel Bodansky concludes, "prevent actors from making decisions that might have serious, even catastrophic consequences for others."[80]

Conclusion

The pressure to consider climate engineering is building. These pressures give rise to significant questions in our increasingly technology-saturated world. Indeed, comprehending the nature, meaning, and drivers of technological change must be considered one of the most pressing intellectual and political challenges of the New Earth. While there have been technologies for as long as there have been human societies, the technologies now possible are qualitatively different from any that we have seen before. We live in a time when information and communications technologies encircle the globe, driving forward and further extending the processes of globalization; when nuclear and nanotechnologies represent increasingly dramatic, sweeping incursions into the material world; and when, with biotechnology, the deep-seated human impulse toward technological wizardry has taken on new and remarkable proportions as we begin to tinker with the very makeup of life itself. Never before have technologies offered such power, along with such an excess of stark prospects.

There is talk now that there can be a "good" Anthropocene—that the arrival of the New Earth can usher in a new era of human flourishing. As recent debates between Andrew Revkin and Clive Hamilton demonstrate, this is difficult and contentious territory.[81] Our own view is that if a desire to produce a "good Anthropocene" leads to a kind of techno-infatuation—a belief that magical technologies will solve all of our problems—we are heading down a disastrous path. Global environmental politics scholar Paul Wapner has written of such efforts as part of a deep "will to mastery"

that infuses much of the contemporary effort to comprehend and respond to a changing environmental condition.[82] Should the global community ultimately feel compelled to embrace climate engineering technologies, it should be done with a spirit of humility, acknowledging it not as triumph but rather a manifestation of our failure to control preceding technological excesses that now threaten catastrophic climate change. We must move toward a vision of a New Earth in which we seek to reconcile humankind's potential reach with the ecological limits intrinsic to our fragile planet.

Notes

1. Garreau, *Radical Evolution*.
2. Victor, "On the Regulation of Geoengineering."
3. Environmental Pollution Panel, "Restoring the Quality of Our Environment," 127.
4. United Nations Framework Convention on Climate Change, 31 I.L.M. 849.
5. Kyoto Protocol.
6. Climate Institute, "Moving Below Zero," 8.
7. International Energy Agency, *World Energy Outlook 2014*.
8. IPCC, *Climate Change 2014: Synthesis Report* 8 (2014).
9. IEA, *World Energy Outlook*, 2 (current emissions path "consistent with a long-term global average temperature increase of 3.6°C"); Rogelj et al., "Analysis of the Copenhagen Accord Pledges," 5 (pledges made by the Parties in the Copenhagen Accord at the Fifteenth Conference of the Parties may result in temperature of increase of 2.5°C to 4.2°C by 2100, with temperatures continuing to increase after this point).
10. Solomon et al., "Irreversible Climate Change Due to Carbon Dioxide Emissions."
11. See Simon Nicholson, "Reimagining Climate Engineering."
12. Crutzen, "Albedo Enhancement by Stratospheric Sulfur Injection," 214.
13. Scott, "International Law in the Anthropocene." More than 700 articles have been published on climate geoengineering in the science and social science literature, the vast majority since 2010.
14. Jha, "Obama Climate Adviser Open to Geo-Engineering to Tackle Global Warming."

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16. House of Commons Science and Technology Committee, *The Regulation of Geoengineering*.
17. Asilomar Conference Recommendations, *Conference Report*.
18. Bipartisan Policy Center, *Geoengineering*.
19. Solar Radiation Governance Initiative, http://www.srmgi.org/.
20. American Meteorological Society, "Geoengineering the Climate System."
21. Bracmort and Lattanzio, *Geoengineering: Governance and Technology Policy*.
22. Testimony by Frank Rusco before the House of Representatives Committee on Science and Technology, March 18, 2010 GAO-10-546T, www.gao.gov/assets/130/124271.pdf.
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24. National Academy of Sciences, "Geoengineering Climate."
25. Schiermeier, "Climate Tinkerers Thrash Out a Plan."
26. IMPLICC, "Implications and Risks of Engineering Solar Radiation."
27. http://www.spice.ac.uk.
28. http://www.eutrace.org. EuTRACE released a major report on climate geoengineering options in mid-2015, EuTRACE, "The European Transdisciplinary Assessment of Climate Engineering (EuTRACE) (Stefan Schäfer, et al., eds. 2015), http://www.iass-potsdam.de/sites/default/files/files/rz_150715_eutrace_digital.pdf
29. http://www.geoengineering.ox.ac.uk/.
30. Inman, "Planning for Plan B."
31. Barrett, "The Incredible Economics of Geoengineering," 49–50.
32. Burns, "Geoengineering the Climate."
33. Tilmes, Müller, and Salawitch, "The Sensitivity of Polar Ozone Depletion."
34. Cullen and Boyd, "Predicting and Verifying the Intended and Unintended Consequences of Large-Scale Ocean Iron Fertilization."
35. Rayfuse, Lawrence, and. Gjerde, "Ocean Fertilisation and Climate Change."

36. Abate and Greenlee, "Sowing Seeds Uncertain."

37. CBD Alliance, "Biofuels, Bioenergy, Biochar and the Technologies of the New Bioeconomy"; Azar, Johansson, and Mattsson, "Meeting Global Temperature Targets" (large-scale BECCS program could require one-third of global crop land).

38. Global Forest Coalition, *Stop the Destruction of Forests*.

39. Virgoe, "International Governance of a Possible Geoengineering Intervention to Combat Climate Change," 117.

40. Bipartisan Policy Center, *Task Force on Climate Remediation Research* 32 (2011), http://bipartisanpolicy.org/library/task-force-climate-remediation-research/.

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42. Convention on Biological Diversity, *Tenth Meeting of the Conference of the Parties*; Convention on Biological Diversity, *Eleventh Meeting of the Conference of the Parties*.

43. Proelss, *Legal Opinion on the Legality of the LOHAFEX Marine Research Experiment*.

44. International Maritime Organization, Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter, http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/Convention-on-the-Prevention-of-Marine-Pollution-by-Dumping-of-Wastes-and-Other-Matter.aspx.

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46. International Maritime Organization, London Convention, *Thirty-Second Consultative Meeting*. See also London Convention, *Assessment Framework for Scientific Research Involving Ocean Fertilization* (2010).

47. International Maritime Organization, London Convention, *Eighth Meeting of the Contracting Parties*.

48. Matthews and Caldeira, "Transient Climate-Carbon Simulations of Planetary Geoengineering."

49. Govindasamy et al., "Impact of Geoengineering Schemes on the Terrestrial Biosphere."

50. Brewer, "Evaluating a Technological Fix for Climate."

51. Brovkin et al., "Geoengineering Climate by Stratospheric Sulfur Injections."

52. Kintisch, "Scientists Say Continued Warming."

53. Ibid.

54. Ibid. See also Ross and Matthews, "Climate Engineering and the Risk of Rapid Climate Change" ("It seems likely that two decades of very high rates of warming would be sufficient to severely stress the adaptive capacity of many species and ecosystems, especially if preceded by some period of engineered climate stability").

55. Van Vliet and Leemans, "Rapid Species' Response to Changes in Climate."

56. Leemans and Eickhout, "Another Reason for Concern."

57. Kintisch, "Scientists Say Continued Warming," 1055.

58. UNFCCC, Article 4(1)(g)(h), Article 4(8).

59. Ibid., Article 4(1)(g)(h), Article 4(8) at Article 2.

60. Ibid., Article 4(1)(b).

61. Virgoe, *International Governance*.

62. United Nations Framework Convention on Climate Change, Article 1(3).

63. Ibid., Article 9(2)(a)(b).

64. UNFCCC, Subsidiary Body for Scientific and Technological Advice, FCCC/SB/2014/L.2.

65. InterAcademy Council, http://www.interacademycouncil.net/.

66. World Climate Research Programme, http://www.wcrp-climate.org/.

67. Craik and Moore, *Disclosure Based Governance for Climate Engineering Research*, 2.

68. Rowe and Frewer, "A Typology of Public Engagement Mechanisms."

69. United Nations Framework Convention on Climate Change, 31 I.L.M. 849.

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71. Knox, "The Myth and Reality of Transboundary Environmental Impact Assessment."

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73. Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary Context.

74. UNFCCC, *Negotiating Text*, para. 8.

75. United Nations, Universal Declaration of Human Rights, Article 3; International Covenant on Civil and Political Rights Article 6.

76. United Nations, Universal Declaration of Human Rights, Article 25; International Covenant on Economic, Social and Cultural Rights, Article 12.

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79. McInerney-Lankford, Darrow, and Rajamani, "Human Rights and Climate Change."

80. Bodansky, "The Who, What, and Wherefore of Geoengineering Governance," 541.

81. Revkin, "The Good, the Bad and the Anthropocene."

82. Wapner, *Living Through the End of Nature*.

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Section 8 Narrative Frames for Living on a New Earth

Narrative frames are, as Paul Wapner states elegantly in chapter 15, "broadly shared understandings that provide an account of reality." Human beings are crafters of tales. We make sense of the world by filtering our sensory experiences through complex layers of concepts, metaphors, and storylines. Such filters can at times appear entrenched and intransigent. For instance, for much of human history it was widely understood across a variety of places and societies that it was fit and proper for some human beings to own other human beings. Slavery was never simply some brute economic arrangement derived from some immutable natural law. Powerful narrative frames, instead, made it appear a universal truth—a truth that broached no alternative—until, that is, an alternative became visible in an antislavery counternarrative and in a social and political movement that emerged to make that counternarrative real in the lived experiences of peoples everywhere.

Paul Wapner makes clear that environmentalism is itself a counternarrative. It is a narrative that runs counter to a dominant storyline of endless, unfettered economic growth and ever-advancing human domination and rule over the workings of the world. He shows, using a history of the Western environmentalist counternarrative and an analysis of the modern climate justice movement, that working within a counternarrative is at once perilous and enlivening. "What is it like," he asks, "to live at the margins of public discourse?" Wapner's keen analysis suggests that a life spent on the margins has much to offer not just to the world but also to the individuals who come together to act under the umbrella of the environmental movement.

Peter Dauvergne's complementary chapter that follows zooms in on the hotly contested environmental narrative surrounding sustainability. *Sustainability* is a term that has received much academic treatment. There are countless articles, and there have been and will continue to be an