NOTE

ENGINEERING OUR CLIMATE: A COMPREHENSIVE LEGAL FRAMEWORK THAT CAPTURES THE HARMFUL EFFECTS OF GEOENGINEERING APPROACHES

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INTRODUCTION

> [G]eoengineering has hubris written all over it. Indeed, it seems paradoxical, and perhaps even a bit tragic, that society would now contemplate the deployment of technological options with potential serious negative climatic side effects to respond to the impacts of technologies with serious negative climate impacts.[1]

Geoengineering—also known as climate modification—is the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change.[2] Recent studies suggest that geoengineering schemes that reduce solar radiation by only a few percentage points could potentially reduce the climatic impacts associated with increased global warming.[3] With global temperatures on track to exceed a safe threshold level,[4] and the promise of devastating environmental disasters to inevitably follow, the notion that "nobody likes geoengineering" has become increasingly less likely.[5] As one commentator aptly put it, "the mere prospect of geoengineering is a profound indictment of decades of failed efforts to reduce greenhouse gases."[6] Given the sustained lack of political will to reduce carbon emissions, and the fact that geoengineering guarantees the preservation of the fossil fuel industry, climate engineering may be a serious mitigation contender.[7]

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1 William C. G. Burns, *Geoengineering the Climate: An Overview of Solar Radiation Management Options*, 46 TULSA L. REV. 283, 304 (2013) (internal quotations omitted).

2 WIL C. G. BURNS & ANDREW L. STRAUSS, CLIMATE CHANGE GEOENGINEERING: PHILOSOPHICAL PERSPECTIVES, LEGAL ISSUES, & GOVERNANCE FRAMEWORKS 2 (2013); *see also* Tracy D. Hester, *Remaking the World to Save it: Applying U.S. Environmental Laws to Climate Engineering Projects*, 38 ECOLOGY L.Q. 851, 865–66 (2013) ("Most [geoengineering] definitions . . . include three common elements: (1) the intentional intervention or manipulation (2) of environmental systems, including systems related to climate, (3) to reduce or offset the effects of anthropogenic global warming.").

3 *See* B. Govindasamy, K. Caldeira & P.B. Duffy, *Geoengineering Earth's Radiation Balance to Mitigate Climate Change from a Quadrupling of* CO_2, 37 GLOBAL & PLANETARY CHANGE 157, 157–59 (2003).

4 U.N. Framework Convention on Climate Change, *Copenhagen Accord*, ¶ 1, U.N. Doc. FCCC/CP/2009/L.7 (Dec. 18, 2009), https://unfccc.int/resource/docs/2009/cop15/eng/l07.pdf ("[T]o stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius . . . ."); *see also* Nina Chestney, *Climate Policies Put World on Track for 3.3C Warming: Study*, REUTERS (Dec. 11, 2018, 2:36 AM), https://www.reuters.com/article/us-climate-change-accord-warming/climate-policies-put-world-on-track-for-3-3c-warming-study-idUSKBN1OA0Z2 ("Average world temperatures are on course to far exceed the main goal set in the 2015 Paris Agreement on limiting global warming . . . .").

5 David Winickoff & Mark Brown, *Time for a Government Advisory Committee on Geoengineering Research*, 29 ISSUES SCI. & TECH. 79, 79 (2013).

6 *Id.*

7 Karen N. Scott, *International Law in the Anthropocene: Responding to the Geoengineering Challenge*, 34 MICH. J. INT'L L. 309, 311 (2013).

The world's inability to adequately respond to climate change is the reason why it might eventually rely on geoengineering—as global temperatures continue to rise, and efforts to reduce emissions continue to fail, geoengineering may be crucial to our survival.[8] Some scientists argue that based on our current trajectory, geoengineering will be an essential tool against climate change and at the very least, must be deployed alongside current efforts to reduce emissions.[9] Therefore, since geoengineering is likely to be used some time in the future, "it would be dangerous for scientists and policymakers to ignore it."[10]

Geoengineering projects can be carried out by wealthy individual actors,[11] and if such projects are deployed, a wide range of potential harms may follow.[12] Consequently, injured citizens may file suit against geoengineering proponents—and will likely rely on existing federal environmental statutes as the basis for their claims.[13] In this Note, I consider how two categories of geoengineering technologies might fit within the framework of existing federal environmental statutes: carbon dioxide removal (CDR) projects, which seek to remove carbon from the atmosphere, and solar radiation management (SRM) projects, which seek to

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[8] David G. Victor, M. Granger Morgan, Jay Apt, John Steinbruner & Katharine Ricke, *The Geoengineering Option: A Last Resort Against Global Warming?*, 88 FOREIGN AFFS. 64, 65, 75–76 (2009) ("The world's slow progress in cutting carbon dioxide emissions and the looming danger that the climate could take a sudden turn for the worse require policymakers to take a closer look at emergency strategies for curbing the effects of global warming.").

[9] *See* AMERICAN GEOPHYSICAL UNION, *Climate Intervention Requires Enhanced Research, Consideration of Societal and Environmental Impacts, and Policy Development* (Jan. 12, 2018), https://www.agu.org/-/media/Files/Share-and-Advocate-for-Science/Position-Statements/Climate-Intervention-Position-Statement-Final-2018-1.pdf?la=EN&hash=DFA6193E45C22F0741FA525C06AEB73A1152F3CD ("[I]t is possible that [geoengineering and cuts in emissions] could contribute to a comprehensive risk-management strategy aimed at reducing the harms of climate change."); *see also* Anthony E. Chavez, *Using Legal Principles to Guide Geoengineering Deployment*, 24 N.Y.U. ENV'T L.J. 59, 62 (2016) ("While mitigation is critical, it is no longer sufficient to enable us to avoid many of the consequences of climate change."); *see also* Burns, *supra* note 1, at 285 ("The feckless response of the global community to climate change has led to increasingly serious consideration of the potential role of geoengineering as a potential means to avert a "climate emergency" . . . or as a stopgap measure to buy time for effective emissions mitigation responses.") (citations omitted).

[10] *See* Victor, *supra* note 8, at 75.

[11] *See* Mark Squillace, *Climate Change and Institutional Competence*, 41 U. TOL. L. REV. 889, 899 (2010) ("[S]ome of the riskier geoengineering options in terms of long-term global impacts . . . are likely to be affordable to a nation of modest means, or even to a very wealthy individual.") (internal quotations omitted).

[12] For example, solar radiation management techniques could affect rainfall distribution and precipitation patterns disproportionately in Africa and Asia. *See* Christopher J. Preston, *Ethics and Geoengineering: Reviewing the Moral Issues Raised by Solar Radiation Management and Carbon Dioxide Removal*, 4 UNIV. MONT. PHIL. FAC. PUBL'NS 23, 33 (2013). Further, ocean iron fertilization could cause water pollution, ecosystem damage, and algae blooms. *See* Tracy Hester, *Liability and Compensation*, *in* CLIMATE ENGINEERING AND THE LAW 241 (2018) [hereinafter *Liability and Compensation*].

[13] *See infra* Section I.C.2

alter the atmosphere to increase the reflectivity of the planet. Ultimately, I conclude that only through a new domestic legal framework can we effectively regulate all geoengineering techniques.

Part I of this Note describes the different geoengineering methods within the solar radiation management and carbon dioxide techniques. This Part also discusses the development of geoengineering projects over the last fifty years. Geoengineering techniques were created in the mid-20th century for military strategy purposes and evolved into what they are today—a means by which to tackle the harmful effects of climate change while simultaneously preserving the status quo.

In Part II, I analyze the challenges of applying geoengineering projects to existing legal frameworks. While some international agreements have succeeded in barring certain geoengineering practices, they only regulate a small number of geoengineering methods. Depending on the technology used, future injured citizens will likely turn to existing U.S. environmental statutes when bringing their claims against geoengineering experimenters. Therefore, this Part addresses the feasibility and viability of applying various geoengineering technologies to both the Clean Air Act and the Clean Water Act.

In Part IV of this Note, I propose a workable framework for regulating geoengineering technologies at the federal level. Ultimately, the United States should not regulate geoengineering projects based on the *mechanism* used to counteract climate change—which is the way existing federal environmental statutes currently regulate pollution[14]—but rather, on the *effects* created by the mechanism. For example, the Clean Air Act regulates air pollutants according to whether a stationary source (i.e. a power plant) exists, rather than by the amount of harm done by that stationary source.[15] By regulating geoengineering projects according to how dangerous or deleterious their resulting effects are, environmental regulations could capture geoengineering approaches whose mechanisms do not fall neatly within the current regulatory framework.

I. BACKGROUND

A. *Geoengineering Options:* CDR v. SRM

The idea that climate change can by counteracted by intentionally manipulating the planetary environment has only recently begun to attract serious attention.[16] Although the idea is not novel, geoengineering has become increasingly salient in discussions surrounding the Earth's

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[14] *See* 42 U.S.C. § 7521(a)(1) (2018) (regulating air pollutants via motor vehicles and engines); *see also* 33 U.S.C. § 1311(a), (b) (2018) (prohibiting discharging pollutants into waters via point sources).

[15] 42 U.S.C. § 7411 (a)(3), (f) (2018).

[16] *See* Squillace, *supra* note 11, at 895.

warming climate.[17] While public awareness of geoengineering remains low,[18] scientific research has grown exponentially since the 1990s.[19] This research tends to separate geoengineering technologies into two general categories: carbon dioxide removal and solar radiation management.[20]

1. Carbon Dioxide Removal

Once carbon dioxide (CO_2) emissions are released into the atmosphere, they linger there for hundreds of years.[21] Even if global emissions halt and begin to decline, approximately 600 billion tons of CO_2 have accumulated in the atmosphere since the Industrial Revolution.[22] Therefore, reducing global CO_2 emissions will not alone reverse global warming—actually removing CO_2 from the atmosphere will be absolutely necessary. Carbon dioxide removal (CDR)—also known as negative emissions technology—diminishes the concentration of CO_2 in the atmosphere by physically removing it and storing the captured CO_2 somewhere long-term.[23]

CDR approaches involve removing CO_2 from the atmosphere and storing it in terrestrial areas, oceans, or engineered technologies.[24] It is possible that, if CDR technologies were deployed at a large enough scale and enough CO_2 was removed from the atmosphere, global warming could halt and the climate could actually become cooler.[25] However, one problem associated with CDR is that it only removes CO_2 and not other harmful greenhouse gases like methane and nitrous oxide, mostly because those technologies have not been developed yet.[26]

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17 *See* BURNS & STRAUSS, *supra* note 2, at 1–8.

18 One study found a total lack of awareness of the term "geoengineering" among respondents. Specifically, the results of the survey suggest that 75% of people have either never heard of geoengineering or know very little about it. *See* Nick Pidgeon et al., *Exploring Early Public Responses to Geoengineering*, 370 PHIL. TRANS. R. SOC. 4176, 4176–86 (2012).

19 For example, nearly 500 geoengineering-related research papers were published in 2016, compared to a mere dozen in the 1990s. The literature on geoengineering has grown consistently at an annual rate of 21%, doubling every 3.4 years. *See* Jan C. Minx et al., *Fast Growing Research on Negative Emissions*, 12 ENV'T RSCH. LETTERS 1, 3–4 (2017).

20 ROYAL SOC'Y, GEOENGINEERING THE CLIMATE: SCIENCE, GOVERNANCE, AND UNCERTAINTY 1, ix (2009).

21 *See* Victor, *supra* note 8, at 65.

22 MICHAEL B. GERRARD & TRACY HESTER, CLIMATE ENGINEERING AND THE LAW 41 (2018).

23 Ralph Bodle, *Climate Law and Geoengineering*, *in* CLIMATE CHANGE AND THE LAW 452 (Erkki J. Hollo, Kati Kulovesi & Michael Mehling eds., 2013).

24 The Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report categorizes some CDR approaches, like afforestation, as conventional mitigation strategies and includes them in future mitigation scenarios. *See* IPCC, CLIMATE CHANGE 2014: SYNTHESIS REPORT SUMMARY FOR POLICYMAKERS 28–29 (2014).

25 ROYAL SOC'Y, *supra* note 20, at 9.

26 *See id.*

CDR options include afforestation, biochar, enhanced weathering, direct air capture of carbon dioxide, and ocean fertilization.[27] Land-based CDR methods focus on absorbing more CO_2 into terrestrial areas by reducing deforestation and increasing afforestation, which establishes forest in new areas and re-forests certain areas.[28] While these land-based options are relatively uncontroversial, fast, and cheap, they are not very effective, as they would have limited potential for mass removal of carbon.[29] The biochar method allows farmers to use less fertilizer, which subsequently reduces emissions resulting from the production of fertilizer chemicals.[30] By converting biochar to charcoal, the carbon in the organic matter is locked in and is not released into the atmosphere when the biomass decomposes.[31] Unfortunately, this option is fairly expensive, slow to reduce global temperatures, and limited by plant productivity and land-use availability.[32]

Another CDR method is enhanced weathering, which would remove CO_2 from the atmosphere over a long period of time by storing CO_2 in natural carbon sinks. On land, this would involve distributing silicate rocks, which would react with rainwater to ultimately store and lock-in CO_2.[33] In the oceans, this method would involve "deriving alkaline material from silicate rocks and dissolving them in the ocean," causing the sea to absorb more CO_2.[34] However, this option could take thousands of year to remove a sufficient amount of CO_2, and thus would not be a feasible, short-term solution.[35] Another option, carbon capture and storage technologies, could be developed for large-scale commercial use, and would capture CO_2 from ambient air and produce a pure CO_2 stream to be used or stored.[36] Although effective, the energy and materials required for CO_2 capture are expensive and could be slow to deploy.[37]

The last option, ocean fertilization, would increase the amount of nutrients that promote the natural "biological pump" of carbon into deep-

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27 Christopher J. Preston, *Ethics and Geoengineering: Reviewing the Moral Issues Raised by Solar Radiation Management and Carbon Dioxide Removal*, 4 WILEY INTERDISC. REV.: CLIMATE CHANGE 23, 24 (2013).

28 DANIEL A. FARBER & CINNAMON P. CARLARNE, CLIMATE CHANGE LAW 245 (2018).

29 ROYAL SOC'Y, *supra* note 20, at 10–11.

30 GERRARD & HESTER, *supra* note 22, at 49.

31 *See id.*

32 ROYAL SOC'Y, *supra* note 20, at 11–12.

33 GERRARD & HESTER, *supra* note 22, at 50.

34 *Id.*

35 ROYAL SOC'Y, *supra* note 20, at 12, 15.

36 *See id. at* 15.

37 *Id.* at 16. However, some carbon dioxide removal projects have already been deployed. One company has commercialized carbon capture technology that removes carbon dioxide from the atmosphere and then converts it into fuel. *See Air to Fuels,* CARBON ENGINEERING, https://carbonengineering.com/about-a2f/.

sea waters.[38] The pumping of limited nutrients such as fixed nitrogen or iron into the ocean would act as ocean fertilizers, which would increase the rate of carbon transfer.[39] However, in addition to it being a slow process, this option is likely to increase the number of dead zones and exacerbate the continued acidification of oceans.[40]

2. Solar Radiation Management

By contrast, solar radiation management (SRM) seeks to reduce the "amount of solar radiation absorbed by the Earth by an amount sufficient to offset the increased trapping of infrared radiation by rising levels of greenhouse gases."[41] SRM is characterized as an adaptive strategy, aimed at reducing the amount of sunlight reaching the Earth by increasing the planetary albedo or by diverting incoming solar radiation.[42] This reduction in solar radiation exerts a cooling effect, thereby artificially reversing temperature increases and therefore potentially reducing the negative impacts associated with warming temperatures.[43]

SRM approaches include surface albedo enhancement, cloud albedo enhancement, space-based systems, and stratospheric sulfur aerosol injections.[44] Surface albedo approaches aim to increase Earth's reflectivity by brightening its surfaces.[45] Since oceans cover most of the planet, land-based surfaces would need to be brightened by four times their current brightness.[46] Increasing the albedo of surfaces can take the form of painting white roofs on buildings, painting roads white, or placing reflective sheeting over deserts.[47] All of these approaches would be fairly costly and would require large-scale deployment throughout the world to be effective.[48] Another option, cloud albedo enhancement, aims to whiten clouds over parts of the ocean by enhancing the cloud condensation nuclei, expanding the droplet surface area, and increasing the lifes-

38 *See* ROYAL SOC'Y, *supra* note 20, at 16–17.

39 *See id.* at 17.

40 *See id.* at 18.

41 Burns, *supra* note 1, at 286; *see also* THE ROYAL SOCIETY, *supra* note 20, at 23 ("[This] class of climate geoengineering methods aims to offset greenhouse warming by reducing the incidence and absorption of incoming solar (short-wave) radiation (often referred to as insolation).").

42 ROYAL SOC'Y, *supra* note 20, at 23.

43 Neil A. Craik & William C. G. Burns, *Climate Engineering Under the Paris Agreement: A Legal and Policy Primer*, CTR. FOR INT'L. GOVERNANCE INNOVATION 2 (Nov. 1, 2016), https://www.cigionline.org/sites/default/files/documents/GeoEngineering%20Primer%20-%20Special%20Report.pdf.

44 ROYAL SOC'Y, *supra* note 20, at 24–36.

45 *See id.* at 24.

46 *See id.* at 24–25.

47 *See id.* at 25–26.

48 *See id.*

pan of clouds.[49] Under this approach, cloud albedo enhancement could be achieved by generating fine particles of sea salt from ocean water and delivering them by aircraft into stratiform clouds.[50] However, cloud albedo enhancement technologies may result in non-uniform effects—weather patterns and ocean currents could respond unpredictably.[51]

Space-based systems require placing reflective mirrors or sun shields in outer space or creating a spacecraft with reflectors in a stationary orbit.[52] These systems serve as an external method of reducing incoming solar radiation.[53] Theoretically, these strategies would reduce the amount of solar radiation entering the planet by reflecting it from outer space.[54] However, due to the huge logistical demands around placing objects in space, it would take several decades before potential deployment.[55] Additionally, cleanup of trillions of debris components potentially spread over 60,000 miles or more in space will prove to be impossible.[56]

Lastly, stratospheric sulfur aerosol injections involve the release of sulfur dioxide gas through sulfate aerosols via "high-flying aircraft, naval guns, or giant balloons,"[57] or even artillery shells and hoses suspended from towers.[58] This method is the most widely discussed climate engineering option because it is cheap to deploy and could prove to be very effective.[59] Under this option, the sulfate particles would scatter light back to space.[60] Once deployed, sulfur aerosol injections could start to reduce global temperatures within one year.[61] Sulfur aerosols can significantly reduce entering solar radiation because their feasible widespread injection could increase the planet's albedo and reflect back a significant amount of sunlight.[62]

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49 *See id.* at 27.

50 *See id.*

51 *See id.* at 28.

52 Burns, *supra* note 1, at 294–95.

53 *See id.*

54 *See id.*

55 *See id.* at 295.

56 This debris could also obstruct spacecraft orbiting the Earth and could potentially lead to collisions in space. *See id.* at 296.

57 *See* Victor, *supra* note 8, at 69.

58 *See* Burns, *supra* note 1, at 289–90.

59 *See id.* at 290.

60 ROYAL SOC'Y, *supra* note 20, at 29.

61 *Id.* at 31.

62 *See id.* at 29–31.

B. *Evolution of Geoengineering as a Climate Change Solution*

1. Geoengineering's Beginning

While geoengineering has received increased attention recently as a solution to climate change, it "is not a new idea."[63] In 1965, the President's Science Advisory Committee (PSAC) sent a report to President Lyndon Johnson, recommending albedo geoengineering methods to counteract the effects of climate change.[64] Specifically, instead of recommending standard emissions reductions, the committee raised the possibility of increasing the reflectivity of the Earth by spreading small reflecting particles over large oceanic areas[65]—marking a jumping off point for geoengineering in general, and solar radiation management in particular.[66]

In the mid-20th century, the United States and the Soviet Union initially explored geoengineering strategies to gain military advantage.[67] These strategies focused primarily on influencing local weather patterns through cloud seeding schemes that aimed to increase precipitation patterns.[68] However, in 1976, the United Nations adopted the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques to bar geoengineering methods used for military advantage in order to "eliminate the dangers to mankind from such use."[69]

As opposed to earlier geoengineering proposals, today's proposals seek to influence weather patterns on a global scale in order to address the growing and widespread harms associated with climate change.[70] However, this larger-scale deployment of geoengineering methods will bring with it the potential for unintended harms.[71]

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63 *See* Victor, *supra* note 8, at 66 (2009).

64 THE ENVIRONMENTAL POLLUTION PANEL PRESIDENT'S SCIENCE ADVISORY COMMITTEE, RESTORING THE QUALITY OF OUR ENVIRONMENT (1965).

65 *See id.* at 127. The committee predicted that even a partial covering would produce a significant change in the amount of reflected sunlight, and that a 1% change in reflectivity would cost only $500 million.

66 *See* Ken Caldeira & Govindasamy Bala, *Reflecting on 50 Years of Geoengineering Research*, 5 EARTH'S FUTURE 10, 10 (2017).

67 *See* Victor, *supra* note 8, at 66.

68 In addition to battlefield advantage, these strategies were also used to enhance crops and lessen the intensity of tropical hurricanes. *See id.*

69 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, Dec. 10, 1976, 1108 U.N.T.S. 151, 153. However, the treaty did acknowledge that environmental modification techniques for peaceful purposes could potentially "contribute to the preservation and improvement of the environment for the benefit of present and future generations." *Id.* at 152.

70 *See* Victor, *supra* note 8, at 67.

71 *See id* at 68.

2. Current Status of Geoengineering Projects

Although most of the world's population is not aware of geoengineering and its implications for climate change, research and debate on the topic have dramatically expanded in recent years.[72] While most geoengineering projects are in the theoretical research stage, corporations and wealthy citizens have fronted a significant amount of the early funding for independent, private projects.[73] In 2012, a rogue American businessman conducted the biggest geoengineering field experiment to date, dumping around 100 tons of iron sulphate into the Pacific Ocean off the west coast of Canada as part of an ocean fertilization scheme.[74] As part of the experiment, the dumped iron was intended to stimulate an artificial plankton bloom in which the large amount of plankton could absorb greater quantities of carbon dioxide as they sink to the bottom of the ocean.[75]

Some research institutions have begun the process of transitioning from merely creating models and simulations to conducting field experiments.[76] For example, a Harvard research group hopes to launch its Stratospheric Controlled Perturbation Experiment (SCoPEx) soon, which would involve a high-altitude balloon that sprays reflective particles, such as calcium carbonate or sulfates, into the atmosphere.[77] In 2019, the Harvard research group formed an advisory committee tasked with ensuring that the SCoPEx researchers take into account health and environ-

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72 FARBER & CARLARNE, *supra* note 28, at 244.

73 For example, Bill Gates has donated $4.5 million to various solar radiation management research projects. *See* Eli Kintisch, *Bill Gates Funding Geoengineering Research*, SCI. MAG. (Jan. 26, 2010, 2:10 PM), https://www.sciencemag.org/news/2010/01/bill-gates-funding-geoengineering-research.

74 Martin Lukacs, *World's Biggest Geoengineering Experiment 'Violates' UN Rules*, GUARDIAN (Oct. 15, 2012, 6:34 PM), https://www.theguardian.com/environment/2012/oct/15/pacific-iron-fertilisation-geoengineering. This experiment garnered uproar from environmentalists, civil society groups, and lawyers who claimed that it contravened two UN conventions—the UN Convention on Biological Diversity and the London Convention on the dumping of wastes at sea. *See id.* This controversy sparked a resolution to amend the London Convention so that it prohibits ocean fertilization experiments and other marine geoengineering techniques. *See infra* note 89 and accompanying text.

75 *See* Lukacs, *supra* note 74.

76 Some scientists believe that the value of models is diminishing. For some geoengineering technologies, outdoor experiments must be conducted because they go "beyond what can be learned from the natural analogues of explosive and effusive volcanic eruptions." Caldeira & Bala, *supra* note 66, at 15 ("We do not believe a cogent argument can be made that the experiments . . . present more direct risks than thousands of other activities undertaken every day."). *Id.*

77 Keutsch Research Group, *SCoPEx Science*, HARV. U., https://projects.iq.harvard.edu/keutschgroup/scopex.

mental risks and incorporate feedback from other scholars and researchers.[78]

C. Potential Legal Frameworks

Currently, no clear legal framework exists for regulating potential geoengineering projects. This gap is primarily due to the diverse array of geoengineering methods, the cross-border nature of their anticipated benefits and harms, and the fact that they touch upon many different subject areas of law.[79]

1. International Agreements

While an international treaty seems like the obvious solution, especially given the transboundary nature of geoengineering, there are many potential barriers.[80] First, many international treaties regarding climate change have not been effective, largely due to their non-binding nature.[81] In 2019, President Trump officially initiated the United States' withdrawal from the Paris Agreement—a voluntary global agreement in which over 200 countries pledged to reduce their greenhouse gas emissions.[82] In the absence of global leadership by the United States, other nations have opted for less onerous emissions-reduction targets.[83] Second, climate change poses a collective action problem—since no nation can solve the issue independently, all nations must work together to reduce emissions.[84] However, some nations will experience the adverse effects of climate change less than others, and thus will be far less motivated to cooperate and take action.[85]

Recently, existing international treaties have expanded and adapted to include moratoriums on geoengineering. Specifically, in 2010, the

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78 James Temple, *Geoengineering is very Controversial. How can you do experiments? Harvard has some ideas*, MIT TECH. REV. (July 29, 2019), https://www.technologyreview.com/s/614025/geoengineering-experiment-harvard-creates-governance-committee-climate-change/.

79 *See* Jane A. Flegal, Anna-Maria Hubert, David R. Morrow, & Juan B. Moreno-Cruz, *Solar Geoengineering: Scientific, Legal, Ethical, and Economic Frameworks*, 44 ANN. REV. ENV'T & RES. 399, 416–17 (2019).

80 Squillace, *supra* note 11, at 902 ("[I]t seems unrealistic to think that an effective and comprehensive climate change agreement can be adopted at the international level within the roughly ten-year time frame for action before we are forced to face some of the more serious and possibly irreversible consequences of climate change.").

81 Steven Cohen, *The Irrelevance of Global Climate Talks*, AM. Q. (July 24, 2013), https://www.americasquarterly.org/fulltextarticle/the-irrelevance-of-global-climate-talks/.

82 Lisa Friedman, *Trump Serves Notice to Quit Paris Climate Agreement*, N.Y. TIMES (Nov. 4, 2019), https://www.nytimes.com/2019/11/04/climate/trump-paris-agreement-climate.html.

83 *See id.*

84 *See* Squillace, *supra* note 11, at 900.

85 *Id.*

Conference of Parties to the Convention on Biological Diversity adopted a resolution temporarily banning all climate-related geoengineering activities that may affect biodiversity "until there is an adequate scientific basis on which to justify such activities."[86] While 196 nations have ratified the Convention on Biological Diversity, the United States has not.[87] However, the Marine Protection, Research and Sanctuaries Act (MPRSA), which implements the United States' requirements under the London Convention, restricts dumping of pollutants into the high seas and creates a regulatory program to govern the release of materials into the marine environment that might harm its health or resilience.[88] In 2013, the parties to the London Convention, including the United States, adopted an amendment which barred the placement of material into the sea from "vessels, aircraft, platforms or other man-made structures at sea for *marine geoengineering activities*" unless authorized by permit.[89] As it relates to the United States, these recent developments in international law seem to only restrict geoengineering methods that would adversely affect the marine environment, like ocean iron fertilization.

2. Domestic Statutes

In terms of U.S. domestic policy, even when dealing with serious social issues, political change is slow and "government action usually proceeds incrementally."[90] Lawmakers' response, or lack thereof, to the pervasive issue of gun violence in our country is the latest example.[91] However, climate change is inherently different—it's a ticking time bomb with a fast-approaching deadline.[92] In 2018, the Intergovernmental Panel on Climate Change declared that the world has only twelve years left to stop global temperature increases of more than 1.5 degrees Celsius

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86 Convention on Biological Diversity, Conference of the Parties Decision X/33 on Biodiversity and Climate Change (Oct. 29, 2010), *available at* https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-33-en.pdf.

87 Catherine Klein, *New Leadership Needed: The Convention on Biological Diversity*, 31 EMORY INT'L L. REV. 135, 138–39 (2016).

88 Marine Protection, Research, and Sanctuaries Act of 1972, 16 U.S.C. § 1431 (1972).

89 London Convention, Resolution LP.4(8): On the Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and Other Marine Geoengineering Activities (Oct. 18, 2013) (emphasis added).

90 Squillace, *supra* note 11, at 902.

91 Mike DeBonis, *Hard-Charging Democrats' Cautious Strategy on Gun Control Reflects Limits of Political Change*, WASH. POST (Feb. 27, 2019, 4:00 PM), https://www.washingtonpost.com/politics/hard-charging-democrats-strategy-on-gun-control-reflects-limits-of-political-change/2019/02/27/a1245d54-39eb-11e9-a2cd-307b06d0257b_story.html ("On gun control, leading Democrats are instead talking about incremental steps . . . . Even so, the bills are unlikely to receive consideration in the Senate, where Republicans have a 53-seat majority and legislation typically needs 60 votes to pass.").

92 Michael H. Fuchs, *The Ticking Bomb of Climate Change is America's Biggest Threat,* GUARDIAN (Nov. 29, 2018, 9:56 AM), https://www.theguardian.com/commentisfree/2018/nov/29/ticking-bomb-climate-change-america-threat.

above pre-industrial levels—the point at which irreversible sea level rise, widespread food shortages, and massive coral reef die-offs begin to occur.[93] Thus, climate change demands swift action; incremental change simply will not suffice. Unfortunately, most U.S. environmental legislation has been enacted incrementally.[94] While the incremental approach can produce real success, it only does so over a long period of time.[95] If we fail to address climate change quickly, "we may hit a tipping point that will make it impossible to restore the natural order."[96]

When the current political climate is factored into these challenges, the chances of the United States enacting new climate change-related geoengineering legislation before the twelve-year deadline become even slimmer. And even assuming a new international treaty on geoengineering is feasible, adherence and cooperation are likely to be minimal. Therefore, it is highly probable that future geoengineering technologies will be regulated under existing environmental statutes.

II. APPLICABILITY TO U.S. ENVIRONMENTAL STATUTES

Geoengineering relies on a radically different assumption about the relationship between humans and the environment than do existing federal environmental statutes. Specifically, geoengineering operates under the assumption that human activity can fix and counteract climate change through man-made technologies and human intervention.[97] In contrast, federal environmental statutes in the United States are premised on the notion that human activity has destroyed the environment and is responsible for much of today's environmental pollution.[98] Therefore,

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93 *See* ROYAL SOC'Y, *supra* note 20, at ix, 9; Chris Mooney & Brady Dennis, *The World has Just Over a Decade to Get Climate Change Under Control, U.N. Scientists Say*, WASH. POST (Oct. 7, 2018, 9:00 PM), https://www.washingtonpost.com/energy-environment/2018/10/08/world-has-only-years-get-climate-change-under-control-un-scientists-say/ ("[T]he report clearly documents that a warming of 1.5 degrees Celsius would be very damaging and that 2 degrees—which used to be considered a reasonable goal—could approach intolerable in parts of the world.").

94 *See generally* Cary Coglianese & Jocelyn D'Ambrosio, *Policymaking Under Pressure: The Perils of Incremental Responses to Climate Change*, 40 CONN. L. REV. 1411 (2008).

95 For example, the Clean Air Act and the Clean Water Act were both enacted via the incremental approach. While both were largely successful in reducing air and water pollution, progress took significantly longer than anyone anticipated at the time of enactment. *See* Squillace, *supra* note 11, at 902–04.

96 *Id.* at 903.

97 Adam Corner, Karen Parkhill, Nick Pidgeon & Naomi E. Vaughn, *Messing with Nature? Exploring Public Perceptions of Geoengineering in the UK,* 23 GLOB. ENV'T CHANGE 938, 939 (2013).

98 Clean Air Act, 42 U.S.C. § 7401(a)(2) ("The Congress finds that the growth in the amount and complexity of air pollution brought about by urbanization, industrial development, and the increasing use of motor vehicles, has resulted in mounting dangers to the public health and welfare . . . ."); National Environmental Protection Act of 1969, 42 U.S.C. § 4331(a) ("The Congress, recognizing the profound impact of man's activity on the interrelations of all

geoengineering necessarily reverses a key approach to environmental law, which will undoubtedly pose a structural impediment when applying geoengineering projects to existing federal environmental statutes.

While it is possible to squeeze various geoengineering methods into many of the existing U.S. environmental statutes, a narrow focus on the Clean Air Act and the Clean Water Act will illuminate the challenges of applying climate modification technologies to traditional environmental legislation approaches. A further reason for confining the domestic framework analysis is that some scholars believe that the Clean Air Act and Clean Water Act are the most likely statutory bases for legal challenges against climate engineering projects.[99]

A. *Clean Air Act (CAA)*

The Clean Air Act (CAA) sets out the Environmental Protection Agency's (EPA) responsibilities for protecting the nation's air quality through emissions reductions standards.[100] The CAA provides a suitable statutory basis for claims against geoengineering proponents for a number of reasons. First, the EPA has already determined that the CAA applies to greenhouse gas emissions.[101] Second, in 2009, the EPA found under Section 202(a) of the CAA that greenhouse gas emissions threaten the welfare of the public and future generations.[102] Because the EPA has taken steps to reduce greenhouse gas emissions, some commentators argue that these actions are evidence that the EPA might take an "expansive view of the Clean Air Act's applicability to other activities that might alter climate processes," including geoengineering schemes.[103]

1. Sulfur Aerosol Injections Under the CAA

Under regulations interpreting the Clean Air Act, major *stationary sources* of greenhouse gas emissions (GHG) must acquire Prevention of Significant Deterioration or New Source Review permits for producing such emissions.[104] A stationary source means "any building, structure, facility, or installation which emits or may emit any air pollutant."[105] A stationary source is major if it is "any stationary facility or source of air

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components of the natural environment, particularly the profound influences of population growth, high-density urbanization, industrial expansion, resource exploitation, and new and expanding technological advances . . . .").

99 *See* Hester, *supra* note 2, at 876, 881–82.

100 *Clean Air Act Overview*, ENVIRONMENTAL PROTECTION AGENCY, https://www.epa.gov/clean-air-act-overview/clean-air-act-text.

101 *See* Hester, *supra* note 2, at 876.

102 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).

103 *See* Hester, *supra* note 2, at 876.

104 42 U.S.C. § 7411(b), (c), (f) (2018); 40 CFR § 52.21 (2011)

105 42 U.S.C. § 7411(a)(3) (2018).

pollutants which directly emits, or has the potential to emit, one hundred tons per year or more of any air pollutant."[106]

Stratospheric sulfur aerosol injections—a form of solar radiation management—may qualify as a release of air pollutants prohibited by the CAA. Under Section 109 of the CAA, the EPA must publish regulations prescribing National Ambient Air Quality Standards (NAAQS) for certain air pollutants.[107] The EPA has deemed sulfur dioxide as one of the six criteria air pollutants explicitly governed by the CAA.[108] Additionally, sulfur particles may fall under another enumerated criteria air pollutant: particulate matter.[109] Therefore, the sulfur dioxide-related SRM technologies could be regulated as multiple criteria pollutants under the NAAQS provisions of the CAA.

Moreover, stratospheric sulfur aerosol injections may also implicate the ozone depletion provisions of the CAA.[110] Injecting sulfur particles into the atmosphere could harm the recovery of the ozone layer by "catalyzing chemical reactions that deplete ozone."[111] It is estimated that sulfur aerosol injections could potentially delay recovery of the ozone layer by at least thirty years.[112] Under the CAA, the EPA is permitted to regulate emissions of ozone depleting substances so that the United States continues to meets its commitments under the Montreal Protocol.[113] According to Title VI of the CAA, the EPA must add "any substance with an ozone depletion potential (ODP) of 0.2 or greater to the list of Class 1 substances" and must add any other substances that could harm the stratosphere to the list of Class 2 substances.[114] Once added to the list, the EPA can implement emissions reduction standards and control the distribution and use of such substances.[115]

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[106] 42 U.S.C. § 7602(j) (2018).

[107] 42 U.S.C. § 7409(a)(1)(A) (2018).

[108] *Criteria Air Pollutants*, ENVIRONMENTAL PROTECTION AGENCY, https://www.epa.gov/criteria-air-pollutants.

[109] *Id.*

[110] KELSI BRACMORT, RICHARD LATTANZIO, CONG. RSCH. SERV., GEOENGINEERING: GOVERNANCE & TECHNOLOGY POLICY 25 (2013).

[111] Burns, *supra* note 1, at 291 ("Recent studies indicate that geoengineering schemes that would enhance aerosol loads in the atmosphere could result in global annual mean decreases of the ozone column of 4.5% more than the annual global mean decreases associated with ozone depleted substances in the early part of this century.").

[112] *See id.*

[113] *Ozone Protection Under Title VI of the Clean Air Act*, ENVIRONMENTAL PROTECTION AGENCY, https://www.epa.gov/ozone-layer-protection/ozone-protection-under-title-vi-clean-air-act.

[114] BRACMORT, *supra* note 110, at 25; 42 U.S.C. § 7671a (2018).

[115] *See* 42 U.S.C. § 7671g (2018).

Further, stratospheric sulfur aerosol injections could also be regulated under the CAA for contributing to the formation of acid rain.[116] Title IV of the CAA requires the EPA to regulate emissions of precursor pollutants—like sulfur dioxide—that might contribute to the formation of acid rain.[117] However, it may be possible for geoengineering experimenters to receive permits through the EPA's market-based auction system, similar to a cap and trade system, which would allow them to emit sulfur dioxide for a specified fee.[118]

However, even if certain SRM techniques are regulated for emitting criteria pollutants, causing ozone depletion, or contributing to acid rain, they may still escape regulation because the CAA regulates emissions via the *mechanism* used to pollute. While it is possible that 100 tons of sulfur particles per year could be released through potential SRM projects,[119] it is unclear whether aircrafts or large balloons would fall under the CAA's "stationary source" definition.[120] Some proposals for sulfate dispersion 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."[121] These proposals may trigger the CAA permitting requirements if the stationary generators emit enough sulfur dioxide to constitute a major source.[122] Alternatively, aircrafts and balloons might better fall under the CAA's mobile source program,[123] although this program has typically only governed emissions from motor vehicle engines.[124]

Further challenges arise when the purpose and history of the CAA's application are accounted for. The CAA has typically only applied to activities that deteriorate and pollute the environment, not activities that seek to improve the health of the atmosphere and environment.[125] Addi-

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116 Title IV of the CAA recognizes that sulfur emissions are a principal source of acid rain and are precursors to acid rain if emitted at large quantities in the atmosphere. *See* 42 U.S.C. § 7651(a)(2) (2018).

117 *See* 42 U.S.C. § 7651(b) (2018).

118 *See* Hester, *supra* note 2, at 879 n. 126.

119 To constitute a major stationary source, a source must emit more than 100 tons of regulated pollutants per year. 42 U.S.C. § 7602(x) (2018).

120 However, since the Supreme Court has adopted a deferential standard to review agency decisions, it is possible that the Court could find it reasonable for the EPA to categorize aircrafts or balloons as stationary sources under the CAA. *See* Chevron U.S.A., Inc. v. Natural Res. Def. Council, 467 U.S. 837 (1984).

121 *See* Hester, *supra* note 2, at 878.

122 *See id.*

123 42 U.S.C. § 7521(a)(1) (2018) ("The Administrator shall by regulation prescribe . . . standards applicable to the emission of any air pollutant from any class or classes of new motor vehicles or new motor vehicles engines . . . .").

124 *See* Hester, *supra* note 2, at 879.

125 42 U.S.C. § 7401(a)(2) (2018) ("[T]he growth in the amount and complexity of air pollution brought about by urbanization . . . and the increasing use of motor vehicles, has resulted in mounting dangers to the public health and welfare.").

tionally, the EPA has treated activities aimed at achieving positive environmental impacts differently than pollution-emitting activities.[126] For example, the EPA has declined to trigger the CAA's permitting requirements for release of "pollutants" for the U.S. Forest Service's deliberate discharge of fire retardant chemicals into the air to combat wildfires.[127] SRM techniques that release sulfur dioxide into the atmosphere to counteract the harmful effects of climate change could, similar to fire retardant chemicals, fail to trigger the CAA's rigid requirements.

2. Other Geoengineering Methods Under the CAA

CDR approaches, such as ocean fertilization and enhanced weathering, as well as SRM approaches, such as space-based systems and cloud albedo enhancement, would likely not be regulated under the CAA because they do not involve the release of a marked amount of any air pollutant.[128] And, given the challenges described above, it is unclear whether stratospheric sulfur aerosol injections—which are likely to produce the most adverse effects out of the geoengineering approaches[129]—can be regulated under the CAA at all.[130] To make matters worse, geoengineering approaches that are not regulated under the CAA could potentially produce harmful effects as well.[131] For example, cloud albedo enhancement could significantly change precipitation patterns.[132]

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[126] *See* Hester, *supra* note 2, at 877.

[127] *See id.* at 877 n. 126.

[128] 42 U.S.C. § 7602(g) (2018). However, carbon dioxide sequestration—a form of carbon dioxide removal—has recently been regulated under the CAA. In 2010, the EPA relied on Section 307(d) and 114 of the CAA to promulgate a rule requiring the reporting of greenhouse gas emissions from carbon dioxide injection and geologic sequestration. *See* Environmental Protection Agency, Federal Requirements Under the Underground Injection Control (UIC) Program for Carbon Dioxide (CO_2) Geologic Sequestration (GS) Wells Final Rule," 76 C.F.R. pt. 124 (2011); *see also* CONG. RSCH. SERV., at 25 (explaining that the EPA issued a rule regulating CO_2 injection under the CAA for the purposes of geological sequestration).

[129] A recent study concluded that if SRM is suddenly terminated, "The climate suppression has been only temporary . . . the now-CO_2-loaded atmosphere quickly bites back, leading to severe and rapid climate change with rates up to 20 times the current rate of warming of ~0.2°C per decade . . . ." *See* Peter G. Brewer, *Evaluating a Technological Fix for Climate*, 104 PROC. NAT'L ACAD. SCI. 9915, 9915 (2007).

[130] *See supra* Section II.A.1.

[131] Harmful side effects include delay or reversal of ozone layer recovery, disruption of seasonal weather patterns, and reduction in the food supply, among others. Rachel Kaufman, *The Risks, Rewards and Possible Ramifications of Geoengineering Earth's Climate*, SMITHSONIAN MAG. (Mar. 11, 2019), https://www.smithsonianmag.com/science-nature/risks-rewards-possible-ramifications-geoengineering-earths-climate-180971666/.

[132] One study found that increasing cloud condensation nuclei, a form of cloud albedo enhancement, could produce a significant decrease in precipitation in South America. *See* Andy Jones, Jay Haywood & Oliver Boucher , *Climate Impacts of Geoengineering Marine Stratocumulus Clouds*, 114 J. GEOPHYS. RES. 1, 1 (2009).

B. *Clean Water Act*

The Clean Water Act (CWA) regulates discharges of pollutants or the dispersal of substances into the waters of the United States.[133] Geoengineering projects that impermissibly scatter substances into U.S. waters could trigger the requirements of the CWA.[134] The CWA prohibits the "discharge of any pollutant"[135] into navigable waters without a National Pollutant Discharge Elimination System (NPDES) permit.[136] The CWA prohibits the discharge of any pollutant from a *point source*[137] into navigable waters or from any point source other than a vessel or other floating craft unless the discharger has such a permit or other form of authorization.[138] The permitting requirements of the CWA extend to point sources discharging to internal waters "as well as non-vessel point sources up to 200 miles from the U.S. shoreline."[139] The CWA expressly exempts any discharges from vessels occurring more than three miles from shore from its NPDES permitting requirements.[140]

Private geoengineering proponents that violate the CWA could be subject to civil or criminal prosecution for violating effluent standards.[141] Depending on the mechanism used to disperse the pollutants, an array of geoengineering methods might implicate the CWA, such as carbon capture and storage, stratospheric sulfur aerosol release, marine cloud brightening, and enhanced weathering.[142]

1. Geoengineering Methods Under the CWA

Some geoengineering techniques might fall within the CWA's ambit and therefore mandate that project operators acquire an NPDES permit before discharging pollutants. For example, direct carbon dioxide

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133 *Summary of the Clean Water Act*, ENVIRONMENTAL PROTECTION AGENCY, https://www.epa.gov/laws-regulations/summary-clean-water-act.

134 *See* Hester, *supra* note 2, at 881.

135 "Pollutant" is defined as "dredged soil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water." 33 U.S.C. § 1362(6) (2018). Interestingly, the EPA has defined "pollutant" to include the addition of heat to bodies of water. *See* Hester, *supra* note 2, at 881.

136 *See* 33 U.S.C. § 1342 (2018).

137 Under the CWA, the term "point source" means any discernible, confined, and discrete conveyance, including any pipe, ditch, channel, tunnel conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are discharged. 33 U.S.C. § 1362(14) (2018) (emphasis added).

138 33 U.S.C. § 1311(a), 1362(12) (2018).

139 Albert C. Lin, *US Law*, *in* CLIMATE ENGINEERING AND THE LAW 154, 180 (Michael B. Gerrard & Tracy Hester eds., 2018).

140 *See id.*

141 *See* 33 U.S.C. § 1252, 1311–13, 1319 (2018).

142 Lin, *supra* note 139, at 179.

capture may require burying or "discharging" large volumes of captured carbon dioxide underground, which could then seep into groundwater or well systems.[143] Additionally, it is possible that some materials dispersed into the atmosphere, such as sulfur particles under the sulfur aerosol injection option, may end up in U.S. waters.[144] However, it is unclear whether materials released into the atmosphere that are later absorbed by U.S. bodies of water would constitute a discharge from a "point source" that triggers CWA's permitting requirements.[145]

Even uncontroversial SRM techniques, like surface albedo enhancement (i.e., painting roofs white or placing reflective sheeting over deserts), could be subject to the CWA's restrictions if they require alterations to land use or geographic features.[146] Specifically, geoengineering proposals that seek to place large mirrors in deserts or other stretches of land in order to increase surface reflectivity might significantly alter land use.[147] Furthermore, large-scale carbon sequestration that requires the construction of artificial wetlands could also be subject to the CWA.[148] For example, if these proposals call for the release of materials into wetlands within three miles of U.S. shores, the project managers would be required to obtain a permit under the CWA.[149]

However, CDR approaches such as ocean fertilization and enhanced silicate weathering (which require the dispersion of iron, olivine, and other nutrients into U.S. waters) would likely fall outside of the CWA's jurisdiction.[150] While fertilizing agents would likely constitute a biological material sufficient to satisfy the CWA's "pollutant" definition, ocean fertilization and enhanced silicate weathering projects are more likely to be subject to the Ocean Dumping Act[151] than the CWA.[152]

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143 *See* Hester, *supra* note 2, at 882. If direct carbon dioxide capture and storage techniques use geologic sequestration to manage and store the capture carbon dioxide, these activities would likely be regulated under the Safe Drinking Water Act rather than the CWA. *See* 75 Fed. Reg. 77,229 (Dec. 10, 2010) (to be codified at 40 C.F.R. pts. 124, 144, 145, 146, and 147).

144 *See* Hester, *supra* note 2, at 882.

145 *Id.* However, the Sixth Circuit held that pesticide residue that indirectly ends up in navigable waters as a result of pesticide spraying qualifies as a discharge of pollutants from a point source under the CWA, suggesting that sulfur particles released into the atmosphere that indirectly precipitate into navigable waters could similarly qualify as pollutants under the CWA. *See* Nat'l Cotton Council of Am. v. EPA, 553 F.3d 927, 940 (6th Cir. 2009).

146 *See* Hester, *supra* note 2, at 881–82.

147 *Id.*

148 *Id.*

149 *Id.*

150 Lin, *supra* note 139, at 180–81.

151 The Ocean Dumping Act is also known as the Marine Protection, Research, and Sanctuaries Act of 1972. *See supra* Section I.C.1.

152 Lin, *supra* note 139, at 180.

2. Challenges with the CWA

While the CWA offers a broader set of definitions than the CAA, many of the same structural challenges arise when applying geoengineering methods to the CWA. First, similar to the CAA, the deliberate release of materials into United States waters for a positive, curative purpose may not amount to a discharge of a "pollutant" because the "materials are not being discarded."[153] Second, the CWA's permitting requirements are only activated after a discharge from a "point source," which like the CAA requires a triggering mechanism.[154] For geoengineering techniques like stratospheric sulfur aerosol injections, sulfur particles released into the atmosphere may only indirectly precipitate into navigable waters of the United States.[155] It is unclear whether an aircraft, artillery shell, or high-altitude balloon would constitute a "point source," especially if the connection between the vessel or conveyance and the effluent discharge is too attenuated.

Additionally, geoengineering methods that do not release a "pollutant" would not fall under the CWA's jurisdiction because nothing would be "discharged." For example, space-based SRM methods would not trigger the CWA's permitting requirements since the discharge of pollutants is not involved in placing mirrors in outer space.[156] Similarly, cloud albedo enhancement would not be regulated under the CWA because it does not involve the release of a pollutant into navigable waters—salt water particles generated from ocean water are likely not "pollutants" for purposes of the CWA.[157]

The applicability of geoengineering techniques to the requirements of the CWA is uncertain at best. While the CWA can likely capture more geoengineering methods than the CAA, issues will still arise over the particular language of the CWA, namely whether certain methods meet the criteria of "point source," "pollutants," "discharge," and "navigable waters."[158] If certain geoengineering technologies do not fall squarely within the CWA's purview, these technologies may escape regulation and potentially result in a host of deleterious environmental dangers.[159]

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153 *See* Hester, *supra* note 2, at 882.

154 33 U.S.C. § 1362(14) (2018).

155 *See* Hester, *supra* note 2, at 882.

156 Daisy Dunne, *Explainer: Six Ideas to Limit Global Warming with Solar Geoengineering*, CARBONBRIEF (Sept. 5, 2018, 3:11 PM), https://www.carbonbrief.org/explainer-six-ideas-to-limit-global-warming-with-solar-geoengineering.

157 33 U.S.C. § 1362(6) (2018).

158 33 U.S.C. § 1362(6), (7), (12) (2018).

159 *See* Kaufman, *supra* note 131; *see supra* note 11 and accompanying text.

III. PROPOSED DOMESTIC LEGAL FRAMEWORK: THE EFFECTS TEST

Under the current United States environmental legal framework, geoengineering technologies are jumbled, mismatched puzzle pieces that are incongruous with existing statutory mandates and schemes. While some pieces fit, many do not. To make matters more complicated, many geoengineering methods are still ideas, which although in the early stages of development, continue to grow and adapt as research expands.[160] As noted above, existing United States environmental legislation will not capture every geoengineering method, nor will it account for the uncertainties surrounding the field in general.[161] Therefore, geoengineering technologies necessarily require a new, comprehensive legal framework to effectively regulate and monitor their activity, which will involve an unorthodox approach to environmental legislation and rulemaking.

A. *The Proposed Test*

The recent rise of geoengineering technologies calls into question the United States' traditional approach to addressing climate change-related issues. As the Clean Air Act and the Clean Water Act demonstrate, the United States regulates bad environmental actors according to the *mechanism* used.[162] Under the Clean Air Act, polluters are only subject to the Act's requirements if they emit from a major stationary source.[163] Similarly, under the Clean Water Act, effluent dischargers must acquire a permit under the Act only if they release materials from a point source.[164] These requirements are triggered only if the actor uses a specified mechanism when polluting, regardless of whether or not the actor polluted in general.[165]

This approach fails to capture the geoengineering technologies that do not fit neatly into each statute's delineated mechanism. Geoengineering mechanisms are not typical—they are unconventional technologies,[166] like balloons, underground facilities, and gigantic mirrors, that cannot be regulated in the same way as motor vehicles or power plants.

Further, geoengineering legislation will be enacted according to a different understanding about human intervention in the environment. Geoengineering technologies presume that technology and human activ-

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160 Albert Lin, *Geoengineering's Thermostat Dilemma*, 2 L. FUTURE & FUTURE L. 173, 173–74 (2012).

161 *See supra* Part II.

162 *See id.*

163 42 U.S.C. § 7411(a)(3), (b)(1) (2018).

164 33 U.S.C. § 1311(a); 33 U.S.C § 1362(12), (14) (2018).

165 33 U.S.C. § 1312(a) (2018); 42 U.S.C. § 7411(a)(3), (b)(1) (2018).

166 *See* Lin, *supra* note 160, at 173; *see supra* notes 56–57 and accompanying text.

ity can cure the harmful effects of climate change.[167] Existing environmental legislation presumes the opposite: the advent of man-made technology since the Industrial Revolution is the cause of greenhouse gas emissions and consequently, the very reason behind rising global temperatures.[168]

Because of these important distinctions, regulating geoengineering technologies requires a different approach. Due to their different mechanisms and potential consequences, geoengineering methods should be regulated according to the *effects* created by each method. For example, stratospheric sulfur aerosol injections likely would not be subject to the CAA's requirements, even though they involve the emission of harmful pollutants, because the CAA typically does not regulate activities that serve a remedial purpose.[169] Additionally, these aerosol injection technologies would not constitute a stationary source, and it is unclear whether they could be considered a mobile source under the Act.[170] Therefore, under the current legal framework, these geoengineering technologies would largely be free from oversight. Yet, sulfur aerosol injection technologies have very serious ramifications globally and regionally.[171] Stratospheric sulfur aerosol injections could substantially alter Asian and African monsoons, "threatening the food and water supplies of billions of people."[172] Further, sulfur injections could increase sulfate emissions in the atmosphere, which could increase sulfate particulate pollution-related injuries and deaths.[173] Lastly, sulfur injections could also delay decades of progress for ozone layer recovery.[174]

Therefore, geoengineering technologies like sulfur aerosol injections, which could result in an array of harmful effects, should be closely monitored and regulated stringently. On the other hand, geoengineering technologies that are likely to produce minimal adverse effects, like surface albedo enhancement methods and space-based methods, should be subject to less onerous regulations.[175] For instance, space-based systems pose very few dangers and could be extremely effective at managing

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167 *See supra* note 96 and accompanying text.

168 *See supra* note 97 and accompanying text.

169 *See* Hester, *supra* note 2, at 877.

170 *See supra* notes 118–23 and accompanying text.

171 Burns, *supra* note 1, at 290.

172 *Id.* at 290–91. Although much of the research surrounding potential effects of sulfur injections is uncertain, there is empirical evidence for this threat. In 1991, a large volcano erupted, naturally releasing large quantities of sulfur dioxide into the atmosphere. Following this eruption, global rainfall plummeted to 50% lower than the previous low of any year, causing a drought in Southeast Asia. *See id.*

173 *See id.* at 292.

174 *See id.* at 291.

175 *See id.* at 295; *see* ROYAL SOC'Y, *supra* note 20, at 25.

incoming solar radiation.[176] While these technologies are expensive and could take decades to deploy, some geoengineering proponents argue that the potential side effects of space-based systems "would be less significant and more predictable than alternative geoengineering options."[177]

This approach does not presume that regulating geoengineering technologies according to their predicted side effects will be easy. Much of the existing research on the consequences of deploying different geoengineering methods is in its infancy and remains unsettled.[178] However, as climate change continues to progress and its harmful effects continue to worsen, the United States will begin funding climate engineering research and development out of necessity and in response to private actors' involvement in geoengineering projects.[179] Therefore, peer reviewed research on geoengineering technologies is predicted to exponentially rise and become more accurate over the next decade.[180]

CONCLUSION

In the coming decades, legal scholars and practitioners will have the unique opportunity to lay the legal foundation for geoengineering disputes. When the time comes, this decision will have lasting implications on the stability of the Earth's global climate and the safety of its inhabitants. While geoengineering technologies could very well be the cure to the disease,[181] their respective adverse side effects cannot go unnoticed or go unaccounted for. Since research suggests that geoengineering technologies could lead to potentially devastating effects,[182] policymakers and lawyers must work to regulate geoengineering projects according to how dangerous or deleterious the resulting effects are. This way, harmful

[176] Burns, *supra* note 1, at 294–95.

[177] *Id.* at 295.

[178] *Outside/In: Is Geoengineering Crazy Enough to Work, or Just Plain Crazy?*, NHPR (July 17, 2020), https://www.nhpr.org/post/outsidein-geoengineering-crazy-enough-work-or-just-plain-crazy#stream/0.

[179] Some commentators believe that it is time for the United States to create a standing government advisory body tasked with promoting research, encouraging societal discussion, and discussing potential modes of governance. *See* Winickoff & Brown, *supra* note 5, at 80.

[180] *See* Minx, *supra* note 19, at 3 ("Our search query identifies a substantive and expanding body of literature on [negative emissions technologies]. . . . The number of NETs publications has grown exponentially . . . .").

[181] *See generally* David Biello, *Is the Cure (Geoengineering) worse than the Disease (Global Warming)?,* SCI. AM. (July 19, 2010), https://blogs.scientificamerican.com/observations/is-the-cure-geoengineering-worse-than-the-disease-global-warming/.

[182] In particular, some studies demonstrate that solar radiation management options have the potential to increase sub-Sarahan Africa's already hot temperatures, deplete the ozone, and cause acid rain in certain regions of the world. *See* Yanzhu Zhang & Alfred Posch, *The Wickedness and Complexity of Decision Making in Geoengineering*, 5 CHALLENGES 390, 401 (2014).

geoengineering approaches that slip through the cracks of existing environmental legislation can be regulated, while safer geoengineering approaches that fall within the jurisdiction of environmental statutes are subject to less burdensome regulations. While geoengineering may have "hubris written all over it," some geoengineering approaches may prove too desirable and crucial to ignore.[183]

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183 Burns, *supra* note 1, at 304.