Remaking the World to Save It: Applying U.S. Environmental Laws to Climate Engineering Projects

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Given the high levels of greenhouse gases already in the atmosphere and the likelihood of growing emissions in the future, even aggressive limits on greenhouse gas emissions might ultimately fail to prevent dangerous climate disruptions. To prepare for this risk, some scientists have started to explore techniques that directly influence or control global and regional climatic systems to offset climate change effects. As climate engineering research expands, U.S. environmental law could become an important forum for efforts to control nascent climate engineering technologies. Federal and state agencies should start now to map out regulatory strategies and guidance for potential requests to authorize climate engineering experiments or to control objectionable projects.

Climate engineering will also offer an unprecedented test of the scope of federal judicial power and the institutional competence of U.S. courts to review environmental projects designed to have a global impact. Prior climate change tort actions have tested the ability of courts to ascribe responsibility or assign liabilities to individual parties for damages caused by widely dispersed global activities. Climate engineering presents the mirror image of climate change public nuisance actions: rather than affixing responsibility for a share of a global phenomenon, lawsuits against climate engineering projects can pursue a clearly identifiable small number of parties who expressly and intentionally attempt to create global climate effects. To properly decide these disputes, federal courts in particular will need to understand how cornerstone U.S. environmental laws and key doctrines, including political question, standing,

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causation, and preemption and displacement, apply to global climate remediation projects.

INTRODUCTION

The long-running struggle over climate change policy may ultimately fall under the shadow of a much larger concern: what if our best strategies and legal measures to control greenhouse gas (GHG) emissions and adapt to climate change, in the end, are simply not enough?

The question is becoming increasingly important. While U.S. regulatory and policy efforts have picked up new momentum, federal legislative efforts in the United States have ebbed after Congress' failure to pass a comprehensive climate change bill.[1] International efforts to limit GHG emissions have not yet

1. The history of prior climate change legislative and regulatory initiatives is complex and fast-moving, and it lies beyond the scope of this article. Significant milestones include President Obama's decision to focus his first Oval Office speech on the need to move away from fossil fuels and to reduce GHG emissions through fostering renewable energy technologies. Barack Obama, President, United States, Remarks by the President to the Nation on the BP Oil Spill (June 15, 2010), *available at* http://www.whitehouse.gov/the-press-office/remarks-president-nation-bp-oil-spill. The U.S. Environmental Protection Agency (EPA) issued its long-pending endangerment finding under the federal Clean Air Act that GHG emissions threaten human health and the environment. National Emission Standards for Hazardous Air Pollutants for Source Categories: Gasoline Distribution Bulk Terminals, Bulk Plants, and Pipeline Facilities; and Gasoline Dispensing Facilities, 74 Fed. Reg. 66,495 (Dec. 15, 2009) (codified at 40 C.F.R. pts. 9 & 63). The EPA's finding, even though it faces numerous petitions for judicial review, has already triggered a cascade of regulations to control industrial GHG emissions. *See,*

achieved significant reductions or even appreciably slowed the rate of increase in emissions.[2] Anthropogenic GHG emissions[3] remain at historically high levels,[4] and the growing use of fossil fuels by developing economies virtually

e.g., N. Richardson, Art Fraas & Dallas Burtraw, *Greenhouse Gas Regulation Under the Clean Air Act: Structure, Effects, and Implications of a Knowable Pathway*, 41 ENVTL. L. REP. (Envtl. Law. Inst.) 10,098, 10,100 (Feb. 2011), *available at* http://www.elr.info/articles/vol41/41.10098.pdf. Several states have also acted to limit GHG emissions in their jurisdictions, and their efforts have helped to form regional compacts to lay the groundwork for future GHG trading and controls. *See infra* note 21 and accompanying text (discussing the Regional Greenhouse Gas Initiative and the Western Climate Initiative).

2. The sixteenth Conference of the Parties to the United Nations Framework Convention for Climate Change in Cancún, Mexico, announced on December 11, 2010, a set of agreements that outlined voluntary commitments to provide financing for green energy development and to reduce GHG emissions. *Cancun Climate Outcome 'Consistent with U.S. Objectives*,*'* ENVTL. NEWS SERV. (Dec. 14, 2010), http://www.ens-newswire.com/ens/dec2010/2010-12-14-02.html. The Cancún agreements do not address any plans or strategy to continue the binding emission limits of the Kyoto Accords, which are set to expire in 2012. *Id.* Similarly, the parties at the fifteenth Conference of the Parties in 2009 in Copenhagen failed to reach any binding agreement that would significantly limit future GHG emissions. *See id*. (noting that attempts during the 2009 Copenhagen Conference were "not fruitful"). A small subgroup (including the United States, China, and India) instead agreed to examine steps to limit the rate of growth of GHG emissions, and the remaining body of delegates desultorily "took notice" of the new Copenhagen Accords. United Nations Framework Convention on Climate Change, Report of the Conference of the Parties on Its Fifteenth Session, Copenhagen, Den., Dec. 7–9, 2009, *Copenhagen Accord*, Decision 2/CP.15, ¶ 6, U.N. Doc. FCCC/CP/2009/11/Add.1 (Mar. 30, 2010), *available at* http://unfccc.int/resource/docs/2009/cop15/eng/11a01; *see also* John M. Broder, *Climate Goal Is Supported by China and India*, N.Y. TIMES, March 9, 2010, at A1, *available at* http://www.nytimes.com/2010/03/10/science/earth/10climate.html. More importantly, some initial assessments of the Cancún Agreement have concluded that it did not include sufficient emission reduction pledges to keep global temperature increases below a target of 2 degrees Celsius or less. CLAUDINE CHEN ET AL., CLIMATE ACTION TRACKER, CANCUN CLIMATE TALKS—KEEPING OPTIONS OPEN TO CLOSE THE GAP 2, Jan. 10, 2011, *available at* http://www.climateactiontracker.org/briefing_paper_cancun.pdf. As this Article was going to press, the seventeenth Conference of the Parties to the UNFCCC was scheduled to begin in Durban, South Africa on November 28, 2011. COP17/CMP7: UNITED NATIONS CLIMATE CHANGE CONFERENCE 2011, DURBAN, SOUTH AFRICA, http://www.cop17-cmp7durban.com/ (last visited on Nov. 27, 2011).

3. Anthropogenic GHG emissions are GHG releases caused by human activities. These activities can include industrial operations, farming activities, transportation emissions, and alterations to natural ecosystem emissions caused by human activities.

4. "The radiative forcing of the climate system is dominated by the long-lived GHGs . . . . Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004." INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: SYNTHESIS REPORT 36 (2007), *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf ("SYNTHESIS REPORT"). The Intergovernmental Panel on Climate Change (IPCC) report further notes that "[g]lobal atmospheric concentrations of CO_2 [carbon dioxide], CH_4 [methane], and N_2O [nitrous oxide] have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The atmospheric concentrations of CO_2 and CH_4 in 2005 exceed by far the natural range over the last 650,000 years."
Id. at 37 (citation to figures omitted). *But cf.* U.S. ENERGY INFO. ADMIN., DOE/EIA-0573(2008), EMISSION OF GREENHOUSE GASES IN THE UNITED STATES 2008, at 1 (2009), *available at* ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057308.pdf (finding total U.S. GHG emissions decreased by 2.2 percent from 2007 to 2008).

guarantees large increases in future emissions.[5] Given the current lack of economically viable alternatives, petroleum will likely remain the primary source of energy for transportation for decades and will further swell GHG emissions.[6] And even if these accelerating GHG sources could be slowed, the atmosphere has already received sufficient anthropogenic GHGs to assure that climate change effects will grow during the next century or even accelerate as self-reinforcing warming processes take root.[7] The risk of self-reinforcing feedback processes has also heightened concerns over abrupt and disruptive climate change.[8]

Against this pessimistic backdrop, some scientists have begun to seriously study direct actions to modify the Earth's climate in ways that would offset anthropogenic global warming. These strategies, discussed further in Part II, include releasing sulfur dioxide aerosols into the upper stratosphere to reflect solar radiation back into space, enhancing the reflectivity of clouds in the polar oceans, constructing and distributing millions of mechanical units to filter

5. In 2009, the International Energy Agency predicted China and India would account for 53 percent of the increase in global demand for energy between 2009 and 2030 and that these two nations will predominantly rely on GHG-emitting technologies to reach that position. INT'L ENERGY AGENCY, WORLD ENERGY OUTLOOK 2009 FACT SHEET 1 (2009), *available at* http://www.iea.org/weo/docs/weo2009/fact_sheets_WEO_2009.pdf. On November 2, 2010, Indian Prime Minister Manmohan Singh said demand for hydrocarbons in his country will increase by 40 percent over the next decade. Walid Mazi, *Indian Energy Firms Advised to Expand Amid Soaring Fuel Demand,* ARABNEWS.COM (Nov. 2, 2010), http://arabnews.com/economy/article177746.ece.

6. The transportation sector is the largest growth segment of total oil demand; by 2030, oil demand in developing countries will exceed oil demand in countries in the Organization of Economically Developed Countries. Jacqueline L. Weaver, *The Traditional Petroleum-Based Economy: An "Eventful" Future*, 36 CUMB. L. REV. 505, 528 (2006) (discussing energy use projections by major energy corporations and U.S. agencies).

7. For example, some scientists have argued that arboreal soils and permafrost may release large amounts of CO_2 as they thaw in a warming climate. E. Schuur et al., *The Effect of Permafrost Thaw on Old Carbon Release and Net Carbon Exchange from Tundra*, 459 NATURE 556 (2009). Such soils contain significantly more carbon than the amount of CO_2 already present in the atmosphere. As a result, those increased CO_2 emissions may in turn magnify climate change effects and enhance ambient temperature increases, which would then accelerate continuing CO_2 emissions from the soils. *See, e.g.*, Eric A. Davidson & Ivan A. Janssens, *Temperature Sensitivity of Soil Carbon Decomposition and Feedbacks to Climate Change*, 440 NATURE 165 (2006).

8. Some climatologists have concluded that geologic records show that Earth's climate can change significantly and abruptly over a time span as short as ten years. Under this model, Earth's climatic system can shift quickly and unpredictably from one stable state into another without gradual or cumulative changes. For example, if increased levels of fresh water in the North Atlantic lead to a disruption or cessation of the Gulf Stream component of the ocean currents that convey warmer waters toward northern Europe and Africa, those regions could see dramatic drops in temperatures and changes in precipitation over a short time span. R. Gagosian, President, Woods Hole Oceanic Inst., Presentation to Davos Summit: Abrupt Climate Change: Should We Be Worried? (Feb. 10, 2003), *available at* http://www.whoi.edu/page.do?cid=9986&pid=12455&tid=282; Wallace S. Broecker, *Thermohaline Circulation, the Achilles' Heel of Our Climate System: Will Man-Made CO_2 Upset the Current Balance?*, 278 SCIENCE 1582, 1584 (1997). The U.S. National Academy of Sciences noted in 2002 that "available evidence suggests that abrupt climate changes are not only possible but likely in the future, potentially with large impacts on ecosystems and societies." U.S. NAT'L ACAD. OF SCIS., ABRUPT CLIMATE CHANGE: INEVITABLE SURPRISES, at v (2002).

ambient air and remove carbon dioxide (CO_2), using reflective satellites to control solar radiation reaching the earth's surface, and seeding oceans with iron to enhance phytoplankton growth and draw large quantities of CO_2 out of the atmosphere.[9] These ideas, collectively labeled "climate engineering" or "geoengineering,"[10] are polarizing and controversial, but their rapid emergence as "Plan B" for climate change strategies will ultimately put federal and state environmental laws squarely in the middle of contentious fundamental disputes over the future direction of U.S. and global climate change policy.

If climate engineering someday becomes a component of U.S. and global climate change policy, U.S. environmental laws will almost certainly be used to attack demonstrations of climate engineering technologies conducted by U.S. corporations and citizens, or those demonstrations in territories or airspace under U.S. jurisdiction. Environmental advocates have frequently turned to U.S. environmental laws to slow or stop the implementation of arguably risky or unexamined technologies. For example, critics of novel technologies used U.S. environmental laws to challenge the deployment of genetically modified organisms into the environment, the distribution of nanomaterials into the workplace and commerce, and the siting of certain renewable energy technologies.[11] Ironically, if climate engineering proves an essential

9. *See* discussion *infra* Part II.

10. In keeping with the developing trend, this article uses the term "climate engineering" instead of "geoengineering." The term "geoengineering" can also apply to large-scale earth moving operations, and some groups have begun to use "climate engineering" as a clearer term. COMM. ON SCI. & TECH., 111TH CONG., ENGINEERING THE CLIMATE: RESEARCH AND STRATEGIES FOR INTERNATIONAL COORDINATION 13 (Comm. Print 2010); J. SHEPHERD, THE ROYAL SOCIETY, GEOENGINEERING THE CLIMATE: SCIENCE, GOVERNANCE AND UNCERTAINTY 30 (2009), *available at* http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/publications/2009/8693.pdf [hereinafter ROYAL SOCIETY STUDY].

11. For example, the Foundation on Economic Trends turned to the National Environmental Policy Act to obtain an injunction halting the deployment of genetically modified tomatoes outside the laboratory setting. Found. for Econ. Trends v. Heckler, 587 F. Supp. 753 (D.D.C. 1984), *aff'd in part*, 756 F.2d 143 (D.C. Cir. 1985). Current environmental groups continue to use environmental statutes to challenge expanded use of genetically modified organisms. *See, e.g.*, Complaint, Ctr. for Food Safety v. Vilsack, No. CV11-1310 (filed Mar. 18, 2011), *available at* http://www.centerforfoodsafety.org/wp-content/uploads/2011/03/1-Complaint.pdf (challenging deregulation of Roundup Ready Alfafa genetically engineered to tolerate glycophosphate-based pesticides). Environmental groups have also repeatedly urged EPA to regulate nanoscale materials more aggressively under the Toxic Substances Control Act. *See, e.g.*, Natural Res. Def. Council, Comments on EPA Proposed Voluntary Pilot Program for Nanomaterials, Docket ID: OPPT-2004-0122, (July 20, 2005), *available at* http://www.nanoaction.org/doc/OPPT-2004-0122-0037.pdf (urging EPA to regulate nanoscale materials as new chemicals under TSCA). Environmental groups and wastewater system operators recently petitioned EPA to promulgate rules to control the potential release of nanoscale silver to wastewater treatment systems and the environment. *See, e.g.*, Letter from Michele Pla, Exec. Dir., Bay Area Clean Water Agencies to Nathanael R. Martin, Office of Pesticide Programs, U.S. EPA, (Mar. 19, 2009), http://bacwa.org/Portals/0/Committees/BAPPG/Archive/BACWA%20Comments%20on%20Petition%20for%20rulemaking%20to%20regulate%20nonsilver%20as%20pesticide%203-09.pdf. Last, environmental groups have also seized upon environmental statutes to oppose renewable energy projects. For example, opponents of the Cape Wind project to place turbines offshore of Massachusetts filed complaints alleging that the wind turbines would kill endangered and threatened species protected under the Endangered Species Act. *See, e.g.*, Complaint, Pub. Emps. for Envtl. Responsibility v. Bromwich,

component of federal climate change policy to control or minimize climatic disruptions, environmental law may play an instrumental role in limiting options available to address one of the most daunting environmental challenges of our time.

If existing U.S. environmental laws become the initial battleground for disputes over climate engineering research and test projects, those fights may yield surprises for litigants on both sides. U.S. environmental laws could extend an unexpectedly long and broad reach over novel climate engineering technologies. The federal courts have allowed administrative agencies, including the EPA, a considerable degree of flexibility and freedom to interpret current statutes to cover emerging environmental threats and concerns.[12] Beyond this statutory malleability, the federal judiciary may provide a more hospitable forum for climate engineering litigation than it has offered to climate change tort claims under federal common law. Climate engineering litigation can sidestep some of the jurisprudential traps that have waylaid other climate change courtroom initiatives by presenting a reversed image of earlier climate change public nuisance lawsuits: rather than attempting to hold innumerable defendants liable for greenhouse gases emitted throughout the globe over extended periods of time, climate engineering lawsuits would target a small number of defendants for projects expressly designed to yield measurable contemporaneous changes to climate.

As a result, climate engineering litigation may provide an unexpected opportunity for U.S. courts to clarify threshold issues on the judicial branch's ability to hear lawsuits over global climate change. While federal climate change nuisance lawsuits have garnered the most immediate attention, legal battles over climate engineering projects may ultimately offer a faster, clearer, and more compelling avenue for the U.S. courts to define their role in the developing law of climate change control and liability.

This Article examines how U.S. environmental laws might apply to climate engineering research and how the U.S. courts would review disputes over those projects. Part I surveys the development and background of climate change policy and explains how climate engineering fits into that structure. Part II outlines specific technologies and techniques used in climate engineering. The attributes of climate engineering itself will define the likely parties involved in future legal actions as well as the likely initial strategies and approaches to these legal issues. Part III examines how challenges to climate engineering might avoid, or fall prey to, roadblocks that have impeded efforts to bring environmental lawsuits under federal environmental statutes and tort law targeting governmental or private entities for their contributions to global

No. 1:10-cv-01067-RMU (D.D.C. filed June 25, 2010), *available at* http://www.marinelog.com/PDF/capewindcomplaint.pdf.

12. Chevron U.S.A., Inc. v. Natural Res. Def. Council, 467 U.S. 837 (1984) (using a deferential standard to review an agency determination within the area of expertise provided to that agency by the statute, where underlying federal statute did not convey congressional intent in unambiguous language).

climate change effects. Some of these litigation pitfalls include doctrines on standing, justiciability, proof of causation, and limitations on remedies that a court can impose. This Article concludes by pointing out how this new type of environmental litigation may provide an opportunity for U.S. courts to address climate change issues in a context better suited to their institutional role and limits and offers suggestions on how the federal government might best respond to these challenges.

I. CURRENT CLIMATE CHANGE LEGAL STRATEGIES: CONTROLLING EMISSIONS AND MITIGATING DAMAGES

Existing international and U.S. regulatory strategies to mitigate climate change—with some important exceptions—focus largely on either mitigation[13] or adaptation.[14] These approaches generally seek to limit future climate disruption by either reducing current or future emissions of GHGs through regulatory controls, incentives, and sequestration activities, or by helping societies or ecosystems to adapt to an environment with higher temperatures.[15] From the U.N. Framework Convention on Climate Change[16] to the Kyoto Protocol[17] to the Cancun Agreement,[18] almost every international agreement has incorporated these two approaches. While the UNFCC and its implementing instruments also offer other compliance options that would arguably reduce ambient GHG levels through afforestation or agricultural activities, these alternatives generally concentrate on generating credits or allowances that can offset GHG emissions from other activities.[19] Individual

13. Mitigation strategies focus on reducing or modifying activities that lead to anthropogenic GHG emissions primarily by reducing current and future emissions per unit output. SYNTHESIS REPORT, *supra* note 4, at 84.

14. Adaptation strategies focus on modifying human societies and ecosystems to exist under higher temperature climates without attempting to minimize those temperature changes. *Id*. at 76 . For a survey of potential strategies that large urban centers may use to deal with higher temperatures, see MATTHEW E. KAHN, CLIMATOPOLIS: HOW OUR CITIES WILL THRIVE IN THE HOTTER FUTURE (2010).

15. SYNTHESIS REPORT, *supra* note 4, at 76, 84.

16. United Nations Conference on Environment and Development, Rio de Janeiro, Braz., June 3–14, 1992, *United Nations Framework Convention on Climate Change*, U.N. Doc. FCCC/INFORMAL/84 (1992) [hereinafter UNFCCC], *available at* http://unfccc.int/resource/docs/convkp/conveng.pdf. After 166 countries ratified the UNFCCC, it entered into force on March 21, 1994. *Status of Ratification of the Convention*, UNITED NATIONS, http://unfccc.int/essential_background/convention/status_of_ratification/items/2631.php (last visited Nov. 29, 2010). Currently, 194 countries have ratified the UNFCCC. *Id.*

17. Kyoto Protocol to the United Nations Framework Convention on Climate Change, Dec. 11, 1997, 2303 U.N.T.S. 148.

18. United Nations Framework Convention on Climate Change, Report of the Conference of the Parties on its Sixteenth Session, Cancún, Mex., Nov. 29–Dec. 10, 2010, *The Cancun Agreements: Outcome of the Work of the Ad Hoc Working Group on Long-Term Cooperative Action Under the Convention*, Decision 1/CP.16, U.N. Doc. FCCC/CP/2010/7/Add.1 (Mar. 15, 2011), *available at* http://unfccc.int/resource/docs/2010/cop16/eng/07a01.pdf#page=2 [hereinafter The Cancun Agreements].

19. The mechanisms under the Kyoto Protocol are emissions trading, the Clean Development Mechanism (CDM), and Joint Implementation (JI). Article 17 of the Kyoto Protocol governs emissions

efforts by other nations primarily adopt mitigation and adaptation techniques as well.[20]

U.S. legislative initiatives and state programs have likewise focused primarily on mitigation and adaptation. For example, both the Regional Greenhouse Gas Initiative (RGGI) and California's Assembly Bill 32 statutory program establish cap-and-trade programs that seek to limit future emissions of carbon dioxide and other greenhouse gases and thereby reduce the growing amount of greenhouse gases in the atmosphere.[21] While this generalization admittedly excludes some projects that actively remove greenhouse gases from the atmosphere (for example, carbon sequestration through afforestation), the majority of climate change strategies focus on either reducing the flow of gases into the atmosphere, promoting or protecting natural processes that absorb GHGs, or planning to adapt to an altered global climate.

A growing group of researchers now believe, however, that efforts to curb current and future GHG emissions may not be sufficient to keep the amount of GHGs in the atmosphere below the critical threshold.[22] These researchers base their concerns on the physical properties of some GHGs and the sheer volume of GHGs already in the atmosphere. One estimate of the longevity of atmospheric CO_2 perturbations concluded that the atmosphere would still retain 40 percent of its peak CO_2 concentration enhancement over pre-industrial values as a quasi-equilibrium state even after 1,000 years.[23] The decay rate of

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trading. Article 12 defines CDM, which allows an Annex B party under the Protocol to implement an emission-reducing program in a developing country and thereby earn certified emission reduction credits equal to one ton of carbon dioxide. The JI falls under Article 6 and allows an Annex B party to earn emission reduction units from emission-reducing or emission removal projects in other Annex B countries. For more information, see *The Mechanisms Under the Kyoto Protocol: Emissions Trading, the Clean Development Mechanism, and Joint Implementation*, UNITED NATIONS, at http://unfccc.int/kyoto_protocol/mechanisms/items/1673.php (last visited 11/8/11).

20. Brazil, for example, has used a mixture of energy efficiency, renewable electricity, cogeneration, and bio-fuels to reduce the country's annual emissions by 10 percent. WILLIAM CHANDLER ET AL., PEW CENTER ON GLOBAL CLIMATE CHANGE, CLIMATE CHANGE MITIGATION IN DEVELOPING COUNTRIES: BRAZIL, CHINA, INDIA, MEXICO, SOUTH AFRICA, AND TURKEY, at iii (2002). The study also notes that deforestation in Brazil is a major contributor to climate change, and the government has done very little to abate that problem. *Id.* at 5.

21. For a comprehensive description of regional initiatives against climate change and a fifty-state survey of state climate change laws, regulations and policies, see GLOBAL CLIMATE CHANGE AND U.S. LAW 315–419 (M. Gerrard ed., 2007).

22. For example, Dr. James Hansen, a well-known and influential scientist advocating aggressive action to constrain GHG emissions, has argued that "[t]he dangerous level of carbon dioxide, at which we will set in motion unstoppable changes, is at most 450 parts per million, but it may be less. . . . We must make significant changes within a decade to avoid setting in motion unstoppable climatic change." James Hansen, *Tipping Point: Perspective of a Climatologist*, *in* STATE OF THE WILD 2008–2009: A GLOBAL PORTRAIT OF WILDLIFE, WILDLANDS, AND OCEANS 6–15 (E. Fearn ed., 2008); *see also* James Hansen & Makiko Sato, *Paleoclimate Implications for Human-Made Climate Change* (forthcoming Jan. 20, 2011), *available at* www.columbia.edu/~jeh1/mailings/2011/20110118_MilankovicPaper.pdf (arguing similar tipping point effects in sea level rise from GHG levels under business-as-usual scenarios).

23. S. Solomon et al., *Irreversible Climate Change Due to Carbon Dioxide Emissions*, 106 PROC. OF THE NAT'L ACAD. OF SCIS. 1704, 1705 (2008), *available at* http://www.pnas.org/content/early/

the remaining CO_2 would fall to even slower rates for years after the 1,000-year mark.[24] While pre-industrial concentrations of carbon dioxide in the atmosphere were approximately 280 parts per million (ppm), the existing atmospheric loads of CO_2 have already reached 388.92 ppm.[25] This CO_2 burden will not cycle out of the atmosphere for several hundred years even if all industrial activities halted immediately.[26] In effect, significant climate changes due to elevated ambient GHG levels may have already happened. We are simply waiting for the full ramifications of changes that will result from prior activities. The risk of self-reinforcing processes that release GHGs and the prospect of abrupt climate change have only heightened these concerns.

Given these daunting challenges, some engineers and scientists began to call for strategies to directly alter climate change processes. The idea of this type of climate engineering is not new. The advent of advanced weather radar systems after World War II raised hopes that the practice of planet-wide climate modification was within reach.[27] In a well-publicized and controversial early climate engineering effort known as "Project Cirrus," General Electric (GE) attempted to modify the strength and path of an Atlantic hurricane. [28] Although the storm originally was drifting away from land into the eastern Atlantic, the storm reversed course after GE's seeding effort and eventually struck the Georgia coast where it inflicted serious damage.[29] GE subsequently abandoned its hurricane program,[30] but discussions of weather engineering

2009/01/28/0812721106.full.pdf+html; H. Damon Matthews & Ken Caldeira, *Stabilizing Climate Requires Near-Zero Emissions*, GEOPHYSICAL RES. LETTERS Vol. 35 L04705, Feb. 27, 2008. By some estimates, 25% of CO2 emitted currently will remain in the atmosphere after 5,000 years. A. Montenegro et al., *Long Term Fate of Anthropogenic Carbon*, GEOPHYSICAL RES. LETTERS, Oct. 2007, at 1.

24. S. Solomon, *supra* note 23*,* at 1705.

25. The monthly mean CO_2 levels for October 2011 reached 388.92 ppm at the National Oceanic and Atmospheric Administration's monitoring post at Mauna Loa, Hawai'i. Nat'l Oceanic & Atmospheric Admin., *Mauna Loa CO_2 Monthly Mean Data* (Nov. 16, 2011, 2:45 PM), ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_mm_mlo.txt.

26. S. Solomon, *supra* note 23*,* at 1705. While emissions of other GHGs such as methane NH_4 or N_2O oxides can affect climate change over a time period of decades or centuries, they do not persist in the atmosphere on the same timescales as CO_2. *Id.; see also* Piers Forster et al., *Changes in Atmospheric Constituents and in Radiative Forcing*, *in* CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS 747–845 (S. Solomon et al. eds., 2007).

27. For an illuminating review of the colorful prior attempts to modify the weather, see JAMES R. FLEMING, FIXING THE SKY: THE CHECKERED HISTORY OF WEATHER AND CLIMATE CONTROL (2010).

28. GEN. ELEC., REPORT NO. RL-758, JULY 1952 GENERAL ELECTRIC RESEARCH LABORATORY, HISTORY OF PROJECT CIRRUS 61–64 (Barrington S. Havens ed., 1952), *available at* http://ia700402.us.archive.org/14/items/historyofproject00have/historyofproject00have.pdf.

29. J. FLEMING, *supra* note 27, at 152–53. Of course, the storm's change in direction after seeding did not directly or conclusively establish that GE's efforts actually steered the hurricane.

30. *Id.* at 153. GE's decision to withdraw from hurricane modification and weather manipulation research after Project Cirrus may reflect in part its earlier concerns over potential lawsuits over damage from weather events that the technologies allegedly affected. *Id.* at 148-149; C. PARKINSON, COMING CLIMATE CRISIS? CONSIDER THE PAST, BEWARE THE BIG FIX 206 (2010) ("No one knows whether this shift [of the hurricane's direction] was or was not influenced by the cloud seeding, but in any event the changed direction resulted in the hurricane's slamming into the coast of the state of Georgia, with the

continued to circulate through the climate community. These efforts included renewed but unsuccessful attempts to modify hurricanes in "Project Stormfury" from 1962 through 1983.[31]

Climate engineering and other adaptation strategies have historically drawn opposition out of concerns that they would simply distract popular attention and political will from needed GHG emission control strategies.[32] That resistance shifted significantly in 2006. After long reluctance to seriously scrutinize climate engineering strategies, several climate scientists stepped forward to urge new efforts to study these alternatives as a fallback strategy to control climate change if current greenhouse gas emission control strategies failed. In particular, Paul Crutzen, a Nobel Prize laureate in atmospheric science studies, published a keynote paper that assessed the feasibility of releasing aerosol particles into the upper atmosphere to reduce the amount of sunlight reaching the earth's surface.[33] Crutzen concluded that this strategy could yield substantial temperature reductions on a global scale, but he also pointed out that there are large areas of uncertainty and undesirable effects that this strategy might cause. For example, he noted that these techniques would not reduce damages due to increased rain acidification or answer the unchecked acidification of ocean waters.[34]

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quite undesired further effect of a flurry of lawsuits against General Electric."). Weather modification (predominantly rain making) has a long legal history where courts or legislatures have attempted to allocate liabilities for damages allegedly caused by cloud seeding or other technologies. These laws are surveyed in the work of the late Professor Ray Jay Davis, who was a recognized expert in weather modification law. R. Davis, *Real Property Issues in Weather Control, in* 8-71 THOMPSON ON REAL PROPERTY § 71.06 (David A. Thomas, ed. 2004).

31. J. FLEMING, *supra* note 27, at 177–79; *see also* Nat'l Atmospheric & Oceanic Admin., *Hurricane Research Division*, http://www.aoml.noaa.gov/hrd/hrd_sub/sfury.html (last visited Nov. 30, 2011). Despite doubts that the Cirrus Project showed that cloud seeding or other weather modification techniques could affect the course of a hurricane or other large storm system, the U.S. government undertook even more ambitious attempts to modify hurricane formation and direction in 1962 through 1983 under Project Stormfury. This effort led to seedings of several hurricanes with silver iodide or dry ice from 1963 through 1971. Ultimately, the project failed to yield unequivocal data to demonstrate that the hurricanes' behavior reflected human intervention rather than normal climatic processes. *See* FLEMING, *supra* note 27, at 177–79 ("Frustration mounted as Stormfury scientists began to realize that their hurricane-seeding hypotheses were flawed. First of all, hurricanes contain very little of the supercooled water that is necessary for effective silver iodide seeding. Also, the effects of seeding were so small that they were impossible to measure. Morale plummeted when Stormfury scientists learned that the navy intended to weaponize their research.").

32. *See, e.g.*, JEFF GOODELL, HOW TO COOL THE PLANET: CLIMATE ENGINEERING AND THE AUDACIOUS QUEST TO FIX THE EARTH'S CLIMATE 13 (2010) ("Although the dream of manipulating the weather is almost as old as civilization itself, the idea of studying ways of deploying technology to manage the earth's climate was seen by some scientists as politically incorrect, dangerous, or just downright silly.").

33. Paul J. Crutzen, *Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?*, 77 CLIMATIC CHANGE 211 (2006).

34. *Id.* at 217; *see generally A Rational Discussion of Climate Change: The Science, the Evidence, the Response: Hearing Before the Subcomm. on Energy and Env't of the H. Comm. on Sci. and Tech.*, 111th Cong. (2010) (testimony of Richard A. Feely, Ph.D., Office of Oceanic and Atmospheric Research) (overview of general effects of ocean acidification due to elevated atmospheric levels of carbon dioxide).

Crutzen also spearheaded a symposium at Harvard University in 2008 to discuss potential climate engineering strategies.[35] After the Harvard symposium, the discussion of climate engineering proposals steadily grew in scientific journals and spilled over into more mainstream sources and policy considerations.[36] The British Royal Society released a comprehensive study of climate engineering options that highlighted major likely technologies and concluded that "further research and development of climate engineering options should be undertaken to investigate whether low risk methods can be made available if it becomes necessary to reduce the rate of warming this century."[37] The same sentiment is also seen in the IPCC's meeting in June 2011 to consider the scientific basis for climate engineering as well as its costs and impacts.[38] Additionally, Congress has held hearings to assess the implications of what committee members called "large-scale climate intervention."[39]

The burst of interest in climate engineering has already sparked efforts to limit research and demonstration projects. Most of the early attention has focused on ocean fertilization because at least thirteen experiments have already occurred on the high seas.[40] One particular proposal by Planktos, Inc., a commercial venture group seeking to generate tradable carbon credits, created controversy because it planned to release one hundred tons of iron ore dust into the Pacific Ocean near the Galapagos Islands in August 2007.[41] The

35. *See generally* Eli Kintisch, *Tinkering with the Climate to Get Hearing at Harvard Meeting*, 318 SCIENCE 551 (Oct. 26, 2007) (discussing Crutzen's upcoming workshop at Harvard).

36. ELI KINTISCH, HACK THE PLANET: SCIENCE'S BEST HOPE—OR WORST NIGHTMARE—FOR AVERTING CLIMATE CATASTROPHE 13–14 (2010) ("Since the Harvard meeting, almost every forum relevant to the climate crisis has reached out to embrace, if tentatively, the former pariah called geoengineering.").

37. ROYAL SOCIETY STUDY, *supra* note 10, at 57.

38. *See also* Alyson Kenward, *Scientists Consider Whether to Cause Global Cooling*, CLIMATE CENTRAL (Oct. 19, 2010), http://www.climatecentral.org/news/newsscientists-consider-whether-to-cause-global-cooling/; Jeff Tollefson, *Geoengineering Faces Ban*, NATURENEWS (Nov. 2, 2010), http://www.nature.com/news/2010/101102/full/468013a.html.

39. The House Science & Technology Committee held hearings in 2009 to explore the technological background, risks, benefits and governance issues surrounding potential climate engineering schemes. *Geoengineering: Assessing the Implications of Large-Scale Climate Intervention: Hearing Before the H. Comm. on Sci. and Tech.*, 111th Cong. (2009); *see also* Press Release, H. Comm. on Sci. and Tech., Climate Engineering Research Needed, Members Hear (Nov. 5, 2009), http://archives.democrats.science.house.gov/press/PRArticle.aspx?NewsID=2676.

40. United Nations Educational, Scientific and Cultural Organization, OCEAN FERTILIZATION: A SCIENTIFIC SUMMARY FOR POLICY MAKERS 3 (2011) [hereinafter OCEAN FERTILIZATION].

41. R. Abate & A. Greenlee, *Sowing Seeds Uncertain: Ocean Iron Fertilization, Climate Change, and the International Environmental Law Framework*, 27 Pace Env. L. Rev. 555, 558 (2010), *available at* http://digitalcommons.pace.edu/pelr/vol27/iss2/5; Int'l Maritime Org., Scientific Group of the London Convention & Scientific Group of the London Protocol, June 18–22, 2007, LC/SG 30/INF.28 (June 1, 2007) ("It is the understanding of the United States Government that the United States-based for-profit company Planktos, Inc., plans to dissolve up to 100 tons of iron dust in a 100 km by 100 km area approximately 350 miles west of the Galapagos Islands in June 2007 in order to stimulate phytoplankton blooms. Because this iron release project will not be done by vessels flagged in the United States or by vessels leaving from the United States, the United States Government does not have jurisdiction to regulate this project under its law implementing the London Convention.").

experiment aimed to investigate marine phytoplankton blooms as a potential tool to sequester CO_2 in deep waters.[42] After strong environmentalist opposition—including a permanent patrol vessel by Greenpeace to intercept and halt any attempt by Planktos to release the iron—Planktos abandoned the project in February 2008.[43]

In response to the controversy, the EPA notified Planktos that the iron seeding might require a permit under the Marine Protection, Research and Sanctuaries Act (MPRSA).[44] EPA also submitted a statement of concern on behalf of the United States to the parties to the London Convention.[45] An International Marine Organization committee then adopted a resolution that included a "scientific statement of concern" and called for a halt to ocean fertilization projects unless they constituted legitimate scientific research.[46] The Convention subsequently adopted another resolution containing an assessment framework for scientific research into ocean fertilization.[47] These resolutions effectively declared that the Convention parties prohibited ocean fertilization projects conducted for commercial or non-scientific purposes; even scientific research could proceed only on a case-by-case basis. The Convention intends to promulgate regulations governing ocean fertilization research by 2012.[48]

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42. *Id.* at 558; Raphael Sagarin et al., *Iron Fertilization in the Ocean for Climate Mitigation: Legal, Economic and Environmental Challenges* 7–8 (Duke Univ. Inst. for Envtl. Policy Solutions, Working Paper 07-07, 2007), *available at* http://nicholasinstitute.duke.edu/oceans/marinees/iron-fertilization-in-the-ocean-for-climate-mitigation-legal-economic-and-environmental-challenges/at_download/paper.

43. *Planktos Kills Iron Fertilization Project Due to Environmental Opposition*, MONGABAY.COM (Feb. 19, 2008), http://news.mongabay.com/2008/0219-planktos.html; *see also Planktos Is a No-Show in the Galapagos,* SEA SHEPHERD (Aug. 10, 2007), http://www.seashepherd.org/news-and-media/news-070810-1.html.

44. EPA notified Planktos that MPRSA might apply to the experiment if it took place in waters under U.S. jurisdiction or if Planktos undertook the project from a United-States-flagged vessel. Planktos responded that it would not use a United-States-flagged vessel for the experiment. See discussion *infra* notes 135–140 of potential MPRSA requirements for climate engineering projects.

45. The London Convention, an international organization consisting of eighty-six member states, is charged with implementation of the London Convention of 1972. This Convention controls the discharge of pollutants into the high seas. In 1996, the London Protocol was agreed to further modernize the Convention and, eventually, replace it. The Protocol prohibits all dumping except for potentially acceptable wastes on the so-called "reverse list." It entered into force on March 24, 2006, and thirty-eight states have joined the Protocol. The United States has joined the London Convention, but it has not subscribed to the London Protocol. INTERNATIONAL MARITIME ORGANIZATION [IMO], THE LONDON CONVENTION AND PROTOCOL: THEIR ROLE AND CONTRIBUTION TO PROTECTION OF THE MARINE ENVIRONMENT (2008) *available at* http://www.imo.org/KnowledgeCentre/ShipsAndShippingFactsAndFigures/TheRoleandImportanceofInternationalShipping/IMO_Brochures/Documents/6%20page%20flyer%20London%20Convention.pdf.

46. IMO, *Resolution on the Regulation of Ocean Fertilization*, Res. LC-LP.1 (Oct. 31, 2008).

47. IMO, *Assessment Framework for Scientific Research Involving Ocean Fertilization*, Resolution LC-LP.2 (2010).

48. IMO, Information on Work on Carbon Capture and Storage in Sub-Seabed Geological Formation and Ocean Fertilization Under the London Convention and London Protocol 2, 16th Conf. of the UNFCCC (Nov. 2010), *available at* http://www.imo.org/OurWork/Environment/

Other governmental entities have also taken action. In 2009, the German federal government ordered a team of researchers from the Alfred Wegener Institute for Polar and Marine Research to halt a test of iron seeding in the Southern Ocean in response to complaints that the iron releases constituted prohibited marine pollution.[49] Although the German government quickly withdrew its order,[50] legal opposition to climate engineering projects escalated. Most notably, the latest Conference of Parties to the Convention on Biological Diversity adopted a resolution that called for a limited moratorium on climate engineering activities "until there is an adequate scientific basis on which to justify such activities."[51] Despite division of opinions on geoengineering research among environmental groups,[52] some entities have actively advocated a moratorium on further climate engineering research at both international conferences[53] and in independent policy statements.[54]

PollutionPrevention/AirPollution/Documents/COP%2016%20Submissions/IMO%20note%20on%20LC-LP%20matters.pdf.

49. *Who Ate All the Algae? Using Phytoplankton to Capture Carbon Dioxide Hits a Snag,* THE ECONOMIST (March 26, 2009), *available at* http://www.economist.com/node/13361464.

50. *Id.*

51. Conference of the Parties to the Convention on Biological Diversity, *Biodiversity and Climate Change: Draft Decision Submitted by the Chair of Working Group I* (Oct. 29, 2010). The original draft text included language that might have supported a blanket ban on climate engineering research projects, but the final text limited the prohibition to climate engineering projects that might affect biodiversity and that lacked transparent and effective governance mechanisms. The final language also included important exceptions for small-scale scientific research as well as a working definition of "geoengineering." *Compare* Convention on Biological Diversity, *Conference of Parties 10 Decision X/33 on Biodiversity and Climate Change* (Oct. 29, 2010) (final text), *available at* http://www.cbd.int/decision/cop/?id=12299, *with* Biodiversity and Climate Change, Draft Decision Submitted by Chair of Working Group I, UNEP/CBD/COP/10/L.36 at 8(w), (Oct. 29, 2010), *available at* http://www.cbd.int/doc/meetings/cop/cop-10/in-session/cop-10-L-36-en.doc.

52. Interestingly, some environmental groups have signaled their willingness to consider carefully controlled research into potential geoengineering strategies. These groups usually emphasize the need for a strong governance structure before significant additional climate engineering research can take place. *See, e.g.*, FRIENDS OF THE EARTH, BRIEFING NOTE: GEOENGINEERING 4–5 (Nov. 2009), *available at* http://www.foe.co.uk/resource/briefing_notes/geoengineering.pdf (while condemning the failure of rich nations to reduce GHG emissions and opposing geoengineering proposals to reduce solar radiation reaching the Earth's surface, Friends of the Earth concludes that "[i]t is now clear that mitigation alone cannot keep global temperatures below a safer threshold of 1–1.5 degrees above preindustrial levels" and that "[l]arge amounts of chemical air capture of carbon and storage—funded and carried out by rich countries—will probably be necessary, as long as safe storage sites can be identified and governance issues addressed"); THE ROYAL SOCIETY ET AL., THE SOLAR RADIATION MANAGEMENT GOVERNANCE INITIATIVE (SRMGI): ADVANCING THE INTERNATIONAL GOVERNANCE OF GEOENGINEERING 1–3 (Oct. 2010), *available at* http://www.srmgi.org/files/2010/10/SRMGI-project-description.pdf (arguing, with Environmental Defense Fund and the Academy of Sciences for the Developing World, for focus on governance of solar radiation management approaches to geoengineering); STEPHEN BRICK, NAT'L RES. DEF. COUNCIL, BIOCHAR: ASSESSING THE PROMISE AND RISKS TO GUIDE U.S. POLICY iv-v, 1, 11–12 (Nov. 2010), *available at* www.nrdc.org/energy/files/biochar_paper.pdf (recommending additional research on biochar and noting its possible use as a "climate mitigation tool" to sequester large amounts of carbon dioxide out of the atmosphere).

53. News Release, Action Grp. on Erosion, Tech. and Concentration, Hands Off Mother Earth! Civil Society Groups Announce New Global Campaign Against Geoengineering Tests, (Apr. 21, 2010). Over sixty civil society groups announced a joint campaign to oppose climate engineering tests. *Id.*

Tests have also begun on climate engineering technologies beyond ocean fertilization. Researchers in the United Kingdom, for example, announced that they intended to lift a hose measuring up to twenty-five kilometers long into the upper atmosphere with a weather balloon so that they could test technologies for potential large-scale dispersion of sulfate aerosols.[55] Russian scientists sprayed a small amount of aerosols into the atmosphere to measure their effect on incoming solar radiation.[56] Another proposed project would assess technologies to reverse the effects of ocean acidification caused by elevated atmospheric CO_2 levels.[57]

Despite calls for a moratorium on climate engineering research, the comparatively low research costs have enticed private investors to take initial steps into the field. For example, Bill Gates has funded more than $4.5 million worth of research on reducing the amount of GHGs in the atmosphere through adaptation measures and climate engineering.[58] In 2010, Gates was part of a group providing funds to a Silicon Valley inventor's plan to make clouds whiter so that they more effectively reflect solar radiation.[59] Additionally, private companies such as Climos have formed to attract capital and to conduct research outside the realm of public subsidies or public policy statements.[60] If climate engineering projects ultimately yield tradable credits for reductions in

54. *Id.*; *see* discussion *infra* at notes 93–94; *see also* ACTION GRP. ON EROSION, TECH. AND CONCENTRATION, GEOPIRACY: THE CASE AGAINST GEOENGINEERING 39–40 (Oct. 2010), *available at* http://www.etcgroup.org/en/node/5217 (calling for ban on climate engineering research until governance framework in place).

55. University of Cambridge, *Stratospheric Particle Injection for Climate Engineering (SPICE)*, http://www2.eng.cam.ac.uk/~hemh/SPICE/SPICE.htm (last visited Nov. 27, 2011). While the research consortium originally intended to conduct its experiment in November 2011, it has postponed the experiment until April 2012 because of criticism and objections from numerous parties. Bob Yirka, *SPICE Geoengineering Project Delayed Due to Critics Issues* (Oct. 5, 2011), http://www.physorg.com/news/2011-10-spice-geoengineering-due-critics-issues.html (last visited Nov. 27, 2011).

56. Yu A. Israel et al., *Field Experiment on Studying Solar Radiation Passing Through Aerosol Layers,* 34 RUSS. METEOROLOGY AND HYDROLOGY 265, 266 (2009).

57. Michael Marshall, *Geoengineering Trials Underway*, NOVIM (Sept. 14, 2011), http://www.novim.org/resources/novim-news/121-geoengineering-trials-get-under-way ("Elsewhere, Ken Caldeira of the Carnegie Institution for Science in Stanford, California, has permission to add sodium hydroxide—an alkali—to a small patch of ocean to see if it can reverse the effects of ocean acidification.").

58. Eli Kintisch, *Bill Gates Funding Geoengineering Research*, SCIENCEINSIDER (Jan. 26, 2010, 2:10 PM), http://news.sciencemag.org/scienceinsider/2010/01/bill-gates-fund.html. Gates has already applied as a co-inventor on a patent in 2008 to "sap hurricanes of their strength by mixing surface and deep ocean water." *Id.*

59. Oren Dorell, *Can Whiter Clouds Reduce Global Warming?*, USA TODAY (June 11, 2010, 12:37 AM), http://www.usatoday.com/weather/research/2010-06-10-cloud-whitening_N.htm.

60. Scant information is available regarding these companies, but for more information on Climos's funding and business model, see *Frequently Asked Questions About Ocean Fertilization*, CLIMOS, http://www.climos.com/faq.php#9 (last visited 11/8/11).

GHG emissions, private investors will have even stronger incentives to become more actively involved in climate engineering research and projects.[61]

II. THE NEXT STEP: POSSIBLE CLIMATE ENGINEERING STRATEGIES

Several possible engineering strategies have surfaced to address global climate change effects. Surprisingly, initial evaluations of some of these strategies show that they might significantly reduce climate change effects caused by current GHG levels in the atmosphere. More research and information will be needed, however, where each of these techniques poses unique risks and areas of concern.

Controversy has already emerged over the definitions of "climate intervention" or "geoengineering." These disagreements arise largely from the fact that the definition of these terms could exclude some technologies from any future regulatory framework or treaty governing climate engineering. For example, some definitions would exclude techniques such as biochar management, carbon capture and sequestration, and albedo enhancement through white roofs and more reflective vegetation.[62] Most definitions, however, include three common elements: (1) the intentional intervention or manipulation (2) of environmental systems, including systems related to

61. As noted in the Introduction, some entrepreneurs have already undertaken ocean iron seeding projects in hopes of generating tradable carbon emission credits for profit. Other entrepreneurs will undoubtedly view climate engineering as a set of valuable marketable technical skills that they can provide to governments or individuals who wish to respond to or forestall climate events. Notably, the final version of the American Clean Energy and Security Act of 2009 specifically excluded ocean fertilization projects from the definition of CO_2 "sequestration" that could receive funding and tax credits. *See* H.R. 2454 (111st Congr., 1st Sess.) (placed on Senate Calendar, July 7, 2009) (section 312 adds new Section 700(44) which defines "Sequestered and Sequestration" as "the separation, isolation, or removal of greenhouse gases from the atmosphere, as determined by the Administrator. The terms include biological, geologic, and mineral sequestration, but do not include ocean fertilization techniques").

62. Biochar is a charcoal-like substance made from biomass such as crop wastes and dross, and it can serve as a soil conditioner or secondary energy source. BRICK, *supra* note 52, at iv (Nov. 2010), *available at* www.nrdc.org/energy/files/biochar_paper.pdf. One study has suggested that the production of biochar may also allow the long-term sequestration in soils of up to 12 percent of global emissions of carbon dioxide. *Id*. at 11–12; Dominic Woolf et al., *Sustainable Biochar to Mitigate Global Climate Change*, NATURE COMMS. (Aug. 10, 2010), http://www.nature.com/ncomms/journal/v1/n5/full/ncomms1053.html. Carbon capture and sequestration technologies could remove GHGs from industrial emissions and then store them in secure geological or engineered structures for long time periods. Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells, 75 Fed. Reg. 77,230, 77,233–35 (Dec. 10, 2010) (to be codified at 40 C.F.R. pts. 124, & 144–147). Albedo enhancement reduces climate change due to solar radiation influx by simply reflecting as much sunlight as possible away from the Earth's surface and back into space. Some albedo enhancement techniques include the use of light-colored material in roofs or placing reflective materials over large areas of unoccupied land. David W. Keith, *Geoengineering the Climate: History and Prospect*, 25 ANN. REV. OF ENERGY & THE ENV'T 245, 264 (2000) (discussing geoengineering through surface albedo enhancement); C. PARKINSON, *supra* note 30, at 173–75, 190 (finding that a square mile of desert covered with light-reflective polyethylene sheets would offset the emissions of 7,000 sports utility vehicles over a fifteen-year period).

climate, (3) to reduce or offset the effects of anthropogenic global warming.[63] The technologies described below contain each of these concepts. This Article will focus on technologies that, by consensus, squarely fall within the definition of climate engineering, but many of the legal issues raised below will also apply to techniques that might lie outside some definitions of the term.[64]

Most proposed climate engineering strategies seek either to remediate existing high stores of CO_2 in the ambient atmosphere or to intervene directly in climatic processes that generate global warming. For example, one category of climate engineering would modify the amount of solar radiation that reaches the Earth's surface (solar radiation management (SRM)). By contrast, other technologies spur uptake of GHG by marine, geological, or arboreal biological sources, or by mechanical devices to remove or directly reduce existing stocks of GHG in the atmosphere (carbon dioxide removal (CDR)). While SRM technologies tend to attract the most concern and legal attention (for reasons discussed below), even CDR technologies can pose nettlesome policy and legal issues. For example, the use of CDR may significantly affect delicate ecosystems where the technology is deployed.[65]

With this division in mind, some of the most imminently feasible climate engineering approaches include the following methods:

> *Reduce Solar Influx.* Much of the initial scientific scrutiny and concern has centered on techniques that directly reduce the amount of sunlight reaching the earth's surface. Several different techniques can achieve this goal. In particular, Crutzen's proposal would use the dispersal of sulfate aerosol particles in the stratosphere to scatter and reflect sunlight back into space. According to his calculations, this approach can yield

63. *See, e.g.,* ROYAL SOCIETY STUDY, *supra* note 10, at 1 ("Geoengineering proposals aim to intervene in the climate system by deliberately modifying the Earth's energy balance to reduce increases of temperature and eventually stabilise temperature at a lower level than would otherwise be attained."); U.S. GOVERNMENT ACCOUNTABILITY OFFICE, CENTER FOR SCIENCE, TECHNOLOGY AND ENGINEERING, TECHNOLOGY ASSESSMENT CLIMATE ENGINEERING: TECHNICAL STATUS, FUTURE DIRECTIONS, AND POTENTIAL RESPONSES, GAO-11-71, at 3 (July 2011).

64. *Id.*; *see also* R. Lal, *Sequestering Atmospheric Carbon Dioxide*, 28:3 CRIT. REV. PLANT SCI. 90, 90 (2009); Keith, *supra* note 62, at 265, 281 (discussing carbon uptake by genetically modified organisms).

65. For example, large-scale iron seeding to enhance algal blooms may deplete levels of oxygen in the water column or promote the production of algal toxins. Large scale CO_2 capture devices may also generate large volumes of calcium carbonate waste streams and possibly create waste disposal issues. Howard Herzog, *Assessing the Feasibility of Capturing CO_2 from the Air* (Oct. 2003) (unpublished thesis, Mass. Inst. of Tech.), *available at* http://step.berkeley.edu/Journal_Club/paper1_02092010.pdf; Diego Alvarez et al., *Behavior of Different Calcium-Based Sorbents in a Calcination/Carbonation Cycle for CO_2 Capture,* 21 ENERGY FUELS 1534, 1540 (2007); Charles G. Trick et al., *Iron Enrichment Stimulates Toxic Diatom Production in High-Nitrate, Low-Chlorophyll Areas,* 107 PROC. OF THE NAT'L ACAD. OF SCI. USA 5887, 5889 (2010); Arthur J. Miller et al., *Global Change and Oceanic Primary Productivity: Effects of Ocean-Atmosphere-Biological Feedbacks*, *in* 73 GLOBAL CLIMATE CHANGE AND RESPONSE OF CARBON CYCLE IN THE EQUATORIAL PACIFIC AND INDIAN OCEANS AND ADJACENT LANDMASSES 473 (2007).

significant reductions in surface global temperatures on a wide scale for a comparatively small cost of $25 to $50 billion annually.[66] Other proposals would involve the use of space-based reflective particles or mirrors placed in low or geostationary orbit to directly scatter sunlight before it reaches the Earth's atmosphere.[67]

Enhance Production of High-Albedo Cloud and Surface Cover. Because certain types of clouds reflect a significant percentage of sunlight back into space, several proposals have focused on using seeding techniques to generate wide swaths of cloud cover over ocean areas. These techniques rely on recent scientific data showing that boat and jet contrails can be surprisingly effective at generating persistent high-level cloud formation. Under these proposals, autonomous sailing craft equipped with solar-powered engines would pump seawater to create a fine mist that they would disperse above sea level. In theory, these mists would have the ability to seed subsequent cloud formations.[68]

Increase Formation of Sea Ice. To halt or reverse the rapid shrinkage of polar ice caps and sea-based ice shelves, some scientists have proposed the use of sea-based snow projection for ice manufacturing that would seed additional production of ice at polar latitudes.[69] This approach, which could also rely on wind and nuclear power to help generate the ice, would theoretically need sufficient sea ice to create an enhanced albedo that would reflect sunlight back into space and reduce surface temperatures.[70]

Direct CO_2 Sequestration Through Ocean Seeding. One frequently discussed method of climate engineering is the addition of trace elements such as iron to certain portions of the ocean to enhance

66. Crutzen, *supra* note 33, at 213 (to counteract global warming effects, the project would need to inject one to two teragrams of sulfur particulates into the stratosphere each year; such an effort would cost $25 to $50 billion annually). Estimates of the cost of unabated climate change damages are notoriously difficult and controversial. *See, e.g.*, NICHOLAS STERN, STERN REVIEW ON THE ECONOMICS OF CLIMATE CHANGE (2006). By comparison, however, one study estimates that the State of Alaska alone will face costs of up to $10 billion over the next few decades to address damage to its infrastructure caused by rising global temperatures. P. LARSEN ET AL., UNIV. OF ALASKA, ESTIMATING FUTURE COSTS FOR ALASKA PUBLIC INFRASTRUCTURE AT RISK FROM CLIMATE CHANGE (2007), *available at* www.iser.uaa.alaska.edu/publications/JuneICICLE.pdf.

67. ROYAL SOCIETY STUDY, *supra* note 10, at 46–48.

68. *Id*. at 27–28.

69. S. Zhou & P.C. Flynn, *Geoengineering Downwelling Ocean Currents: A Cost Assessment*, 71 CLIMATIC CHANGE 203, 220 (2005) (concluding that formation of thicker sea ice by pumping ocean water onto the surface of ice sheets is the least-expensive proposed method to enhance downwelling ocean currents that would remove GHGs from the atmosphere).

70. *Id.* at 207, 211.

blooms of algae.[71] Because certain portions of the ocean ecosystem are limited by the scarce amounts of iron, even a comparatively small addition of distributed iron particles can lead to a burst of phytoplankton growth that can absorb CO_2 from the atmosphere directly above the ocean's surface.[72] In theory, the phytoplankton would then die and precipitate downward with CO_2 locked in their body mass.[73] At the ocean floor, the phytoplankton and the CO_2 would be sequestered on a long-term basis.[74] According to some studies, this process has already begun on a natural basis due to releases of particulate iron from receding glaciers that have enhanced polar phytoplankton blooms.[75] Recent proposals have noted that iron fertilization of the ocean can also have substantial regional effects on wind patterns and the albedo of clouds affected by the release of sulfates from the enhanced phytoplankton growth.[76]

Marine Heat Transfer. Many of the most problematic climate change effects arise from higher ocean surface temperatures. For example, some climate models show that a broader difference between ocean surface temperatures and ambient air temperatures may lead to the

71. As noted above, the Alfred Wegener Institute in Germany planned to conduct an iron seeding experiment in 2009. *See*, *e.g.*, *supra* note 49-50 and accompanying text. The research ship was loaded with twenty tons of iron and ready to sail when the German government ordered them to stop and conduct further research before attempting the experiment. Quirin Schiermeier, *Ocean Fertilization Experiment Suspended*, NATURENEWS (Jan. 14, 2009), http://www.nature.com/news/2009/090114/full/news.2009.26.html.

72. OCEAN FERTILIZATION, *supra* n. 40 at 1, 5, 7.

73. R.S. Lampitt et al., *Ocean Fertilization: A Potential Means of Geoengineering?*, 366 PHIL. TRANSACTIONS OF THE ROYAL SOC'Y A 3919, 3922 (2008) (concluding that CO_2 absorbed by algae can be sequestered from atmosphere for over one hundred years). Some researchers have raised concerns that the sinking of large amounts of algae into the deep ocean could convey nutrients such as nitrogen and phosphorous that would alter ocean ecological systems in unpredictable ways. Aaron Strong et al., *Ocean Fertilization: Time to Move on*, 461 NATURE 347 (2009). In particular, these concerns include the risk that ocean fertilization on a global scale could cause oxygen starvation in large regions of the ocean. *Id.*

74. One common criticism of ocean fertilization experiments (and, indeed, of climate engineering approaches in general) is that they do not address other serious consequences of elevated ambient CO_2 levels. For example, heightened CO_2 levels have contributed to growing acidification of ocean waters. Some researchers have suggested that some technologies could directly reduce or at least not increase ocean acidification on at least a regional level. Marshall, *supra* note 57, at 8; *see* K. House et al., *Electrochemical Acceleration of Chemical Weathering as an Energetically Feasible Approach to Mitigating Anthropogenic Climate Change,* 41 ENVTL. SCI. & TECH. 8464, 8464 (2007). While these additional large-scale projects also likely qualify as climate engineering, this article will focus instead on projects directly aimed at either SRM or CDM.

75. Rob Raiswell et al., *Contributions from Glacially Derived Sediment to the Global Iron (Oxyhydr)Oxide Cycle: Implications for Iron Delivery to the Oceans*, 70 GEOCHIMICA ET COSMOCHIMICA ACTA 2765 (2006) (concluding that delivery of iron nanoparticles through glacial shedding of icebergs may fertilize oceanic productivity and draw down atmospheric levels of carbon dioxide).

76. Nicholas Meskhidze et al., *Phytoplankton and Cloudiness in the Southern Ocean,* 314 SCIENCE 1419, 1420–21 (2006).

formation of stronger and potentially more destructive hurricanes.[77] Ocean temperatures at deeper levels, however, remain much less affected by higher ambient air temperatures or surface solar radiation. As a result, some researchers have suggested that ocean heat pumps could moderate these climate effects by exchanging cooler deep marine waters with warmer surface waters.[78] These ocean heat pumps would consist of a large number of floating columns that would rely on the energy of wave motions to transport cooler water to the surface.[79] Some models show that a significant number of these floating heat exchangers could arguably reduce ocean surface temperatures over a broad area and potentially mitigate processes that might exacerbate the risk of more severe hurricanes.[80]

Direct Air Capture. Another proposed strategy would tackle ambient CO_2 levels in a direct fashion by using a large number of mechanical devices to "scrub" the CO_2 out of the air. This approach, if adopted on a large scale, would use liquid or dry sorbents[81] to capture CO_2 (typically in a carbonate), chemically release the CO_2 in a subsequent step, and then reuse the restored sorbent to collect more CO_2.[82] The captured CO_2 could either be sold for commercial use or geologically sequestered.[83] Under these scenarios, the global deployment of ten million CO_2 capture units could theoretically reduce ambient CO_2 levels by five parts per million per year, and the projected costs could drop to $30 per ton of CO_2 captured.[84] If it proves cost-effective, this

77. Kevin E. Trenberth, *Warmer Oceans, Stronger Hurricanes*, SCI. AM., June 14, 2007, at 44. Professor Kerry Emanuel from MIT was one of the first to publish research connecting these areas, and in 2008 Professor Emanuel released new findings further supporting his 2005 research. *See, e.g.*, *Interview: Exploring the Links Between Hurricanes and Ocean Warming*, YALE ENV'T 360 (Sept. 15, 2010), http://e360.yale.edu/feature/exploring_the_links_between_hurricanes_and_ocean_warming/2318/.

78. Kelly Klima et al., *Does It Make Sense to Modify Tropical Cyclones? A Decision-Analytic Assessment*, 45 ENVTL. SCI. & TECH. 4242, 4242 (2011) (discussing a computer model that indicated that use of wind-wave pumps in path of tropical cyclone approaching South Florida "could reduce net losses from an intense storm more than hardening structures").

79. David Biello, *Halting Hurricanes*, SCI. AM., Nov. 2011, at 24.

80. *Id.*

81. A sorbent is "[a] material having the property of collecting molecules of a substance by sorption." Sorption in turn is "[t]he combined or undifferentiated action of adsorption [the adherence of specific gases, liquids or substances to the exposed surfaces of materials, usually solids, they are in contact with] and absorption [the swallowing up of items through their inclusion in or assimilation to something else]." OXFORD ENGLISH DICTIONARY (compact ed. 1987) (definitions of sorbent, absorption and adsorption).

82. Klaus S. Lackner, *Washing Carbon Out of the Air*, SCI. AM., June 2010, at 66, 66–69.

83. *Id.* at 70.

84. *Id.* at 65; David W. Keith et al., *Climate Strategy with CO_2 Capture from the Air*, 74 CLIMATIC CHANGE 17–45 (Jan. 2006).

> technology could reduce ambient CO_2 levels with fewer side effects than other potential climate engineering techniques.[85]

As climate engineering studies continue to refine potential methods and techniques, some of the strategies above may undergo significant revisions. For example, one suggested modification would use precisely engineered nanoparticles in place of sulfate aerosols to scatter sunlight from the upper atmosphere back into space.[86] The proposal notes that these particles could remain in the upper stratosphere for a much longer time than sulfate aerosols, and the nanoparticles can be engineered to cause them to aggregate in polar regions.[87] This type of regional climate engineering may offer an important step in protecting the environments facing the highest risks, such as the polar ice caps and the Great Barrier Reef,[88] but regional SRM climate engineering efforts may pose especially high risks of weather disruption and governance challenges.[89]

While the field is in its infancy, several striking characteristics of these various climate engineering techniques may affect future assessments of their legal status. First, all of these techniques offer the prospect of immediate and short-term moderation of climate change effects. This benefit, however, comes with a high degree of uncertainty about other potential costs and damages. For example, proposals to reduce solar influx through stratospheric distribution of aerosols have raised concerns that aerosol distribution might alter regional precipitation patterns, could delay recovery of the ozone layer and thereby increase skin cancer rates, will not address—and in fact may enhance—ocean acidification, could increase risk of damage to aircraft engines, and might cause particulates to precipitate onto surface environments in ways that affect human or ecological systems.[90]

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85. Lackner, *supra* note 82, at 70–71 (refusing to classify direct removal of carbon dioxide from the atmosphere as geoengineering because it "does not change the natural dynamics of the earth or create a potential environmental risk," and "[a]ir capture simply withdraws the excess CO_2 from the atmosphere that humans are putting there").

86. David W. Keith, *Photophoretic Levitation of Engineered Aerosols for Geoengineering*, 107 PROC. OF THE NAT'L ACAD. OF SCI. USA 16,428 (Sept. 21, 2010), *available at* www.pnas.org/cgi/doi/10.1073/pnas.1009519107.

87. *Id.*

88. COMM. ON SCI. & TECH., 111TH CONG., ENGINEERING THE CLIMATE: RESEARCH AND STRATEGIES FOR INTERNATIONAL COORDINATION 41 (Comm. Print 2010).

89. *Staff of H. Comm. on Sci. and Tech., 111th Cong., Rep. on Geoengineering: Assessing the Implications of a Large Scale Climate Intervention: Hearing* (2009) (testimony by Dr. Shepherd of the Royal Society) (that "[i]t would . . . be generally undesirable to attempt to localize SRM methods, because any localized radiative forcing would need to be proportionally larger to achieve the same global effect, and this is likely to induce modifications to normal spatial patterns of weather systems including winds, clouds, precipitation and ocean currents and upwelling patterns").

90. *See, e.g.*, Victor Brovkin et al., *Geoengineering Climate by Stratospheric Sulfur Injections: Earth System Vulnerability to Technological Failure*, 92 CLIMATIC CHANGE 243, 255 (2008), *available at* http://www.springerlink.com/content/271270616u1x1666/fulltext.pdf (concluding that "stratospheric sulfur injections might be a feasible emergency solution for cooling the planet," but the injections would

The second notable common effect of these climate engineering approaches is that they can be performed unilaterally. As opposed to global emission control conventions that require participation from all of the significant players to yield any material effects, a single nation or even large corporation may have the resources to undertake one or many of these climate engineering projects.[91] For example, the cost of an aerosol distribution project could easily fall within the scope of one nation's resources.[92]

Third, every one of these climate engineering techniques will likely spark strong and impassioned opposition from potentially affected individuals and interest groups. Because of the large unknowns associated with each of these techniques and the risk of unintentional damages that they pose, several environmental advocacy groups have already soundly denounced any approach that would use climate engineering.[93] Other groups and governments have opposed the use of climate engineering projects, or even investigations into their soundness, because they might detract from efforts to reduce ongoing emissions.[94] This opposition will likely grow if concerns that elevated greenhouse gas levels already in the atmosphere may lead to cataclysmic climate change because even comparatively small amounts of change to the atmosphere's composition may have large, unpredictable or chaotic effects on climate. In other words, while the prospect of abrupt climate change might give climate engineering projects a sense of urgency, it also creates a risk of unexpected catastrophic effects.

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have to continue "for millennia unless future generations find a secure way to remove CO_2 from the atmosphere." The authors also point out that "[a] critical consequence of climate engineering is a possibility of extremely rapid warming in case the emissions are abruptly interrupted" leading to warming in polar regions that could exceed 10 degrees Celsius within a few decades).

91. David Victor et al., *The Geoengineering Option: A Last Resort Against Global Warming?,* FOREIGN AFFAIRS (March/April 2009), *available at* http://iis-db.stanford.edu/pubs/22456/The_Geoengineering_Option.pdf ("By contrast, geoengineering is an option at the disposal of any reasonably advanced nation. A single country could deploy geoengineering systems from its own territory without consulting the rest of the planet. . . . Although governments are the most likely actors, some geoengineering options are cheap enough to be deployed by wealthy and capable individuals or companies.").

92. This prospect of unilateral climate engineering efforts by a major national power has already surfaced. In November 2005, the head of the Russian Global Climate and Energy Institute (and previously a vice-chair of the Intergovernmental Panel on Climate Change) urged Russian President Vladimir Putin that Russia should immediately discharge into the atmosphere 600,000 tons of sulfur aerosol particles. C. Brahic, *Hacking the Planet: The Only Climate Solution Left?*, 2697 NEW SCIENTIST 8, 10 (2009), *available at* http://www.newscientist.com/article/mg20126973.600-hacking-the-planet-the-only-climate-solution-left.html.

93. Lauren Morello et al., *At U.N. Convention, Groups Push for Geoengineering Moratorium*, SCI. AM. (Oct. 20, 2010), http://www.scientificamerican.com/article.cfm?id=at-un-convention-groups-push. *But see* Keith, *supra* note 86 (discussing the division of opinion among environmental groups, and that some of the largest environmental advocacy organizations have signaled willingness to accept climate engineering research if performed with adequate controls and governance).

94. For example, a large collection of environmental groups have banded together into a campaign named "Hands Off Mother Earth" (HOME). *See About*, HOME, http://www.handsoffmotherearth.org/about/ (last visited Nov. 29, 2010). The HOME coalition will advocate for an international prohibition or regulation of efforts to test or implement climate engineering technologies. *Id.*

III. LEGAL PRINCIPLES FOR CLIMATE ENGINEERING DISPUTES

Most of the nascent legal challenges to climate engineering projects have focused on using existing international legal regimes to oppose or control test programs or demonstration efforts. This initial orientation appropriately reflects the global consequences of climate change issues and the planned location for climate engineering experiments, such as polar environments or on the high seas, which fall within the jurisdiction of international laws and treaties. The UNFCCC Conference of the Parties in Cancún, Mexico saw efforts to persuade delegates to begin initial discussions over the regulation of climate engineering approaches and define the coalitions on either side of the suits, but the modest climate agreement from the conference did not expressly discuss this issue.[95]

A. Potential Challenges Under U.S. Environmental Laws to Climate Engineering Projects

Approaches that would use domestic national laws to control unilateral climate engineering projects, by contrast, have received less attention.[96] In particular, U.S. courts will likely host some of the initial legal actions to fight climate engineering efforts that might cause environmental damage or large-scale unanticipated effects. Use of U.S. courts for these challenges would follow existing trends towards early interest and action on climate engineering research within the United States. Research projects on climate engineering have already received a high level of attention in the United States: U.S. citizens and corporations have provided significant early funding for climate engineering theoretical research.[97] Some early climate engineering projects will likely be directed by U.S. citizens or within U.S. territory, and domestic U.S. environmental statutes would offer attractive opportunities to challenge

95. *See* The Cancun Agreements, *supra* note 18.

96. U.S. GOV'T ACCOUNTABILITY OFFICE, CLIMATE CHANGE: A COORDINATED STRATEGY COULD FOCUS FEDERAL GEOENGINEERING RESEARCH AND INFORM GOVERNANCE EFFORTS, GAO-10-903, at 27 (Sept. 2010) ("EPA officials stated that the extent to which existing federal environmental laws apply to geoengineering is unclear, largely because detailed information on most geoengineering approaches and effects is not available."). This general statement by the EPA notably does not reflect either EPA's assertion of MPRSA jurisdiction over ocean fertilization experiments by ships flying the U.S. flag. By comparison, the German federal government relied on domestic German law to temporarily restrict ocean fertilization experiments in the Southern Ocean in 2009. *See supra* notes 44, 49-50.

97. For example, Bill Gates has provided at least $4.5 million in funding on geoengineering research for many years, although none of those funds have gone to any field experiments. *See supra* note 58. Entrepreneurs have obtained funding for demonstration projects on ocean iron seeding. *See* discussion *supra*, notes 41-43 (initial seeding projects by Planktos) and notes 77-79 (wind-wave pump demonstration projects to dampen the effects of climate change on hurricane intensification); *see also* K. Jerch, *Capitalizing on Carbon*, *in* Alan Robock, *20 Reasons Why Geoengineering May Be a Bad Idea*, 64 BULL. OF THE ATOMIC SCIENTISTS 16 (May/June 2008), *available at* http://www.thebulletin.org/files/064002006_0.pdf (explaining that Climos obtained $3.5 million in funding from Braemar Energy Ventures for ocean iron fertilization projects; other ocean fertilization ventures by Ocean Nourishment Corporation and Atmocean obtained funding).

those first efforts. Federal and state courts may offer personal jurisdiction over U.S. citizens who undertake or participate in other climate engineering projects. U.S. courts and environmental laws may also provide opportunities for injunctive relief or damages that other national court systems might not grant as readily.[98]

For example, if a corporation with significant operations in the United States (or that had incorporated itself within a U.S. state) decides to undertake a climate engineering project within the United States, environmental groups could draw on many potential options under multiple federal environmental statutes to contest the project. Only some of those challenges are within the scope of this Article. Most importantly, the specific facts surrounding each climate engineering project—including its location, type of technology, scale and projected effects—will play a critical role in invoking the jurisdiction and application of particular federal or state environmental statutes. Current nascent climate engineering proposals simply lack enough detail as yet to allow a fully focused assessment of the environmental statutory and regulatory duties that they might trigger.

While these proposals remain partially undefined, we can still forecast general principles and strategies for the application of federal U.S. environmental statutes to climate engineering efforts. First, and surprisingly, the United States may have already established—albeit unintentionally—a statutory framework to mandate reporting of any climate engineering projects. While the federal government has left the substantive regulation of weather modification (predominantly cloud seeding and rain making ventures) to local and state authorities, Congress passed the National Weather Modification Policy Act of 1972 to track burgeoning weather modification activities.[99] Pursuant to this Act, the National Oceanic and Atmospheric Administration promulgated regulatory reporting requirements for such projects.[100] In particular, these regulations require persons who engage in weather modification to keep and preserve records of their activities and to report the results of their actions to the federal government.[101] The activities subject to this reporting requirement expressly include "[m]odifying the solar radiation energy exchange of the earth or clouds, through the release of gases, dusts,

98. In addition to federal environmental laws, state laws have a rich body of regulatory requirements for weather modification activities. These laws typically addressed efforts to make or control amounts of rainfall in a local region. *See supra* note 30. While weather modification laws might provide a useful historical backdrop, these state and local laws ultimately will not likely play a significant role in legal challenges to climate engineering projects on a global or regional scale.

99. Weather Modification Reporting Act of 1972, Pub. L. No. 92-205, § 3(a), 85 Stat. 735 (1971) (uncodified provisions where Congress declared a policy to establish a national policy for weather modification and appropriated $1,000,000 to the Secretary of the U.S. Department of Commerce to prepare a comprehensive study on the effects and potential of weather modification).

100. 15 C.F.R. § 908 (2011).

101. *Id.* §§ 908.4–908.9.

liquids or aerosols into the atmosphere"[102]—a definition that seems to apply readily to climate engineering technologies that employ solar radiation management. To date, no one has notified the federal government that it has undertaken a climate engineering project under this regulatory program.

Beyond this federal reporting requirement, a few key questions will guide the application of federal environmental statutes generally to climate engineering projects:

> *Whom does the statute regulate?* Most environmental statutes expressly define the "person" who falls within the statute's requirements. The definition of "person" in the Clean Air Act, for example, expressly includes individuals, corporations, states and federal governmental agencies.[103] This broad scope of "person" means that virtually anyone sponsoring a climate engineering project—including state agencies or federal entities—could fall within the ambit of "persons" who must comply with Clean Air Act requirements.
>
> *Where does the statute apply?* While this analysis focuses on climate engineering projects occurring within U.S. territory, many initial projects may occur outside U.S. territory or on the high seas. If so, climate engineering litigation could pose difficult questions of extraterritorial application of federal environmental laws. The federal courts have generally disfavored a broad application of those laws outside U.S. borders without express Congressional authorization.[104]

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102. *Id.* § 908.3(a)(3). The reporting requirement applies to broad categories of activities that might encompass other emerging climate engineering technologies, including "[s]eeding or dispersing of any substance into clouds or fog, to alter drop size distribution, produce ice crystals or coagulation of droplets, alter the development of hail or lightning, or influence in any way the natural development cycle of clouds or their environment;" "[m]odifying the characteristics of land or water surfaces by dusting or treating with powders, liquid sprays, dyes, or other materials;" "[r]eleasing electrically charged or radioactive particles, or ions, into the atmosphere;" "[a]pplying shock waves, sonic energy sources, or other explosive or acoustic sources to the atmosphere;" "[u]sing lasers or other sources of electromagnetic radiation" and "other similar activities falling within the definition of weather modification as set forth in § 908.1." *Id.* §§ 903(a)(1)–(b). While this reporting requirement does not apply to "activities of a purely local nature that can reasonably be expected not to modify the weather outside of the area of operation," this exemption will facially not apply to climate engineering projects. *See id.* § 908.3(c). The regulations also limit this exemption solely to the use of lightning rods, deploying small heat sources to prevent frost damage, and religious activities and ceremonies seeking to alter the weather. *Id*.

103. 42 U.S.C. § 7602(e) (2011) (defining "person").

104. *See, e.g.*, Corrosion Proof Fitting v. EPA, 947 F.2d 1201 (5th Cir. 1991) (holding that Canadian asbestos producers lacked standing to challenge EPA regulations because the Toxic Substances Control Act did not require EPA to consider extraterritorial effect of domestic regulations); Arc Ecology v. U.S. Dep't. of the Air Force, 294 F. Supp. 2d 1152 (N.D. Cal. 2003) (dismissing a claim by two Filipino citizens seeking declaration that CERCLA could be applied to two former U.S. military bases in the Philippines); *cf.* Lujan v. Defenders of Wildlife, 504 U.S. 555, 563 (1992) (holding that plaintiffs lacked standing to challenge rule that limited federal consultation requirements under Section 7 of the Endangered Species Act only to actions within the United States or on the high seas).

> Actions outside the United States that have direct effects within U.S. borders, however, have provided a basis for application of U.S. environmental laws to foreign actors.[105]
>
> *Will the court have jurisdiction over the defendants?* Even if the federal courts upheld the extraterritorial application of U.S. environmental statutes, claimants would still need to satisfy minimum contacts required for the constitutional exercise of in personam jurisdiction over persons or corporations acting entirely outside the United States.[106] The simple fact that the individual may be an individual U.S. citizen or be incorporated in a U.S. state, by itself, may not suffice without further statutory authorization or additional contacts to the U.S. forum.
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> *Who is opposing the project?* The identity of the persons challenging the climate engineering project can play a large role in determining which causes of action and remedies might be available. In particular, the U.S. government, a state entity, or a local governmental unit would have access to a broader array of potential actions and remedies than private parties in citizen suits. For example, the federal government can bring actions or issue administrative orders to respond to emergencies or to imminent threats to human health or the environment. Governmental entities, as trustees for natural resources, might also have the ability to seek compensation for any damage to natural resources caused by climate engineering projects.[107]

With these questions in mind, the federal environmental statutes that might first apply to climate engineering projects would probably include the Clean Air Act, Clean Water Act, Endangered Species Act, National Environmental Policy Act, Marine Protection, Research and Sanctuaries Act, and several other federal statutes that could regulate aspects of specific types of projects (e.g., projects that might affect migratory birds).

105. *See, e.g.*, Pakootas v. Teck Cominco Metals, Ltd., 452 F.3d 1066 (9th Cir. 2006) (holding that CERCLA liability does not reach beyond the U.S. border into Canada, but finding that a Canadian factory created a "facility" within the definition of CERCLA in the United States because its discharges flowed directly into a U.S. water body).

106. World-Wide Volkswagen Corp. v. Woodson, 444 U.S. 286, 292 (1980).

107. For example, *see* discussion *infra* notes 162–164 on the United States' broad emergency authorities under the Comprehensive Environmental Response, Compensation, and Liability Act to respond to releases of "pollutants" that pose an imminent and substantial threat to human health and the environment.

1. The Clean Air Act

The federal Clean Air Act[108] provides the most likely statutory basis to challenge climate engineering projects. Most notably, EPA has already determined that the Clean Air Act applies to GHG emissions and provides an appropriate statutory vehicle to address climate change.[109] EPA has relied on existing Clean Air Act authorities to undertake an ambitious regulatory initiative to require GHG emission controls. This effort has included a finding under the Clean Air Act that GHG emissions endanger public health and welfare as well as a determination that major stationary sources of GHG emissions must obtain Prevention of Significant Deterioration or New Source Review permits for producing the emissions.[110] Given its willingness to regulate activities to reduce the effects of GHG emissions, EPA may take an expansive view of the Clean Air Act's applicability to other activities that might alter climate processes or directly release aerosols or other compounds into the atmosphere to mitigate climate change effects.

The Clean Air Act therefore offers obvious avenues for claimants who oppose certain types of climate engineering projects. For example, an environmental advocate might assert that the dispersion of a sulfate aerosol in the upper stratosphere constituted a release of an air pollutant that violates Clean Air Act prohibitions or requires a permit or authorization.[111] If so, they

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108. 42 U.S.C. §§ 7401–7661 (2006). The CAA sets out complex inter-locking requirements for facilities that emit sufficient amounts of specified air pollutants. In particular, the CAA requires owners and operators to obtain permits if their facilities (1) emit sufficient amounts of criteria air pollutants to qualify as major sources that need either Prevention of Significant Deterioration permits for areas that meet ambient air quality standards, or New Source Review permits for facilities in non-attainment areas, *id.* §§ 7470–7479, 7501–7503; (2) install maximum available control technology on sources in a facility that emit hazardous air pollutants, *id.* § 7412; (3) control emissions or leaks of certain substances that deplete stratospheric ozone, *id.* §§ 7671a–7671e; or (4) obtain tradable emission credits or limit emissions of sulfur dioxide (SO_2) that can contribute to the formation of acid rain, *id.* §§ 7651–7651o. The operators must include all of these controls in a comprehensive federal facility operating permit under Title V of the CAA, and they must submit a certified statement that verifies that the facility has either complied with its permit requirements or has listed all of its deviations from the permit. *Id.* §§ 7661–7661c. This cursory overview of the CAA obviously and intentionally overlooks the vast and rich body of complex statutory and regulatory requirements set out by the Act. *See* CLEAN AIR ACT HANDBOOK (Robert J. Martineau & David P. Novello eds., 2004) (providing further background on the CAA).

109. By contrast, the U.S. government has not supported the use of other federal environmental statutes in other contexts to regulate activities that might affect climate change. *See* discussion *infra* notes 147–148 (Interior Department's refusal to use Endangered Species Act authorities to designate critical habitat for threatened species as a basis to regulate activities that might contribute generally to climate change).

110. Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 74 Fed. Reg. 66,496 (Dec. 15, 2009) (to be codified at 40 C.F.R. Ch. I); Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule, 75 Fed. Reg. 31,514 (June 3, 2010).

111. A significant portion of sulfate particulates released into the upper stratosphere might also fall down to the troposphere where it could directly contribute to aggravated acid deposition in rain or snow. Alan Robock, *20 Reasons Why Geoengineering May Be a Bad Idea*, 64 BULL. OF THE ATOMIC SCIENTISTS 14, 16 (May/June 2008), *available at* http://www.thebulletin.org/files/064002006_0.pdf.

could bring a citizen suit to compel the EPA Administrator to use her non-discretionary duty to stop or control those emissions from the project.[112]

Such a citizen suit action, however, would throw a sharp light on potentially difficult jurisdictional questions evoked by applying the Clean Air Act to climate engineering projects. One threshold issue would be whether stratospheric aerosols, when released to achieve a specific purpose, constitute a "pollutant" that would trigger Clean Air Act jurisdiction.[113] Second, the Clean Air Act has historically not applied to activities that promote healthier ambient atmospheric conditions through any means other than emission controls.[114] For example, prior efforts to reduce ambient particulate matter concentrations or directly reduce ambient ozone levels have not triggered Clean Air Act regulatory requirements.[115] The Clean Air Act also lacks an express regulatory framework for emission limitations on climate engineering projects that might not conveniently fall into the existing rules for industrial source categories, priority pollutants under Title I for ambient air quality standards, air toxics regulated under Title III, or even stratospheric ozone protection under Title VI.

Some of these difficult questions will ultimately turn on the specific design of the proposed climate engineering technology. For example, proposals to reduce solar radiation influx through releasing sulfate aerosols in the upper

112. The federal government would have different tools to fight a proposed climate engineering project, including enforcement actions for failure to comply with federal environmental statutes as well as administrative orders to abate imminent endangerments to human health or the environment. *See* discussion *infra* notes 162–164.

113. The Clean Air Act only applies to releases of "pollutants" that meet statutory and regulatory criteria. 42 U.S.C. § 7602(g). For example, the intentional discharge of chemicals into the air to fight forest fires has not triggered a need for Clean Air Act permits. U.S. FOREST SERV., DECISION NOTICE AND FINDING OF NO SIGNIFICANT IMPACT: AERIAL APPLICATION OF FIRE RETARDANT (2008), *available at* http://www.fs.fed.us/fire/retardant/Aerial_Application_of_Fire_Retardant.pdf. Historical attempts to modify weather through cloud seeding or other rain-making technology have fallen under separate state regulatory regimes rather than the Clean Air Act. *See* discussion *infra* note 181

114. While they have received comparably little attention, other proposed technologies would directly remove or absorb criteria pollutants from the ambient atmosphere. For example, state environmental agencies have explored the use of certain catalytic coatings for mobile sources, concrete structures, high-volume air conditioning systems, and road surfaces to directly absorb ozone and its precursors. Such materials have been successfully introduced in Japan, Italy, and Great Britain as a method of controlling emissions, and since 2005 they have been proposed for use as part of the air pollution control strategy for the Dallas-Ft. Worth area. *See* TEX. COMM. ON ENVTL. QUALITY, DRAFT: AREA—POTENTIAL CONTROL STRATEGIES FOR DFW ATTAINMENT DEMONSTRATION (Oct. 10, 2005), http://www.tceq.state.tx.us/assets/public/implementation/air/sip/miscdocs/area_8-31-05.pdf.
Theoretically, EPA and delegated states could also authorize techniques that directly remove air pollutants from the ambient atmosphere as an appropriate technology to satisfy BACT requirements for Title I permitting purposes. No BACT approvals have been located, however, that have authorized this approach.

115. While EPA has not used the Clean Air Act to regulate technologies that directly reduce ambient levels of criteria pollutants, states have sought EPA's approval of these techniques so that they could claim credit for pollutant reductions for SIP modeling purposes. *See id*. at 1–2 (discussing the Texas Commission on Environmental Quality's (TCEQ) proposal of an emission reduction increment for requiring catalytic coating for pavement and building surfaces to directly reduce nitrogen oxides and volatile organic compounds).

stratosphere may open several legal challenges under the Clean Air Act. This particular technology could pose regulatory obligations under:

> (1) Title I for non-attainment of national ambient air quality standards (NAAQS).[116] Sulfur dioxide is a criteria pollutant with a NAAQS level as well as extensive permitting requirements for areas not in attainment with that standard.[117] In addition, sulfate aerosols could constitute a precursor to the formation of particulate matter that falls within either particulate matter NAAQS standard.[118] Some proposals for sulfate dispersion in the upper atmosphere would rely on large stationary generators that would then convey their sulfate emissions into the stratosphere through immensely long flexible tubes supported by high-altitude balloons.[119] These sources may arguably trigger Clean Air Act permitting requirements if the generators emit enough sulfur dioxide or particulate matter (PM) to constitute a major source.[120]
>
> Title I also imposes restrictions on emissions from major sources that might impair visibility in mandatory Class I areas.[121] It is unclear whether sulfate aerosol or other scattering media would potentially affect visibility or regional haze formation. If so, visibility New Source

116. Section 109 of Title I requires EPA to identify National Ambient Air Quality Standards (NAAQS) for several air pollutants. EPA must design each NAAQS to assure that it protects public health and welfare with an adequate margin of safety. To date, EPA has promulgated NAAQS for six air pollutants: ozone, particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and lead. If the air within a designated geographic region exceeds the NAAQS level for any pollutant, either EPA or the state must provide an implementation plan designed to help the affected region attain compliance with the NAAQS. 42 U.S.C. §§ 7401–7431, 7501–7515 (2006).

117. It is unclear whether the generation and dispersal of sulfate aerosols would require the direct emission of sulfur dioxides, which would fall within the sulfur dioxide NAAQS. In addition, sulfate aerosols may also come within air quality planning and permitting requirements under Title I if their emission would contribute to the formation or decomposition of compounds into sulfur dioxide in ambient environmental conditions.

118. EPA has promulgated two NAAQS for particulate matter. In 1987, EPA changed the indicator for particles from Total Suspended Particulates to PM_{10}, including particles with a mean aerodynamic diameter less than or equal to ten micrometers not to be exceeded once per year. Revisions to the National Ambient Air Quality Standard for Particulate Matter, 52 Fed. Reg. 24,634 (July 1, 1987) (codified at 40 C.F.R. pt. 50). EPA later issued a second NAAQS that set a lower ambient concentration threshold for $PM_{2.5}$—particulate matter with a mean aerodynamic diameter less than or equal to 2.5 micrometers—because the agency had concluded that ultrafine PM contributed to increased incidents of pulmonary disease and other human health effects. National Ambient Air Quality Standards for Particulate Matter, 62 Fed. Reg. 38,652 (July 18, 1997) (codified at 40 C.F.R. pt. 50).

119. Philip Rasch et al., *An Overview of Geoengineering of Climate Using Stratospheric Sulphate Aerosols,* 366 PHIL. TRANSACTIONS OF THE ROYAL SOC'Y 4007, 4013 (2008).

120. If these stationary source facilities were located in non-attainment areas, it would raise the interesting question of whether they fall under non-attainment emission limitations even though their ultimate discharge actually occurs far above or outside the non-attainment area itself.

121. CLEAN AIR ACT HANDBOOK, *supra* note 108, at 196–97.

Review requirements might apply to climate engineering projects that qualify as stationary major sources.[122]

(2) Title II.[123] Releases of large amounts of sulfates from aircraft flying in the upper atmosphere may invoke complex regulatory provisions that govern emissions from mobile sources and aircraft. The Clean Air Act's mobile source program may have limited application, however, because it largely targets emissions from the operation of engines rather than intentional releases conveyed by the mobile sources themselves.

Title II may have a more direct application to other climate engineering proposals that rely on solar radiation scattering by stratospheric aerosol particulates. Recent models have shown that aircraft contrails in the upper atmosphere can have a significant effect on climate systems.[124] As a result, at least one proposal has suggested that aircraft fuels could be formulated to enhance their scattering effect by promoting the creation of high-altitude contrails or by encouraging formation of particulates.[125] An aircraft operator who sought to use these fuels may have to assure that the fuel meets mobile source fuel standards set out by the EPA under Title II or obtain a waiver from the EPA.

(3) Title IV.[126] Sulfur dioxide is also a regulated precursor to the formation of acid rain.[127] While this program regulates stationary

122. *See* 42 U.S.C. § 7491 (2006); *see also* CLEAN AIR ACT HANDBOOK, *supra* note 108, at 203–08.

123. Title II requires EPA to promulgate emission standards for automobiles and other mobile sources of air pollutants. Under this program, EPA has also comprehensively regulated the content and distribution of fuels for mobile sources, including fuels from renewable energy sources such as ethanol. 42 U.S.C. §§ 7521–7574 (2006).

124. Most computer models show that aircraft contrails from current high-altitude operations contribute to climate change effects because their radiative forcing traps significant energy in the atmosphere. *Contrails Warm the World More Than Aviation Emissions*, 2806 NEW SCIENTIST 16 (Apr. 2, 2011), *available at* http://www.newscientist.com/article/dn20304-contrails-warm-the-world-more-than-aviation-emissions.html; *see also* Ulrike Burkhardt & Bernd Karcher, *Global Radiative Forcing from Contrail Cirrus*, 1 NATURE CLIMATE CHANGE 54 (Mar. 29, 2011).

125. The U.S. Patent Office issued a patent for the addition of metallic Welsbach materials to jet fuels to provide "a method of reducing atmospheric warming." U.S. Patent No. 5,003,186, at [1] (filed Apr. 23, 1990) (issued Mar. 26, 1991). Notably, none of these proposals has appeared in peer-reviewed journals and the field has become mired in accusations of covert government action and conspiracy theories. *See, e.g.*, Traci Watson, *Conspiracy Theories Find Menace in Contrails*, USA TODAY (Mar. 7, 2001, 10:38 AM), http://www.usatoday.com/weather/science/2001-03-07-contrails.htm.

126. Title IV requires EPA to control the emissions of precursor pollutants that might cause the formation of acid rain. Under this program, EPA has comprehensively regulated emissions of sulfur dioxide from power generation units, including large electrical power generation plants. 42 U.S.C. §§ 7651–7651O (2006). Most notably, EPA has relied on a market-based auction system to allocate credits that allow operators to emit sulfur dioxide from their power generation units. This approach has led to significant reductions in sulfur dioxide emissions at less cost than a traditional command-and-

> sources in specific industrial categories (e.g., power plants), large-scale releases of sulfur aerosols that may affect the acidity of regional precipitation might lead to regulatory scrutiny.[128]
>
> (4) Title VI. The Clean Air Act empowers the EPA to regulate emissions of stratospheric ozone depleting substances (ODS) to assure that the United States meets its obligations under the Montreal Protocol. Under Title VI, the EPA can add certain compounds to the list of ODS if it concludes that they contribute to ozone depletion. Some scientists have raised concerns that the release of sulfur aerosols into the upper stratosphere may cause significant ozone depletion.[129] If so, the EPA may have regulatory authority to add these types of activities and substances to the list of ODS and implement controls on their distribution and use. To date, the EPA has not included stratospheric sulfate aerosols to the list of ODS under Title VI.

Importantly, the potential application of these Clean Air Act requirements to climate engineering projects does not necessarily deny the EPA the flexibility to modify these regulatory standards in certain circumstances. For example, the Clean Air Act's provisions and exemptions for research projects may provide the EPA with some degree of flexibility to handle initial rounds of climate engineering projects or experiments.[130] The EPA may also have the

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control regulatory approach. Dallas Burtraw & David Evans, *Tradable Rights to Emit Air Pollution* 4–5 (Res. for the Future, Discussion Paper No. 08-08, 2008), *available at* http://www.rff.org/Documents/RFF-DP-08-08.pdf ("The administrative performance of the SO_2 program has been nearly perfect, with virtually 100 percent compliance and unexpectedly little litigation."). Burtraw and Evans cite studies concluding the SO_2 trading system saved 43 to 55 percent in costs compared with a uniform standard. *Id.* at 5.

127. *See* 42 U.S.C. § 7651(a) (2011) (Congressional finding that sulfur and nitrogen dioxides are the "principal sources of acidic compounds . . . in the atmosphere").

128. This regulatory scrutiny would arise from the possible effects that sulfate dispersion might have on regional precipitation. *See* Marshall, *supra* note 57 ("Spraying aerosols locally [into the stratosphere with a hose] allows the particles to clump together, making them less effective at reflecting sunlight and more likely to be swept down by rain"); P. Heckendorn et al., *The Impact of Geoengineering Aerosols on Stratospheric Temperature and Ozone,* ENVTL. RES. LETTERS, Nov. 2009, at 6–7, *available at* http://www.see.ed.ac.uk/~shs/Climate%20change/Stratospherics/Heckendorn_et_al_ERL2009.pdf. But Title IV and its implementing regulations currently do not address emissions from any of the types of sources that might be used in climate engineering projects. As noted previously, the application of these requirements for SO_2 to sulfate aerosol projects might also depend on whether dispersal of sulfates requires the direct emission of SO_2 into the atmosphere or will contribute to heightened SO_2 ambient levels due to the decomposition of other compounds or through other atmospheric chemical processes. *See* discussion *supra* notes 111–112 and accompanying text.

129. *See generally* Heckendorn et al., *supra* note 128, at 1 ("Therefore, geoengineering by means of sulfate aerosols is predicted to accelerate the hydroxyl catalyzed ozone destruction cycles and cause a significant depletion of the ozone layer even though future halogen concentrations will be significantly reduced."); Patricia Kenzelmann et al., *Geoengineering Side Effects: Heating the Tropical Tropopause by Sedimenting Sulphur Aerosol?*, IOP CONFERENCE SERIES: EARTH & ENVTL. SCI. 6 (2009), *available at* http://www.iac.ethz.ch/people/kenzelpa/EGU2008_quer_handout.pdf.

130. 42 U.S.C. § 7403 (2006) (discussing alternative permitting options for research projects).

ability to modify some regulatory obligations through consent agreements or compliance schedules that provide supplemental pathways for satisfying Clean Air Act requirements.

2. *Clean Water Act*

Climate engineering projects that require the addition of substances to waters of the United States may require authorization under the Federal Clean Water Act.[131] This Act prohibits the discharge of any pollutant from a point source into navigable waters unless that discharger has a permit or other form of authorization.[132] For example, a project that disperses iron or other nutrients into U.S. marine waters for a fertilization demonstration project may constitute a discharge that requires a permit under either the National Pollutant Discharge Elimination System (NPDES) or a delegated state program.[133] Notably, the EPA has construed the definition of "pollutant" to include the addition of heat to water bodies.[134] If a climate engineering project involves the addition or alteration of heat levels within U.S. waters, those transfers of heat may trigger NPDES permitting requirements.[135]

The Clean Water Act may also directly affect climate engineering projects that require alterations to land use or geographic features. For example, some climate engineering proposals would encourage the placement of highly reflective materials onto large swaths of land to increase surface albedo. By reflecting more sunlight back into space, these projects would reduce solar influx and ultimately reduce projected climate change effects.[136] Other projects would encourage large-scale CO_2 sequestration through the construction of

131. 33 U.S.C. § 1251 (2006).

132. 33 U.S.C. § 1311(a) (2006) (prohibiting the discharge of any pollutant by any person into waters of the United States except in compliance with requirements of the Clean Water Act).

133. *Id.* The prospects for significant field tests of iron fertilization in U.S. waters is likely low because waters identified as suitable for fertilization (i.e., high in chlorine but low in nutrients) are in the Southern Ocean and in the Indo-Pacific regions. Most of the experiments are also likely to occur on the high seas. Attempts to replicate these conditions in U.S. waters for such a test might trigger Clean Water Act obligations.

In addition to the CWA, the Rivers & Harbors Act of 1899 ("Refuse Act") imposes strict liability for discharges of "refuse" into waters of the United States. 33 U.S.C. § 407 (2006). While this statute has historically applied to the discharge of refuse or solid waste that poses a threat to navigability of U.S. waterways, federal courts have interpreted the Refuse Act to prohibit the unpermitted discharges of pollutants into U.S. waters. *See* New York v. New Jersey, 256 U.S. 296 (1921). If a climate engineering demonstration arguably requires discharge into U.S. waters of a material that might constitute a "refuse" (e.g., the large scale deposition of iron or other nutrients into U.S. waters), that project may therefore require authorization from the U.S. Army Corps of Engineers.

134. 40 C.F.R. § 122.2 (2011) (regulatory definition of "pollutant" expressly includes heat).

135. *See supra* notes 77–80 and accompanying text (discussing climate engineering proposals to use marine heat pumps to reduce the surface temperature of ocean waters and thereby arguably reduce the risk of the formation of extreme storms or hurricanes).

136. *See* discussion *supra* at note 62 (use of reflective ground cover for albedo enhancement).

artificial wetlands or restrictions on land uses that release trapped carbon.[137] If these efforts would involve alterations or placement of materials into wetlands within the jurisdictional reach of the Clean Water Act, the project operators may have to obtain authorization or permits from the U.S. Army Corps of Engineers.

Water quality concerns could also indirectly affect climate engineering projects. For example, direct CO_2 capture will generate a large volume of CO_2 in either a gaseous or liquid form. While some of that CO_2 will likely be used as a product or in other industrial processes, direct capture strategies may have to address the management or disposal of large volumes of captured CO_2. If direct capture systems use geologic sequestration to manage that CO_2, those sequestration wells will likely trigger EPA regulatory requirements under its underground injection well program.[138] State regulatory programs will also affect geologic sequestration aspects of any significant direct CO_2 capture systems.[139]

Climate engineering permitting under the Clean Water Act may pose some of the same conceptual challenges raised by the Clean Air Act. For example, the intentional release of materials into U.S. waters for an express remedial purpose may not constitute a discharge of a "pollutant" because the materials are not being discarded.[140] In addition, materials released into the ambient air for a climate engineering project may ultimately precipitate into U.S. waters, but that type of generalized deposition may not constitute a discharge from a "point source" that would trigger NPDES permitting requirements.[141]

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137. R. Lal, *Sequestering Atmospheric Carbon Dioxide*, 28 CRIT. REV. PLANT SCI. 90, 96 (2009) (suggesting that carbon sequestration in terrestrial ecosystems would provide potential total CO_2 drawdown of 50 ppm of atmospheric concentration over a period of five decades, and proposing that large scale terrestrial sequestration could provide a valuable complement to other geoengineering schemes).

138. On December 10, 2010, EPA promulgated final rules under the Safe Drinking Water Act to govern the injection of CO_2 for geologic sequestration. 75 Fed. Reg. 77,229 (Dec. 10, 2010) (to be codified at 17 C.F.R. pt. 275). Storage of CO_2 in these wells may also trigger EPA regulatory requirements for greenhouse gas reporting. Mandatory Reporting of Greenhouse Gases: Injection and Geologic Sequestration of Carbon Dioxide, 75 Fed. Reg. 75,059 (Dec. 1, 2010) (to be codified at 29 C.F.R. pt. 403).

139. *See, e.g.*, 16 TEX. ADMIN. CODE ANN. § 5.301 (West 2011). These rules implemented Senate Bill 1387, 81st Legislature (Regular Session 2009) to "provide for the implementation of projects involving the capture, injection, sequestration, or geologic storage of carbon dioxide." 36 Tex. Reg. 4397 (July 8, 2011).

140. *See* discussion *supra* at note 113.

141. The Clean Water Act sets out much less onerous requirements for discharges from non-point sources into U.S. waters. 33 U.S.C. § 1329 (2011) (establishing nonpoint source management programs, but not requiring nonpoint sources to obtain discharge permits). In an analogous situation, however, at least one federal court has ruled that the generalized spraying of pesticides that precipitate into navigable waters constitutes a discharge of pollutants from a point source that triggers NPDES permitting requirements. Nat'l Cotton Council of Am. v. EPA, 553 F.3d 927 (6th Cir. 2009) (striking down EPA regulations attempting to exempt pesticide application from NPDES permit requirements).

3. *Endangered Species Act*

The federal Endangered Species Act[142] imposes stringent limits on the actions of governments and individuals that might result in the taking of an endangered or threatened species by directly harming individuals of that species or by damaging the species' critical habitat.[143] If a climate engineering project could potentially affect a large region, that geographic area may include habitat for endangered or threatened species. In those circumstances, a claimant may seek to halt the project through a citizen suit or a request for injunctive relief if the proposed climate engineering project could injure any members of an endangered species or damage critical habitat.[144]

Obviously, such an action could face significant standing, causation and evidentiary challenges. The U.S. Supreme Court has already held that plaintiffs cannot bring citizen suits under the Endangered Species Act to challenge funding decisions for actions abroad that arguably threaten a listed species unless the plaintiffs show that they have suffered a concrete, specific, and actual or imminent injury arising from that action.[145] Persons challenging climate engineering projects under the Endangered Species Act may face similarly challenging burdens of proof to demonstrate standing. Those burdens may be alleviated somewhat because climate engineering projects expressly seek to cause detectable changes in climate patterns. As a result, the defendant's own statements related to the project may remove the need to prove at least some causation issues—namely, whether the defendant's actions have resulted in altered climate effects. Plaintiffs would likely still have to show, however, that these climate effects resulted in some threat to the listed species at issue.

More importantly, the plaintiffs would also have to demonstrate that the climate engineering project's impact rises to the level of a "taking" through alteration of critical habitat or injury to individual members of the species. If the nexus between the climate engineering project and the injuries is too

142. 16 U.S.C. § 1531 (2006).

143. *Id.* § 1538(a)(1)(B) (2006) (prohibiting the "taking" of any endangered species within the United States or the territorial sea of the United States); *id.* § 1532(19) (defining "taking" as "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct"); *see also* Babbit v. Sweet Home Chapter of Cmtys. for a Great Or., 515 U.S. 687, 691 (1995) (upholding regulatory interpretation of "harm" to include "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering").

144. This challenge could allege that the climate engineering project itself threatens to cause a taking of a protected species, which would violate the prohibition on any actions that "take" or "harass" protected species contained in Section 9 of the Endangered Species Act and its implementing regulations. In addition, if the project requires federal approval, funding or permitting, the Endangered Species Act may require the federal agency performing the action to consult with the U.S. Fish & Wildlife Service or the National Marine Fisheries Service to assure that the federal action does not jeopardize the continued existence of a listed species or result in the destruction or adverse modification of critical habitat. 16 U.S.C. § 1536(a)(2) (2006); 50 C.F.R. § 402.01 (2011).

145. Lujan v. Defenders of Wildlife, 504 U.S. 555 (1992).

indirect, it may not demonstrate that the project proximately caused the injury within the statutory meaning of "take."[146]

Last, the U.S. Department of the Interior promulgated interpretative rules on May 14, 2008, for the proposed designation of polar bears as a threatened species. These rules sought to limit the scope of Endangered Species Act listings and protections to exclude measures that addressed global climate change mitigation as a necessary step to protect critical habitat for endangered or threatened species.[147] The final polar bear listing rules expressly declined to use the Endangered Species Act to address broad climate change concerns.[148] These same policy choices may drive the United States to use caution when adapting federal environmental statutes to oppose climate engineering projects.

4. National Environmental Policy Act

The National Environmental Policy Act (NEPA)[149] requires the federal government to undertake an environmental review of any major federal agency action that is likely to have a significant impact on the environment.[150] While NEPA applies solely to governmental actions, it could play an important role if a climate engineering project required the federal government to undertake any significant discretionary permitting action or any other major actions related to the project.[151] The Council on Environmental Quality has expressly directed

146. *Sweet Home Chapter*, 515 U.S. at 709 (O'Connor, J., concurring) (incorporating "ordinary requirements of proximate causation" and foreseeability into section 9 taking prohibition).

147. Endangered and Threatened Wildlife and Plants; Determination of Threatened Status for the Polar Bear (*Ursus maritimus*) Throughout Its Range, 73 Fed. Reg. 28,211–28,303 (May 15, 2008) (to be codified at 50 C.F.R. pt. 17) [hereinafter Polar Bear Threatened Status]; Endangered and Threatened Wildlife and Plants; Special Rule for the Polar Bear, 73 Fed. Reg. 28,306–28,318 (May 15, 2008) (to be codified at 50 C.F.R. pt. 17) [hereinafter Polar Bear Special Rule]. The Interior Department has issued a new designation of critical habitat for polar bears. The habitat designation includes 187,157 square miles of protected habitat. Endangered and Threatened Wildlife and Plants, Designation of Critical Habitat for the Polar Bear (*Ursus maritimus*) in the United States, 75 Fed. Reg. 76,085, 76,137 (Dec. 7, 2010) (to be codified at 50 C.F.R. pt. 17); *see also In re* Polar Bear Endangered Species Act Listing and § 4(d) Rule Litig., 794 F. Supp. 2d. 65 (D.D.C. 2011) (upholding the final rule listing the polar bear as threatened under the Endangered Species Act).

148. Polar Bear Threatened Status, *supra* note 147, at 28,247 ("Some commenters to the proposed rule suggested that the Service should require other agencies (e.g., the EPA) to regulate emissions from all sources, including automobiles and power plants. The science, law, and mission of the Service do not lead to such action. Climate change is a worldwide issue. A direct causal link between the effects of a specific action and 'take' of a listed species is well beyond the current level of scientific understanding."); *id.* at 28,300 ("Without sufficient data to establish the required causal connection—to the level of 'reasonable certainty'—between a new facility's GHG emissions and impacts to polar bears, section 7 consultation would not be required to address impacts to polar bears."); Polar Bear Special Rule, *supra* note 147, at 28,313.

149. 42 U.S.C. § 4321—4370h (2006).

150. *Id.* § 4332(2)(C) (2006); 40 C.F.R. §§ 1502.1–1502.25 (2011) (implementing environmental impact statement requirements).

151. Notably, if the responsible federal agency had to conduct an environmental assessment or a full environmental impact statement, that action could also trigger a requirement for the agency to enter into the federal consultation process under Section 7(a)(2) of the Endangered Species Act. *See* discussion *supra* note 144.

federal agencies to account for climate change implications in their review of governmental actions for potential NEPA assessment.[152] If a federal agency must review a proposed climate engineering project for permitting, government financial assistance or other support, it will likely conduct an environmental assessment of the project's purported impact on climate systems to determine whether it qualifies for a categorical exclusion—although an environmental assessment is not required prior to issuing a categorical exclusion[153]—or if it might have a significant impact which would require a fuller environmental impact statement.[154]

The federal government's environmental review may extend beyond an assessment of individual climate engineering projects. If a federal agency decides to craft a strategy for authorizing or supervising climate engineering projects, that policy decision may lead the agency to undertake a programmatic environmental impact statement (PEIS).[155] This PEIS could require a comprehensive assessment of the cumulative and global effects of a decision to allow or control climate engineering projects. That assessment would explicitly and expressly focus on the possible climate change effects that the projects might have on their targeted climate systems.

The applicability of NEPA requirements will turn heavily on the specific factual context for the climate engineering project as well as the nature of the federal government's action related to the project. For example, statements by proponents about a climate engineering experiment's intended regional or global effects might constitute a prima facie demonstration that the project will have a significant impact and thereby trigger the need for a full environmental impact statement.

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152. Memorandum from Nancy Sutley, Chair, Council on Envtl. Quality, for Heads of Fed. Dep'ts and Agencies, Draft NEPA Guidance on Consideration of the Effects of Climate Change and Greenhouse Gas Emissions (Feb. 18, 2010), *available at* http://pbadupws.nrc.gov/docs/ML1035/ML103510433.pdf.

153. 40 C.F.R. § 1508.4 (2011).

154. *See id.* § 1508.18 (2011) (defining "major Federal action"); *id.* § 1508.9 (outlining the purpose and contents of an environmental assessment); *id.* § 1508.4 (defining "categorical exclusion"). Importantly, the environmental assessment process must investigate whether the major Federal action's consequences, when combined with other actions, might lead to a cumulative impact that could require a full environmental impact statement. *Id.* § 1508.7 (defining cumulative impact as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions").

155. A programmatic environmental impact statement assesses the environmental impact of broad governmental policies or initiatives. As a result, it can focus on agency program, area-wide actions in a region, or multiple actions that share a common geography or timing. The Commission on Environmental Quality's regulations do not define the term "programmatic environmental impact statement" specifically, but those rules provide enough flexibility for the definition of "environmental impact statements" to include programmatic impacts. 40 C.F.R. §§ 1502.4(b) (2011) (an "Environmental impact statement[] may be prepared . . . for broad federal actions such as the adoption of new agency programs or regulations"); *id.* § 1502.4(c) (allowing grouping of actions for EIS to include geography and generically similar actions or similar stages of technological development).

5. Marine Protection, Research and Sanctuaries Act

In contrast to other federal environmental statutes, the Marine Protection, Research and Sanctuaries Act (MPRSA, or "Ocean Dumping Act") has already been invoked to challenge climate engineering projects.[156] The MPRSA implements the United States' obligations under the London Convention to restrict the dumping of pollutants or refuse into the high seas, and it also sets out a comprehensive regulatory program to govern the placement of materials into the marine environment that might impair its health or ecological functions.[157] The MPRSA, as a result, applies to discharges into waters under U.S. jurisdiction as well as to acts on the high seas by ships under the U.S. flag.[158]

Because it applies to actions on the high seas, opponents invoked the MPRSA to fight Planktos' planned release of iron filings into the Pacific Ocean. Several environmental groups filed a petition with the EPA that contended the planned experiment would constitute the dumping of pollutants that violated the MPRSA, and they asked the EPA to intervene and halt the experiment. The EPA responded by notifying Planktos that the MPRSA could apply to the planned release, and it asked Planktos to confirm whether it would seek a permit or other authorization before proceeding with the project. Planktos answered that it would not trigger MPRSA obligations because it would use a vessel flying under a non-U.S. flag for the experiment. Planktos' response in part led the United States to alert the parties to the London Convention and seek consideration by the parties for a regime to govern ocean fertilization experiments.[159]

The MPRSA may offer a powerful initial platform to regulate climate engineering projects that involve actions in waters under U.S. jurisdiction or on vessels flying the U.S. flag. The MPRSA's express legislative purpose is to "regulate the dumping of all types of materials into ocean waters and to prevent or strictly limit the dumping into ocean waters of any material which would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities."[160] Unless authorized by a permit, MPRSA generally prohibits (1) transportation of material from the United States for the purpose of ocean dumping; (2) transportation of material from anywhere for the purpose of ocean dumping by U.S. agencies or U.S.-flagged vessels; and (3) dumping of material transported from outside the United States into the U.S. territorial sea or into the

156. *See supra* at note 44 (EPA invoked MPRSA as potential regulatory basis to restrict Planktos's planned discharge of iron into ocean waters).

157. 33 U.S.C. § 1401(a)–(c) (2006).

158. *Id*. §§ 1441(a)(1)–(2).

159. *See supra* note 41–43 and accompanying text (describing EPA response to proposed Planktos project).

160. 33 U.S.C. § 1401(b) (2006).

contiguous zone to the extent that it may affect the territorial sea or the territory of the United States.[161] Given its broad scope and its express extraterritorial application to activities by U.S. vessels, the MPRSA may offer a strong and clear platform to challenge climate engineering projects that might otherwise lie outside the reach of other domestic federal environmental statutes.

6. Other Statutes

This initial survey of federal environmental statutes has focused on major laws that offer the clearest opportunity to challenge climate engineering research projects. Several other federal statutes, however, could offer additional avenues for legal review if the specific climate engineering proposal fell within their coverage. For example, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) might create liability for persons responsible for releases of hazardous substances as part of a climate engineering project.[162] Because liability would be strict as well as joint and several (if the release caused an indivisible harm), potentially responsible parties for response costs resulting from a climate engineering project might face the daunting task of proving which portion of those costs should be attributed to their activities. More importantly, the United States might have a broader scope to compel persons performing a climate engineering project to undertake emergency action to abate an imminent and substantial threat to human health and the environment. While CERCLA fixes liability on potentially responsible parties for costs incurred to respond to a release of "hazardous substances",[163] CERCLA authorizes the federal government to undertake any action needed to respond to a release of "pollutants"—a broader

161. *Id*. § 1401(c).

162. 42 U.S.C. §§ 9601–9630 (2006). For example, the dispersal of large quantities of aerosols or engineered particulates into the stratosphere may constitute an arrangement for the disposal of those materials once they inevitably precipitate onto the ground. Similar arguments might be made for minerals or compounds dispersed onto the ocean surface for fertilization projects. If these materials fall within CERCLA's broad definition of "hazardous substance," researchers who arranged for the dispersal of those materials may face strict liability for costs incurred to respond to those releases. This risk could be especially problematic if the releases allegedly cause natural resource damages in addition to costs incurred to respond to the release. *See id.* § 9607(a); U.S. GOV'T ACCOUNTABILITY OFFICE, *supra* note 96, at 29 ("Although a stream of pure CO_2 is not a hazardous substance under CERCLA, an EPA official noted that injected CO_2 streams could contain hazardous substances, thus subjecting the parties injecting the CO_2 to liability for any release that did not qualify as federally-permitted release. In addition, if CO_2 enters groundwater, it might also cause hazardous substances, such as some metals, to be dissolved by the groundwater from enclosing strata. If that constitutes a release of hazardous substances from a 'facility,' such as the strata, then the owner of that facility could be liable for any cleanup costs caused by that release.").

The targets of CERCLA actions, however, will likely point to cases that exempt the dispersal of certain materials from CERCLA's definition of "release" if the intended use of those materials foresaw their dispersal and eventual placement onto land. In addition, if climate engineering projects obtain permits under the CAA or other federal statutes, releases pursuant to those permits may fall under relaxed requirements for federally permitted releases. *See id.* § 9601(10).

163. 42 U.S.C. § 9607(a) (2006).

category than "hazardous substances."[164] While this action may not result in liability for potentially responsible parties, it could nonetheless empower the government to impose substantial restrictions on an ongoing climate engineering project that arguably created a threat to human health or the environment.

Other federal environmental statutes might apply to climate engineering projects. The Migratory Bird Treaty Act imposes strict liability on persons whose activities cause the taking of a migratory bird, and that liability can be criminal.[165] A climate engineering project that unintentionally causes the deaths of migratory birds therefore might pose a risk of liability.[166] In addition, ocean fertilization projects in coastal waters that might affect marine sanctuaries could be subject to regulation under the National Marine Sanctuaries Act[167] or the Marine Mammal Protection Act.[168] The Offshore Continental Shelf and Lands Act may also provide a basis for citizen suits to

164. *Id*. § 9604(a)(1). CERCLA defines "pollutant" much more broadly than the term "hazardous substance." *Id*. § 9601(33) (defining "pollutant" to "include, but not be limited to, any element, substance, compound, or mixture, including disease-causing agents, which after release into the environment and upon exposure, ingestion, inhalation, or assimilation into any organism, either directly from the environment or indirectly by ingestion through food chains, will or may reasonably be anticipated to cause death, disease, behavioral abnormalities, cancer, genetic mutation, physiological malfunctions (including malfunctions in reproduction) or physical deformations, in such organisms or their offspring" with the exception of petroleum).

165. The Migratory Bird Treaty Act (MBTA) implements the treaty obligations that the United States incurred in the Migratory Bird Treaty of 1918, Convention for the Protection of Migratory Birds, Aug. 16, 1916, U.S.-U.K., 39 Stat. 1702, T.S. 628, as well as subsequent treaties with Mexico, Japan and Russia. Convention for the Protection of Migratory Birds and Game Mammals, Feb. 7, 1936, U.S.-Mex., 50 Stat. 1311, T.S. 912; Convention for the Protection of Migratory Birds in Danger of Extinction and Their Environment, Mar. 4, 1972, U.S.-Japan, 25 U.S.T. 3329, T.I.A.S. 7990 (ratified 1973); Convention Concerning the Conservation of Migratory Birds and Their Environment, U.S.-U.S.S.R., Nov. 19, 1976, 92 Stat. 3110, T.I.A.S. 9073. Section 703 of the MBTA prohibits the taking, killing, or unlawful possession of migratory birds without a permit. 16 U.S.C. § 703 (2006). A violation of this prohibition can constitute a misdemeanor punishable by a fine up to $15,000 and up to six months imprisonment. *Id.* § 707(a) (2011). Notably, the MBTA would treat such an offense as a strict liability misdemeanor that would allow the United States to prosecute responsible corporate officers without proof that they knew about the violation or acted negligently in supervising actions that led to injury to migratory birds. David M. Uhlmann, *After the Spill Is Gone: The Gulf of Mexico, Environmental Crime, and the Criminal Law*, 109 MICH. L. REV. 1413, 1444 n.204 (2011). Historically, the U.S. Department of Justice does not prosecute environmental cases under strict liability theories unless the defendants have also acted at least negligently. *Id.*

166. *See* 16 U.S.C. § 703 (2006). For example, a demonstration project to adjust the acidity of marine waters may involve the addition of chemical buffering agents to affect the pH level of waters over a broad area. If these chemicals injured or killed migratory birds feeding in the area, the project's operator might arguably face civil and criminal liability under the MBTA.

167. *Id.* §§ 1431–1445c1 (2006). The NMSA authorizes the Secretary of Commerce to designate and protect areas of the marine environment with special national significance, and it authorizes civil fines up to $100,000 per violation per day and damages against persons who injure marine sanctuary resources. *Id*. §§ 1436, 1437(d)(1), 1443(a)(1).

168. *Id.* § 1361–1423H (2006). The MMPA generally prohibits the taking of marine mammals without a permit in waters of the United States or by U.S. citizens on the high seas. *Id.* § 1372(a).

challenge climate engineering projects that involve use of submerged lands in the U.S. territorial sea or exclusive economic zone.[169]

Notably, this initial overview of potential environmental challenges touches solely on federal statutory options. Claimants may find that state environmental laws offer richer opportunities to challenge climate engineering projects that might require an environmental impact statement or a state permit with more stringent emission or operating requirements.[170] In addition, states are not bound by federal determinations on standing that apply to limited jurisdiction federal courts, and as a result state courts can use thresholds for standing or justiciability that favor environmental claimants.[171]

B. Potential Barriers to U.S. Judicial Review of Challenges to Climate Engineering Projects

In addition to federal environmental statutory programs, federal or state common law nuisance claims may provide a viable avenue for judicial review of climate engineering projects. This field of law is in a state of high flux after the U.S. Supreme Court's recent decision in *American Electric Power Co. v. Connecticut* that federal courts cannot hear federal common law claims alleging that climate change effects had created a public nuisance.[172] The Court concluded that passage of the Clean Air Act had displaced federal common law actions that might impose public nuisance liability for interstate emissions.[173]

The Court's ruling follows several federal appellate court decisions that had already undertaken searching scrutiny of climate change public nuisance claims—*Native Village of Kivalina v. ExxonMobil Corp.*,[174] *Comer v. Murphy Oil*,[175] and *Connecticut v. American Electric Power Co.*[176]—to address the role that federal courts can or should play in global climate change tort disputes. These decisions centered on the political question doctrine, standing, ability to prove causation, and displacement or preemption. The appellate

169. 43 U.S.C. § 1331–1356a (2006).

170. While federal environmental statutes can set minimum standards that states must meet, those statutes often also allow states to impose more stringent environmental standards or to require permits from sources exempt under federal law. As a result, states often have their own environmental statutes and regulatory systems that precede—and go beyond—federal environmental programs. For example, the California Environmental Quality Act has provided the basis for numerous citizen suits to challenge state actions where the government failed to properly account for climate change effects in state environmental impact statements. *See* Cal. Pub. Res. Code §§ 21000–21177; *see*, *e.g.*, Santa Clarita Org. for Planning the Env't v. City of Santa Clarita, 129 Cal. Rptr. 3d 183 (2011) (CEQA citizen suit objecting to adequacy of GHG mitigation measures for hospital expansion project).

171. T. Hester*, A New Front Blowing In: State Law and the Future of Climate Change Public Nuisance Litigation*, 31 STAN. ENVTL. L. J. 101, 115-119 (2012).

172. Am. Elec. Power Co. v. Connecticut, 131 S. Ct. 2527 (2011).

173. *Id.* at 2537.

174. Native Village of Kivalina v. ExxonMobil Corp., 663 F. Supp. 2d 863 (N.D. Cal. 2009).

175. Comer v. Murphy Oil USA, 585 F.3d 855 (5th Cir. 2009), *vacated,* 607 F.3d 1049 (5th Cir. 2010).

176. Connecticut v. Am. Elec. Power Co., 582 F.3d 309 (2d Cir. 2009).

courts rendered mixed decisions on climate change public nuisance claims, and the U.S. Supreme Court's decision in *American Electric Power* shed some much-needed light on this field of law.

While the *American Electric Power* Court ultimately dismissed the plaintiffs' claims, the ruling does not automatically preclude the application of public nuisance tort principles to climate engineering projects. Most importantly, the decision presents climate engineering proponents with a Hobson's choice: either risk public nuisance liability by arguing that the Clean Air Act does not apply to climate engineering projects, or accept the prospect of Clean Air Act permitting obligations. In addition, the Court's rationale—that Congress displaced federal common law by giving the EPA the authority to regulate GHG emissions under the Clean Air Act—would not apply to climate engineering projects that create public nuisances without emitting significant GHGs—for example, albedo enhancement projects or solar radiation management without aerosols. The *American Electric Power* decision expressly did not overturn earlier precedents that plaintiffs claiming climate change damages could satisfy Article III threshold requirements for standing and avoid the political question doctrine.[177] In contrast to public nuisance damage lawsuits for climate alterations arising from past and global GHG emissions, climate engineering challenges may provide a clearer avenue to bring climate change tort actions into the federal courts. While still raising important claims over climate change responsibilities and liability, these actions will neatly sidestep—or even reverse—the typical challenges raised against climate change nuisance suits under federal common law.

Before examining the application of federal tort liability theories to climate engineering projects, it is important to note that the primary challenges to climate engineering projects will likely rely on federal environmental statutes rather than federal common law tort claims. While statutory claims can still face standing and justiciability problems, those concerns are greatly reduced when Congress has established a statutory framework for judicial review. By doing so, Congress can exercise its power to define a property interest or procedural right which can become a legally protectable interest. An invasion of that statutory right thereby can support standing and justiciability. For example, the U.S. Supreme Court in *Massachusetts v. EPA* held that where Congress gives a procedural right to protect a plaintiff's concrete interests, the plaintiff "can assert that right without meeting the normal standing requirements of redressability and immediacy . . . the litigant has standing if

177. *American Electric Power* allowed the claims to proceed because the Court split 4-4 on whether the Second Circuit had correctly approved the plaintiffs' standing and justiciability claims. Notably, the Court relied on its prior ruling in *Massachusetts v. EPA* that states deserved "special solicitude" on their standing claims because of their special role as sovereigns with an interest in their state's citizens and resources. Massachusetts v. EPA, 549 U.S. 497, 520 (2007). The availability of standing and justiciable claims for private plaintiffs alleging climate injuries remains controversial. *See infra* notes 182–203 and accompanying text.

there is some possibility that the requested relief will prompt the injury-causing party to reconsider the decision that allegedly harmed the litigant."[178] Claimants attacking a climate engineering project could meet standing and justiciability requirements by showing a federal environmental statute provides them with a similar substantive or procedural right. As noted previously, U.S. environmental statutes could provide an array of possible options to contest climate engineering research or demonstration projects.[179]

Numerous other articles have surveyed the key challenges and procedural status of the three key climate change public nuisance lawsuits currently before the federal appellate courts,[180] and this Article will only recount the key aspects of those cases as they might illuminate the role of public nuisance lawsuits in halting climate engineering efforts. It will also focus on the trial court decisions to some extent because their rationales offer the most insight on how federal trial courts will initially respond to climate engineering lawsuits. In each of the problematic areas for climate change public nuisance actions, a legal action seeking damages or injunctive relief against a climate engineering project would face significantly less difficulty in presenting a viable claim.[181]

178. *Massachusetts*, 549 U.S. at 517–18 (2007).

179. *See supra* Part III.A.

180. For some of the most recent analyses, see Robin Kundis Craig, *Adapting to Climate Change: The Potential Role of State Common-Law Public Trust Doctrines*, 34 VT. L. REV. 781 (2010); Randall S. Abate, *Public Nuisance Suits for the Climate Justice Movement: The Right Thing and the Right Time*, 85(2) WASH. L. REV. 197 (2010); Michael B. Gerrard, *What the Law and Lawyers Can and Cannot Do About Global Warming,* 16 SOUTHEASTERN ENVTL. L.J. 537 (2007); David Hunter & James Salzman, *Negligence in the Air: The Duty of Care in Climate Change Litigation*, 155 U. PA. L. REV. 1741 (2007); Shi-Ling Hsu, *A Realistic Evaluation of Climate Change Litigation Through the Lens of a Hypothetical Lawsuit*, 79 U. COLO. L. REV. 701 (2008).

181. This Article does not explore whether prior tort litigation over damages from weather modification efforts might offer a precedent for liability for climate engineering projects. In particular, while efforts to modify precipitation patterns or affect local weather patterns have historically triggered lawsuits for trespass and negligence for damages allegedly caused by flooding or drought due to the projects, not one of those cases has yielded a final judgment for legal damages. Gregory N. Jones, Comment, *Weather Modification: The Continuing Search for Rights and Liabilities*, 1991 BYU. L. Rev. 1163, 1167–70 (1991).

It may become relevant for climate engineering tort liability that some states have statutorily exempted weather modification activities from private or public nuisance liability. *See, e.g.*, COLO. REV. STAT. § 36-20-123 (2011); UTAH CODE ANN. § 73-15-7 (West 2011). Other states provide similar statutory exemptions from trespass liability for weather modification efforts. These statutory protections only apply if the defendant holds a permit or authorization from the state to perform weather modification. *See, e.g.*, COLO. REV. STAT. § 36-20-123 (2011) (permit required); *see also* N.D. CENT. CODE ANN. § 61-04.1-37(2) (West 2011) ("Dissemination of materials and substances into the atmosphere by a permittee acting within the conditions and limits of the permittee's permit shall not constitute trespass."); WIS. STAT. ANN. § 93.35(14)(b) (2011) ("Dissemination of materials and substances into the atmosphere by a permittee acting within the conditions and limits of his or her permit shall not give rise to the contention that the use of the atmosphere constitutes trespass."); COLO. REV. STAT. § 36-20-123(2)(a) (2011) ("Failure to obtain a permit before conducting [a weather modification] operation . . . shall constitute negligence per se.").

1. Political Question

The most threatening jurisprudential shoal for public nuisance climate change suits has been the political question doctrine. The political question doctrine, while much debated over its doctrinal justifications and exact formulation, holds generally that federal courts cannot entertain cases that present controversies or issues that either the U.S. Constitution has committed to the other two political branches or the judicial branch lacks the institutional capacity to resolve or enforce.[182] In particular, the political question doctrine can allow a federal court to dismiss requests for relief that would require the court to implement a long-term and complex remedial scheme in an area where the court lacks discernable legal standards to guide its supervision.[183] The political question doctrine has also been applied to cases that turn on multifaceted non-legal factors which ultimately rest on political judgments on allocation of benefits or responsibilities.[184]

Climate change public nuisance suits are highly susceptible to political question challenges, and the three key cases have each spurred numerous motions to dismiss on political question grounds. Because each of the three

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182. Baker v. Carr, 369 U.S. 186, 189 (1962). In this seminal opinion, the U.S. Supreme Court described the specific factors that identify a political question. The well-known *Baker* factors include "[1] a textually demonstrable constitutional commitment of the issue to coordinate political department; [2] or a lack of judicially discoverable or manageable standards for resolving it; [3] or the impossibility of deciding without an initial policy determination of a kind clearly for non-judicial discretion; [4] or the impossibility of a court's undertaking independent resolution without expressing lack of the respect due coordinate branches of the government; [5] or an unusual need for unquestioning adherence to a political decision already made; [6] or the potentiality of embarrassment from multifarious pronouncements by various departments on one question." *Id.* at 217.

For an analysis of the political question doctrine as it specifically relates to climate change cases, see James May, *Climate Change, Constitutional Consignment, and the Political Question Doctrine*, 85 DENV. U. L. REV. 919 (2008); Shawn M. LaTourette, *Climate Change: A Political Question?*, 40 RUTGERS L.J. 219 (2008). The foreign policy aspect of the political question doctrine is likely to see fresh scrutiny by the courts as an increasing number of lawsuits swirl around the activities of American companies in theaters of war. *See* Note, *The Political Question Doctrine: Executive Deference, and Foreign Relations*, 122 HARV. L. REV. 1193 (2009).

183. *See, e.g.*, California v. Gen. Motors Corp., No. C06-05755 MJJ, 2007 WL 2726871, at *14–16 (N.D. Cal. 2007) (dismissing federal common law tort action against automobile manufacturers for damages arising from climate change due to GHG emissions by pointing in part to the lack of judicially manageable standards; "[t]he crux of this inquiry is not whether the case in unmanageable in the sense of being large, complicated or otherwise difficult to tackle from a logistical standpoint. . . . Rather, courts must ask whether they have the legal tools to reach a ruling that is 'principled, rational, and based upon reasoned distinctions.'").

184. For example, the federal courts have pointed to the lack of any judicially discernible and manageable standards to decline to review challenges to federal immigration programs or military policies. *See, e.g.*, Texas v. United States, 106 F.3d 661, 664–65 (5th Cir. 1997) (action to recover costs from federal government for expenditures related to undocumented aliens fell under political question doctrine because of lack of manageable standards); Carmichael v. Kellogg, Brown & Root Servs., 572 F.3d 1271, 1288–92 (11th Cir. 2009) (political question barred negligence action against military contractor because court could not identify readily ascertainable and judicially manageable standards); *cf.* Crockett v. Reagan, 720 F.2d 1355, 1357 (D.C. Cir. 1983) (refusing to review decisions related to military aid because of equitable restraint doctrine).

suits raise different claims and seek varying types of relief, the trial courts have offered different rationales in their opinions granting each motion to dismiss. For example, in *American Electric Power*, the plaintiffs requested an injunction that would limit greenhouse gas emissions from coal-fired power plants in multiple northeastern states under a plan that would compel the plants to gradually reduce their emissions over decades of operation.[185] Not unexpectedly, the trial judge concluded that the plaintiff's request would force the trial court to make decisions that effectively allocated liabilities and influenced regional power generation over an extended period of time.[186] Judge Preska described this type of injunctive relief as squarely within the sphere of issues that the political question doctrine barred from federal court review:

> [A] non-justiciable political question exists when a court confronts 'the impossibility of deciding without an initial policy determination of a kind clearly for non-judicial discretion.' As the Supreme Court has recognized, to resolve typical air pollution cases, courts must strike a balance 'between interests seeking strict schemes to reduce pollution rapidly to eliminate its social costs and interests advancing the economic concern that strict schemes [will] retard industrial development with attendant social costs.' In this case, balancing those interests, together with the other interests involved, is impossible without an 'initial policy determination' first having been made by the elected branches to which our system commits such policy decisions, viz., Congress and the President.[187]

The Second Circuit reversed the trial court's dismissal order because the appellate panel concluded that the requested relief only affected a small number of power plants and that the courts could handle the admittedly complex allocation of liabilities and obligations required by such injunctive relief.[188] The federal courts, according to the Second Circuit, had long handled complex questions like these as part of their inherent award of equitable relief to multiple parties.[189]

Comer and *Kivalina* also yielded initial trial court rulings that dismissed the complaints because they posed political questions, but the courts diverged on their rationales. The *Comer* trial court stated that the plaintiffs' claim asked the court to "balance economic, environmental, foreign policy and national security interests and make an initial policy determination of a kind which is simply non-judicial."[190] The court further held that such "policy decisions are best left to the executive and legislative branches of the government, who are

185. Connecticut v. Am. Elec. Power Co., 406 F. Supp. 2d 265, 267–70 (S.D.N.Y. 2005).
186. *See id.* at 272–74.
187. *Id.* at 272.
188. Connecticut v. Am. Elec. Power Co., 582 F.3d 309, 326-30 (2d Cir. 2009).
189. *Id*. at 326.
190. Comer v. Murphy Oil USA, 585 F.3d 855, 860 n.2 (5th Cir. 2009).

not only in the best position to make those decisions but are constitutionally empowered to do so."[191] While the Fifth Circuit panel decision disagreed and concluded that the complaint raised no political question,[192] the full Fifth Circuit subsequently vacated that opinion without issuing a substantive analysis of its own to replace it.[193]

By contrast, the *Kivalina* trial court concluded that the limited relief sought by the plaintiffs nonetheless posed a political question because (i) the plaintiffs' claims rested on allegations of emissions and damages on a global scale that lacked any judicially discoverable or manageable standards, and (ii) the issues raised by the plaintiffs' claims would require the trial court to make a fundamentally legislative policy judgment.[194] The district court gave no credit to the defendants' argument that the global warming issue may involve foreign policy and related economic issues, and therefore it failed to satisfy the first step in the *Baker* test. The court wrote that "the fact that this case 'touches foreign relations' does not ipso facto place it beyond the reach of the judiciary," and it noted that *Baker* itself cautions against sweeping generalities regarding foreign policy being textually delegated to the executive.[195]

Interestingly, the U.S. Supreme Court did not resolve this issue in *American Electric Power.* The Court noted briefly that four members found that at least some plaintiffs had standing under *Massachusetts v. EPA,*[196] and that "no other threshold obstacle bars review."[197] A footnote appended to this statement observed that the plaintiffs had renewed their political question objections made below,[198] so presumably the four members believed that the case did not present a political question. The other four members would have found that the plaintiffs lacked standing, but the opinion does not disclose their opinion on political question and justiciability issues.[199] Because the Court split evenly (in light of Justice Sotomayor's recusal), the Court affirmed the Second Circuit's exercise of jurisdiction.[200]

A lawsuit seeking to halt a climate engineering project probably would not face the vulnerabilities to a political question attack described in the three public nuisance trial court opinions. Rather than seek a judicial determination on liabilities arising from global activities over decades arguably caused by thousands (if not millions) of other parties in both the United States and throughout the world, a judicial challenge to a climate engineering project

191. *Id.*
192. *Id.* at 878–80.
193. Comer v. Murphy Oil USA, 607 F.3d 1049 (5th Cir. 2010).
194. Native Village of Kivalina v. ExxonMobil Corp., 663 F. Supp. 2d 863, 868, 873–77 (N.D. Cal. 2009).
195. *Id.*
196. Am. Elec. Power Co. v. Connecticut, 131 S. Ct. 2527, 2535 (2011).
197. *Id.*
198. *Id.* at 2535 n.6.
199. *Id.* at 2535.
200. More accurately, the Court lacked a majority that could reverse the Second Circuit's ruling. *Id.*

could involve plaintiffs who challenge a discrete set of proposed actions by a limited and readily identifiable group of defendants that the court could easily address through injunctions or other equitable relief. Depending on the scope of the project, this relief would likely not require any continuing oversight by the court of complex technical activities with sweeping economic consequences, and the court's actions would not impinge on any overt textual commitment of the issue to either other governmental branch.[201]

2. Standing

Standing has also posed a significant hurdle for federal public nuisance lawsuits seeking damages or injunctive relief for climate change effects.[202] While standing pitfalls in climate change public nuisance litigation have already spurred a large amount of scholastic analysis and commentary,[203] the basic principles of Article III standing illuminate why plaintiffs might face significant challenges in bringing claims for damages allegedly caused by generalized climate change attributable to specific defendants. As the U.S. Supreme Court has repeatedly noted, a plaintiff must meet three factors to demonstrate standing: an injury-in-fact (a specific and concrete invasion of a protectable interest held by the plaintiff), causation (a fairly traceable connection between the injury-in-fact and the defendant's conduct), and

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201. Some aspects of climate engineering lawsuits may arguably ask the court to take actions that fall into the sphere of foreign affairs powers because they involve activities outside the United States. Unless those projects involved foreign governments or their instrumentalities, though, it is unlikely that these types of disputes will fall within the core activities that the U.S. Constitution textually commits to the legislative and executive branches.

If the United States itself chose to undertake a climate engineering project on any significant scale, however, the court could face many of the same issues raised in federal common law public nuisance tort actions against large GHG emitters. For example, if the U.S. government pursued a large-scale program to forestall an alleged climate emergency, the court hearing a challenge to that program could find itself wrestling with complex technical monitoring issues and foreign policy concerns.

202. Because the trial court dismissed the plaintiffs' claims in *Connecticut v. American Electric Power* solely on political question grounds, it expressly declined to rule on whether the plaintiffs had standing to bring their claims. Connecticut v. Am. Elec. Power Co., 406 F. Supp. 2d at 271 n.6. The vacated *Comer* appellate panel opinion concluded that the plaintiffs had standing because they needed only to show that the defendants' actions had contributed to (rather than solely or materially caused) global warming harms. Comer v. Murphy Oil USA, Inc., 585 F.3d 855, 864-65 (5th Cir. 2009). The *Comer* plaintiffs filed a petition for certiorari to the U.S. Supreme Court for review of the Fifth Circuit's decision to vacate the panel opinion; the Fifth Circuit subsequently lacked sufficient judges to conduct an en banc review. Comer v. Murphy Oil USA, 607 F.3d 1049 (5th Cir. 2010).

203. Michael B. Gerrard, *Survey of Climate Change Litigation*, 238 N.Y. L.J. 63 (2007); Matthew E. Miller, Note, *The Right Issue, The Wrong Branch: Arguments Against Adjudicating Climate Change Nuisance Claims*, 109 MICH. L. REV. 257 (2010); Richard O. Faulk & John S. Gray, *Defending Against Climate Change Litigation: Threshold Issues*, 29 ANDREWS LIT. RPTR. 2–3 (2008), *available at* http://works.bepress.com/richard_faulk/16/; Holly Doremus, *The Persistent Problem of Standing in Environmental Law*, 40 ENVTL. L. REP. 10956 (2010).

redressability (it is likely and not speculative that the plaintiff's injury will be remedied by the relief sought by the plaintiff).[204]

Given that GHG emissions worldwide contribute to global warming and that any effective relief arguably requires reductions in GHG emissions from a vast array of sources located throughout the world, these irreducible constitutional standing requirements obviously may pose a challenge for most federal climate change public nuisance claimants. The *Kivalina* trial court did not allow the case to go forward because of the political question doctrine discussed above and because the plaintiffs could not show that any particular act by the defendants could be fairly traced to the plaintiffs' injuries. In particular, the judge noted that, "[e]ven accepting the allegations of the Complaint as true and construing them in the light most favorable to Plaintiffs, it is not plausible to state which emissions—emitted by whom and at what time in the last several centuries and in what place in the world—'caused' Plaintiffs' alleged global warming injuries."[205] Allowing the suit to go forward, the court held, would make the dozen defendants responsible for the emissions released by "virtually everyone on Earth."[206] The *American Electric Power* trial court added in a footnote that, "because the issue of Plaintiffs' standing is so intertwined with the merits and because the federal courts lack jurisdiction over this patently political question, I do not address the question of Plaintiffs' standing."[207] The Second Circuit disagreed, finding it had a duty to determine sua sponte whether or not the plaintiffs had Article III standing before delving into the merits of the case.[208] As noted above, the U.S. Supreme Court did not resolve the issue because it affirmed the Second Circuit's opinion in a 4-4 split that expressly relied on *Massachusetts v EPA* and its "special solicitude" for state plaintiffs bringing public nuisance claims.[209]

By contrast, plaintiffs seeking to challenge a proposed climate engineering project would have an easier burden of proof for standing. First, a climate

204. Sprint Commc'ns Co. v. APCC Servs., Inc., 554 U.S. 269, 273 (2008); Lujan v. Defenders of Wildlife, 504 U.S. 555, 560–61 (1992).

205. Native Village of Kivalina v. ExxonMobil Corp., 663 F. Supp. 2d 863, 880-81 (N.D. Cal. 2009). The *Comer* trial court reached a similar conclusion on standing by noting that "[t]hese are not injuries which are fairly attributable to these individual defendants . . . . I do not think that under our system of jurisprudence [harm from CO_2 emissions] is attributable to a larger group that are not before this Court, not only within this nation but outside of our jurisdictional boundaries as well." Transcript of Hearing on Defendants' Motions to dismiss at 36, Trial transcript at p. 36, Comer v. Murphy Oil, U.S.A., 2007 WL 6942285 (S.D. Miss. Aug. 30, 2007) (No. 1:05-CV-436-LG-RHW) (on file with author).

206. *Village of Kivalina*, 663 F. Supp. 2d at 874.

207. Connecticut v. Am. Elec. Power Co., 406 F. Supp. 2d 265, 271 n.6 (S.D.N.Y. 2005). The Second Circuit's panel opinion overruled this aspect of the trial court's opinion and found that the plaintiffs had standing to bring their claims because they need only show that the defendants "contributed to" the undifferentiated harms of global warming and that the court could grant some measure of relief, even if that relief could not result in measurable decreases in overall global warming effects. Connecticut v. Am. Elec. Power Co., 582 F.3d 309, 345-347 (2d Cir. 2009).

208. *Am. Elec. Power Co.*, 582 F.3d at 333.

209. Am. Elec. Power Co. v. Connecticut, 131 S. Ct. 2527, 2535 (2011).

engineering demonstration project will presumably involve an effort expressly designed to generate a measurable regional (or ultimately global) effect distinguishable from general climate change impacts. The plaintiffs in turn could attribute those effects and potential risks to the defendants' specific actions in the tests. As a result, plaintiffs could use the defendants' explanations to justify the basis for the experiment or project to build a prima facie case for both injury-in-fact and causation. Proof of redressability also might not pose a major hurdle because the court presumably could address the alleged risks or injuries by enjoining the climate engineering project or awarding damages to compensate the specific injuries alleged by the plaintiffs.[210]

3. Causation

Aside from the difficulties they have faced in showing that the defendants' actions could be "fairly traced" to alleged harms, climate change public nuisance plaintiffs will face even higher causation hurdles if their claims proceed to trial. The same features that make standing difficult to establish—the thorough mixing of CO_2 emissions on a global basis in relatively short time period, the long residence time of CO_2 in the atmosphere, and the complex processes by which CO_2 and other GHGs can lead to multiple changes to climate and, in turn, to weather or marine conditions—will pose daunting challenges for public nuisance plaintiffs who wish to establish specific causation as well as causation-in-fact between the defendants' emissions and the alleged damages from climate change. By contrast, demonstration efforts and test projects for climate engineering research will have the express goal of altering climate globally or in a discrete region in measurable ways. The overt aims, design, and public statements for climate engineering projects may help reduce the evidentiary burdens to show that the projects caused, or might cause in the future, harms to individuals or the environment.[211]

4. Preemption and Displacement

While the trial courts in the *Kivalina, Comer*, and *American Electric Power* cases each dismissed the claims on political question or standing grounds, they also heard vigorous arguments that any federal common law public nuisance claims had been displaced by subsequent federal governmental

210. While climate engineering opponents might face serious difficulties in quantifying the amount of harm or damages they might suffer from a research test or demonstration project, the federal courts have long issued injunctions to halt activities that might increase the risk of harm if that harm satisfied general or statutory tests for issuance of injunctions. *See* Winter v. Natural Res. Def. Council, 555 U.S. 7 (2008) (setting out standards for issuance of injunctions to halt alleged violations of NEPA requirements by the Navy's sonar tests).

211. Claimants would still have to link alleged climatic changes to actionable harms such as economic loss or aesthetic injuries before they could demonstrate individual or organizational standing. *See Am. Elec. Power Co.*, 582 F.3d at 346 (2d Cir. 2009).

actions that fully occupied the field. In particular, the defendants alleged that the Executive Branch's efforts to persuade other nations to reduce their GHG emissions through international negotiations demonstrated the Executive's exercise of its constitutional authority over foreign affairs, and that any attempt by the federal courts to impose GHG emission limits through public nuisance verdicts could undermine the United States' negotiation position.[212] The defendants also argued that the failure of Congress to pass any GHG emission limits reflected a policy decision not to impose GHG emission limits displacing any federal common law causes of action that might lead to conflicting results.[213] As EPA has promulgated an increasingly large array of regulatory limits and permitting obligations for GHG emissions, the growing federal regulatory presence has led to increasing arguments that federal common law in this arena is simply displaced.[214]

To the extent that federal environmental statutes might apply to climate engineering projects, federal common law tort plaintiffs may need to plead their cases carefully to sidestep displacement arguments. If they fail to persuade the court that federal environmental statutes can support challenges to climate engineering projects, the plaintiffs could argue in the alternative that the failure of environmental statutes and regulations to expressly address climate engineering concerns leaves undisturbed the federal courts' common law authority to hear tort claims. Given the lack of any express U.S. treaty, legislation or regulation to address climate engineering, defendants may not be able to prove that current federal statutes and regulations have displaced the federal courts' authority to hear common law challenges to climate engineering projects that may affect specific plaintiffs.[215]

Lastly, federal common law may also provide a scaffold in U.S. courts for climate engineering legal attacks that rely on U.S. environmental treaties and other international obligations. As confirmed by long-standing U.S. Supreme Court precedent, federal common law incorporates customary international

212. *Am. Elec. Power Co.*, 406 F. Supp. 2d at 273–74; Native Village of Kivalina v. ExxonMobil Corp., 663 F. Supp. 2d 863, 872-873 (N.D. Cal. 2009); Brief of Defendants-Appellees, Comer v. Murphy Oil USA, No. 07-60756 (5th Cir. Jan. 9, 2008), 2008 WL 8094253 at *48 n.19.

213. *Am. Elec. Power Co.*, 582 F.3d at 378–88; Answering Brief for Defendants-Appellees, Kivalina v. ExxonMobil Corp., No. 09-17490 (9th Cir. June 30, 2010), 2010 WL 3299982 at *61-66; Comer v. Murphy Oil USA, 585 F.3d 855, 875–76 (5th Cir. 2009) (reviewing displacement and preemption as component of political question analysis). Alternatively, those same defendants also contended that Congress had displaced federal common law for nuisance actions by promulgating the federal Clean Air Act (even if EPA chose not to exercise that authority). As discussed below, the U.S. Supreme Court ultimately accepted this line of argument in *American Electric Power v. Connecticut*. Am. Elec. Power Co. v. Connecticut, 131 S. Ct. 2527, 2530-41 (2011).

214. *Am. Elec. Power Co.*, 131 S. Ct. at 2530–41.

215. To the extent the plaintiffs bring nuisance claims under state law under either the federal court's supplemental or diversity jurisdiction, or they simply bring their claims in state courts, these same analytical concerns will probably dominate an analysis of whether federal activities have preempted either conflicting state court actions or the entire field in general under the Supremacy Clause. *See* U.S. CONST. art. VI, § 2.

laws as the law of the United States for purposes of the Supremacy Clause.[216] In addition, treaties can become directly enforceable (if implemented by the Senate or if self-executed) as supreme federal law in U.S. courts. If climate engineering challenges assert that prior international conventions or treaties or international customary law prohibit those experiments, U.S. federal and state courts may provide a potentially viable forum to assert those claims.[217]

CONCLUSION

The challenge of climate engineering governance ultimately should require an international framework. Climate engineering projects will inherently affect multiple nations and will cross jurisdictional lines in a way that will make it difficult for any regional or national regulatory scheme to effectively control risks posed by these projects.[218] Even viewed solely as a national regulatory initiative, the novel risks and aspects of climate engineering point out the need for an explicit federal legislative response that would give

216. The Paquete Habana, 175 U.S. 677 (1900) (in ruling that customary international law prohibited the capture and sale of a Spanish fishing vessel as a prize of war, the Court famously declared that "[i]nternational law is part of [U.S.] law, and must be ascertained and administered by the courts of justice of appropriate jurisdiction as often as questions of right depending upon it are duly presented for their determination. For this purpose, where there is no treaty and no controlling executive or legislative act or judicial decision, resort must be had to the customs and usages of civilized nations, and, as evidence of these, to the works of jurists and commentators who by years of labor, research, and experience have made themselves peculiarly well acquainted with the subjects of which they treat"); Sosa v. Alvarez-Machain, 542 U.S. 693, 729 (2004) ("For two centuries we have affirmed that the domestic law of the United States recognizes the law of nations.").

217. The United States has already entered into one international convention that might limit climate engineering experiments if an experiment has military motives or implications. Under the Environmental Modification Treaty, the parties agree "not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party." Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, Art. I, § 1, *opened for signature* May 18, 1977, 1108 U.N.T.S. 151 (effective Jan. 17, 1980). If an individual sought to conduct a climate engineering demonstration or research project in a fashion that might constitute such a military or "hostile use," the United States may have a treaty obligation to take all constitutional steps to stop the project. *Id.* art. IV ("Each State Party to this Convention undertakes to take any measures it considers necessary in accordance with its constitutional processes to prohibit and prevent any activity in violation of the provisions of the Convention anywhere under its jurisdiction or control."). The Convention does not provide for any private actions by citizens of member States to directly enforce its provisions.

218. One concern not addressed here is whether principles of international and domestic law for transnational claims may raise additional opportunities for application of U.S. environmental laws and tort standards to climate engineering projects. For example, a foreign court may reach a judgment under its domestic law that would either seek to restrain or impose damages against operators of a climate engineering project. Attempts to enforce that judgment in the United States may raise complex issues of comity, enforcement of foreign judgments that conflict with U.S. public policy, and due process constraints. The prospect of multiple and overlapping domestic court judgments arising from a single climate engineering project raises the risk of a patchwork array of national laws that will yield conflicting direction and liability standards. It also may empower nations with the harshest liability standards to seek to constrain or entirely halt climate engineering projects sponsored in other nations because of concerns of climate engineering liability.

clear direction to both agencies and researchers on critical issues such as permitting, liability, and oversight.

In the absence of international action or federal legislative direction, however, U.S. environmental statutes and laws may provide a workable initial forum to lay the groundwork for risk management and governance of climate engineering projects that take place in the United States or which involve U.S. citizens or vessels. Researchers seeking to test or deploy climate engineering technologies will first have to determine whether federal and state environmental regulatory programs could apply to their projects. While Congress clearly did not foresee these technologies when it passed the key federal environmental statutes, certain aspects of climate engineering projects may fall under current federal environmental regulatory authority. In particular, climate engineering projects that seek to reduce solar radiation influx through large scale releases of sulfate aerosols from stationary sources may find themselves potentially subject to Clean Air Act regulation. To the extent federal environmental laws may oblige climate engineering researchers to seek authorizations or permits, the federal agencies in charge of those programs might need to begin drafting regulatory strategies and guidance that discuss the procedures and standards for their decisions to approve or reject these projects. Alternatively, federal agencies may also wish to explore their powers to halt objectionable climate engineering projects that pose unacceptable risks or spark strong public concern.

To the extent these federal and state environmental programs may not apply to specific climate engineering projects, challengers may instead turn to common law public nuisance causes of action to seek injunctions or damages. While U.S. federal common law on climate change public nuisance is in a deep state of flux after the U.S. Supreme Court's ruling in *American Electric Power Co. v. Connecticut*, climate engineering tort challenges may sidestep the controversy. In contrast with public nuisance actions under federal common law over the effects of current and historical GHG emissions, climate engineering tort suits will present a better match with the U.S. courts' institutional constraints and constitutional competencies, although they will still test the U.S. courts' facility with highly complex and technical scientific issues. Absent earlier regulatory or legislative action to establish a framework for governing climate engineering efforts within U.S. jurisdiction, the federal and state courts should prepare for the bracing task of resolving domestic disputes over projects that are literally intended to reshape the global climate.

Aside from these immediate legal questions, advocates on both sides of the climate engineering debate will face deep and difficult questions of environmental policy and judicial review. Environmental petitioners, for example, might find themselves wrestling over whether to oppose projects that would counteract disruptive climatic change effects and reduce ongoing environmental damage. Alternatively, defendants may find themselves arguing that federal environmental laws do not apply to their actions because they have

not altered the environment as much as they have attempted to preserve or restore it. They will likely contend that federal agencies and the courts should use a more generous or accommodating standard when reviewing climate engineering projects that serve, ultimately, a restorative goal.[219]

The federal judicial branch has been rightly categorized as the least dangerous branch because of the unique limits and fragility of judicial review and the judicial power to resolve cases and controversies.[220] Some climate engineering disputes may squarely meet the definition of case or controversy under federal constitutional law, yet still raise questions over projects that literally and intentionally have global consequences. If so, the federal courts may find that even the most circumspect exercise of their judicial power to review climate engineering disputes could place the least dangerous branch squarely at the center of global efforts to address climate change. Climate engineering legal actions, as a result, could become an important crucible to test new legal theories for global environmental projects that invoke domestic or international mechanisms for liability and governance.

219. This issue evokes an even more challenging issue: can environmental statutes drive the use of climate engineering techniques in certain circumstances? The ESA arguably mandates the use of habitat alteration or adaptation measures to save imperiled species. *See, e.g.*, P. Shirley and G. Lamberti, *Assisted Colonization Under the Endangered Species Act*, 3 CONSERVATION LETTERS 45–52 (2010). That same legal rationale could extend to regional or global climate engineering technologies that would allow threatened or endangered species to avert certain extinction.

220. *See* ALEXANDER BICKEL, THE LEAST DANGEROUS BRANCH: THE SUPREME COURT AT THE BAR OF POLITICS (1962).