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Barometer Rising: The Cartagena Protocol on Biosafety as a Model For Holistic International Regulation of Ocean Fertilization Projects and Other Forms of Geoengineering

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BAROMETER RISING: THE CARTAGENA PROTOCOL ON BIOSAFETY AS A MODEL FOR HOLISTIC INTERNATIONAL REGULATION OF OCEAN FERTILIZATION PROJECTS AND OTHER FORMS OF GEOENGINEERING

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"Give me a half a tanker of iron and I'll give you the next ice age."[1] John Martin, the architect of what came to be known as the iron hypothesis, once made this statement jokingly in a lecture he gave at the Woods Hole Oceanographic Institution.[2] Shortly after his death, in October of 1993, the research vessel *Columbus Iselin* departed Miami to head toward the Galapagos Islands where his colleagues conducted the first ever large-scale iron fertilization experiments.[3] While the line may have been intended as hyperbole, Martin could have no idea how controversial his theory would become amidst a growing international debate about global climate change.

Earth's average surface temperature has risen roughly 0.15 degrees Celsius every decade since 1970.[4] Additionally, atmospheric temperatures reflect increasing variability and a gradual increasing trend since their first measurement by satellite in 1979.[5] For various reasons, including melting of the polar ice caps, these temperature trends have led to the phenomenon of sea level rise.[6] The Intergovernmental Panel on Climate Change ("IPCC") estimates that the global mean rate of sea level rise

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[1] John Weier, *John Martin (1935–1993)*, NASA EARTH OBSERVATORY, http://earthobservatory.nasa.gov/Features/Martin/ [https://perma.cc/58J5-GL7G?type=source] (last visited Jan. 22, 2016).

[2] *Id.*

[3] Caroline Dopyera, *The Iron Hypothesis*, 5 EARTH (Issue 5) 26, 27, 29 (1996).

[4] DAVID HELD ET AL., THE GOVERNANCE OF CLIMATE CHANGE: SCIENCE, ECONOMICS, POLITICS & ETHICS 34 (David Held et al. eds., 2011).

[5] *Id.* at 35.

[6] *Id.* at 43–45.

was 1.7 mm/yr between 1901 and 2010, which increased to 3.2 mm/yr between 1993 and 2010.[7] The ramifications of global climate change, however, extend much further even than sea level rise. Climate change is creating physical effects such as changing weather patterns, melting arctic ice, and a loss of food production, but it is also beginning to create distinct political and social unrest.[8] As an emerging issue in global politics, any long-term solution necessitates additional scientific information and technological innovation to inform major policy decisions.[9]

Increasing emissions of greenhouse gases, particularly carbon dioxide, are one of the driving factors behind climate change.[10] The amount of carbon dioxide in our atmosphere tripled between the years 1900 and 2000.[11] These elevated levels of carbon dioxide trap heat from escaping our atmosphere, which in turn increases ocean temperature, reduces drinkable water, and promulgates erratic climate patterns.[12] The overall threat of global climate change has prompted various policy initiatives in an attempt to curb these greenhouse gas emissions, but with limited effectiveness.[13]

Geoengineering is a novel and controversial climate change mitigation theory, defined by the IPCC as "a broad set of methods and technologies that aim to deliberately alter the climate system in order to alleviate the impacts of climate change."[14] The concept encourages the development of technological innovation to actually change the climate itself, in contrast with currently focused efforts on reducing human impact and emissions.[15]

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[7] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, FIFTH ASSESSMENT SYNTHESIS REPORT 40 (2014), *available at* http://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full_wcover.pdf [https://perma.cc/YG69-HM6B?type=source].
[8] HELD ET AL., *supra* note 4, at 2.
[9] John Barry, *Foreword* to POLITICAL THEORY AND GLOBAL CLIMATE CHANGE vii–viii (Steve Vanderheiden ed., 2008).
[10] *Causes of Climate Change*, ENVTL. PROT. AGENCY, http://www.epa.gov/climatechange/science/causes.html [http://perma.cc/LA53-W7XS] (last visited Jan. 22, 2016).
[11] JAMES A. KUSHNER, GLOBAL CLIMATE CHANGE AND THE ROAD TO EXTINCTION 9 (Carolina Academic Press ed., 2009).
[12] *Id.* at 10–11.
[13] Steve Vanderheiden, *Introduction* to POLITICAL THEORY AND GLOBAL CLIMATE CHANGE xi–xiii (Steve Vanderheiden ed., 2008) (explaining the U.S. withdrawal from the Kyoto Protocol and its subsequent effect on UN climate policy).
[14] IPCC EXPERT MEETING ON GEOENGINEERING, MEETING REPORT, 2 (2012), *available at* https://www.ipcc-wg2.gov/meetings/EMs/EM_GeoE_Meeting_Report_final.pdf [https://perma.cc/57KQ-488Z].
[15] David A. Wirth, *Engineering the Climate: Geoengineering as a Challenge to International Governance*, 40 B.C. ENVTL. AFF. L. REV. 413, 414 (2013).

Most major geoengineering ideas fit within two main groups: projects that aim to reduce the amount of solar radiation entering our atmosphere and projects that aim to remove carbon dioxide from the atmosphere.[16] The first category includes a wide variety of concepts ranging from simple ideas such as painting roofs white instead of dark colors, to extremely complex ideas such as sending reflective objects into outer space.[17] The second category focuses on finding methods to enhance existing natural processes that already remove carbon dioxide from the atmosphere.[18]

Ocean fertilization is one of the most theoretically viable and widely discussed forms of geoengineering.[19] It falls in the second category of geoengineering projects, and its purpose is to enhance the natural processes of the earth's oceans in absorbing carbon dioxide.[20] Iron is a limiting reagent in the growth process of phytoplankton, which naturally consume carbon dioxide from the earth's atmosphere.[21] Ocean fertilization involves introducing large quantities of iron into areas with low concentrations of phytoplankton to spur a rapid population increase in these organisms.[22]

There are, however, significant obstacles to the implementation of ocean fertilization as a climate change tool. The principal issue is the unknown environmental consequences of the introduction of iron into the ocean ecosystem in quantities significantly "greater than has been naturally supported."[23] There are also multiple international agreements that have taken measures to regulate ocean fertilization projects, which have produced a fractured and inconsistent area of law.[24]

This Note argues that there is a strong comparison between biotechnology and geoengineering, and that the current regulatory framework for biosafety can serve as a model for similar regulation of ocean

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[16] *Id.* at 415.
[17] *Id.* at 418–19.
[18] *See id.* at 417–18.
[19] Michael C. Branson, *A Green Herring: How Current Ocean Fertilization Regulation Distracts from Geoengineering Research*, 54 SANTA CLARA L. REV., 163, 167–68, 170 (2014).
[20] *Id.* at 167–68.
[21] *See* Dopyera, *supra* note 3, at 27.
[22] *Id.*
[23] Hugh Powell, *Fertilizing the Ocean with Iron*, 46 OCEANUS MAG. (Issue 1) 4, 5–6 (2008), *available at* http://www.whoi.edu/oceanus/feature/fertilizing-the-ocean-with-iron [http://perma.cc/2Z2N-8SAU].
[24] Randall S. Abate & Andrew B. Greenlee, *Sowing Seeds Uncertain: Ocean Fertilization, Climate Change, and the International Environmental Law Framework*, 27 PACE ENVTL. L. REV. 555, 585–87 (2010).

fertilization. Ocean fertilization has the potential to have a significant effect on global climate change, and it requires more than a basic regulatory scheme set by tangentially related legal authorities. Geoengineering reflects both the importance and environmental concerns of biotechnology, and the success of international regulation in this area can be modeled for application to ocean fertilization.

Part One of the Note explains the concept of ocean fertilization, its potential as a climate change mitigation tool, and the environmental dangers that it poses. Part Two examines the three sources of international law that have jurisdiction over ocean fertilization activities: the London Convention and Protocol, the United Nations Convention on the Law of the Sea, and the Convention on Biological Diversity. Part Three explores the Cartagena Protocol as a successful international agreement and framework for environmental regulation of biotechnology. Part Four argues that the Cartagena Protocol's approach to biotechnology should serve as a model for the creation of a supplementary protocol to the Convention on Biological Diversity that consists of a regulatory framework for ocean fertilization. Finally, the conclusion will review the Note and briefly address the possible future of ocean fertilization projects.

I. SCIENTIFIC BACKGROUND OF OCEAN FERTILIZATION, ITS POTENTIAL TO AFFECT GLOBAL CLIMATE CHANGE, AND ITS COUNTERBALANCING THREAT TO OCEAN ECOSYSTEMS

Geoengineering is considered by many to be a last-ditch effort to respond to climate change following failures both in developing comprehensive adaptation and mitigation measures as well as in promulgating adequate greenhouse emission regulations.[25] The deliberate intervention into the climate system is decidedly unnatural, and the subject has remained largely taboo for scientists and policymakers.[26] Ocean fertilization reflects this dilemma. The theory is firmly rooted in natural oceanographic processes, but human intervention has a variety of possible effects. To evaluate the viability of ocean fertilization, it is important to understand its potential to remove atmospheric carbon in contrast with its potential to negatively impact the ocean ecosystem.

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[25] Charles Q. Choi, *Geoengineering Ineffective Against Climate Change, Could Make Worse*, LIVESCIENCE (Feb. 25, 2014), http://www.livescience.com/43654-geoengineering-ineffective-against-climate-change.html [http://perma.cc/37YT-GDG4].

[26] *See id.*

A. *Origins and Scientific Theory Underlying Ocean Fertilization*

The theory behind ocean fertilization originates with John Martin's "Iron Hypothesis," which he first developed in 1990.[27] Martin was a celebrated oceanographer and long-time director of the Moss Landing Marine Laboratories.[28] He observed that over the course of history, during periods when carbon dioxide levels in the atmosphere were low, high concentrations of iron dust were being swept into the ocean.[29] Specifically, Martin noted that during the last glacial maximum (ice age) carbon removal productivity in the eastern equatorial Pacific was significantly higher than during the normal climate period.[30] At the same time, he calculated that tropical arid areas (where iron dust originates) were 5 times larger and wind speeds were 1.3–1.6 times greater than normal, leading to 10–20 times larger amounts of iron rich atmospheric dust being carried into the ocean.[31] Martin used this information to evaluate which shallow ocean nutrients correlated with lower carbon levels and then studied how they were incorporated in oceanographic processes.[32] His observations ultimately led to the identification of what he labeled the ocean's "biological pump," which absorbs carbon dioxide from the atmosphere into the upper ocean and then cycles it downward into the deeper water.[33]

Various ocean characteristics, such as temperature and biological activity, affect the partial pressure of carbon dioxide between the water and the atmosphere.[34] The surface ocean absorbs inorganic carbon from the atmosphere to maintain equilibrium, where it becomes dissolved inorganic carbon ("DIC").[35] The DIC is contained in the upper surface of the ocean, specifically the top 200 meters, which is called the euphotic zone.[36] Containing both the necessary nutrients and sunlight to facilitate

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[27] *See generally* John H. Martin, *Glacial-Interglacial CO2 Change: The Iron Hypothesis*, 5 PALEOCEANOGRAPHY 1 (1990).
[28] Weier, *supra* note 1.
[29] *See* Martin, *supra* note 27, at 2.
[30] *See id.*
[31] *Id.* at 7.
[32] *See id.* at 7–8.
[33] *Id.* at 2.
[34] *See* Sallie W. Chisholm, *Stirring Times in the Southern Ocean*, 407 NATURE 685 (2000).
[35] *See id.*
[36] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2001: THE SCIENTIFIC BASIS, 198 (J.T. Houghton et al. eds., 2001), *available at* https://www.ipcc.ch/ipccreports/tar/wg1/pdf/TAR-03.PDF [https://perma.cc/Z7KW-LPA6].

photosynthesis by marine plants, the euphotic zone is the setting for the first stage of the biological pump.[37] Here, the phytoplankton consume the DIC as well as other important nutrients, including nitrogen, phosphorus, and iron.[38] The phytoplankton use these nutrients in photosynthesis, and in the process they convert the DIC into organic carbon.[39] While some of the organic carbon is consumed by marine life in the surface waters, some of it also sinks to the deeper parts of the ocean in the second stage of the pump.[40] Organic carbon that sinks out of the euphotic zone will remain for an average of 1,000 years.[41] To complete the cycle, when the DIC (transformed into organic carbon) sinks through the second stage of the pump, it creates a carbon pressure difference between the air and the water, and the ocean then absorbs more atmospheric carbon in an effort to establish a pressure equilibrium.[42]

While this "biological pump" is just one of several ways that DIC is transferred to the deep ocean, it is the process with the greatest potential for engineered improvement. So long as phytoplankton can thrive in the euphotic zone, the process is self-sustaining and can continue to remove atmospheric carbon dioxide through photosynthesis.[43] Iron factors into the "biological pump" as one of the nutrients consumed by phytoplankton.[44] Specifically, it is a micronutrient that enables the phytoplankton to use the macronutrients of carbon, nitrogen, and phosphorus to complete photosynthesis.[45] Iron has particular importance because it is often the limiting reagent, meaning that its small concentration limits the overall production of the "biological pump."[46] As Martin initially noted, much of the iron present in the ocean originates as windblown particles off of land masses.[47] Sediment dust that contains high concentrations of

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[37] *See id.*
[38] *See* Aaron L. Strong et al., *Ocean Fertilization: Science, Policy, and Commerce*, 22 OCEANOGRAPHY (Issue 3) 236, 240 (2009).
[39] *See id.*
[40] *See id.*
[41] Chisholm, *supra* note 34.
[42] Hugh W. Ducklow & Ken O. Buesseler, *Upper Ocean Carbon Export and the Biological Pump*, 14 OCEANOGRAPHY (Issue 4) 50, 51 (2001).
[43] *Id.*
[44] *Id.* at 52.
[45] Paul G. Falkowski, *The Role of Phytoplankton Photosynthesis in Global Biochemical Cycles*, 39 PHOTOSYNTHESIS RESEARCH 235, 237 (1993).
[46] Strong et al., *supra* note 38, at 240.
[47] Woods Hole Oceanographic Inst., *How Does Iron Get Into The Ocean?* (Feb. 23, 2006), *available at* http://www.whoi.edu/main/news-releases/2006?tid=3622&cid=10586 [http://perma.cc/79VQ-W5YA].

iron originate only from certain parts of the Earth, primarily from desert areas.[48] As a result, the windblown particles lead to extremely inconsistent dispersion of iron, both in amount and concentration, which causes some areas of the ocean to have iron deficiencies.[49] Modeling studies have demonstrated that while the North Atlantic and Indian Oceans receive 68% of atmospheric dust, the South Pacific and Southern Ocean each receive 6%, and the South Atlantic receives only 4%.[50] In these areas, iron is a limiting nutrient that prevents phytoplankton growth, the accompanying photosynthesis, and activation of the "biological pump."[51] Known as "high-nutrient, low-chlorophyll" oceanic regions, these areas have normal macronutrient levels (nitrogen, phosphorus, carbon) but low production of chlorophyll because photosynthesis can only take place on a very small scale.[52]

Scientist John H. Martin has summarized the "biological pump" as "the photosynthetic uptake of CO_2 and removal to the deep ocean when the remains of the phytoplankton sink away from the surface."[53] These processes are extraordinarily effective, and have absorbed approximately one third of all carbon dioxide released into the atmosphere by humans since 1800.[54] Ocean fertilization simply seeks to stimulate these natural processes, collectively the "biological pump," by increasing primary production of iron, the limiting nutrient to marine photosynthesis.[55]

B. *Potential for Ocean Fertilization to Serve as an Important Climate Change Mitigation Tool*

Global climate change is primarily caused by rising amounts of greenhouse gases which trap heat in the atmosphere.[56] Carbon dioxide

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[48] Tim D. Jickells et al., *Global Iron Connections Between Desert Dust, Ocean Biochemistry, and Climate*, 308 SCI. MAGAZINE (Issue 5718) 67 (2005).
[49] John H. Martin et al., *Iron in Antarctic Waters*, 345 NATURE 156 (1990).
[50] Jickells et al., *supra* note 48, at 70.
[51] *Id.* at 69 (Chlorophyll is a byproduct of photosynthesis, and therefore a measure of photosynthesis production).
[52] *Id.*
[53] Martin, *supra* note 27, at 1–2.
[54] Christopher L. Sabine et al., *The Oceanic Sink for Anthropogenic CO_2*, 305 SCI. MAGAZINE 367, 370 (2004).
[55] Branson, *supra* note 19, at 166–68.
[56] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS, 103, 105–06 (Susan Solomon et al. eds., 2007), *available at* http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter1.pdf [http://perma.cc/MCJ9-E54Z].

makes up the major portion of these gases, 82% of all greenhouse emissions.[57] In fact, the ten warmest years in history have all occurred in the past fifteen years during which time the atmospheric carbon level has increased to 400 parts per million ("ppm"), 40% higher than preindustrial levels.[58] The primary factor behind increasing carbon dioxide levels is the proportionate increase in combustion of fossil fuels, which has contributed 78% of all greenhouse gas emission increases between 1970 and 2010.[59] Carbon is one of the building blocks of all life on earth, and the process of burning something that was once alive releases that carbon in the form of carbon dioxide.[60] Oil, coal, and natural gas are labeled fossil fuels because they consist of the fossilized remains of ancient living organisms, and the carbon inside them is released during combustion.[61]

Carbon dioxide is naturally removed from the atmosphere through various atmospheric, land biotic, marine biotic, and mineral reservoir processes.[62] The purpose of ocean fertilization is to enhance part of the marine biotic carbon cycling process, the "biological pump," to remove more atmospheric carbon than it does naturally.[63] Its viability as a climate change tool depends on two factors: 1) the expense of implementation and 2) the amount of carbon dioxide the process can actually remove from the atmosphere.[64]

Iron, as a micronutrient for phytoplankton photosynthesis, is only required in trace amounts to activate the "biological pump."[65] Additionally, the specific form of iron used for ocean fertilization experiments, iron

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[57] *National Greenhouse Emissions Data*, ENVTL. PROT. AGENCY, http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html [http://perma.cc/LS53-R9CB] (last visited Jan. 22, 2016).
[58] ENVTL. PROT. AGENCY, INVENTORY OF U.S. GREENHOUSE GAS EMISSIONS AND SINKS 1–3 (2014), *available at* http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Main-Text.pdf [http://perma.cc/MRH6-CV8G]; *Greenhouse Gas Bulletin*, WORLD METEOROLOGICAL ORG., 2 (Nov. 6, 2013), http://www.wmo.int/pages/prog/arep/gaw/ghg/documents/GHG_Bulletin_No.9_en.pdf [http://perma.cc/9SCE-7N3B].
[59] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, *supra* note 7, at 5.
[60] GABRIELLE WALKER & DAVID KING, THE HOT TOPIC: WHAT WE CAN DO ABOUT GLOBAL WARMING 13–14 (2008).
[61] *Id.* at 14.
[62] ENVTL. PROT. AGENCY, *supra* note 10, at 2–3.
[63] John J. Cullen, *Hypotheses to Explain High-Nutrient Conditions in the Open Sea*, 36 LIMNOLOGY & OCEANOGRAPHY (Issue 8) 1578, 1596 (1991).
[64] *See* Hugh Powell, *Will Ocean Iron Fertilization Work?*, 46 OCEANUS MAGAZINE 10 (2008), *available at* http://www.whoi.edu/oceanus/feature/will-ocean-iron-fertilization-work [http://perma.cc/Q2VF-FXNC]; A.U. Watson et al., *Minimal Effect of Iron Fertilization on Sea-Surface Carbon Dioxide Concentrations*, 371 NATURE 143, 143 (1994).
[65] Cullen, *supra* note 63, at 1586–87.

sulfate, is relatively inexpensive.[66] The compound can be purchased from garden supply stores for as low as $1.67 per pound.[67] However, while the principle of dumping the iron sulfate and observing the results seems simple, the logistics can become very complex. First, the dispersion vessel will use a zigzagged pattern to drizzle the iron sulfate over a theoretical square of ocean.[68] Difficulties emerge in tracking and analyzing the resulting phytoplankton bloom. The iron becomes largely undetectable after several days as it reacts with the seawater, dissolves, and dilutes.[69] The bloom itself also becomes exceptionally difficult to manage as it expands in shifting ocean currents, which can result in a substantial amount of time and effort being used just to map the outer boundary.[70] These challenges require additional manpower and expense as demonstrated by a 2002 ocean fertilization experiment employing three research ships, multiple helicopters, and 76 scientists.[71] Despite these logistical challenges, researchers are optimistic about the feasibility of future endeavors as scientists learn more about upper ocean physics, engineering improves, and techniques become more efficient.[72]

The more important factor to viability, and a source of significant debate, is how much carbon dioxide can actually be neutralized using this process. There are two central criticisms to the hypothesis, primarily that it is difficult to know how much carbon is actually being sequestered by sinking biomass and also that it may not actually remain on the sea floor.[73]

In the Spring of 2004, a research team led by Dr. Victor Smetacek conducted one of the few large-scale ocean fertilization experiments to date.[74] Labeled the European Iron Fertilization Experiment ("EIFEX") and sponsored by the Alfred Wegener Institute, the group embarked for a

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[66] GrowOrganic, Iron Sulfate 20, http://www.groworganic.com/iron-sulfate-20-50-lb.html [http://perma.cc/BM95-AYLK] (last visited Jan. 22, 2016).
[67] *Id.*
[68] Powell, *supra* note 64.
[69] *Id.*
[70] *Id.*
[71] *Id.*
[72] *Id.*
[73] Watson et al., *supra* note 64, at 145.
[74] Rob Waugh, *Could Dumping Iron in the Oceans Cure Climate Change? First 'Geo-engineering' Trial is Hailed a Success*, DAILY MAIL, July 18, 2012, http://www.dailymail.co.uk/sciencetech/article-2175477/Eifex-New-hi-tech-geo-engineering-trial-hailed-success--cure-climate-change.html [https://perma.cc/B4KN-5366?type=source].

marine eddy in the Southern Ocean aboard the research vessel *Polarstern*.[75] After five weeks of monitoring the growth of the phytoplankton, the experiment yielded positive results.[76] The team dispersed iron sulfate in a patch of water measuring 167 km^2, which dissolved down to 100 meters in depth.[77] Not only did the experiment produce the highest growth rate for phytoplankton of any experiment to that point, but it also proved for the first time that a plankton bloom can occur that far beneath the surface.[78] The depth of this bloom, coupled with high sinking rates and low respiratory losses, indicates that much of the carbon contained in the biomass became sequestered on the sea floor.[79] While Dr. Smetacek's group concluded that larger and longer-term experimentation was necessary to determine the viability of ocean fertilization in the field of climate change, their work was an important substantiation of Dr. Martin's hypothesis.[80] Experiments like EIFEX indicate that while it is indeed possible for ocean fertilization to have a large-scale impact on atmospheric carbon levels and thereby climate change, its actual viability is a different question.[81]

In February of 2015, the National Academy of Sciences, with the support of the National Oceanic and Atmospheric Administration ("NOAA") and the Department of Energy ("DOE") published a comprehensive report evaluating the technical feasibility and impacts of all current geoengineering techniques.[82] The report labels ocean fertilization as an immature technology principally because of "the limited knowledge regarding the method's effectiveness, . . . concerns regarding the environmental impacts[,] and [the] cost of large-scale and sustained [projects]."[83] Relying on data collected by the experiments conducted to date, including

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[75] *Id.* (An eddy is a circular current of water, which allowed the experiment to track the iron deposit more easily).
[76] *Id.*
[77] Victor Smetacek et al., *Deep Carbon Export From a Southern Ocean Iron-Fertilized Diatom Bloom*, 487 NATURE 313, 315 (2012).
[78] *Id.* at 319 (The experiment produced a peak chlorophyll stock of 286 mg m -2, a significantly larger amount than under normal conditions and a direct product of sufficient iron levels interacting with other nutrients).
[79] *Id.*
[80] *Id.; see also* Waugh, *supra* note 74.
[81] *See* Smetacek et al., *supra* note 77, at 318–19.
[82] COMM. ON GEOENGINEERING CLIMATE, NATIONAL ACADEMY OF SCIENCES, CLIMATE INTERVENTION: CARBON DIOXIDE REMOVAL AND RELIABLE SEQUESTRATION (2015).
[83] *Id.* at 62.

EIFEX, this report illustrates that the key to truly answering the viability question will only come with additional research and analysis.

C. *Environmental Risks to Ocean Ecosystems Posed by Ocean Fertilization*

The largest environmental risk posed by ocean fertilization experimentation is simply a lack of knowledge.[84] Field experimentation has produced inconsistent ecological data, which prevents any confidence in available biogeochemical modeling of the downstream effect of high concentrations of iron.[85] The result is a variety of theoretical possibilities, each of which requires extensive additional research before the full effect of ocean fertilization can be understood.[86] One possible effect is that the fertilization process will remove nutrients and stunt phytoplankton growth that is naturally occurring in other areas, which has been demonstrated in model simulations of the tropical eastern Pacific Ocean.[87] Another observation of an experiment in the Southern Ocean suggests that organic aerosols, a byproduct of phytoplankton growth, could have a significant effect on cloud formation and subsequently air quality.[88] Yet another model predicted that large areas of the ocean could become anoxic (oxygen depleted) under large-volume iron fertilization, a common effect of algal blooms in other environments that leads to fish kills and other forms of ecological destruction.[89] Each of these possibilities is largely theoretical, principally due to the lack of scientific research.[90] While funding is minimal for such a theoretical concept, the economic potential under carbon trading markets is spurring commercial efforts "with or without scientific input."[91] These commercially run ocean fertilization projects are unconcerned with

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[84] Andrew J. Watson et al., *Designing the Next Generation of Ocean Fertilization Experiments*, 364 MARINE ECOLOGY PROGRESS SERIES 303, 308 (2008).
[85] *Id.* at 303–04.
[86] *Id.* at 304.
[87] X. Jin et al., *The Impact on Atmospheric CO_2 of Iron Fertilization Induced Changes in the Ocean's Biological Pump*, 5 BIOGEOSCIENCES 385, 390–92 (2008).
[88] Nicholas Meskhidze & Athanasios Nenes, *Phytoplankton and Cloudiness in the Southern Ocean*, 314 SCI. 1419, 1423 (2006).
[89] Jorge L. Sarmiento & James C. Orr, *Three-Dimensional Simulations of the Impact of Southern Ocean Nutrient Depletion on Atmospheric CO_2 and Ocean Chemistry*, 36 LIMNOLOGY AND OCEANOGRAPHY 1928, 1935–49 (1991); *see also* Patricia M. Gilbert et al., *Ocean Area Fertilization for Carbon Credits Poses High Ecological Risks*, 56 MARINE POLLUTION BULLETIN 1049, 1051 (2008).
[90] *See id.* at 1948.
[91] Powell, *supra* note 23.

environmental effects, focusing solely on carbon reduction.[92] As a result, ocean fertilization in its current state could lead to any or all of these environmental harms, and the risk is unquantifiable without additional scientific data.

II. CURRENT INTERNATIONAL GOVERNANCE OF OCEAN FERTILIZATION: A FRACTURED APPROACH LED BY THE LONDON CONVENTION AND PROTOCOL

Ocean Fertilization, along with most other forms of geoengineering, has not yet been widely considered by policymakers as a potential tool that warrants dedicated attention and regulation.[93] In fact, it wasn't until 2009 that a U.S. cabinet member stated that geoengineering has "got to be looked at," including its environmental side effects.[94] Consequently, ocean fertilization is being regulated as the act of dumping a substance into the ocean rather than a measure to counteract climate change.[95] Additionally, because its regulatory jurisdiction stems from its underlying procedures, multiple sources of international law have taken steps to address the issue.[96] The result is an overlapping patchwork of law from different international agreements that has generated important environmental restrictions but also created significant uncertainty. Currently, an agreement promulgated by the United Nations Environment Programme known as the London Convention and Protocol is the leading instrument of this patchwork.[97]

A. *Brief History of the London Convention and Protocol*

For several hundred years the world's oceans have been used as a resource for the disposal of human garbage and waste.[98] By the early

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[92] *Id.* at 1.
[93] *Id.* at 2–3.
[94] Alok Jha, *Obama Climate Adviser Open to Geo-engineering to Tackle Global Warming*, THE GUARDIAN (Apr. 8, 2009, 17:42 EDT), http://www.theguardian.com/environment/2009/apr/08/geo-engineering-john-holdren [http://perma.cc/ZFZ8-E4PH].
[95] *Id.*
[96] INT'L MAR. ORG., ORIGINS OF THE LONDON CONVENTION 1 (2012), http://www.imo.org/KnowledgeCentre/ReferencesAndArchives/IMO_Conferences_and_Meetings/London_Convention/VariousArticlesAndDocumentsAboutTheLondonConvention/Documents/Origins%20of%20the%20London%20Convention%20-%20Historic%20events%20and%20documents%20%20M.%20Harvey%20September%202012.pdf [https://perma.cc/W8ZT-9F2X?type=source] [hereinafter IMO].
[97] *Id.* at 1.
[98] *Id.*

1970s, however, levels of waste dumped into the oceans reached several million metric tons with very few controls on the extent or makeup of the materials.[99] Responding to growing concerns in many countries, the United Nations General Assembly began to recognize and discuss the issue, and in 1986 adopted a resolution to establish the United Nations Conference on the Human Environment.[100] Shortly after this announcement, President Richard Nixon followed suit on the U.S. domestic level by echoing the U.N.'s concerns regarding waste disposal in a 1970 special address to Congress.[101] Nixon stated: "we are only beginning to find out the ecological effects of ocean dumping and current disposal technology is not adequate to handle wastes of the volume now being produced. Comprehensive new approaches are necessary if we are to manage this problem expeditiously and wisely."[102] The President then directed the Council on Environmental Quality to work with other departments to submit a comprehensive study on ocean dumping by September of that year.[103]

The report, published in October of 1970 and titled "Ocean Dumping, A National Policy," identified both a critical need for domestic dumping policy as well as the development of an international regulatory scheme.[104] The report established a distinct domestic policy position on the issue, leading to the U.S.'s involvement in the UN Conference on the Human Environment, and specifically as a member of the Intergovernmental Working Group on Marine Pollution—created in 1971 by the Preparatory Committee for the conference.[105] The working group, after meeting four times, submitted a set of draft articles for a convention on ocean dumping to the official UN Conference on the Human Environment, held in Stockholm in 1972.[106] Finally, from October 30 to November 13, 1972, the U.K. convened a conference in London to promulgate international regulations pursuant to the Conference and the draft articles it had reviewed.[107]

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[99] *Id.*
[100] *Id.* at 4–5.
[101] President Richard Nixon, Special Message to Congress about Waste Disposal (Apr. 15, 1970), *available at* http://www.presidency.ucsb.edu/ws/index.php?pid=2464 [http://perma.cc/NF5K-HZQU].
[102] *Id.*
[103] *Id.*
[104] COUNCIL ON ENVTL. QUALITY OCEAN DUMPING, A NATIONAL POLICY 6 (1970), http://files.eric.ed.gov/fulltext/ED055891.pdf [http://perma.cc/6RFV-FRPU].
[105] IMO, *supra* note 96, at 2.
[106] *Id.* at 3–4.
[107] *Id.* at 5.

The conference in London resulted in the adoption of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, which came into force on August 30, 1975.[108] The Convention specifically prohibits the dumping of certain hazardous materials outright, requires a special permit for the dumping of certain other materials, and requires a general permit for other wastes or matter.[109]

In 1996, parties to the London Convention created the London Protocol to modernize the Convention and eventually replace it altogether.[110] The protocol takes the reverse approach from the Convention by stipulating a general prohibition on all dumping, and it lists only those categories of waste that are exempt from that prohibition.[111] The London Protocol represents a significantly more strict regulatory scheme than the London Convention, and reflects a modern trend toward an increasingly conservative approach.[112] The Protocol also includes several other important updates, the most significant of which is the adoption of the precautionary approach.[113]

The concept of precautionary thinking in regard to environmental policies emerged first in German policies promulgated in the 1980s.[114] Although it is a common regulatory principle, the precautionary approach has no commonly agreed definition or strategy for implementation.[115] The protocol defines the principle in the context of ocean dumping to require that "appropriate preventative measures are taken when there is reason to believe that wastes or other matter introduced into the marine environment are likely to cause harm even when there is no conclusive evidence

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[108] Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, Dec. 29, 1972, 26 U.S.T. 2403, 1046 U.N.T.S. 138 [hereinafter London Convention].
[109] INT'L MAR. ORG., A SUMMARY OF IMO CONVENTIONS 53 (2009), http://www.imo.org/KnowledgeCentre/ReferencesAndArchives/FocusOnIMO(Archives)/Documents/Focus%20on%20IMO%20-%20A%20summary%20of%20IMO%20Conventions%20(2009).pdf [https://perma.cc/HGG9-5BNS?type=source].
[110] 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, Nov. 7, 1996, S. Treaty Doc. No. 110-5, 36 I.L.M. 1 [hereinafter London Protocol].
[111] Till Marcus & Harald Ginzky, *Regulating Climate Change Engineering: Paradigmatic Aspects of the Regulation of Ocean Fertilization*, 4 CARBON & CLIMATE L. REV. 477, 479–80 (2011).
[112] *Id.* at 479.
[113] SUMMARY OF IMO CONVENTIONS, *supra* note 109, at 54.
[114] WORLD HEALTH ORG., THE PRECAUTIONARY PRINCIPLE: PROTECTING PUBLIC HEALTH, THE ENVIRONMENT, AND THE FUTURE OF OUR CHILDREN 33 (Marco Martuzzi & Joel A. Tickner eds., 2004).
[115] *Id.* at 36.

to prove a causal relation between inputs and their effects."[116] The protocol also implements the principle that the polluter should bear the cost of the pollution for permitted waste.[117]

The London Convention currently consists of 87 member states, while the London Protocol entered force in 2006 with 45 total members.[118] Through its reverse framework and adoption of environmental principles, the protocol represents a significantly stricter regulatory approach than the convention, and reflects a modern trend toward an increasingly conservative approach.[119]

B. Current Application of the London Convention and Protocol to Ocean Fertilization

The London Convention and London Protocol, collectively the LCLP, is specifically designed to regulate "dumping," and included in its definition is the "deliberate disposal into the sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea."[120] While ocean fertilization is not waste and does not fall within the usual class of regulated activities under the LCLP, it does involve the deliberate disposal of a substance (iron sulfate) into the ocean.[121] As such, it technically represents "other matter" and could be considered by the contracting parties to be within the scope of the instruments.[122] The LCLP also states, however, that its definition of dumping does not include the placement of matter into the sea for a purpose other than mere disposal, which would seemingly exclude ocean fertilization activities.[123] In 2007, the governing bodies of the LCLP first addressed the issue and agreed that the scope of the LCLP should be interpreted to include ocean fertilization activities.[124] The group also published the "Statement of Concern

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[116] London Protocol, *supra* note 110, art. 3, sec. 1.
[117] SUMMARY OF IMO CONVENTIONS, *supra* note 109, at 54.
[118] *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, INT'L MAR. ORG., http://www.imo.org/en/OurWork/Environment/LCLP/Pages/default.aspx [https://perma.cc/PR6N-KQEM?type=source] (last visited Jan. 22, 2016).
[119] Marcus & Ginzky, *supra* note 111, at 479.
[120] London Protocol, *supra* note 110, art. 4, sec. 1.
[121] Marcus & Ginzky, *supra* note 111, at 479.
[122] *Id.*
[123] David Freestone & Rosemary Rayfuse, *Ocean Iron Fertilization and International Law*, 364 MARINE ECOLOGY PROGRESS SERIES 227, 229 (2008).
[124] Duncan E.J. Currie, *Brief Primer on Ocean Fertilization in the CBD and the London Convention and Protocol*, ETC GRP.(Oct. 19, 2012), http://www.etcgroup.org/content/brief

Regarding Iron Fertilization of the Oceans to Sequester CO_2," which laid out an action step for the next meeting of the contracting parties to consider the possibility of specific regulation for ocean fertilization activities.[125]

The following year, the contracting parties adopted Resolution LC-LP.1, or the Annex 6 Resolution, during the third meeting between the protocol's parties.[126] This resolution built on the platform decision from the prior year to clarify exactly how the LCLP would apply to ocean fertilization.[127] The Annex 6 Resolution states that ocean fertilization activities which constitute "legitimate scientific research" qualify as a purpose other than mere disposal and are therefore exempt from the LCLP.[128] The resolution did not define what constitutes "legitimate scientific research" but instead tasked the Scientific Group with creating an assessment framework to evaluate research projects.[129] In 2010, the contracting parties published a second resolution, LC-LP.2, which incorporated the new Assessment Framework created by the Scientific Group.[130] LC-LP.2 uses the framework to lay out a two-step process for determining whether a proposed project can be considered "legitimate scientific research," which includes the Initial Assessment and the Environmental Impact Assessment.[131] The Initial Assessment focuses on the scientific attributes of the project to ensure that its purpose is to expand the current base of knowledge and that it is not motivated by economic goals.[132] The Environmental Impact Assessment then requires the project to lay out any expected environmental effects and possible risks of ecological harm.[133]

-primer-ocean-fertilization-cbd-and-london-convention-and-protocol [http://perma.cc/73HG-YQZC].

125 *Id.*

126 *See* Int'l Mar. Org., Annex Six Resolution LC-LP.1 (2008) on the Regulation of Ocean Fertilization, LC 30/16, annex 6, res. LC-LP.1 (Oct. 31, 2008), *available at* http://www.imo.org/blast/blastDataHelper.asp?data_id=24337&filename=LC-LP1%2830%29.pdf [http://perma.cc/7HUM-V55V] [hereinafter Annex Six Resolution].

127 *Id.*

128 *Id.*

129 Marcus & Ginzky, *supra* note 111, at 480.

130 Int'l Mar. Org., Resolution LC-LP.2 (2010) On the Assessment Framework for Scientific Research Involving Ocean Fertilization, LC 32/15. annex 6 para. 1.2 (Oct. 14, 2010), *available at* http://www.imo.org/OurWork/Environment/LCLP/EmergingIssues/geoengineering/Documents/OFassessmentResolution.pdf [https://perma.cc/KN82-KU6U?type=source].

131 *Id.*

132 *Id.*

133 *Id.*

While these resolutions represent the final details of the LCLP's 2007 decision to encompass ocean fertilization, neither carry binding force on the contracting parties.[134] In October, 2013, the LCLP incorporated the substance of the resolutions as a formal amendment prohibiting any marine geoengineering activities other than those authorized by permit (which is to be informed by the Assessment Framework).[135] The amendment represents both the most concrete and thorough regulation of ocean fertilization to date, elevating the LCLP "to be among the most advanced international regulatory instruments addressing human activities in the marine environment."[136] The amendment has yet to come into force, however, which it can only do after two thirds of the 43 contracting parties deposit instruments of acceptance.[137] Until then, the resolutions carry no legal weight and are just guidance for LCLP's contracting parties.[138]

C. Additional and Overlapping Regulation of Ocean Fertilization

In addition to the LCLP, two other sources of international law have regulatory frameworks that govern ocean fertilization.[139] Negotiated between 1973 and 1982, the United Nations Convention on the Law of the Sea ("LOSC") obtained the necessary ratifications and formally came into force as an international treaty in 1994.[140] While the LOSC has jurisdiction over ocean fertilization activities, it so far has chosen not to assert any regulatory control.[141] LOSC is a comprehensive legal framework that

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[134] Marcus & Ginzky, *supra* note 111, at 481.
[135] Press Briefing 45, INT'L MAR. ORG., Marine Geoengineering Including Ocean Fertilization to be Regulated Under Amendments to International Treaty (Oct. 18, 2013), *available at* http://www.imo.org/MediaCentre/PressBriefings/Pages/45-marine-geoengineering.aspx#.VGuH-FfF95g [https://perma.cc/HW44-KJC3?type=source].
[136] *Id.*
[137] *Id.*
[138] *Address of the IMO Secretary-General at the Opening of the Thirty-Fifth Consultative Meeting of Contracting Parties to the London Convention and the Eighth Meeting of Contracting Parties to the London Protocol*, INT'L MAR. ORG. (Oct. 14, 2013), *available at* http://www.imo.org/en/MediaCentre/SecretaryGeneral/Secretary-GeneralsSpeechesToMeetings/Pages/LC35LP8.aspx [https://perma.cc/3PTC-5NEE?type=source].
[139] UN Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397; Convention on Biological Diversity, June 5, 1992, 1760 U.N.T.S. 79.
[140] The United Nations Convention on the Law of the Sea (A historical perspective), UN DIVISION FOR OCEAN AFFAIRS AND THE LAW OF THE SEA (last updated May 21, 2012), http://www.un.org/Depts/los/convention_agreements/convention_historical_perspective.htm [http://perma.cc/3TL5-AXA7] [hereinafter Historical Perspective].
[141] Robin Warner, *Preserving a Balanced Ocean: Regulating Climate Change Mitigation Activities in Marine Areas Beyond National Jurisdiction*, 14 AUSTL. INT'L L. J. 99, 100.

attempts to regulate all aspects of international maritime areas, and it also influences individual state actions that could have effects outside of territorial waters.[142] One of the major focuses of the LOSC is the protection of the marine environment, and it seeks to regulate pollution as stringently as possible.[143] The LOSC presents a unique definition of pollution, which focuses on the affect foreign substances have on the marine environment as opposed to the harmful characteristics of particular substances.[144] Additionally, LOSC Article 194(1) specifically requires that states take necessary measures to prevent any pollution activities.[145] It is possible, especially when viewed under a precautionary principle, to argue that ocean fertilization clearly falls under this definition of pollution because potential environmental harm is likely.[146] The LOSC can also be construed to regulate ocean fertilization activities because Article 194(3)(a) includes the release of harmful substances by "dumping" as a polluting activity.[147] Because the LOSC expressly recognizes any definitions of "dumping" that are promulgated by other international treaties, the LCLP's inclusion of ocean fertilization in its own definition enables the LOSC to exert simultaneous jurisdiction over the activity.[148] Principally because of the LCLP's distinct and proactive steps toward regulation of ocean fertilization activity, however, LOSC has so far declined to take any steps to act on its regulatory jurisdiction.[149]

The 1992 Convention on Biological Diversity ("CBD") is another international treaty that has taken some action to govern ocean fertilization activities.[150] In contrast with the LOSC, the CBD has acted proactively to address ocean fertilization, but it still lags behind the LCLP because it has yet to even attempt to use its binding authority.[151] Developed in

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[142] Historical Perspective, *supra* note 140.
[143] *Id.*
[144] Convention on the Law of the Sea, *supra* note 139, at 26 (LOSC Article 1(1)(4): "the introduction by man, directly or indirectly, of substances or energy into the marine environment, . . . which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities").
[145] *Id.* at 478.
[146] Abate & Greenlee, *supra* note 24, at 573 (while the LOSC does not expressly adopt the precautionary principle, some scholars have read in such a principle because of the phrase "results or is likely to result" in Article 1(1)(4)).
[147] Convention on the Law of the Sea, *supra* note 139, at 478.
[148] *Id.* at 108.
[149] Warner, *supra* note 141, at 100, 118–19.
[150] *Id.* at 109–10, 113.
[151] *Id.* at 116–19.

response to growing concerns about human impact on biological diversity, the CBD seeks to provide a regulatory framework to promote sustainable growth and protect the natural diversity of Earth's various ecosystems.[152] With 196 parties, including the European Union, the CBD is effectively a universally recognized treaty.[153] The contracting parties to the CBD have issued several documents concerning ocean fertilization, most recently *Decision X/33: Biodiversity and Climate Change*, released in October of 2010.[154] X/33, in addition to offering guidance on climate change mitigation and adaptation, invites the parties of the CBD to consider a ban on "climate-related geo-engineering activities . . . until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies."[155] While the language of X/33 suggests a moratorium on any ocean fertilization activity, it has no binding legal effect and in fact refers parties to the LCLP as such an authority.[156]

III. CURRENT INTERNATIONAL GOVERNANCE OF BIOTECHNOLOGY AND GENETICALLY MODIFIED CROPS: THE CARTAGENA PROTOCOL ON BIOSAFETY

The scientific breeding of plants, like most forms of modern genetics, has its origins in the famous work of Gregor Mendel and his pea plant experiments.[157] The possibility for commercial application, however, did not arise until the 1970s with the creation of a new technique first known as genetic engineering and now known as genetic modification.[158] Commercial growing of genetically modified crops began in the early 1990s, and within a fifteen-year period the percent of global farmland being

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[152] Convention on Biological Diversity, *supra* note 139, at 3.
[153] List of Parties, CONVENTION ON BIOLOGICAL DIVERSITY, http://www.cbd.int/information/parties.shtml [http://perma.cc/MJM2-BBJR] (last visited Jan. 22, 2016).
[154] *See* Conference to the Parties to the Convention on Biological Diversity, Decision X/33: Biodiversity and Climate Change UNEP/CBD/COP/DEC/X/33 (Oct. 29, 2010) [hereinafter Decision X/33].
[155] *Id.* ¶ 8(w). (Paragraph 8(w) also highlights the potential for the CBD to be an avenue for necessary future regulation by identifying "the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering").
[156] *Id.* ¶ 8(x).
[157] NIGEL G. HALFORD, GENETICALLY MODIFIED CROPS 12 (2003).
[158] *Id.* at 16.

used for these crops went from 0 to 10% making biotech crops the most quickly accepted technology in the history of modern agriculture.[159]

A. There Are Distinct Parallels Between Agricultural Biotechnology and Iron Fertilization from a Regulatory Perspective

Genetically modified ("GM") crops are considered by many as the future for sustainable food growth, as well as a possible solution toward curbing world hunger.[160] The United Nations, as part of its Millennium Development Goals, has set a target to halve the proportion of the world's population suffering from hunger by 2015.[161] In 2008, a World Bank Development Report indicated that science and technology should play an important role in food production, security, and ultimately result in a significant reduction in global poverty.[162]

The main advantage of GM crops is that they can be engineered for herbicide and insect resistance, i.e., weeds and pests.[163] As a result, growers can generate higher yield harvests for significantly lower costs.[164] In addition to their use as a food source, GM crops have also been linked to the production of commercially viable biofuel.[165] The Advanced Research Projects Agency–Energy ("ARPA-E"), a subset of the Department of Energy that funds research and development of energy technology not

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159 Elizabeth Weise, *More of World's Crops Are Genetically Engineered*, USA TODAY (Feb. 22, 2011, 7:55 PM), http://usatoday30.usatoday.com/tech/news/biotech/2011-02-22-biotech-crops_N.htm [http://perma.cc/Y9P4-D8WG]; *Pocket K No. 16: Global Status of Commercialized Biotech/GM Crops in 2014*, INT'L SERV. FOR THE ACQUISITION OF AGRI-BIOTECH APPLICATIONS (Jan. 2015), https://isaaa.org/resources/publications/pocketk/16/default.asp [https://perma.cc/MG3G-J3EE].

160 Weise, *supra* note 159.

161 UN Millennium Development Goals, Goal One: Eradicate Extreme Poverty and Hunger, http://www.un.org/millenniumgoals/poverty.shtml [http://perma.cc/U737-4UAQ] (last visited Jan. 22, 2016).

162 THE WORLD BANK, WORLD DEVELOPMENT REPORT 2008: AGRICULTURE FOR DEVELOPMENT 158–59 (2008), *available at* http://siteresources.worldbank.org/INTWDRS/Resources/477365-1327599046334/WDR_00_book.pdf [http://perma.cc/PK4E-CY3U].

163 L. LaReesa Wolfenbarger et al., *Environmental Opportunities and Challenges of Genetically-Engineered Crops*, 25 CHOICES: THE MAGAZINE OF FOOD, FARM & RESOURCE ISSUES (Issue 2) 2 (2010).

164 Matin Qaim, *The Benefits of Genetically Modified Crops—and the Costs of Inefficient Regulation*, RES. FOR THE FUTURE (Apr. 2, 2010), http://www.rff.org/blog/2010/benefits-genetically-modified-crops-and-costs-inefficient-regulation [http://perma.cc/EG8F-WDHZ].

165 Alexandra Goho, *Corn Primed for Making Biofuel*, MIT TECH. REVIEW (Apr. 16, 2008), http://www.technologyreview.com/news/409913/corn-primed-for-making-biofuel/ [http://perma.cc/G2F6-BDHD].

yet viable for private investment, provides funding for a set of projects called "Plants Engineered to Replace Oil" ("PETRO").[166] These projects are aimed specifically at the development of a new class of genetically engineered non-food crops to create transportation fuel.[167] While the use of biofuels as a competitive source of energy is currently speculative at best, it demonstrates the dramatic future possibilities for GM crops.

Along with this growing use of GM crops, however, swirls significant controversy related to the uncertainty of their environmental effects. Regarding the for-food GM crops, these arguments can be broken down into the herbicide-tolerant ("HT") crops and the pesticide-producing crops.[168] HT crops are argued both to have toxic effects on ecosystems and to increase weed tolerance to herbicide.[169] Pesticide-producing crops have been argued to be toxic to both harmless nontarget species and beneficial insects, a threat to soil ecosystems, and a water contaminant.[170] These crops secrete a bacterium-based toxin known as Bt, for which there exists significant scientific uncertainty as to its effect when introduced into the soil, bodies of water, or directly consumed by other plants and animals.[171]

B. The Cartagena Protocol on Biosafety, an International Regulatory Framework for Biotechnology

The Cartagena Protocol on Biosafety came into force on September 11, 2003, as a supplementary agreement to the UN Convention on Biological Diversity ("CBD").[172] Adopted in 1992, the CBD is a product of

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[166] *PETRO: Plants Engineered to Replace Oil*, ARPA-E, http://arpa-e.energy.gov/?q=arpa-e-programs/petro [http://perma.cc/733E-S8HF] (last visited Jan. 22, 2016).
[167] *Id.*
[168] *Environmental and health impacts of GM crops*, GREENPEACE (Sept. 2011), http://www.greenpeace.org/australia/PageFiles/434214/GM_Fact%20Sheet_Health_%20and_Env_Impacts.pdf [http://perma.cc/8778-58M5].
[169] Caroline Cox, *Glyphosate*, 24 J. PESTICIDE REFORM (No. 4) 10, 13–14 (2004), *available at* http://www.pesticide.org/get-the-facts/pesticide-factsheets/factsheets/glyphosate [http://perma.cc/A9HD-QQ6H] (Glyphosate, the active ingredient of Roundup, is a widely used element in HT crops that can be toxic to both plant and animal organisms and is possibly associated with nutrient deficiencies in soil.); *see also* Rosa Binimelis et al., *Transgenic Treadmill: Responses to the Emergence and Spread of Glyphosate-Resistant Johnsongrass in Argentina*, 40 GEOFORUM (Issue 4) 623 (2009) (examining Argentine Johnsongrass as a case study of herbicide resistant superweeds).
[170] GREENPEACE, *supra* note 168.
[171] Bryan W. Clark et al., *Environmental Fate and Effects of Bacillus thuringiensis ("Bt") Proteins from Transgenic Crops: a Review*, 53 J. AGRIC. FOOD CHEM. (Issue 12) 4643, 4649–50 (2005) (examining the effects of Bt specifically in its use in GM crops).
[172] UN Convention on Biological Diversity, *About the Protocol*, http://bch.cbd.int/protocol/background/ [http://perma.cc/Q9DY-ZC3G] (last visited Jan. 22, 2016).

the United Nations Environment Programme ("UNEP"), and its purpose is to create an international legal framework for the conservation as well as equitable and sustainable uses of biological diversity.[173] In 1994, parties initiated the process of enacting a supplementary protocol that would implement procedures for the safe use of biotechnology, which involved the creation of an open-ended ad hoc working group.[174] The working group represented a large faction of CBD parties, consisting of representatives from over 90 countries in addition to various non-governmental organizations and private parties.[175] The group would go on to meet a total of six times between 1996 and 1999 before submitting a draft text of the protocol to a full meeting of the convention.[176] Negotiations then stalled, however, as contested importation issues led to the development of three major factions: the European Union, the developing countries, and the major agricultural exporting countries.[177] Despite this major gridlock the parties continued to negotiate toward a compromise that was finally reached in January of 2000, when they adopted the protocol and submitted it for ratification.[178]

The Cartagena Protocol represents a milestone in the formation of international legal frameworks. It is the first ever international legal instrument to combine health, safety, and environmental concerns within a single global regulatory trade scheme.[179] Margot Wallstrom, European Commissioner for Environment, hailed the protocol as "a historical moment and a breakthrough for international agreements on trade and the environment . . . reflect[ing] the common will to protect the world's environment."[180]

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[173] Convention on Biological Diversity, *supra* note 139, at 3.
[174] Decision II/5, *Report of the Second Meeting of the Conference of the Parties to the Convention on Biological Diversity* at 47–48, U.N. Doc. UNEP/CBD/COP/2/19 (1995).
[175] *See* Decision I/9, *Report of the First Meeting of the Conference of the Parties to the Convention on Biological Diversity* at 5–10, U.N. Doc. UNEP/CBD/COP/1/17 (1995).
[176] *About the Protocol*, *supra* note 172.
[177] Paul E. Hagen & John B. Weiner, *Cartagena Protocol on Biosafety: New Rules for International Trade in Living Modified Organisms*, 12 GEO. INT'L ENVTL. L. REV. 697, 701–03 (2000).
[178] *Report of the Resumed Session of the Extraordinary Meeting of the Conference of the Parties for the Adoption of the Protocol on Biosafety to the Convention on Biological Diversity: 24–28 January 2000*, EARTH NEGOTIATIONS BULL. (Jan. 31, 2000), *available at* http://www.iisd.ca/vol09/ [http://perma.cc/S5D7-ZAW9].
[179] Hagen & Weiner, *supra* note 177, at 712.
[180] *EU Welcomes International Bio-safety Trade Pact*, REUTERS (Jan. 29, 2000), http://www.iatp.org/news/eu-welcomes-international-bio-safety-trade-pact [http://perma.cc/GCQ8-RVHH].

There are two aspects, in particular, that have precedential value for future environmentally focused regulatory frameworks. First, in Article I, the protocol adopts the precautionary principle as a basis and goal for the agreement and its included provisions.[181] The precautionary principle is a legal maxim common to many environmental statutes and agreements, including the LCLP.[182] Second, the protocol includes a clause to explain that it "shall not be interpreted as implying a change in the rights and obligations of a Party under any existing international agreements."[183] This "savings clause" refers mainly to the protocol's relationship with the treaty establishing the World Trade Organization, and is an important tool in navigating subject areas where multiple regulatory instruments apply.[184] While an additional clause somewhat limits the scope of this provision, it enables the protocol to serve as an example of cooperative regulation that can effectively coexist with existing international law.[185]

The protocol is not, however, without its shortcomings as a legal instrument. The main roadblocks to negotiations, which nearly crippled the protocol before it was ever presented to the CBD, are the differing perspectives on biosafety regulation between the European Union, the developing countries, and the major agricultural exporting countries.[186] While the agricultural exporting countries, led by the United States, sought relaxed regulatory standards to bolster their large GM crop industry, the European Union and developing countries, with little or no GM crop industries, advocated extremely strict regulatory measures aimed at ensuring environmental health and public safety.[187] The result is a compromise that some argue fails to go far enough to address the dangers of GM crop production and transportation and that others argue overly burdens an important agricultural technology.[188] Additionally, the

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[181] *See* Cartagena Protocol on Biosafety to the Convention on Biological Diversity, Jan. 29, 2000, U.N. Doc. UNEP/CBD/ExCOP/1/3, reprinted in 39 I.L.M.
[182] London Protocol, *supra* note 110, at 1, 3.
[183] Cartagena Protocol, *supra* note 181, at 2.
[184] *Id.*
[185] *Id.* at 2 (a later clause states that the "above recital is not intended to subordinate this Protocol to other international agreements," preserving the Protocol's authority to regulate).
[186] *See* Jonathan A. Glass, *The Merits of Ratifying and Implementing the Cartagena Protocol on Biosafety*, 21 NW. J. INT'L L. & BUS. 491, 502–03 (2001).
[187] *Id.*
[188] *Compare* Jessica E. McDonald, *Precautionary Pioneer Evades Biotech Giant? Beyond the Cartagena Protocol: The EU Offers the World a Model*, 8 OR. REV. INT'L L. 157 (2006) (arguing that the Protocol is a good regulatory start, but that more work needs to be done to protect biodiversity), *with* Jonathan H. Adler, *The Cartagena Protocol and Biological Diversity: Biosafe or Bio-Sorry*, 12 GEO. INT'L ENVTL. L. REV. 761 (2000) (arguing that stringent regulation is burdening the introduction of new technologies).

Cartagena Protocol remains unratified by 26 of the 194 CBD parties.[189] The main barrier to full ratification, especially from the perspective of the United States, is the presence of an already burgeoning GM crop industry, which is focused on minimalist regulation.[190] For many nations, industry will not only influence public policy but it will dictate involvement in the Cartagena Protocol altogether.[191] The United States has failed to ratify because its GM crop industry has yet to take a firm stance, caught between arguments that membership would allow the United States to influence decision-making and counter-arguments that membership would inevitably lead to more stringent regulation regardless of United States sway.[192]

The negotiating parties never designed the Cartagena Protocol to be a perfectly functioning regulatory framework, but instead created the protocol as a work in progress that could adapt to implementation challenges, changing technology, and new scientific data.[193] In fact, one of the major unresolved issues of the initial compromise led to the creation of the Nagoya–Kuala Lumpur Supplementary Protocol, which created a scheme for liability and redress.[194] While the effectiveness of the Cartagena Protocol in reference to conservation of biological diversity is yet to be determined, it stands already as a hallmark of international negotiation and a clear guide for future international environmental agreements.

IV. THE CARTAGENA PROTOCOL ON BIOSAFETY AS A MODEL FOR THE DEVELOPMENT OF A HOLISTIC REGULATORY FRAMEWORK FOR OCEAN FERTILIZATION

A singular source of comprehensive regulation for iron fertilization activities is necessary because multiple and overlapping sources of

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[189] CONVENTION ON BIOLOGICAL DIVERSITY, *supra* note 153 (The United States has signed the CBD but has ratified neither the CBD nor the Cartagena Protocol).

[190] JACOB WINIECKI ET AL., COLUMBIA UNIVERSITY, CARTAGENA PROTOCOL ON BIOSAFETY: A REPORT ON POLICY ANALYSIS, PROGRAM DESIGN AND IMPLEMENTATION 21–22 (2004), *available at* http://mpaenvironment.ei.columbia.edu/files/2014/06/Cartagena_Final_Report_121.9.04.pdf [http://perma.cc/AY25-GLM5].

[191] Brian Kirsop, *The Cartagena (Biosafety) Protocol*, 8 J. COM. BIOTECHNOLOGY 214 (2002).

[192] WINIECKI ET AL., *supra* note 190, at 21–22.

[193] Cartagena Protocol, *supra* note 181, at 1042 (authorizing a set of parties to review implementation and make decisions necessary to update the Protocol).

[194] Nagoya–Kuala Lumpur Supplementary Protocol, Oct. 15, 2010, UNEP/CBD/BS/COP-MOP/5/17, Report of the Fifth Meeting of the Conference of the Parties to the Convention on Biological Diversity Serving as the Meeting of the Parties to the Cartagena Protocol on Biosafety, Decision BS-V/11, 62–71.

law have created uncertainty, inhibiting technological and scientific growth. The achievement of the Cartagena Protocol, both in its strengths and weaknesses, serves as the optimal guide for the creation of an effective and inclusive source of regulation. First, the similarities between iron fertilization and GM agriculture provide the perfect opportunity to build upon its success. Second, the Cartagena Protocol draws significance through its precedential value as an international agreement just as much as through its regulatory effect, and ocean fertilization is the perfect subject to build on this type of international law.

A. *The Need for Comprehensive Regulation of Iron Fertilization*

As the issues of climate change and sea level rise continue to demand increasing global attention, ocean fertilization and other forms of geoengineering will entice both scientists and entrepreneurs. As it exists currently, the fractured international framework regarding ocean fertilization projects acts as a barrier rather than a conduit for responsible research and growth.

A prime example is the LOHAFEX expedition, a second expedition conducted by the Alfred Wegener Institute following the initial research of the EIFEX expedition.[195] Much larger than the 2004 experiment, LOHAFEX planned to dump six tons of iron over 116 square miles of the Southern Ocean to induce a major phytoplankton bloom.[196] At the time, the LCLP was still operating under its Annex 6 Resolution, and LOHAFEX satisfied its threshold as a scientific project.[197] The German Science Ministry suspended the experiment, however, because of claims that it violated the CBD's latest decision placing a moratorium on large-scale studies.[198] The Bureau of the Conference of the Parties to the CBD concluded that their rules of procedure did not encompass this type of issue

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[195] Press Release, ALFRED-WEGENER-INSTITUT, Lohafex Provides New Insights on Plankton Ecology—Only Small Amounts of Atmospheric Carbon Dioxide Fixed (Mar. 23, 2009) *available at* http://www.awi.de/en/about-us/service/press/archive/lohafex-provides-new-insights-on-plankton-ecology-only-small-amounts-of-atmospheric-carbon-dioxide.html [http://perma.cc/DV69-ZCZ6].

[196] *LOHAFEX, An Indo-German Open Ocean Experiment to Test the Effects of Iron Fertilization on the Ecology and Carbon Uptake Potential of the Southern Ocean*, INDIA NAT'L INST. OF OCEANOGRAPHY, http://www.nio.org/index.php?option=com_projdisp&task=show&tid=2&sid=15&pid=31 [http://perma.cc/62LG-U3VL] (last visited Jan. 22, 2016).

[197] *See* Annex Six Resolution, *supra* note 126.

[198] *See* 9th Meeting of the Conference of the Parties to the Convention on Biological Diversity, DECISION IX/16 (May 2008).

and addressed the experiment only by sending a letter to Germany expressing the Bureau's concerns.[199] The Bureau eventually lifted the suspension and the Wegener Institute was able to conduct the experiment, although as a result it took place amidst substantial controversy surrounding its suspect legality.[200] The LOHAFEX experiment is illustrative of the problems presented by the current legal landscape. Two major sources of international law, both of which were originally designed to regulate other areas, contained conflicting requirements that created substantial confusion.[201] Additionally, the CBD itself was unable to decipher how it applied to the experiment and was forced to act only by expressing concern.[202]

An additional problem with the current legal system is the LCLP's Assessment Framework. The issue with the most recent source of regulation is that it may be too burdensome even for serious scientific researchers.[203] As of last year, there has not been a single peer-reviewed ocean fertilization experiment conducted since creation of the Assessment.[204] Instead, the most recent ocean fertilization project was a large-scale experiment conducted by a California entrepreneur, which has been condemned as environmentally unconscionable and a clear violation of international law.[205]

Productive scientific research will not be completed until a bright line source of law is drafted with the specific goal of encouraging environmentally responsible growth. The fractured approach of the current system has served only to stunt genuine scientific research and cast a controversial shadow over a potentially valuable environmental tool.

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[199] Minutes of the Meeting of the Bureau of the Conference of the Parties to the Convention on Biological Diversity Held in Nairobi, on 13 February 2009, CONVENTION ON BIOLOGICAL DIVERSITY, *available at* http://www.cbd.int/doc/meetings/cop-bureau/cop-bur-2009/cop-bur-2009-02-13-minutes-en.pdf [http://perma.cc/2F9L-BZLM].
[200] Branson, *supra* note 19, at 178.
[201] *Id.* at 173.
[202] *Id.* at 176.
[203] Melissa Eick, *A Navigational System for Uncharted Waters: The London Convention and London Protocol's Assessment Framework on Ocean Iron Fertilization*, 46 TULSA L. REV. 351, 373–74 (2010).
[204] Branson, *supra* note 19, at 186.
[205] *See* Henry Fountain, *A Rogue Climate Experiment Outrages Scientists*, N.Y. TIMES (Oct. 18, 2012), http://www.nytimes.com/2012/10/19/science/earth/iron-dumping-experiment-in-pacific-alarms-marine-experts.html?_r=0 [https://perma.cc/UU35-WS6T?type=source].

B. *Similarities Between Genetically Modified Crops and Iron Fertilization for the Purposes of Regulation*

From a regulatory perspective, ocean fertilization projects share significant similarities with the early technologies of GM crop production. Both concepts introduce man-made technology into a carefully balanced ecosystem, presenting substantial risk of unintended environmental externalities.[206] At the same time, however, both concepts could be at least partial solutions to two of the world's most pressing issues: climate change and poverty. Additionally, the potential for the widespread use of these technologies attracts commercial involvement that is more concerned with profit margins than environmental impacts.

There are two specific similarities between GM crops and ocean fertilization that call for the use of common techniques in regulation. First, is the lack of collected data to enable informed decisions regarding environmental risks.[207] While components of GM crops, such as Bt and Roundup, have been subject to scrutiny and scientific study, there is a distinct lack of scientific exploration because of the constantly evolving growing methods and technology within transgenic agricultural processes.[208] Chemical proteins are developed and implemented in commercially engineered plants too quickly to study any long-term effects and interactions with the surrounding ecosystem, leading to uncertainty regarding environmental consequences.[209]

Environmental risks from ocean fertilization present a similar lack of scientific knowledge, and although this is mainly because of its novelty as an atmospheric carbon reduction tool as opposed to changing technology, it poses the same problem for regulators.[210] To be truly effective, regulations for both GM crops and iron fertilization need to create a balance between environmentally driven limitations and the promotion of scientific and technological development.

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[206] Chunglin Kwa & Mieke van Hemert, *Engineering the Planet: The Issue of Biodiversity in the Framework of Climate Manipulation and Climate Governance*, 76 QUADERNI 79, 84, 86 (2011).
[207] *Id.* at 84.
[208] *See* Clark et al., *supra* note 171, at 4650; *see also* Cox, *supra* note 169, at 10.
[209] NASSIM NICHOLAS TALEB ET AL., NYU SCHOOL OF ENGINEERING WORKING PAPER SERIES, THE PRECAUTIONARY PRINCIPLE (WITH APPLICATION TO THE GENETIC MODIFICATION OF ORGANISMS) 8–10 (2014), *available at* http://arxiv.org/pdf/1410.5787v1.pdf [http://perma.cc/698J-FLLP].
[210] MICHELLE ALLSOPP ET AL., A SCIENTIFIC CRITIQUE OF OCEANIC IRON FERTILIZATION AS A CLIMATE CHANGE MITIGATION STRATEGY 3 (2007), http://www.climos.com/imo/Other/Other_greenpeace_iron_fert_critiq_Sep2007.pdf [http://perma.cc/K5KJ-2N4X].

Second, the regulation of both activities present distinctly international legal issues. GM crops are not only grown around the world but their transportation through international trade causes environmental problems, as well as health and ethical issues, for the international community as a whole.[211] The Cartagena Protocol also serves dual functions: its effort to create uniform standards in GM crop production and its goal to effectuate the safe transfer of GM crops in international trade.[212]

Ocean fertilization activities fall under the purview of international law because ocean areas with iron deficiencies are generally outside the territorial jurisdiction of any nation's 200-mile exclusive economic zone.[213] These international waters are common areas to all nation states and only established sources of international law, principally international agreements, have legal effect on activities that occur there.[214]

C. *Benefits of Using the Cartagena Protocol as the Model for an Ocean Fertilization Agreement*

Parties to the CBD should establish an additional supplementary protocol for the purpose of regulating ocean fertilization activities. The CBD has unique characteristics as an international agreement that make it the perfect forum for unilateral regulation. Specifically, the CBD has more expansive legal authority than other applicable agreements and a built-in model in the form of the Cartagena Protocol.

First, the CBD effectively constitutes a universally recognized international agreement with 194 of the 196 countries of the world as listed parties.[215] Only the Vatican and the United States are not parties, and while various reasons exist as to why the United States has not yet ratified the CBD, its domestic law currently comports with CBD's requirements anyway.[216] Additionally, the CBD has a strong record of party

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[211] Simonetta Zarrilli, United Nations Conference on Trade and Development, Policy Issues in International Trade and Commodities Study Series No. 29, International Trade in GMOs and GM Products: National and Multilateral Legal Frameworks (2005) (analyzing both national and international legal frameworks that govern agro-biotechnology).

[212] Cartagena Protocol, *supra* note 181, at 1027, 1029.

[213] Hugh Powell, *Dumping Iron and Trading Carbon: Profits, Pollution, and Politics will Play Roles in Ocean Iron Fertilization*, 46 OCEANUS 22 (2008).

[214] *IEG of the Global Commons*, UNITED NATIONS ENVIRONMENT PROGRAMME, http://www.unep.org/delc/GlobalCommons/tabid/54404/ [http://perma.cc/U6WH-EGVM] (last visited Jan. 22, 2016).

[215] CONVENTION ON BIOLOGICAL DIVERSITY, *supra* note 153.

[216] William J. Snape III., *Joining the Convention on Biological Diversity: A Legal and*

participation in decisions of the convention as well as its supplementary protocols.[217] In contrast, the LCLP currently consists of only 45 parties and therefore carries only limited legal authority.[218] Finally, the LOSC falls in-between the two and currently consists of 167 parties.[219] In addition to its expansive jurisdiction, CBD stands in a perfect position to incorporate the current ocean fertilization regulations as a starting point for the development of a protocol. In addition to having independently promulgated advisory decisions regarding ocean fertilization activities, the CBD has also expressly recognized the work of the LCLP.[220] As a result, the LCLP's work in creating the Assessment Framework doesn't have to be wasted but can be recognized as a basis for a CBD formed protocol.

Second, the Cartagena Protocol can easily be used to model the formation of an ocean fertilization protocol. Its use of the precautionary principle and its "savings clause" are general legal principles that could be placed directly into a new protocol, and would add to its legitimacy and appeal. The Cartagena Protocol can also be broken down into three main functions that would have similar application to ocean fertilization regulation: mandated risk assessments, creation of the Biosafety Clearing-House, and a system for liability and redress.

The Protocol's risk assessment provisions are the core of the agreement, requiring an exporting country to submit detailed health and environmental risk assessment data before any shipment of GM crops can be made.[221] This assessment operates under the same principles of LCLP's Assessment Framework, and should be a point of focus for an ocean fertilization protocol. Parties to the CBD are situated perfectly to build on the work already done by the LCLP and create an assessment that will protect ecological interests while facilitating scientific research.

Another of the Protocol's primary functions is to facilitate the sharing of information between its parties to generate scientific understanding and technological growth.[222] The goal is to enable a cooperative effort

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Scientific Overview of Why the United States Must Wake Up, 10 SUSTAINABLE DEV. L.& POL'Y (Issue 3) 6 (2010).

[217] CONVENTION ON BIOLOGICAL DIVERSITY, *supra* note 153 (the Cartagena Protocol has 168 parties, and more nations are joining each year).

[218] London Protocol, *supra* note 110.

[219] United Nations Division for Ocean Affairs and the Law of the Sea, Chronological List of Ratifications of, Accessions and Successions to the Convention and the Related Agreements as at 3 October 2014 (Jan. 7, 2015), http://www.un.org/depts/los/reference_files/chronological_lists_of_ratifications.htm [http://perma.cc/H5ZK-Q4TG].

[220] Branson, *supra* note 19, at 176.

[221] Cartagena Protocol, *supra* note 181, at 1033–34.

[222] WINIECKI ET AL., *supra* note 190, at 12.

to expand the GM crop industry safely, utilizing research and best practices from around the globe.[223] As a result, the parties created the Biosafety Clearing-House specifically for "the exchange of scientific, technical, environmental and legal information on, and experience with, living modified organisms."[224] As discussed, the largest obstacle to the viability of ocean fertilization as a climate change tool is the fractured nature of a limited amount of existing research.[225] A similar informational clearinghouse in conjunction with a centralized protocol would ensure that not only is research being conducted safely, but also that efforts are efficient and not duplicative.

Finally, the Cartagena Protocol's liability and redress system provides a solution to the uncertainty surrounding experiments conducted in non-compliance with international law. The original draft of the protocol didn't include a redress function, instead opting to wait until evaluation could be made of the instrument in practice.[226] The Nagoya–Kuala Lumpur Supplementary Protocol on Liability and Redress to the Cartagena Protocol on Biosafety was adopted for ratification in 2010, and its primary component requires parties to develop domestic legal frameworks for redress of environmental damage.[227] An effective ocean fertilization protocol will need to adopt a similar system to alleviate any uncertainty in regard to CBD responsive action. The reaction of the Bureau of the Conference of the Parties regarding the LOHAFEX experiment illustrates the need for this type of provision.[228] Had a protocol been in place to provide bright line procedure, promulgated regulations could have actually been enforced, and any controversy avoided.

While the direct application of these three major components make an ocean fertilization agreement the ideal candidate to serve as the first of Cartagena's progeny, its negotiation history is also informative. The major source of disagreement in creation of the protocol stemmed from the influence of commercial interests, pitting industrialized countries against developing countries.[229] Ocean fertilization has not yet reached the stage of major commercial viability, and by drafting a protocol now the parties to the CBD can come to consensus more easily.

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[223] *Id.* at 3.
[224] Cartagena Protocol, *supra* note 181, at 1036.
[225] Kwa & van Hemert, *supra* note 206, at 84.
[226] Cartagena Protocol, *supra* note 181, at 1036 (directing the parties to create a process for liability and redress within four years).
[227] Nagoya–Kuala Lumpur Supplementary Protocol, *supra* note 194, at 64, 138, 142.
[228] Branson, *supra* note 19, at 178.
[229] WINIECKI ET AL., *supra* note 190, at 14.

At its initial adoption, policymakers hailed the Cartagena Protocol as a "breakthrough for international agreements."[230] As significant as the Protocol was for the future of GM crops, it has the potential to have even greater importance as a trailblazer for future environmental agreements.

CONCLUSION

Ocean fertilization exists today as a concept shrouded in controversy, considered by many to be closer to science fiction than reality. Headlines are made by commercial enterprises known as "climate hackers" rather than by serious scientific ventures, distorting what was originally hypothesized as part of the solution to climate change.[231] As a result, the potential for ocean fertilization to have an actual impact on atmospheric carbon levels has been lost in the controversy. Legitimate scientific research and analysis is the only solution to this debate, and the uncertainty of our fractured legal landscape represents the major barrier to progress.

Clear and comprehensive regulation, aimed at striking a balance between environmental safety and the need for scientific evaluation, holds the key to the future of ocean fertilization. The Cartagena Protocol marked a huge achievement in the progress of GM crops, ensuring both environmentally benign development and transportation as well as cooperative technological and scientific advancement. Ocean fertilization shares these same goals, and the Cartagena Protocol should mark yet another huge achievement by serving as a guide for an additional protocol. The resulting source of international law will provide the requisite limitations and clarity to promote the scientific research necessary to safely realize the true potential of ocean fertilization.

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[230] REUTERS, *supra* note 180.

[231] Raymond T. Pierrehumbert, *Climate Hacking Is Barking Mad*, SLATE (Feb. 10, 2015), http://www.slate.com/articles/health_and_science/science/2015/02/nrc_geoengineering_report_climate_hacking_is_dangerous_and_barking_mad.html [http://perma.cc/2WJA-BKX2].