Florida State University Journal of Land Use and Environmental Law

Volume 33
Number 1 *Fall 2017*

Article 6

April 2018

Geoengineering: A Promising Weapon or an Unregulated Disaster in the Fight against Climate Change?

J. Brent Marshall

GEOENGINEERING: A PROMISING WEAPON OR AN UNREGULATED DISASTER IN THE FIGHT AGAINST CLIMATE CHANGE?

J. BRENT MARSHALL*

"It seems almost preposterous to buck the trends of holistic systems management and suggest running like the Sorcerer's Apprentice from symptom to symptom. It may also seem as though driving less or cutting fewer trees is simpler than scattering dust particles in the stratosphere. It is certainly more elegant. But when the Damocles' sword of massive biotic disruption is hanging over our heads, we should choose what works."[1]

I. INTRODUCTION

Climate change is increasingly moving towards becoming the most devastating force humanity has ever had to deal with, but legislative and regulatory entities are not keeping pace with the danger.[2] International action has primarily created emission goals,

* J.D. Candidate 2018, Florida State University College of Law.

1. Jay Michaelson, *Geoengineering and Climate Management: From Marginality to Inevitability*, *in* CLIMATE CHANGE GEOENGINEERING: PHILOSOPHICAL PERSPECTIVES, LEGAL ISSUES, AND GOVERNANCE FRAMEWORKS 81, 114 (Wil C.G. Burns & Andrew L. Strauss eds., 2013).

2. Edward A. Parson & Lia N. Ernst, *International Governance of Climate Engineering*, 14 THEORETICAL INQUIRIES L. 307, 308 (2013) ("There is a large and growing gulf between the gravity of threats posed by climate change and the seriousness with which the issue is being addressed. Politically motivated attacks on climate science and scientists notwithstanding, evidence continues to mount of rapid climate changes underway, their predominant cause in human emissions of carbon dioxide (CO2) and other greenhouse gases (GHGs), the likelihood of more extreme changes over coming decades, and the potential of serious and disruptive impacts — many already observable." (footnotes omitted)).

very little has addressed potential efforts to remedy anthropogenic (man-made) climate change, as it increases in severity. Reduction of emission of greenhouse gasses will lessen the progression of climate change. It is also necessary to counteract greenhouse gasses already in the atmosphere through processes called geoengineering.[3] As the domestic and international communities begin to realize the importance of mitigation techniques, implementation must be regulated. Geoengineering technologies are advancing rapidly—the debate must pivot quickly from *the existence of climate change*, to *how to safely regulate its cure*.

This note will first address the most popular types of proposed geoengineering, including the dangers, and the possible outcomes. Second, it will outline regulation of geoengineering: the current laws in place; the policy needs of geoengineering regulation; and finally a proposal which bridges the gap between these.

Anthropogenic climate change began halfway through the eighteenth century during the industrial revolution.[4] Human activities have increased the airborne concentrations of greenhouse gasses, such as carbon dioxide (CO_2), methane, and nitrous oxide, to exceed levels the planet has seen for at least 800,000 years.[5] These changes have been primarily caused by the burning of fossil fuels, the changing ways land is utilized, and agriculture emissions.[6] Some argue that climate change is not anthropogenic, that the warming is natural–gradual occurrence–as a result of the last major glaciation, 18,000 years ago.[7] This claim is disproven by

3. *See* Zahra Hirji, *Removing CO2 From the Air Only Hope for Fixing Climate Change, New Study Says*, INSIDE CLIMATE NEWS (Oct. 6, 2016), https://insideclimatenews.org/news/04102016/climate-change-removing-carbon-dioxide-air-james-hansen-2-degrees-paris-climate-agreement-global-warming.

4. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *Climate Change 2013: The Physical Science Basis* 467 (Thomas F. Stocker et al. eds., 2013), http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf [hereinafter IPCC Climate Change 2013].

5. *Id.*; *Climate Change: How Do We Know?*, NASA GLOBAL CLIMATE CHANGE & GLOBAL WARMING: VITAL SIGNS OF THE PLANET, https://climate.nasa.gov/evidence/ (last updated Oct. 30, 2017).

6. IPCC CLIMATE CHANGE 2013, *supra* note 4, at 2.

7. *See* PATRICK MOORE, *Climate of Fear*, *in* CONFESSIONS OF A GREENSPACE DROPOUT: THE MAKING OF A SENSIBLE ENVIRONMENTALIST (2014) 342, 348, *available at* https://www.epw.senate.gov/public/_cache/files/415b9cde-e664-4628-8fb5-ae3951197d03/22514hearingwitnesstestimonymoore.pdf. *But see Climate Change: How Do We Know?*, *supra* note 5 (attributing modern global-warming trends to human activity); *see also* B.D. Santer et al., *A Search for Human Influences on the Thermal Structure of the Atmosphere*, 382 NATURE 39 (1996); Gabriele C. Hegerl, *Detecting Greenhouse-Gas-Induced Climate Change with an Optimal Fingerprint Method*, 9 J. CLIMATE 2281 (1996); V. Ramaswamy et al., *Anthropogenic and Natural Influences in the Evolution of Lower Stratospheric Cooling*, 311 SCIENCE 1138 (2006); B.D. Santer et al., *Contributions of Anthropogenic and Natural Forcing to Recent Tropopause Height Changes*, 301 SCIENCE 479 (2003).

ice core samples formed over the last 400,000 years.[8] These show that levels of CO_2 historically fluctuate between roughly 180 parts per million (PPM) at the end of an ice age and 280 PPM after a warming period that follows.[9] Temperatures hold a direct correlation to this fluctuation in CO_2 and other greenhouse gasses with linked trends.[10] The earth reached 280 PPM around the turn of the century, but the global levels have now soared over 400 PPM. Thus, the hypothesis that we are currently being subjected to the natural warming of the planet is not viable or intellectually honest. The political argument does not substantially permeate into the scientific community.[11] The earth has been warming drastically since 1880,[12] with the vast majority of warming

---

8. *Climate Change: How Do We Know?*, *supra* note 5 (providing evidence of increased atmospheric CO2 in ice cores since the start of the Industrial Revolution, which are well-above historical, maximum levels).

9. *See id.*

10. *Id.*

11. *See id.*; *see also* John Cook et al., *Consensus on Consensus: A Synthesis of Consensus Estimates on Human-Caused Global Warming*, 11 ENVTL. RES. LETTERS 4, 1–2 (2016), http://iopscience.iop.org/article/10.1088/1748-9326/11/4/048002/pdf (verifying the consensus through six independent studies conducted by the author and co-authors concluding that 90-100% of publishing climate scientists agreed with a 97% consensus previously studied); *Scientific Consensus: Earth's Climate Is Warming*, NASA GLOBAL CLIMATE CHANGE & GLOBAL WARMING: VITAL SIGNS OF THE PLANET, https://climate.nasa.gov/scientific-consensus/ (last updated Oct. 30, 2017) (clarifying that the scientific community is in 97% agreement of the above climate change numbers on an individual basis and worldwide scientific organizations have endorsed this position extensively); *Human-Induced Climate Change Requires Urgent Action*, AM. GEOPHYSICAL UNION: SCI. POL'Y, http://sciencepolicy.agu.org/files/2013/07/AGU-Climate-Change-Position-Statement_August-2013.pdf (last updated Aug. 2013) ("Humanity is the major influence on the global climate change observed over the past 50 years. Rapid societal responses can significantly lessen negative outcomes. . . . Climate models predict that global temperatures will continue to rise, with the amount of warming primarily determined by the level of emissions."); *Climate Change: An Information Statement of the American Meteorological Society*, AM. METEOROLOGICAL SOC'Y, https://www.ametsoc.org/ams/index.cfm/about-ams/ams-statements/statements-of-the-ams-in-force/climate-change/ (last updated Aug. 20, 2012) ("It is clear from extensive scientific evidence that the dominant cause of the rapid change in climate of the past half century is human-induced increases in the amount of atmospheric greenhouse gases, including carbon dioxide (CO2), chlorofluorocarbons, methane, and nitrous oxide."). This note will not address the argument against anthropogenic climate change, the sources in this footnote state the thorough and well documented evidence for it, and the reason why the theory of global warming must now be approached as fact.

12. *See Global Climate Change Indicators: Warming Climate*, NOAA NAT'L CTR. FOR ENVTL. INFO., https://www.ncdc.noaa.gov/monitoring-references/faq/indicators.php (last visited Oct. 30, 2017).

occurring in the past thirty-five years,[13] and temperatures continue to rise even in the face of a solar minimum.[14]

Temperatures themselves do not pose the only threat to the planet. Sea levels rose 6.7 inches in the last century from melting ice.[15] If trends continue as they have for the last two decades, they will rise by 11 to 13.5 inches more in the next eighty years.[16] These rising oceans have also taken on the majority of the heat increase, soaking up as much as 90% of excess heat, and between 0.5 and 1 watt of energy per square meter over the last decade.[17] This heat uptake of oceans is equal to more than 2 X 10^{23} joules of energy, "the equivalent of roughly five Hiroshima bombs exploding every second . . . ."[18] The discussion and discourse in the political sphere can no longer afford to address the existence of scientifically proven anthropogenic climate change. Instead, the domestic and international communities must focus on discussions that address the problems humanity is facing and attempt to address these directly.

There are three primary ways to address anthropogenic climate change. First, initiatives reducing new greenhouse gasses added to the atmosphere. Second, technology aiming to remove those gasses. Third, scientists are researching ways to cool the climate in lieu of the greenhouse gasses released.

---

13. *See* T.C. Peterson & M.O. Baringer, *State of the Climate in 2008*, 90 BULL. AM. METEOROLOGICAL SOC'Y 8, S12 (2009), http://journals.ametsoc.org/doi/pdf/10.1175/BAMS-90-8-StateoftheClimate (explaining that while there have been some outlier years, such as the cool 2008 when the report was written, given the context of the last three decades, the earth has risen in temperature at an astronomical and dangerous rate).

14. Joe Kunches, *We're Entering a 'Solar Minimum' – What it Means, and How It Influenced 2015*, WASH. POST, Dec. 22, 2015, https://www.washingtonpost.com/news/capital-weather-gang/wp/2015/12/22/were-entering-a-solar-minimum-what-it-means-and-how-it-influenced-2015/ (explaining the declining solar output that is associated with a solar minimum, and the implied lower temperatures it would normally bring if not for anthropogenic climate change); *2009: Second Warmest Year on Record; End of Warmest Decade*, NASA GODDARD INSTITUTE FOR SPACE STUDIES (Jan. 21, 2010), https://www.giss.nasa.gov/research/news/20100121/ ("In 2009, it was clear that even the deepest solar minimum in the period of satellite data hasn't stopped global warming from continuing."); J. Hansen et al., *Global Surface Temperature Change*, 48 REVS. GEOPHYSICS RG4004, https://pubs.giss.nasa.gov/docs/2010/2010_Hansen_ha00510u.pdf.

15. *See* John A. Church & Neil J. White, *A 20th Century Acceleration in Global Sea-Level Rise*, 33 GEOPHYSICAL RES. LETTERS L01602, 1 (2006), http://onlinelibrary.wiley.com/doi/10.1029/2005GL024826/epdf.

16. *See id.*

17. Cheryl Katz, *How Long Can Oceans Continue to Absorb Earth's Excess Heat?*, YALE ENV'T 360 (Mar. 30, 2015), http://e360.yale.edu/features/how_long_can_oceans_continue_to_absorb_earths_excess_heat.

18. *Id. See generally* S. Levitus, *Global Ocean Heat Content 1955–2008 in Light of Recently Revealed Instrumentation Problems*, 33 GEOPHYSICAL RES. LETTERS L07608 (2009) http://onlinelibrary.wiley.com/doi/10.1029/2008GL037155/epdf (providing estimates of world ocean warming).

The first method is by far the most popular and most researched, with the United Nations (U.N.) committing to reduced emissions in 2005 via the Kyoto Protocol,[19] and 195 nations adopting the first universal global climate treaty at the Paris Agreement in 2015.[20] These attempts, contrary to the current climate trends, are not failing entirely. The global economy has grown by over 6.5% in the past three years, but the CO_2 emissions stemming from energy generation and transport have stayed level.[21] Global emissions since 1975 have risen every year there was a positive global economy except the late 2010s.[22] Global CO_2 emissions have failed to substantially increase since 2013, the first time a growing global economy has not been met with growing emissions since the start of the industrial revolution.[23] This "decoupling" of emissions and economic growth has been led by the United States (U.S.) and China, who were both able to lower emissions by approximately 1.5% during this time frame.[24] The largest factor in this phenomenon comes from the growths in the renewable energy sector.[25] Renewables only deliver about 10% of global electricity, but as these technologies continue to compete with fossil fuels in economic efficiency, this number will grow quickly.[26]

These trends paint an optimistic picture of humanity solving problems as they are recognized. Unfortunately, these successes are simply not enough. Emissions from fuel combustion have reached a plateau as 32.325 gigatonnes of CO_2 were released in 2014.[27] This can be compared to 13.942 gigatonnes in 1971.[28]

---

19. *See Kyoto Protocol*, UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE, http://unfccc.int/kyoto_protocol/items/2830.php (last visited Oct. 10, 2017).

20. Conference of the Parties, *Adoption of the Paris Agreement*, U.N. Doc. FCCC/CP/2015/L.9/Rev.1 (Dec. 12, 2015). *See also Paris Agreement*, EUR. COMMISSION: CLIMATE ACTION, https://ec.europa.eu/clima/policies/international/negotiations/paris_en (last updated Oct. 30, 2017).

21. Fred Pearce, *Can We Reduce CO2 Emissions and Grow the Global Economy?*, YALE ENV'L 360, (Apr. 14, 2016), http://e360.yale.edu/features/can_we_reduce_co2_emissions_and_grow_global_economy.

22. *Decoupling of Global Emissions and Econ. Growth Confirmed*, INT'L ENERGY AGENCY (Mar. 16, 2016), https://www.iea.org/newsroom/news/2016/march/decoupling-of-global-emissions-and-economic-growth-confirmed.html (explaining that emissions have failed to grow from year to year only during four global events: the oil shock in the late 1970s, the failure of the Soviet Union in the early 1990s, the global economic crisis of the late 2000's, and now the global emission reduction initiatives of the mid 2010s).

23. *Id.*

24. Pearce, *supra* note 21.

25. *See id.*

26. *Id.*

27. INT'L ENERGY AGENCY, *Summary Tables*, *in* CO2 EMISSIONS FROM FUEL COMBUSTION: HIGHLIGHTS 2017, 93, 94 (2017), http://www.iea.org/publications/freepublications/publication/CO2EmissionsfromFuelCombustionHighlights2017.pdf.

28. *Id.*

Reducing and even eliminating release of greenhouse gasses will not reverse damage done up to this point. These cooperative initiatives are also in jeopardy of collapsing. In July of 2017, the U.S. announced withdrawal from the Paris Climate Agreement.[29] Ten governors have renounced this move, and 382 mayors across the nation have vowed to uphold the agreement.[30] This is promising for domestic actions, but internationally it may unravel as the largest CO_2 producer per capita exits. In addition, reduction initiatives may also lack viability, even if they are able to survive. For example, the current average temperatures are caused by emissions in the 1970s, due to a forty-year delay between emissions and climate effect; thus, today's impact will not be felt until the 2050s.[31] It is time for a shift in focus towards the second and third options for addressing anthropogenic climate change, which instead aim at reversal. Carbon dioxide removal (CDR) technologies and solar radiation management (SRM) techniques are conceptual methods of reducing global temperatures–referred to collectively as geoengineering–and may be the only viable options.[32]

II. GEOENGINEERING

Climate policy since the 1980s has focused on mitigation and emission control, but it is nearly impossible for these methods to correct the climate on their own.[33] Geoengineering aims to deliberately manipulate the climate and reverse damage. Efforts to remove CO_2 and directly manage solar radiation are more realistic, long-term goals for addressing this threat.[34]

---

29. Michael D. Shear, *Trump Will Withdraw U.S. From Paris Climate Agreement*, N.Y. TIMES, June 1, 2017, https://www.nytimes.com/2017/06/01/climate/trump-paris-climate-agreement.html.

30. Pam Wright, *More Than 200 Mayors, 10 Governors Denounce Trump's Withdrawal from the Paris Climate Agreement*, THE WEATHER CHANNEL (June 5, 2017, 7:15 AM), https://weather.com/science/environment/news/mayors-governors-denounce-trump-climate-accord-decision; *Climate Mayors Commit to Adopt, Honor and Uphold Paris Climate Agreement Goals*, CLIMATE MAYORS (June 1, 2017), https://medium.com/@ClimateMayors/climate-mayors-commit-to-adopt-honor-and-uphold-paris-climate-agreement-goals-ba566e260097 (with updated signatories as of Oct. 17, 2017).

31. Alan Marshall, *Climate Change: The 40 Year Delay Between Cause and Effect*, SKEPTICAL SCI. (Sept. 22, 2010), https://skepticalscience.com/Climate-Change-The-40-Year-Delay-Between-Cause-and-Effect.html.

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

33. *Id.* at 4 ("[T]here is no realistic scenario under which it would be possible for greenhouse gas emissions to be reduced sufficiently to lead to a peak and subsequent decline in global temperatures this century . . . .").

34. *See id.* at 1.

Geoengineering is not always met with support. The National Academies of Sciences, Engineering, and Medicine have urged lawmakers and the public to continue to reduce emissions, arguing that a dramatic reduction of emissions is necessary, and that there is no replacement for this mitigation.[35] Others lack faith in this potential technology, stating that these "schemes" aiming to reverse or minimize climate changes aren't likely to be successful and could actually worsen the situation.[36] Climate scientists are skeptical of the long-term results from geoengineering, finding that carbon dioxide removal efforts, when modelled over time, will not be able to sequester more than a small amount of CO_2 compared to the cumulative emissions in the atmosphere.[37] Further, even if hypothetical solar radiation management efforts end up causing the necessary change, they have the potential to damage the sky and disrupt ecosystems.[38] Scientists further assert that in order to succeed, SRM efforts would need to be perpetual to combat unsafe levels of greenhouse gasses.[39] If intervention was suddenly discontinued, it could cause a global catastrophe, as carbon is released from the soil rapidly when the temperature rapidly increases.[40] The potential dangers of geoengineering efforts and the dire outlook for the earth if these potential solutions are ignored require action. International regulations need to address risk and exercise caution in the deployment of geoengineering efforts based on the deployment.

A. Carbon Dioxide Removal (CDR)

The most significant greenhouse gasses are: water vapor, CO_2, methane, nitrous oxide, ozone, halocarbons, carbon monoxide, nitrous oxides, non-methane volatile organic compounds, and aerosols.[41] The most commonly released greenhouse gas is CO_2.[42]

35. *Climate Intervention is Not a Replacement for Reducing Carbon Emissions; Proposed Intervention Techniques Not Ready for Wide-Scale Deployment*, NAT'L ACAD. SCI. ENGINEERING & MED. (Feb. 10, 2015), http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=02102015.

36. Charles Q. Choi, *Geoengineering Ineffective Against Climate Change, Could Make Worse*, LIVE SCI. (Feb. 25, 2014 11:40AM), http://www.livescience.com/43654-geoengineering-ineffective-against-climate-change.html.

37. David P. Keller et al., *Potential Climate Engineering Effectiveness and Side Effects During a High Carbon Dioxide-Emission Scenario*, NATURE COMM., (Feb. 25, 2014), at 1, 9, http://www.nature.com/articles/ncomms4304.pdf.

38. *Id.*

39. *Id.* at 6–8.

40. *Id.*

41. U.S. ENVTL. PROT. AGENCY, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS: 1990–2014, at 1–6 to –8 (Apr. 15, 2016).

42. *Id.* at 2–1 to –9.

Efforts seeking to reduce greenhouse gasses in the atmosphere focus on CO_2 because of the substantial role it plays, and because it remains in the atmosphere for a long time once emitted, unlike many of these other gasses.[43] It is possible to at least reduce the speed the planet is warming, even reverse climate change, if CO_2 levels are reduced.[44]

There are two separate categorizations of CDR methods, based on the type of CO_2 being removed and the methods being employed.[45] First, CDR techniques are divided into land-based and ocean-based technologies; second, these methods are biological, physical or chemical in nature.[46] Both methods of categorization are a crucial distinction for a climate scientist, but less important for the devising of regulatory schemes—where the first categorization is far more important.

Land-based systems mimic the natural system of vegetation constantly storing CO_2, which removes approximately 30% of emissions, and semi-permanently stores over twice the carbon in the atmosphere (see Figure 1 below).[47] Some biological land-based CDR systems can be created gently, through implementation of: new policy instruments, economic incentives, and regulatory mandates to foster land-use decisions that sequester CO_2.[48] If emissions are dramatically reduced, then it would be possible for a substantial portion of excess CO_2 to be removed from the atmosphere through natural processes.[49] Nurturing these natural CDR systems could lend a massive help to the battle against climate change. Deforestation and other emissions from land use account for 20% of greenhouse emissions.[50] Widespread utilization of natural systems seems unlikely. Instead, individuals are quickly designing technologies that will serve as CDR systems without the need for biological processes, and without the limits the natural system creates. These technologies will instead capture CO_2 from the ambient air using machines, but are not yet economical or available on a widespread level.[51] Air capture techniques such as

43. THE ROYAL SOC'Y, *supra* note 32, at 1.

44. *Id.* at 9.

45. *Id.*

46. *Id.*

47. *Id.* at 10.

48. Mercedes Bustamante et al., *Co-benefits, Trade-offs, Barriers and Policies for Greenhouse Gas Mitigation in the Agriculture, Forestry and Other Land Use (AFOLU) Sector*, 20 GLOBAL CHANGE BIOLOGY 3270, 3270 (2014).

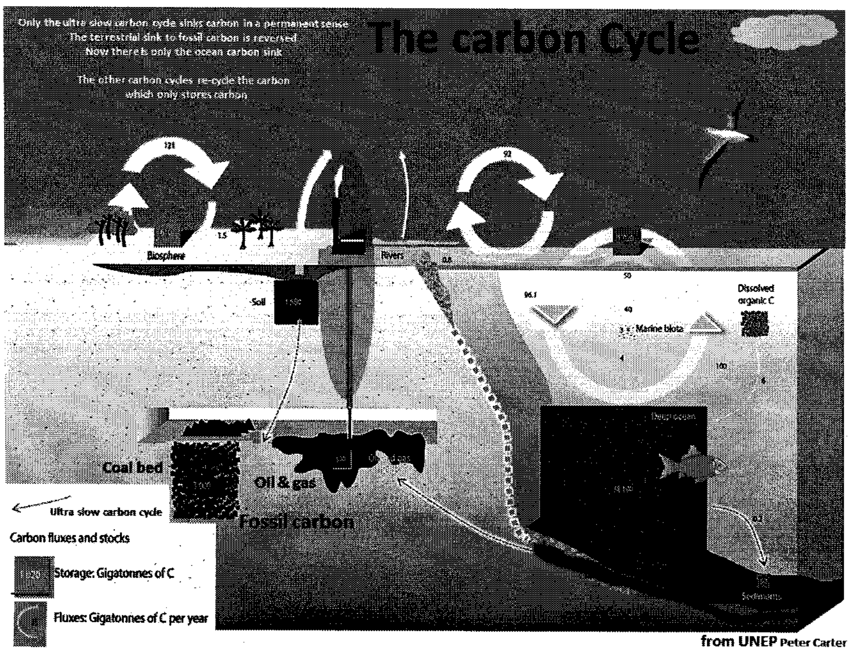
49. Hirji, *supra* note 3 (citing James Hansen et al., *Young People's Burden: Requirement of Negative CO2 Emissions*, 8 EARTH SYS. DYNAMICS 577 (2017)).

50. THE ROYAL SOC'Y, *supra* note 32, at 10.

51. *Id.* at 15; *see* Eli Kintisch, *Can Sucking CO2 Out of the Atmosphere Really Work?*, MIT TECHNOLOGY REVIEW (Oct. 7, 2014), https://www.technologyreview.com/s/531346/can-

these are very safe and are unlikely to require much in the way of regulation,[52] but are also unlikely to be viable in the near future.[53] Looking past land-based systems, ocean-based systems show an alternative.

Figure 1. The Carbon Cycle[54]



Oceans are absorbing most of the heat trapped in Earth's atmosphere from climate change.[55] The oceans are also absorbing

---

sucking-co2-out-of-the-atmosphere-really-work/ (reporting on a Columbia University scientist who has raised twenty-four million dollars in investments for his company, Global Thermostat, to create CO2 sucking towers); Chris Mooney, *The Suddenly Urgent Quest to Remove Carbon Dioxide From the Air*, WASH. POST, Feb. 26, 2016, https://www.washington-post.com/news/energy-environment/wp/2016/02/26/weve-reached-the-point-where-we-need-these-bizarre-technologies-to-stop-climate-change/ (discussing a direct air-capture system that pulls air via fans though a web-like substance that serves as an absorbent membrane for CO2, which is then converted into a carbonate solution and trapped).

52. *See* THE ROYAL SOC'Y, *supra* note 32, at 16 (contrasting ambient air capture from biological methods; biological methods create energy through the generation of fuel, but ambient air methods conversely use energy introduced from an outside source in order to function—this creates a severe economic inequity between the two).

53. Kevin Bullis, *What Carbon Capture Can't Do*, MIT TECHNOLOGY REVIEW (June 16, 2013), https://www.technologyreview.com/s/516166/what-carbon-capture-cant-do/ (explaining that ambient air capture is not just limited by the economic costs of the actual process, but also the infrastructure that would be needed to store the volume of CO2 once it has been sequestered from the air).

54. *Only Zero Carbon Emissions Can Result in the Stabilization of Atmospheric CO2*, ONLY ZERO CARBON, http://www.onlyzerocarbon.org/carbon_dioxide.html (last visited Jan. 1, 2018).

as much as half of the CO_2 released by humans.[56] Some estimate that the areas of the oceans with the most marine life will be more acidic than they have been in five million years.[57] Removing CO_2 from the ocean allows the oceans to absorb more CO_2 from the air, decreases greenhouse effects, and serves to correct pH imbalances.[58] Ocean fertilization is often the first ocean-based solution suggested, largely, because it has been field tested on a big enough scale that some promising results have been measured.[59] This method seeks to hijack the standard cycle of CO_2 circulation between the air, land, water and organisms, in order to force the splitting of CO_2 into carbon and oxygen—creating a decrease in CO_2.[60]

Ocean fertilization methods can be cost-effective, but could create serious safety issues. Ocean fertilization is designed to intentionally manage the marine ecosystem, a complex and misunderstood system of geological, chemical, and biological structures spanning the globe.[61] These efforts could affect weather systems and jeopardize at least a hundred million tons of food a

55. *See supra* note 17 and accompanying text.

56. John Pickrell, *Oceans Found to Absorb Half of Man-Made Carbon Dioxide*, NAT'L GEOGRAPHIC NEWS (July 15, 2004), http://news.nationalgeographic.com/news/2004/07/0715_040715_oceancarbon.html.

57. *Id.*

58. *Id.*

59. *See* Ralph Bodle, *Geoengineering and International Law: The Search for Common Legal Ground*, 46 TULSA L. REV. 305, 305 (2010). *See also* THE ROYAL SOC'Y, *supra* note 32, at 16, 18.

60. THE ROYAL SOC'Y, *supra* note 32, at 16–17 ("Carbon dioxide in the surface ocean rapidly exchanges with the atmosphere, while the transfer of CO2 into the deep sea is much slower. Most of the CO2 being released today will eventually be transferred into the deep sea given an elapsed time of order 1,000 years. [Ocean fertilization aims] to increase this rate of transfer by manipulating the ocean carbon cycle . . . . Carbon dioxide is fixed from surface waters by photosynthesisers—mostly, microscopic plants (algae). Some of the carbon they take up sinks below the surface waters in the form of organic matter composed of the remains of planktonic algal blooms, faecal material and other detritus from the food web. As this material settles into the deep ocean by gravity, it is used as food by bacteria and other organisms. They progressively consume it, and as they respire they reverse the reaction that fixed the carbon, converting it back into CO2, that is re-released into the water. The combined effect of photosynthesis in the surface followed by respiration deeper in the water column is to remove CO2 from the surface and re-release it at depth. This 'biological pump' exerts an important control on the CO2 concentration of surface water, which in turn strongly influences the concentration in the atmosphere. If this mechanism were suddenly to stop operating for example, atmospheric CO2 would increase by more than 100 ppm in a few decades . . . . *The ability of the biological pump to draw carbon down into deeper waters is limited by the supply of nutrients available that allow net algal growth in the surface layer. Methods have been proposed to add otherwise limiting nutrients to the surface waters, and so promote algal growth, and enhance the biological pump. This would remove CO2 faster from the surface layer of the ocean, and thereby, it is assumed (sometimes incorrectly) from the atmosphere.*" (emphasis added) (citations omitted)).

61. *Id.* at 17.

year.[62] Ocean fertilization threatens to increase anoxic regions of the ocean and acidification of the deep ocean (which currently has not been affected nearly as much as the surface).[63] The cheap and dangerous nature of ocean fertilization has led to fears that rogue states or private parties may pursue unregulated implementation.[64] The relative lack of constraints on an individual or organization that would like to begin an ocean fertilization initiative, coupled with the severe implications, highlights the need for some kind of legal oversight of its use.

Another method designed for managing the transfer of atmospheric CO_2 to the deep sea is known as oceanic upwelling and downwelling (see Figure 1).[65] As part of these methods, CO_2 is naturally absorbed at the surface of the ocean, then transferred to the deep sea where it is sequestered.[66] Some proposals aim to force this process at an increased rate, piping water from the deep sea to the surface and vice versa.[67] Unfortunately, increasing the downwelling of water by a million cubic meters is estimated to still have only a marginal effect on CO_2 sequestration and relies on undeveloped piping technologies.[68] The best outcome is only estimated to be approximately 0.02 gigatons of carbon sequestration a year.[69] Regulation is needed not only because funds may be wasted on a fruitless endeavor, but these processes could also have the opposite effect of the intent—instead releasing CO_2 from the deep ocean.[70] A lot more research needs to be completed before these processes can be effectively and safely implemented and regulated.[71]

CDR techniques are already being implemented, and the dangers are tangible, but both the risks and the results are long-

---

62. FISHERIES & AQUACULTURE DEP'T, FOOD & AGRIC. ORG. OF THE U.N. [FAO], THE STATE OF WORLD FISHERIES AND AQUACULTURE 2006, 3 (2007), (showing in Table 1 that total marine production in 2005 was estimated to be 103.1 million tonnes).

63. THE ROYAL SOC'Y, *supra* note 32, at 17–18.

64. Joshua B. Horton, *Geoengineering and the Myth of Unilateralism: Pressures and Prospects for International Cooperation*, *in* CLIMATE CHANGE GEOENGINEERING, *supra* note 1, 168, 168, 171–74; *see generally* Conference of the Parties to the Convention on Biological Diversity [CBD], Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting, Biodiversity and Climate Change, U.N. Doc. UNEP/CBD/COP/DEC/X/33 (Oct. 29, 2010) [hereinafter CBD Decision X/33], https://www.cbd.int/doc/decisions/cop-10/cop-10-dec-33-en.pdf; PLANKTOS ECOSYSTEMS, http://www.planktos.com/ (last visited Oct. 31, 2017) (outlining the goals of a private party created solely to implement ocean fertilization techniques).

65. THE ROYAL SOC'Y, *supra* note 32, at 19.

66. *Id.*

67. *Id.*

68. *Id.*

69. *Id.*

70. *See id.*

71. *Id.*

term in nature. In the future, removal of non-CO_2 gases, such as methane, may even become researchable goals.[72] The law needs to catch up to progress in order to prevent irreparable harm and propel concepts that are proven to show promise. Currently, many researchers have instead turned their attention to insolation management directly—possibly due to the lack of economic viability of these CDR methods.

B. Solar Radiation Management (SRM)

Benjamin Franklin made an observation in 1784 while in Paris. He noticed that the preceding summer was extremely cold both in Europe and back home.[73] This was the result of the Laki volcanic eruptions, which produced an ash cloud in the form of aerosol that likely stretched all the way into the stratosphere and blocked the sun's rays creating record low temperatures during 1783 and 1784.[74] Triggering a volcanic eruption is hardly an answer to climate change, as eruptions also release large amounts of CO_2, ultimately increasing warming.[75] However, the effect of these aerosols binding to water molecules and counteracting the effects of the sun[76] are promising, when addressed separately. Forced SRM efforts have yet to be instituted, but even lawmakers are beginning to take notice of the possibilities. Budget makers in 2016 directed the Department of Energy to begin researching ways to reflect sunlight into space.[77] *The New York Times* has even gone as far as stating that SRM techniques can serve as politicians' "Plan B" after failing to adequately respond to greenhouse gas emissions.[78] However, viewing mainstream and lawmaker attention being drawn to SRM techniques as a saving grace fails to highlight the potential issues: both the danger these various techniques could cause and the harm created by a false hope.[79]

---

72. *Id.* at 21.

73. Benjamin Franklin, *Meteorological Imaginations and Conjectures*, *in* 2 MEMOIRS OF THE LITERARY AND PHILOSOPHICAL SOCIETY OF MANCHESTER 373, 373–77 (2d ed. 1784); Karen Harpp, *How Do Volcanoes Affect World Climate?*, SCI. AM. (Apr. 15, 2002), https://www.scientificamerican.com/article/how-do-volcanoes-affect-w/.

74. Franklin, *supra* note 73 at 373–77; Harpp, *supra* note 73.

75. Harpp, *supra* note 73.

76. *Id.*

77. Adrian Cho, *To Fight Global Warming, Senate Calls for Study of Making Earth Reflect More Light*, SCI. MAG. (Apr. 19, 2016, 4:00 PM), http://www.sciencemag.org/news/2016/04/fight-global-warming-senate-calls-study-making-earth-reflect-more-light.

78. Clive Hamilton, *The Risks of Climate Engineering*, N.Y. TIMES, Feb. 12, 2015, https://www.nytimes.com/2015/02/12/opinion/the-risks-of-climate-engineering.html.

79. *Id.*

The first terrestrial approach of SRM is to increase the albedo of the earth's surface. This essentially means altering the surface of the planet so that instead of absorbing the sun's rays and warming the planet, more of that energy is reflected back into outer space.[80] The leading surface-reflecting SRM approaches have been modelled to potentially reduce the temperature of the planet by up to 1.46°C *after* the global CO_2 level has been doubled and the average surface air temperature increased by 3.0°C above pre-industrial levels.[81] There are a few proposed ways of increasing this albedo and each brings unique regulatory and technological hurdles.

Urban albedo geoengineering is the theoretical outfitting of roofs and roads to reflect energy.[82] In sunnier regions, this reflection could essentially triple-dip by rejecting heat transfer; lowering the energy costs and greenhouse additions from air conditioning;[83] and reducing the petroleum needed to produce asphalt.[84] Approximately three billion people live in urban areas, about 1.2% of the land area.[85] Standard roof materials have an albedo of roughly 0.1–0.25, but different methods and types of roofs can be employed to bring this average to 0.55–0.6.[86] These roofing methods could create the equivalent CO_2 offset of 44 gigatonnes, more than is released yearly at this time.[87] Urban albedo geoengineering would require the appropriate technology and long-term upkeep of the surfaces, but would be equal to $1,100 billion in today's CO_2 trading markets.[88] However, the installment and upkeep costs could be astronomical, and the low coverage would make this method completely unfeasible with today's

---

80. THE ROYAL SOC'Y, *supra* note 32, at 24 n.10 (defining albedo as a value between 0 and 1, with 0 being zero reflectivity and a surface with a value of 1 being perfectly reflective).

81. *See* Peter J. Irvine et al., *Climatic Effects of Surface Albedo Geoengineering*, 116 J. GEOPHYSICAL RES. D24112, 6 (2011), http://onlinelibrary.wiley.com/doi/10.1029/2011JD016281/epdf.

82. *Id.* at 2.

83. THE ROYAL SOC'Y, *supra* note 32, at 25.

84. Kelsi Bracmort & Richard K. Lattanzio, CONG. RESEARCH SERV., R41371, GEOENGINEERING: GOVERNANCE AND TECHNOLOGY POLICY 17 (2013).

85. Hashem Akbari et al., *Global Cooling: Increasing World-Wide Urban Albedos to Offset CO2*, 94 CLIMATIC CHANGE 275, 276 (2009) (verifying estimates with data from Global Rural-Urban Mapping Project's Urban Extent Mask); *see* Ctr. for Int'l Earth Sci. Info. Network et al., *Urban Extents Grid*, *in* GLOBAL RURAL-URBAN MAPPING PROJECT, VERSION 1 (GRUMPv1) (SOCIOECON. DATA & APPLICATIONS CTR.), http://sedac.ciesin.columbia.edu/data/set/grump-v1-urban-extents (last visited Nov. 1, 2017).

86. Akbari et al, *supra* note 85, at 277.

87. *Id.* at 283.

88. *Id.*

technology.[89] Therefore, the regulatory hurdle will be making sure resources are spent on researching cheaper and more practical methods.

Aside from increasing the albedo of homes and roads, some scientists are actively researching attempts to increase natural sources of reflectivity. Reforestation is generally considered for CDR, but forests (and specifically tropical rain forests) can have significant regional cooling effects.[90] However, forests do not hold the most promise, because when trees are replaced with crops, the surface albedo is, generally speaking, increased because of the increased reflective nature of the leaves themselves.[91] This effect can be amplified through legal and regulatory efforts to influence the growing of crops that have a higher albedo effect.[92] Using standard crops, optimizing all cropland on the planet could result in as much as a 0.02–0.08 albedo increase without co-opting non-cropland.[93] Researchers worry that growing of crops simply for albedo benefits could influence the economy or access to food, but some have optimistic views, arguing that a change in the variety of crops could see significant difference.[94] Research into these methods does not have a regulatory body standing in its way or an international body to foster further efforts. Isolating which crops will cool the planet and how is only the first step. Legal bodies are needed to make sure that whenever this "spectral

---

89. THE ROYAL SOC'Y, *supra* note 32, at 25 (calculating the cost of urban albedo to be roughly $300 billion a year, and "one of the least effective and most expensive methods [of geoengineering] considered").

90. *Id.* at 26.

91. *See* H. Damon Matthews et al., *Radiative Forcing of Climate by Historical Land Cover Change*, 30 GEOPHYSICAL RES. LETTERS 2, 4 (2003), http://onlinelibrary.wiley.com/doi/10.1029/2002GL016098/pdf (concluding that the natural spread of agriculture by humanity and the increased albedo that brought has decreased the worldwide temperature by approximately 0.17°C); *see also* Irvine, *supra* note 81, at 2 ("Crop albedo is often higher than the albedo of natural vegetation, for example, barley, at European latitudes, has a higher albedo (0.23) than deciduous (0.18) or coniferous (0.16) woodland.") (referencing JOHN L. MONTEITH & MIKE H. UNSWORTH, PRINCIPLES OF ENVIRONMENTAL PHYSICS (2d ed. 1990)).

92. *See* JOHN L. MONTEITH & MIKE H. UNSWORTH, PRINCIPLES OF ENVIRONMENTAL PHYSICS: PLANTS, ANIMALS, AND THE ATMOSPHERE 337 (4th ed. Elsevier 2013) (showing that, independent of the solar radiation barley is exposed to, carbon sequestration remains constant throughout the day, converting a forest to barley, only as an example, would likely serve to both increase albedo and add a secondary CDR effect).

93. Irvine, *supra* note 81, at 2.

94. Joy S Singarayer et al., *Assessing the Benefits of Crop Albedo Bio-Geoengineering*, 2 ENVTL. RES. LETTERS 045110, 2 (2009), http://iopscience.iop.org/article/10.1088/1748-9326/4/4/045110/pdf ("There also need not be deleterious implications for yield, as increasing the fraction of incoming photosynthetically active radiation (PAR) reflected back by the canopy does not necessarily imply a reduction in total photosynthesis and by inference, productivity.") (referencing Adolfo Rosati et al., *Effects of Kaolin Application on Light Absorption and Disruption, Radiation Use Efficiency and Photosynthesis of Almond and Walnut Canopies*, 99 ANNALS OF BOTANY 255 (2007)).

characterization," aimed at growing "climate-friendly" crops, becomes possible it is able to be integrated into a complete approach.[95] Outside of utilizing the albedo effect of crops, proposals and research are currently looking into methods that won't affect human housing or food supplies.[96]

Systems are being developed and proposed that would increase the albedo of deserts and oceans.[97] Proposals include covering deserts with reflective metal surfaces,[98] and even creating microbubbles placed below the surface of the ocean to raise albedo.[99] Very little has been published regarding ocean methods so far.[100] Some argue however that deserts are perfect for albedo enhancement.[101] Unlike urban centers, deserts are relatively empty; very few people live in these locations, and there is a high solar flux with very low humidity.[102] Deserts make up approximately 2% of the total surface of the Earth,[103] approximately 7.5 million square miles, 4.5 million of which is possibly suited for covering by a reflective surface.[104] Deserts are already the second most reflective surfaces after ice caps,[105] yet covering desert surfaces is estimated to bring their average albedo from 0.36 to approximately 0.8, if done correctly.[106]

Once again, the technology needed to actually carry this out presents a dangerous mix of ineffectiveness, unaffordability, and unpredictability.[107] Only 75% of deserts are "gravel plains, dry lakebeds and mountains," and while deserts such as the Sahara, Arabian, Australian, and Gobi could be potentially used to great benefit, that leaves approximately 1.875 million square miles of

95. *Id.* at 8.

96. *See generally* THE ROYAL SOC'Y, *supra* note 32, at 23–36 (outlining the various SRM methods being developed).

97. *Id.*

98. *Id.* at 26.

99. CAO Long et al., *Geoengineering: Basic Science and Ongoing Research Efforts in China*, 6 ADVANCES IN CLIMATE CHANGE RES. 188, 190 (2015), http://www.sciencedirect.com/science/article/pii/S1674927815000829.

100. THE ROYAL SOC'Y, *supra* note 32, at 26.

101. ALVIA GASKILL, SUMMARY OF MEETING WITH U.S. DOE TO DISCUSS GEOENGINEERING OPTIONS TO PREVENT ABRUPT AND LONG-TERM CLIMATE CHANGE (June 29, 2004), http://www.homepages.ed.ac.uk/shs/Climatechange/Geo-politics/Gaskill%20DOE.pdf.

102. *Id.* (noting that because of the lower humidity in deserts, heat is absorbed much less by water vapor, acting as a greenhouse gas, than in most other places in the world).

103. THE ROYAL SOC'Y, *supra* note 32, at 26.

104. GASKILL, *supra* note 101.

105. *Id.*

106. *Id.*; *see* T.M. Lenton & N.E. Vaughan, *The Radiative Forcing Potential of Different Climate Geoengineering Options*, 9 ATMOSPHERIC CHEMISTRY AND PHYSICS 5539 (2009).

107. THE ROYAL SOC'Y, *supra* note 32, at 26.

desert which we lack the technology to utilize for this approach.[108] In addition to the constraints on which deserts can actually be covered, the costs approach that of urban painting and covering, and could completely disrupt worldwide air circulation and habitat management.[109] In order to completely offset the radiation forcing from post-industrial anthropogenic climate change, approximately 7.9 million square miles would need to be covered.[110] Just to offset proposed climate change from 2010–2070 would require four million square miles of desert, more than can realistically be covered,[111] and would have a price tag of several trillion dollars per year.[112] Nevertheless, this *is* one way that climate change could be seriously mitigated; it would just require worldwide cooperation, for which there is neither precedent nor a governing body. Not all methods of albedo reduction require global cooperation, and this is where governments should begin to worry about regulation.

Benjamin Franklin observed temperature change as a result of volcanic eruption over two hundred years ago,[113] but scientists today are able to study this phenomenon far more in depth. Some experts go as far as to argue that aerosols mimicking volcanoes are one of the only methods of geoengineering that have the potential to cool the planet economically enough be to implemented.[114] Volcanoes inject huge levels of sulfur dioxide (SO_2) gas into the atmosphere between six and thirty-one miles from the surface, in a section of the atmosphere known as the stratosphere.[115] This SO_2 turns into sulfuric acid and forms a cloud of droplets that is able to reflect sunlight back into space.[116] The majority of studies have been done on sulphate aerosols such as SO_2 and hydrogen sulphide (H_2S).[117] Other aerosol techniques are likely to be promising, but at this time the level of research makes discussion on them, let alone implementation, premature.[118] The goal of these sulphate releases is to increase overall albedo of the earth.[119] Scientists estimate that

---

108. *See* GASKILL, *supra* note 101.
109. THE ROYAL SOC'Y, *supra* note 32, at 26.
110. GASKILL, *supra* note 101.
111. *Id.*
112. THE ROYAL SOC'Y, *supra* note 32, at 26.
113. *See supra* note 73 and accompanying text.
114. Alan Robock, *Stratospheric Aerosol Geoengineering*, 38 ISSUES ENVTL. SCI. & TECH. 162, 163 (2014) (citing Lenton & Vaughan, *supra* note 106, at 5539–41).
115. *Id.* at 164.
116. *Id.*; Alan Robock, *Volcanic Eruptions and Climate*, 38 REV. GEOPHYSICS 191, 193–94 (2000), http://onlinelibrary.wiley.com/doi/10.1029/1998RG000054/epdf.
117. THE ROYAL SOC'Y, *supra* note 32, at 29.
118. *See id.*
119. *Id. See also* B. Govindasamy et al., *Geoengineering Earth's Radiation Balance to Mitigate Climate Change from a Quadrupling of CO2*, 37 GLOBAL & PLANETARY CHANGE

reducing solar input by 2% would be able to balance out the warming effect of doubling CO_2 levels, even as CO_2 levels continue to rise.[120]

Regulatory issues surround aerosol deployment, because it is the most discussed dangerous geoengineering technique. Aerosol deployment is unique in that it is likely to be effective, affordable and quick.[121] This worries regulators, because these potentially huge benefits are coupled with potentially catastrophic safety issues.[122] Stratospheric aerosols are predicted to run the risk of hydrologic impacts, stratospheric damage, shifting in tropospheric structures, and damage to biological productivity; however, the technology is so untested that these are merely hypothetical issues.[123] As technology progresses the world will have access to affordable aerosol deployment techniques, and there will exist no practical prerequisite of cooperation before deployment commences.[124] The fear of unilateral deployment by a state is lessened by international law and the way it naturally creates restraints on state actors.[125] However, these restrictions do not apply to non-state actors—they would do little to stop a billionaire "philanthropist" who aims to release sulfates into the air.[126] With

157 (2003) [hereinafter *Quadrupling CO2*] (examining the potential of reducing solar luminosity in order to counteract temperature increases from increasing CO_2).

120. THE ROYAL SOC'Y, *supra* note 32, at 29. *See also* Bala Govindasamy & Ken Caldeira, *Geoengineering Earth's Radiation Balance to Mitigate CO2-Induced Climate Change*, 27 GEOPHYSICAL RES. LETTERS 2141, 2141 (2000) [hereinafter *CO2 Climate Change*] (concluding that doubling CO2 would warm the earth by approximately 1.75 K; the same model shows that a 1.8% reduction of solar luminosity could cool the earth 1.88 K in this "doubled CO2 state"); B. Govindasamy et al., *Impact of Geoengineering Schemes on the Terrestrial Biosphere*, 29 GEOPHYSICAL RES. LETTERS 22, at 18-2 (2002) [hereinafter *Terrestrial Biosphere*] (increasing the estimate from the 2000 levels to a 2.42 K increase from a "doubled CO2 state," curiously though, the same 1.8% reduction in luminosity was modelled to cancel these effects, showing promise for a scalable solution using aerosols).

121. THE ROYAL SOC'Y, *supra* note 32, at 31.

122. *Id.*

123. Robock, *supra* note 114, at 177–81.

124. *Id.* at 165–66.

125. *See* Horton, *supra* note 64, at 171–74 (arguing that states are strongly discouraged from implementing unilateral deployment postures due to a "web of technical and political constraints").

126. David G. Victor, *On the Regulation of Geoengineering*, 24 OXFORD REV. ECON. POL'Y 322, 324 (2008) ("Geoengineering may not require any collective international effort to have an impact on climate. One large nation might justify and fund an effort on its own. A lone Greenfinger, self-appointed protector of the planet and working with a small fraction of the Gates bank account, could force a lot of geoengineering on his own. Bond films of the future might struggle with the dilemma of unilateral planetary engineering."). *See also* Horton, *supra* note 64, at 171–74; David Appell, *The Ethics of Geoengineering*, YALE CLIMATE CONNECTIONS (Dec. 13, 2012), https://www.yaleclimateconnections.org/2012/12/the-ethics-of-geoengineering/ ("For one, it's now clear that deploying SRM by injecting aerosols into the upper atmosphere (stratosphere) would be quite cheap. . . . the anticipated extra climate forcing over the next 50 years could be offset with existing technology at a cost of less than $8 billion per year.").

today's technologies, this deployment could be performed in the ten billion dollar range, a cost predicted to drop drastically in the upcoming decades.[127] The need for continuous injection means that the dangers are not limited to the biosphere. Discontinuation could cause war, and illuminates the need to regulate.[128] Scientist's solutions to this need for continuous injection have begun to look even higher, outside of the atmosphere, at methods that would require only deployment and upkeep.[129]

High above the atmosphere and beyond the reach of any aerosol injections, space-based solar methods of geoengineering would effectively reduce solar radiation by preventing it from ever reaching the atmosphere.[130] As the most theoretical type of geoengineering, many methods have been proposed at low-earth orbit. However for the most part, they attempt to simulate a target solar radiation reduction of 1.7% in order to offset the proposed doubling of CO_2.[131] These hypothetical reflectors must balance the cost of deployment, because the larger they are, the more expensive deployment and launch costs are; but the more these reflectors shrink, the more of them are lost from solar radiation forcing them out of orbit.[132] The most effective methods at reaching this 1.7% goal may be sun-shade deployment at the L_1 Lagrange equilibrium;[133] a spot about a million miles from earth, which has an uninterrupted view of the sun and currently houses the Solar

127. THE ROYAL SOC'Y, *supra* note 32, at 32.

128. Gordon MacKerron, *Costs and Economics of Geoengineering* 23 (Climate Geoengineering Governance, Working Paper No. 013, 2014).

129. *See* Joan-Pau Sánchez & Colin R. McInnes, *Optimal Sunshade Configurations for Space-Based Geoengineering Near the Sun-Earth L1 Point*, 10 PLOS ONE 1, 2 (2015), http://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0136648&type=printable ("Space-based proposals however are not seen as affordable and timely as compared to terrestrial geoengineering techniques, such as stratospheric aerosols. Yet, they do have the fundamental advantage that they do not involve direct manipulation of either the Earth's atmosphere or its surface properties.").

130. THE ROYAL SOC'Y, *supra* note 32, at 32.

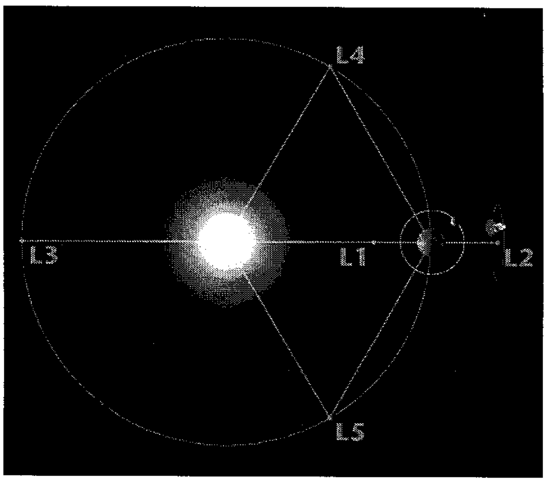
131. *CO2 Climate Change*, *supra* note 120, at 2141; *see* Sánchez & McInnes, *supra* note 129, at 2–3 (listing hypothetical space-based techniques such as: an artificial ring of particles to scatter solar radiation, either synthetized on earth or taken from space objects; and unprocessed space particles which are forced in to clouds circling the earth). *See also* THE ROYAL SOC'Y, *supra* note 32, at 32 (expanding on these potential techniques by including: mirrors circling in random orbits around the earth, deploying as many as 55,000, all with an area as large as 100 m2; a refractor built on the moon using lunar glass; a superfine mesh of metal threads a millionth of a millimeter thick; trillions of thin reflecting discs 50cm in diameter, built from near-earth asteroids; and ten trillion highly refracting discs about 60cm launched into space a million at a time, with one stack every minute for thirty years).

132. *See* THE ROYAL SOC'Y, *supra* note 32, at 32.

133. Sánchez & McInnes, *supra* note 129, at 2–3 (placing a sun-shade at this equilibrium could effectively shade the earth the necessary amount).

and Heliospheric Observatory (see Figure 2[134]) and the Deep Space Climate Observatory.[135] It is theoretically possible to balance the pressure of solar radiation by pushing a sun-shade-structure away from the sun and towards us with the gravitational forces of both the earth and sun in order to keep it balanced and orbiting the sun in the perfect location.[136] The technology to keep such a structure at an ideal location is not contemporaneously available, but the scale of construction is not unheard of—the structure would need to be approximately the size and mass of the Chinese Three Gorges Dam.[137]

Figure 2. Earth's Lagrange Points.



An endeavor such as this could theoretically end anthropogenic climate change, but the regulatory issues shift from protection against reckless development (as seen with aerosols and ocean fertilization) towards a need to foster cooperation and collection of economic, intellectual, and human capital.[138] However, these

---

134. Neil J. Cornish, *The Lagrange Points*, NASA: WMAP MISSION, https://map.gsfc.nasa.gov/mission/observatory_l2.html (last updated Aug. 18, 2012).

135. Elizabeth Howell, *Lagrange Points: Parking Places in Space*, SPACE.COM (Aug. 21, 2017, 9:30 PM), http://www.space.com/30302-lagrange-points.html.

136. THE ROYAL SOC'Y, *supra* note 32, at 32 (further explaining that, unlike other space-based methods, this would not endanger satellites in low-earth orbit).

137. Sánchez & McInnes, *supra* note 129, at 2.

138. *See generally* Shi-Ling Hsu, *Capital Transitioning: An International Human Capital Strategy for Climate Innovation*, 6 TRANSNAT'L ENVTL. L. 153 (2017) (proposing a global, two-pronged strategy of climate change cooperation, the second prong of which aims to build human capital geared towards climate system research to facilitate geoengineering; this strategy can be emulated for the development of a system, such as an L1 located sun-shade in hopes of enabling international cooperation that is deeper than mere economic infusions, and justifiable in the face of the universal threat humanity faces).

methods still need to be regulated in the name of safety, because an L1 sun-shade would require constant adjustment, which would dramatically affect the climate on different regions of earth and potentially create one more level of disagreement.[139] With the various risks and benefits of SRM methods, it is easy to forget that each has one commonality (besides the reflection of solar radiation)—to circumvent the release of fossil fuels. This creates both a risk of, and a regulatory need to, prevent world leaders from either slowing down current measures or reversing them entirely.

There are many possible issues with SRM deployment. These methods could destabilize the biome or the climate; and could damage the economy[140]—both factors that can lead to political unrest.

Aside from these hypothetical issues, the first regulatory need is to device a system that will allow the technology to progress to the stage where these methods work, while not diverting efforts and economic capital from current climate change solutions. One fear is that reversing the *effects* of climate change will make the current emphasis on CO_2 reduction a less important goal.[141] State actors may begin to shift focus away from these efforts as public opinion sees them as less and less urgent.[142] As long as fossil fuels remain the cheapest method of producing energy, the threat of climate change is needed to continue reducing emissions.[143] Geoengineering successes may end up being a detriment if an international regulatory body is not in place to remind lawmakers of the real need; the world could end up a far worse place even if geoengineering efforts are safe and successful.[144] In order to truly discuss a solution, any regulatory body seeking to fulfill this goal must contend with laws already in place.

139. Sánchez & McInnes, *supra* note 129, at 10.

140. *See* THE ROYAL SOC'Y, *supra* note 32, at 34-36.

141. The Editors, *The Hidden Dangers of Geoengineering*, SCI. AM. (Nov. 1, 2008), https://www.scientificamerican.com/article/the-hidden-dangers-of-geoengineering//.

142. *Id.*

143. *Id.*

144. *Id.*; *see* Garrett Hardin, *Tragedy of the Commons*, THE CONCISE ENCYCLOPEDIA OF ECON. (July 19, 2006), http://www.econlib.org/library/Enc/TragedyoftheCommons.html (explaining the concept of tragedy of the commons). The tragedy of the commons provides a backbone for environmental regulation, there is economic incentive to use up everything that is shared, or common; environmental regulations step in to prevent this "tragedy" from occurring. The original problem could be greatly exacerbated by successful geoengineering. Nations and individuals would no longer be incentivized to reduce carbon emissions, if the result of those emissions has been corrected. This could lead to an *increase* of emissions into the atmosphere making geoengineering less effective or impossible. This could put the climate in a far worse position than it currently is.

III. CURRENT GOVERNANCE

A. Domestic Regulations

Geoengineering as a regulatory concept has gone largely ignored, both internationally and domestically; if focus ever shifts within climate change policy however, current laws will initially be used by courts and litigants challenging these actions.[145] Current U.S. environmental strategies focus primarily on mitigation, adaptation, or both.[146] CDR techniques are analogous to mitigation strategies, whereas SRM methods resemble those ideas seeking to adapt.[147] Legislators have begun to evaluate the risks and benefits of geoengineering, at least to peripherally research how the government should proceed, but existing laws will be the first barrier for challenges.[148] Most environmental laws and regulations could allow challenges to these techniques, but the Clean Air Act, Clean Water Act, and Endangered Species Act are the most likely to be called upon.[149]

When Congress passed the Clean Air Act, the emission of aerosols reduced significantly.[150] The Act will still likely open the door for challenges to geoengineering deployment.[151] The Clean Air Act does not offer direct challenges—past challenges to activities that promote healthier atmospheric conditions have not been allowed by the courts.[152] It may nevertheless create a framework and guide for challenges, especially considering the EPA always could amend regulations to allow or discourage these types of actions.[153]

145. Tracy Hester, *Remaking the World to Save It: Applying U.S. Environmental Laws to Climate Engineering Projects, in* CLIMATE CHANGE GEOENGINEERING, *supra* note 1, at 263, 266.

146. *Id.* at 268 nn.15–16; *see* INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: SYNTHESIS REPORT, 56–58 (2007), https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf (explaining the two primary goals of climate change *response*, which naturally are mirrored by regulatory concerns and priorities).

147. *See* Hester, *supra* note 145, at 268 (explaining the nature of CDR and SRM methods).

148. Press Release, House Sci. Space & Tech. Comm. – Democrats, Geoengineering Research Needed, Members Hear (Nov. 5, 2009), https://democrats-science.house.gov/news/press-releases/geoengineering-research-needed-members-hear.

149. Hester, *supra* note 145, at 287.

150. Brett Cherry, *Air Pollution, Geoengineering and Climate Change,* INST. OF HAZARD, RISK AND RESILIENCE BLOG (May 29, 2012), http://ihrrblog.org/2012/05/29/air-pollution-geoengineering-and-climate-change/.

151. Hester, *supra* note 145, at 287–89.

152. *Id.* at 287–92.

153. *Id.*

The Clean Water Act could also affect U.S. based geoengineering techniques. Dispensing of or discharging any pollutants into navigable waters requires a permit under the National Pollutant Discharge Elimination System.[154] While it is technically unclear whether or not iron fertilization in the oceans would classify as a "discharge,"[155] the regulations allow for heat to be included, so there is legislative precedent for a broad interpretation.[156] Further, the guidelines for determining water degradation for ocean discharge specifically list the effect on plankton as part of the measuring criteria, without specifying that the effect be *negative*.[157] Other methods could potentially trigger the Clean Water Act as well, such as the creation of wetlands to sequester CO_2, or the discharge of chemically sequestered carbon in gas or liquid form.[158] The effect on waters may not be important however, if an attempt at geoengineering is going have wide effects on habitats. If this is the case, laws protecting organisms will be the most stringent.[159]

The Endangered Species Act creates strict rules on any actions which may harm an endangered species or destroy habitat.[160] Individuals and agencies hoping to engage in geoengineering are intentionally altering climate patterns, which lessens the burden of proving standing, one aspect of the Endangered Species Act which sometimes makes litigation difficult.[161] Those hoping to challenge actions would still have to prove that the impact actually constituted a "taking" under the Act's language, and show a nexus between the options, but this burden is likely to be satisfied.[162] According to the Government Accountability Office, agencies would be required to consult with at least the Fish and Wildlife Service and NOAA to evaluate any potential impacts in accordance with, not only the Endangered Species Act, but also the local state implementation plan of the Clean Air Act.[163]

---

154. *Id.* at 293.

155. 33 U.S.C. § 1362(16) (2012) ("The term 'discharge' when used without qualification includes a discharge of a pollutant, and a discharge of pollutants.").

156. Hester, *supra* note 145, at 293 ("Notably, the EPA has construed the definition of 'pollutant' to include the addition of heat to water bodies."). *See* 33 U.S.C. § 1342 (2012) (requiring permits for discharge of pollutants); 40 C.F.R. § 122.2 (2017) (defining "pollutant" to include heat).

157. *See* 33 U.S.C. § 1343(c)(1)(A).

158. Hester, *supra* note 145, at 293.

159. *Id.* at 294.

160. *Id.*

161. *Id.*at 295.

162. *Id.*

163. U.S. GOV'T ACCOUNTABILITY OFF., GAO-10-903, CLIMATE CHANGE: A COORDINATED STRATEGY COULD FOCUS FEDERAL GEOENGINEERING RESEARCH AND INFORM GOVERNANCE EFFORTS 30 (2010).

There are many other federal laws which may be used to justify challenges, such as the National Environmental Policy Act and the Marine Protection, Research and Sanctuaries Act.[164] While a wide berth of federal laws touch peripherally on geoengineering concepts, nothing speaks directly, and it appears as if these acts may be the only remedy.

Attempts could be made to challenge geoengineering activity under federal common law, but following the Supreme Court's decision in *American Electric Power Company v. Connecticut*,[165] these challenges may not be possible. The Court ruled that the passing of the Clean Air Act displaced federal common law and prevented any suits for greenhouse gas emissions against corporations under a federal public nuisance claim.[166] As geoengineering becomes more viable and mainstream, it will be important to see how the courts interpret this case. Can reversal of global warming ever be considered a nuisance? If so, how much has this common law been displaced by legislative action? Even if claims are brought, can damages be attributed to these actions? Will a certain amount of nuisance be tolerable for the greater good? These are questions that will need answering as common law challenges are brought and considered. At this time, the admittedly thin network of international regulations is more comprehensive than domestic law.

B. International Regulations

Geoengineering has the possibility and likelihood to influence the climate of the entire planet. Domestic regulations serve only to address those actions with some kind of tie to the U.S. Instead, international law is the obvious solution to regulating these kinds of actions. It has been established that there are no current binding constraints or regulations on the specific actions constituting geoengineering.[167] Currently there are three types of international law that touch on geoengineering: 1) treaties that may apply generally; 2) treaties whose application may depend on

164. Hester, *supra* note 145, at 287.

165. 564 U.S. 410 (2011).

166. *Id.* at 424.

167. THE ROYAL SOC'Y, *supra* note 32, at 40 ("At present international law provides a largely permissive framework for geoengineering activities under the jurisdiction and control of a particular state, so long as these activities are limited in their scope and effects to that state's territory." *But* even without these *specific* restrictions on the actions themselves, ". . . further obligations for environmental protection (i.e., air pollution control, or species and habitat conservation) may apply depending on the nature, size and location of such [geoengineering] activities.").

the method or medium; and 3) customary international law and legal norms that may shape CDR and SRM deployments.[168] The purpose of this note is to propose a fourth category of international law, a form of regulation that would serve not only to apply generally, but also to specific methods and foster new customary international norms.

First, there are a few international treaties that are likely to influence decision-makers regarding research and deployment of geoengineering techniques in a very general sense; these treaties are the starting point for the proposal found here.[169] The most comprehensive and universal attempt to address climate change by the international community can be found in the United Nations Framework Convention on Climate Change (UNFCCC).[170] The UNFCCC has 195 signatory states who have agreed to stabilize greenhouse gas emissions in order to prevent further danger to the climate.[171] These states returned to the discussion table in Kyoto to slabel specific targets just five years later.[172] The members of the UNFCCC have already come together to establish these goals, even if attempts at meeting them have been difficult.[173] The UNFCCC does not explicitly regulate geoengineering methods, but it does serve to offer a foundation for more specific agreements. This function could be easily utilized by a future geoengineering-specific treaty.[174] The goal of the UNFCCC clearly encompasses geoengineering efforts,[175] and while the individual objectives it produces in its current form do not, it may serve as one stepping stone towards a proper framework.

Second, unlike general treaties, more specific treaties may force the international community to prevent implementation of some techniques. The two most feared methods of geoengineering are ocean fertilization methods[176] and aerosol deployment

168. Albert C. Lin, *International Legal Regimes and Principles Relevant to Geoengineering, in* CLIMATE CHANGE GEOENGINEERING, *supra* note 1, at 182, 182.

169. *See id.* at 182–83.

170. *See id.* at 182–85.

171. Karen N. Scott, *International Law in the Anthropocene: Responding to the Geoengineering Challenge,* 34 MICH. J. INT'L L. 309, 314 (2013).

172. *Id.* at 314–15.

173. *Id.* at 316–17 (describing the politics involved as "nasty, brutish and endless," and emphasizing the difficulty in convincing the heaviest emitters to agree to binding emission targets).

174. Lin, *supra* note 168, at 183.

175. United Nations Framework Convention on Climate Change art. 2, May 9, 1992, 1771 U.N.T.S. 107 ("[UNFCCC's objective is to effect] stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.").

176. *See supra* text accompanying note 64.

techniques.[177] The United Nations Convention of the Law of the Sea (UNCLOS) is in place to codify international customary law surrounding the oceans. The UNCLOS requires members to take all measures to prevent the oceans from any pollution harm.[178] This may prevent any ocean fertilization measures that could hurt the ocean, or could compel states to engage in geoengineering methods in order to protect the ocean from the damage of greenhouse gas pollution.[179] In contrast to this undefined obligation, the London Convention (LC) and London Protocol (LP) were designed to regulate the dumping of waste into the ocean,[180] but have been expanded to ban ocean fertilization following attempts at implementation in 2007 and 2012.[181] The danger is that both treaties lack the power to stop a private actor from implementation and lack the ability to force implementation to save the planet.

Like ocean fertilization, aerosol release techniques are particularly dangerous as they are cheap to implement and could catastrophically damage the planet. The Convention on Long-Range Transboundary Air Pollution (LRTAP) is a framework encompassing fifty-one nations.[182] It aims to reduce air pollution, and has been broadly defined to include substances or energy which could have negative effects on air quality.[183] The Montreal Protocol to the Vienna Convention for the Protection of the Ozone Layer (MPVCPOL) requires the member parties to review control measures aimed at restoring the ozone layer every four years.[184] The MPVCPOL restricts the use and production of substances which will deplete the ozone layer.[185] Both treaties fail once again to prevent unilateral aerosol deployment. LRTAP (besides from only having fifty-one member states) will likely fail to regulate aerosol deployment, as studies have shown it will not have an

---

177. *See supra* text accompanying note 121.

178. United Nations Convention on the Law of the Sea, art. 194, Dec. 10, 1982, 1833 U.N.T.S. 397.

179. Lin, *supra* note 168, at 191.

180. *Id.* at 190.

181. Press Release, Umwelt Bundesamt, Geo-Engineering: Commercial Fertilization of Oceans Finally Banned, (Dec. 30, 2013), http://www.umweltbundesamt.de/en/press/pressinformation/geo-engineering-commercial-fertilization-of-oceans (explaining that negotiations were triggered after a corporation named Planktos submitted a 2007 proposal to fertilize the oceans near the Galapagos, which resulted in non-binding controls; in 2012, implementation occurred off the coast of Canada, triggering a ban a year later).

182. Convention on Long-Range Transboundary Air Pollution, art. 1, Mar. 16, 1983, 1302 U.N.T.S. 217.

183. *See id.*

184. Lin, *supra* note 168, at 196.

185. *Id.*

overwhelmingly negative effect on ecosystems.[186] Likewise, the MPVCPOL fails to regulate sulfate aerosols projected for use in geoengineering methods because these chemicals do not reduce ozone; the overall effect *may* reduce ozone slightly through chemical processes, but these chemicals themselves are unlikely to qualify.[187]

Two popular treaties to discuss with regard to geoengineering are the 1967 Outer Space Treaty (OST) and the Convention on Biological Diversity (CBD).[188] Predictions that these will be major road blocks are largely unfounded. [189] The OST is easily navigated regularly with peaceful satellite deployment. The CBD (which notably has banned ocean fertilization techniques like the LC/LP) is non-binding and unlikely to trigger any actual response on its own.[190] The more likely candidate for international response to geoengineering will be through the triggering of international regulatory norms through customary law.[191]

Third, the class of laws containing these norms, known as customary law.[192] Unlike treaties, these norms could create a complete and direct response to unwanted geoengineering deployment. These norms are subjectively deployed (unless established via treaty), but can sometimes restrict behavior of state actors more significantly than treaty-made restrictions when the threat of military deployment becomes a factor.[193] The breathtaking web of international customary law is outside the scope of this note, but there are some international norms most

---

186. Ben Kravitz et al., *Sulfuric Acid Deposition From Stratospheric Geoengineering with Sulfate Aerosols*, 114 J. GEOPHYSICAL RES. D14109, 7 (2009), http://onlinelibrary.wiley.com/doi/10.1029/2009JD011918/epdf ("Analysis of our results and comparison to the results of [other studies] lead to the conclusion that the additional sulfate deposition that would result from geoengineering will not be sufficient to negatively impact most ecosystems, even under the assumption that all deposited sulfate will be in the form of sulfuric acid. . . . Furthermore, our results show that additional sulfate deposition tends to preferentially occur over oceans, meaning the chance of such a sensitive ecosystem receiving enough additional sulfate deposition to suffer negative consequences is very small.").

187. Lin, *supra* note 168, at 195–96.

188. *See generally* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205 [hereinafter Outer Space Treaty]; Convention on Biological Diversity, Dec. 29, 1993, 31 I.L.M. 818, 1760 U.N.T.S. 79.

189. Mika Klaus, *The International Regulation of Geo-Engineering*, SECJURE (Oct. 17, 2016, 12:00 PM), http://www.secjure.nl/2016/10/17/the-international-regulation-geo-engineering/.

190. *Id.*

191. Lisa Dilling & Rachel Hauser, *Governing Geoengineering Research: Why, When and How?*, 121 CLIMATE CHANGE 553 (2013).

192. *See* Lin, *supra* note 168, at 197.

193. *See id.*

likely to be triggered.[194] The obligation to prevent transboundary harm includes an obligation to notify states that may be affected and to consult with them;[195] this concept has been confirmed by the International Court of Justice has a foundation of international law as a whole,[196] and specifically environmental law.[197]

In addition to this general transboundary harm principle, states have a separate obligation to not cause environmental harm to others, and to create necessary safeguards to control any unavoidable harm.[198] If a nation is responsible for causing harm, environmental or otherwise, it is also responsible for mitigating and compensating these harms, and any costs associated.[199] Using domestic environmental and land use law as a guide, this norm may be satisfied by requiring the setting up of a fund in order to settle compensation claims, before any geoengineering deployments even take place.[200] This note has addressed international norms with the least extensive discussion of the three types; this is only due to the sheer complexity of international law, any international solution will need to take into account a web of laws so complex and elusive, it merits its own separate analysis.

IV. REGULATORY NEEDS

A solution to geoengineering regulation will need to: define geoengineering, address crucial policy areas, and foster international cooperation. The most effective solution to this issue is the creation of an international regulatory body, reminiscent of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) in

194. *See id.* at 197–98; Bodle, *supra* note 59, at 305–06. *See generally* Parson & Ernst, *supra* note 2 (explaining thoroughly the concepts of geoengineering and the general regulations regarding implementation, both contemporaneously and in the future); Scott, *supra* note 171; Jay Michaelson, *Geoengineering: A Climate Change Manhattan Project*, 17 STAN. ENVTL. L.J. 73 (1998); Adam D.K. Abelkop & Jonathan C. Carlson, *Reining in Phaëthon's Chariot: Principles for the Governance of Geoengineering*, 21 TRANSNAT'L L. & CONTEMP. PROBS. 763 (2013).

195. Lin, *supra* note 168, at 197–98; THE ROYAL SOC'Y, *supra* note 32, at 40.

196. Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion, 1996 I.C.J. 226, ¶ 29 (July 8).

197. Scott, *supra* note 171, at 333.

198. Lin, *supra* note 168, at 197–98 (citing Stockholm Declaration of the United Nations Conference on the Human Environment, Principle 21, U.N. Doc. A/CONF.48/14/Rev.1 (June 16, 1972)).

199. *Id.* at 198.

200. *Id.*

structure,[201] and drawing from the goals, economic strength, and human capital of the United Nations and specifically the UNFCCC.[202]

A. Defining Geoengineering

There is no universal definition of geoengineering or climate engineering stemming from the fragmented regulatory scheme governing their use. The ban on ocean fertilization by the Convention of Biological Diversity[203] was later followed up with the most comprehensive international legal definition of geoengineering to date.[204] The CBD clarified in the footnote of a later decision that:

> Without prejudice to future deliberations on the definition of geo-engineering activities, understanding that any technologies that deliberately reduce solar insolation or increase carbon sequestration from the atmosphere on a large scale that may affect biodiversity (excluding carbon capture and storage from fossil fuels when it captures carbon dioxide before it is released into the atmosphere) should be considered as forms of geo-engineering which are relevant to the Convention on Biological Diversity until a more precise definition can be developed. It is noted that solar insolation is defined as a measure of solar radiation energy received on a given surface area in a given hour and that carbon sequestration is defined as the process of increasing the carbon content of a reservoir/pool other than the atmosphere.[205]

This definition correctly defines both CDR and SRM techniques, which is essential to any thorough definition; especially when used by any kind of legislative or regulatory organization. Two key issues arise with this definition as a global benchmark though.

First, the inclusion of the word "deliberate" could potentially exclude efforts which aim to accomplish one goal, but unintentionally accomplish another, leaving those unregulated.[206]

---

201. *See infra* text accompanying note 221.
202. *See infra* text accompanying note 220.
203. *See supra* text accompanying note 190.
204. Bodle, *supra* note 59, at 315–17.
205. CBD Decision X/33, *supra* note 64, at 5 n.3.
206. Bodle, *supra* note 59, at 316.

This is a fine solution for the purposes of the COP, but once again, when implemented by a different, hypothetical regulatory body with more control, this exclusion could create unnecessary loopholes. This should be removed, but with care.

The definition of solar insolation is overly broad, and relies on the inclusion of "large-scale," which some scholars have argued is not restrictive enough.[207] The exclusion of small-scale efforts, however, is necessary, and this is illuminated by the definition of solar insolation. There are an incredibly diverse number of activities that could theoretically reduce solar insolation or sequester carbon while affecting biodiversity—from installing solar panels to planting trees, many of these concepts are entirely innocuous. What necessarily forces this definition within the realm of reason is the inclusion of either large-scale or deliberately.

Second, the COP does not address when and how a more precise definition will be developed. The future of this definition is addressed within the decision itself,[208] but not with any kind of closure. This is not an issue that directly impacts future definitions created by the international community. However, it does show the problem with defining geoengineering in this manner. The primary goal in creating a legal framework for geoengineering is to actually authorize a body to define, regulate, and control its use, and this should be the very first step of cooperation.

B. Policy Considerations

To effectively regulate geoengineering, the international community must consider ethical and fairness considerations as well as the need for research management.

The British Royal society consulted a team of ethicists to discuss the ethical implications of geoengineering deployment. The panel identified three main ethical considerations: "consequentialist," holding the value of the outcomes as the

---

207. *Id.*

208. CBD Decision X/33, *supra* note 64, at 1, 5, 7 ("The Conference of the Parties . . . 9. *Requests* the Executive Secretary to: . . . (l) Compile and synthesize available scientific information, and views and experiences of indigenous and local communities and other stakeholders, on the possible impacts of geo-engineering techniques on biodiversity and associated social, economic and cultural considerations, and options on definitions and understandings of climate-related geo-engineering relevant to the Convention on Biological Diversity and make it available for consideration at a meeting of the Subsidiary Body on Scientific, Technical and Technological Advice prior to the eleventh meeting of the Conference of the Parties . . . .").

primary consideration and ethical determinant; "deontological," considering primarily the "right" behavior and less the outcome; and "virtue-based," measuring actions based on the context of arrogance and hubris.[209] Regardless of the label placed on these ethical standpoints, the unifying concepts seem to be consequence and justice. Most concerned parties focus on: how much research is needed before deployment is justifiable; how much harm is acceptable; and whether methods with unequal results are acceptable.[210] The way these questions are answered brings up the issue of fairness. There will necessarily be a power struggle regarding how much decision-making power each state should. Customary international law could solve these power struggles with military action and economic sanctions,[211] but a more reasonable and equitable solution will be needed. A framework to address geoengineering will have to be flexible enough to address these issues of ethics and fairness, but must also be concrete enough to foster appropriate deployment.

It is crucial to regulate the research of geoengineering methods in order to make sure funds are spent appropriately and an organized network of development is achieved. An international framework will need to efficiently decide which methods are justifiable and bring them to deployment. Beyond the efficiency issues is the regulation of large-scale field testing, which crosses the line back into ethical considerations.

Testing geoengineering methods for global deployment is a dangerous endeavor, and could lead to catastrophic damage without even the chance of thorough success. For example, China's Weather Modification Office made the decision to seed clouds with silver iodide to trigger rain, hoping to end a drought. This accidentally triggered the worst blizzard China had seen in five decades, causing $650 million in damage and the deaths of at least forty people.[212] These regional ramifications of climate engineering gone-wrong could easily spread to other countries. An international framework for geoengineering cooperation cannot settle for simply ensuring safe deployment, it must also provide measures for unilateral and multilateral actions with harmful effects. This key policy purpose starts with research management,

---

209. THE ROYAL SOC'Y, *supra* note 32, at 39.
210. *See id.*
211. Lin, *supra* note 168, at 182.
212. Erica C. Smit, Note, *Geoengineering: Issues of Accountability in International Law*, 15 NEV. L.J. 1060, 1060–61 (2015).

ensuring that only the safest technologies are used. This goal ends with a monetary safeguard for when geoengineering ultimately goes wrong.

C. International Cooperative Solution

In the early 2010's the idea started to be suggested that some kind of international treaty may need to be developed, but simply that the time was not yet right.[213] A lot has changed in the past decade: geoengineering has become far more accepted,[214] technologies have advanced considerably,[215] and anthropogenic climate change has become far more severe.[216] Suggested solutions based on developing current norms into a viable framework no longer have a chance at success.[217] Current international law can no longer deal with the looming threat of untested geoengineering, or the current danger of climate change. Notwithstanding these inadequacies, international law *can* be used as a guiding force in creating a functional solution.

The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is a near-universal treaty, constructed as a sign of cooperation between member states.[218] There is a clear analogy between the need for nuclear regulation and the need to regulate climate engineering; both dangers are catastrophic in nature, and require the cooperation of large first-world countries, who are predominately responsible for creating the problem in the first place.[219] A second, crucial element of this institution is the economic and structural complexities. The UNFCCC is unique as

---

213. *See generally* Parson & Ernst, *supra* note 2.

214. Michaelson, *supra* note 194, at 77–78.

215. *See generally* THE ROYAL SOC'Y, *supra* note 32.

216. *See supra* text accompanying notes 11–14.

217. *See* Jesse Reynolds, *The International Regulation of Climate Engineering: Lessons from Nuclear Power*, 26 J. ENVTL. L. 269, 273–74 (2014).

218. Treaty on the Non-proliferation of Nuclear Weapons, Mar. 5, 1970, 7 I.L.M. 8809, 729 U.N.T.S. 161. *See* U.S. DEP'T OF STATE, U.S. DELEGATION TO THE 2010 NUCLEAR NON-PROLIFERATION TREATY REVIEW CONFERENCE [hereinafter U.S. DELEGATION WHITE PAPER] https://www.state.gov/documents/organization/141503.pdf (last visited Nov. 3, 2017).

219. Reynolds, *supra* note 217, at 275–76. *But see* THE ROYAL SOC'Y, *supra* note 32, 37 (suggesting that other collaborations—aimed at positive change rather than averting catastrophe—may be a better match as a guide) ("To overcome this problem, some commentators have suggested forming an international consortium to explore the safest and most effective options, while also building a community of responsible geoengineering researchers, along the lines of other international scientific collaborations, such as the European Organisation [sic] for Nuclear Research (CERN) and the Human Genome Project." (citing WALLACE S. BROECKER & ROBERT KUNZIG, FIXING CLIMATE: WHAT PAST CLIMATE CHANGES REVEAL ABOUT THE CURRENT THREAT – AND HOW TO COUNTER IT, (2009)); David G. Victor, *The Geoengineering Option: A Last Resort Against Global Warming?*, 88 FOREIGN AFF. (2009)).

an international cooperation in eliminating climate change. Further, the UNFCCC, already has an institutionalized procedure for passing further amendments.[220] Many suggest that using this procedure to approve a new protocol is an extreme approach to the issue, but as the world heads toward the end of the decade, the situation needs an extreme solution.[221]

This institution, under the auspices of the U.N., would be able to manage member-state funds to accomplish policy goals through regulation and direct involvement. The issue, while potentially more complex than nuclear non-proliferation, will be well served with a similarly structured solution. The NPT has what is referred to as "three pillars," non-proliferation, peaceful uses, and disarmament.[222] This geoengineering institution similarly needs three pillars to stand on: deployment, research, and response.

First, a committee of member-state representatives need to be responsible for a democratically chosen solution in the face of deployment opportunities. A framework will be necessary to objectively decide when an action should be taken, but even individual deployments should be based on compromise and agreement. This requirement is also needed to promote fairness. International norms currently in place will allow these decisions to be made by the most powerful states. Contemporary treatment of climate change issues by the U.S. shows that single nations cannot be trusted to save the world, no matter how powerful. Serving as a gateway to geoengineering creates potential road blocks to dangerous implementation strategies, but more actions must be taken to reverse climate change.

Second, this institution should have access to a pool of funds to foster research that has the highest viability to cost-effectiveness ratio, to steer academic and human capital towards geoengineering. Like the Paris Accord, this requires a pledge from the developed world to contribute funds; Sections 8 and 9 of Article 9 of the Accord outline how these funds are to be distributed, a very similar procedure can be used to propel geoengineering.[223] The UNFCCC and specifically the Paris Accord are essential models for the development of this second prong, but even with these guides, there is no solution for those affected after inadvertent damage has been done.

---

220. United Nations Framework Convention on Climate Change, *supra* note 175, at art. 15.

221. *See* Reynolds, *supra* note 217, at 273.

222. U.S. DELEGATION WHITE PAPER, *supra* note 218.

223. Paris Agreement art. 9, Dec. 12, 2015, T.I.A.S. NO. 16-1104.

Third, a separate pool of funds should be available and managed by the committee. Serving as an insurance of sorts, state and non-state actors who wish to engage in geoengineering can be compelled to contribute. Of all proposals contained in this Note, this is simultaneously the most novel, and the most likely to be dismissed. It is however also the most important. Increasing the cost of geoengineering through contribution to this fund will serve three purposes. First, it will deter those without the financial strength to properly research and implement technology. Second, it will serve to alleviate public fears of geoengineering gone wrong. Third, it will restore some level of power that the first pillar removed from the most developed of nations. This institution removes a certain amount of decision-making from the most powerful states at the regulatory review step. Through this requirement, this institution will also restore some level of power to those states with deep pockets. Only parties able to afford the proposals to be reviewed will even have the option to deploy, and with that option the power to shape geoengineering progress.

This is not the first proposal to suggest that the UNFCCC, or the NPT, could be used as a framework for geoengineering regulation.[224] Commentators have been careful in the past to avoid pushing for such a radical solution to geoengineering regulation to leave room for gradual change.[225] Gradual change has not come, norms have not shifted into trends, and states have barely reached any agreements on geoengineering. It is time now for drastic action—as the largest economy in the world pulls out of the most successful climate change agreement, the international community no longer has the option to conservatively save the planet.

V. CONCLUSION

The current efforts to regulate climate change are in the process of failing because they require worldwide cooperation and unselfish change in behavior,[226] a situation that the world has arguably never been able to achieve. It is difficult to imagine any level of unanimous cooperation, but the earth stands on a precipice, and the only possible chance at recovery will be a meeting of the minds. Emission reform on its own simply cannot reverse anthropogenic climate change for at least a millennium.[227]

224. Reynolds, *supra* note 217, at 273.

225. *See generally id.;* Michaelson, *supra* note 194.

226. Michaelson, *supra* note 194, at 75–76.

227. Abelkop & Carlson, *supra* note 194, at 764 (citing ROBERT L. OLSON, WOODROW WILSON INT'L CTR. FOR SCHOLARS, GEOENGINEERING FOR DECISION MAKERS 2 (2011).

It is with this fact that humanity stands on its own ledge, lawmakers around the world must make the risky choice to jump—to shape, utilize, research and control geoengineering as a positive force. Any chance at preventing the climate change the world is already condemned to struggle with required the entire planet to have begun cooperating decades ago; the reversal will conversely require action from only a small minority, but cooperation from all. The concept of geoengineering is no longer a pipe dream, or a concept within the realm of science fiction.[228] The continuing convergence of climate-altering technologies and the dire need for a planetary cure *will* lead to geoengineering deployment, and sooner rather than later. The real challenge with geoengineering will be balancing the danger of unregulated efforts with the guaranteed destruction should progress be halted. Humanity has one last, but fortunately optimistic chance to cooperate to save the planet—lawmakers need to muster the courage to jump off that ledge, and the foresight to prepare in every way to make sure it's a jump forward, to safety and a continued future. The solution proposed herein, while dramatic and costly, is one way a continued future can be guaranteed.

228. *See* Michaelson, *supra* note 194, at 77; Michaelson, *supra* note 1, at 81, 113, 114 ("In 1998, I wrote the first law review article advocating geoengineering as a climate change mitigation strategy . . . . At the time, geoengineering was both unknown and unpopular – a seemingly impossible combination, but as soon as anyone heard of it, they disliked it. Twelve years later, the political economy of geoengineering . . . has shifted . . . . Geoengineering is, as the New American Foundation dubbed it, 'a horrifying idea whose time has come.' As Scott Barrett said, geoengineering's "future application seems more likely than not.' It is a matter of simple economics: 'the incentives for countries to experiment with geoengineering, especially should climate change prove abrupt or catastrophic, are very strong. It is also because the incentives for countries to reduce their emissions are weaker.' . . . 'In the end, the debate about geoengineering is largely a debate about what sorts of environmental policies to pursue in an imperfect world. It seems almost preposterous to buck the trends of holistic systems management and suggest running like the Sorcerer's Apprentice from symptom to symptom. It may also seem as though driving less or cutting fewer trees is simpler than scattering dust particles in the stratosphere. It is certainly more elegant. But when the Damocles' sword of massive biotic disruption is hanging over our heads, we should choose what works.'").