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# Climate Geoengineering: Solar Radiation Management and its Implications for Intergenerational Equity

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Abstract

As a result of the power of the present generation to unilaterally inflict enormous environmental harm on generations yet unborn, there is a clear need to address intergenerational relations within international environmental law.[1]



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[1] Lynda M. Collins, *Revisiting the Doctrine of Intergenerational Equity in Global Environmental Governance*, 30 DALHOUSIE L.J. 79, 98 (2007).

## I. INTRODUCTION

As David Victor recently observed, climate geoengineering, broadly defined as "the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change,"[2] was once viewed as "a freak show in otherwise serious discussions of climate science and policy."[3] However, in the past few years, the feckless response of the world community to burgeoning greenhouse gas emissions[4] has led to increasingly serious consideration of the potential role of geoengineering as a potential means to avoid a "climate emergency,"[5] such as rapid melting of the Greenland and West Antarctic ice sheets,[6] or as a stopgap measure to buy time for effective emissions

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[2] The Royal Soc'y, *Geoengineering the Climate: Science, Governance and Uncertainty* (Sept. 2009), at 11, *available at* http://royalsociety.org/Geoengineering-the-climate/.

[3] David G. Victor, *On the Regulation of Geoengineering,* 24(2) OXFORD REV. ECON. POL'Y 322, 323 (2008).

[4] Since the Kyoto Protocol was signed in the 1990s, the annual rate of greenhouse gas emissions has actually accelerated from 1.3% in the 1990s to 3.3% from 2000-2006, though that rate has slowed during the current economic downturn. A.J. Dolman et al., *A Carbon Cycle Science Update Since IPCC AR-4,* 39 AMBIO 402, 403 (2010); Stefan Folster & Johan Nystrom, *Climate Policy to Defeat the Green Paradox,* 39 AMBIO 223, 223 (2010). As a consequence, even limiting projected temperature increases to less than 4º Celsius above pre-industrial levels may require a "radical reframing of both the climate change agenda, and the economic characterization of contemporary society." Kevin Anderson & Alice Bows, *Reframing the Climate Change Challenge in Light of Post-2000,* PHIL. TRANSACTIONS ROYAL SOC'Y A, 18, (2008); *see also* INT'L ENERGY AGENCY, WORLD ENERGY OUTLOOK 2010: EXECUTIVE SUMMARY 11 (2010), *available at* http:/*/www.worldenergyoutlook.org/docs/weo2010/WEO2010_ES_English.pdf* (stating that Copenhagen Accord pledges put us on track for more than a 3.5º Celsius increase in temperatures); Joeri Rogelj et al., *Analysis of the Copenhagen Accord Pledges and its Global Climatic Impacts—A Snapshot of Dissonant Ambitions,* 5 ENVTL. RES. LETTERS, 034013 (2010), at 7 (stating that pledges made by the Parties in the Copenhagen Accord at the fifteenth Conference of the Parties may result in a temperature increase of 2.5-4.2º Celsius by 2100, with temperatures continuing to increase after this point). This is an extremely foreboding development, as most scientists and policymakers now believe that even a 2º-Celsius increase from pre-industrial levels will have a serious impact on human institutions and ecosystems. GERMAN ADVISORY COUNCIL FOR GLOBAL CHANGE, *New Impetus for Climate Policy: Making the Most of Germany's Dual Presidency,* WBGU Policy Paper 5 (2007); Comm'n of European Cmtys., *Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, Limiting Global Climate Change to 2ºC the Way Ahead for 2020 and Beyond* (October 1, 2007); James Hansen et al. *Dangerous Human-Made Interference with Climate: A GISS Model Study,* 7 ATMOSPHERIC CHEMISTRY & PHYSICS 2287-2312 (2007), *available at* http://pubs.giss.nasa.gov/docs/2007/2007_Hansen_etal_1.pdf.

[5] Ken Caldeira & David W. Keith, *The Need for Climate Engineering Research,* ISSUES SCI. & TECH. 57, 57 (2010).

[6] JASON BLACKSTOCK ET AL., CLIMATE ENGINEERING RESPONSES TO CLIMATE EMERGENCIES 1-2 (Novim 2009), *available at* http://arxiv.org/ftp/arxiv/papers/0907/0907.5140.pdf; Peter J. Irvine et al., *The Fate of the Greenland Ice Sheet in a Geoengineered, High $CO_2$ World,* 4 ENVTL. RES. LETTERS, 045109 (2009), at 2. A complete melting of the Greenland Ice Sheet could occur with temperature increases of 2-3º Celsius. Stephen Schneider, *The Worst-Case Scenario,* 458 NATURE 1104,1104 (2009). This could raise global sea level by approximately seven meters and trigger a slowdown or collapse of the ocean thermohaline circulation, which could result in significant cooling over much of the northern hemisphere. Julian A. Dowdeswell, *The Greenland Ice Sheet and Global Sea-Level Rise,* 311 SCIENCE 963, 963 (2004); Jason A. Lowe et al., *The Role of Sea-Level Rise and the Greenland Ice Sheet in Dangerous Climate Change: Implications for the Stabilisation of Climate, in* AVOIDING DANGEROUS CLIMATE CHANGE 30 (Hans Joachim Schellnhuber ed., 2006). Global average temperature increases of 1-4º Celsius relative to 1990-2000 could result in sea level rise of four to six meters. CLIMATE CHANGE 2007: CLIMATE CHANGE

mitigation responses.[7] Indeed, a number of recent studies indicate that geoengineering schemes could potentially mitigate the climatic impacts associated with a doubling of atmospheric carbon dioxide levels from pre-industrial levels.[8]

However, many policymakers and commentators, even including some who signaled tentative support for geoengineering options, have expressed serious reservations. Most of the focus of these concerns has been on *intragenerational* considerations associated with the two major categories of geoengineering, solar radiation management (SRM)[9] and carbon dioxide removal (CDR)[10] schemes. For

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IMPACTS, ADAPTATION AND VULNERABILITY, CONTRIBUTION OF WORKING GROUP II TO FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 17 (Martin L. Parry et al. eds., 2007). Even a 5-meter rise in sea level could affect 5% of the world's population and threaten two trillion dollars of Gross Domestic Product. U.N. Framework Convention on Climate Change, *Mechanisms to Manage Financial Risks from Direct Impacts of Climate Change in Developing Countries* 35, U.N. Doc. FCCC/TP/2008/9 (Nov. 21, 2008). Some proponents of geoengineering also cite concern about temperatures reaching a critical "tipping point," or a "regime shift," triggering "non-linear self-reinforcing further warming or other dangerous environmental effects beyond those resulting immediately from the temperature rise itself." Alan Carlin, *Why a Different Approach is Required If Global Climate Change is to Be Controlled Efficiently or Even At All,* 32 WM. & MARY ENVTL. L. REV. 685, 706-07 (2008); *see also* Rob Swart & Natasha Marinova, *Policy Options in a Worst Case Climate Change World,* 15 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 531, 532-33 (2010). Potential regime shifts could include the complete disappearance of Arctic sea ice in summer, leading to drastic changes in ocean circulation and climate patterns across the whole Northern Hemisphere; acceleration of ice loss from the Greenland and Antarctic ice sheets; ocean acidification from carbon dioxide absorption, potentially wreaking havoc on ocean ecosystems, massive dieback of forests, and shutdown of the Atlantic Thermohaline Circulation system. Alan Hastings & Derin B. Wysham, *Regime Shifts in Ecological Systems Can Occur with No Warning*, 13 ECO. LETTERS 464, 472 (2010); *Runaway Tipping Points of No Return*, REALCLIMATE (July 5, 2006), http://www.realclimate.org/index.php/archives/2006/07/runaway-tipping-points-of-no-return (last visited Feb. 13, 2011). Moreover, temperature increase of this magnitude could lead to a release of greenhouse gases double that produced by humans to date, triggering a "runaway greenhouse effect." Carlin, *supra* at 691; *see also* Fred Pearce, *Climate Warming as Siberia Melts,* NEW SCI. 12 (2009); Kevin Schaefer et al., *Amount and Timing of Permafrost Carbon Release in Response to Climate Warming,* TELLUS (2011) *available at* http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0889.2011.00527.x/pdf.

[7] Martin Bunzl, *Research Geoengineering: Should Not or Could Not?,* 4 ENVTL. RES. LETTERS 045104 (2009), *available at* http://iopscience.iop.org/1748-9326/4/4/045104/fulltext; Christopher Mims, *'Albedo Yachts' and Marine Clouds: A Cure for Climate Change?,* SCI. AM. 3 (2009).

[8] Ken Caldeira & Lowell Wood, *Global and Arctic Climate Engineering: Numerical Model Studies,* 366 PHIL. TRANSACTIONS ROYAL SOC'Y A 4039, 4044 (2008); Bala Govindasamy, Ken Caldeira, & Philip Duffy, *Geoengineering Earth's Radiation Balance to Mitigate Climate Change from a Quadrupling of $CO_2$,* 37 GLOBAL & PLANETARY CHANGE 157, 158 (2003).

[9] Climate geoengineering schemes seek to reduce net radiative forcing by balancing the forcing associated with greenhouse gases with negative forcing by reducing the amount and characteristics of solar radiation. Carlin, *supra* note 6, at 688. It has been calculated that solar irradiance would have to be reduced by 1.8% to offset the radiative forcing associated with a doubling of carbon dioxide concentrations from pre-industrial levels. The Royal Soc'y, *supra* note 2, at 23. Solar radiation management methods seek to reduce net incoming short-wave solar radiation by deflecting sunlight or increasing the reflectivity of the atmosphere, clouds, or the Earth's surface.

[10] Carbon dioxide removal (CDR) schemes remove carbon dioxide from the atmosphere after they have been released, facilitating the escape of more long-wave heat radiation. The Royal Soc'y, *supra* note 2, at 1. The most prominent CDR approaches include ocean iron fertilization (*see infra* note 16), air capture of carbon dioxide (David Biello, *Pulling CO2 from the Air: Promising Idea, Big Price Tag,* YALE ENVIRONMENT 360, http://www.360.yale.edu/content/print.msp?id=2197 (last visited Oct. 12, 2010)) and mineral sequestration of carbon dioxide by combining it with suitable rocks such as olivine or serpentine,

example, several recent studies have concluded that stratospheric sulfate aerosol injection,[11] perhaps the most widely discussed SRM scheme,[12] could lead to a substantial reduction in precipitation in monsoon regions in East and South-East Asia and Africa. This could result in a severe reduction in monsoonal intensity, potentially undermining the food security of 2 billion people in the region.[13] Diebacks of tropics forests could also be triggered by substantial precipitation declines in the Amazon and Congo valleys.[14] Additionally, sulfate aerosol loading of the atmosphere could create chemical reactions that may result in severe depletion of the ozone layer. For example, a recent study concluded that sulfate aerosol loading could result in an annual 4.5% decrease in stratospheric ozone levels, more than the annual mean global total loss due to the emission of anthropogenic ozone depleting substances in recent years.[15] Several studies have also indicated that ocean iron fertilization,[16] a CDR approach, could undermine

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or injection into the ground to react with local mineral rock (*Geoengineering II: The Scientific Basis and Engineering Challenges*: *Hearing Before the H. Comm. on Sci. & Tech., Subcomm. on Energy & Env't.*, 111th Cong. (2010) (statement of Klaus S. Lackner), *available at* http://democrats.science.house.gov/Media/file/Commdocs/hearings/2010/Energy/4feb/Lackner_Testimony.pdf), and biochar and biomass methods (The Royal Soc'y, *supra* note 2, at 11).

[11] Stratospheric sulfate aerosol injection is a geoengineering scheme that involves the release of large quantities of sulfur into the stratosphere, or a precursor gas that oxidizes in the stratosphere, for the purpose of scattering incoming solar radiation. Utilizing a delivery system such as a highflying jet, artillery shells or balloons would facilitate sulfur injection. Philip J. Rasch et al., *An Overview of Geoengineering of Climate Using Stratospheric Sulphate Aerosols,* 366 PHIL. TRANSACTIONS ROYAL SOC'Y A 4007, 4013-14 (2009). While sulfur dioxide is the most widely discussed candidate for atmospheric injection, other candidates include hydrogen sulfide ($H_2S$), carbonyl sulfide, ammonium sulfide, and engineering nanoscale particles. *See, e.g.*, Ben Kravitz et al., *Sulfuric Acid Deposition from Stratospheric Geoengineering with Sulfate Aerosols,* 114 J. GEOPHYSICAL RES. D14109 (2009), at 2; David W. Keith, *Photophoretic Levitation of Engineered Aerosols for Geoengineering,* 108(38) PNAS 16428-16431 (2010).

[12] ERIC BICKEL & LEE LANE, COPENHAGEN CONSENSUS CTR., AN ANALYSIS OF CLIMATE ENGINEERING AS A RESPONSE TO CLIMATE CHANGE 17 (2009), *available at* http://fixtheclimate.com/fileadmin/templates/page/scripts/downloadpdf.php?file=/uploads/tx_templavoila/AP_Climate_Engineering_Bickel_Lane_v.5.0.pdf. One commentator has identified sulfur injection as "probably the most seriously discussed geoengineering proposal." Albert C. Lin*, Balancing the Risks: Managing Technology and Dangerous Climate Change*, 8(3) ISSUES IN LEGAL SCHOLARSHIP 1, 4 (2009).

[13] Victor Brovkin et al., *Geoengineering Climate by Stratospheric Sulfur Injections: Earth System Vulnerability to Technological Failure,* 92 CLIMATIC CHANGE 243, 252 (2009); Alan Robock, Luke Oman & Georgiy L. Stenchikov, *Regional Climate Responses to Geoengineering with Tropical and Arctic $SO_2$ Injections,* 113 J. GEOPHYSICAL RES. D16101 (2008), at 13.

[14] Alexey V. Eliseev et al., *Global Warming Mitigation by Sulphur Loading in the Stratosphere: Dependence of Required Emissions on Allowable Residual Warming Rate,* 101 THEORETICAL APPLIED CLIMATOLOGY 67, 79 (2010).

[15] P. Heckendorn et al., *The Impact of Geoengineering Aerosols on Stratospheric Temperature and Ozone,* 4 ENVTL. RES. LETTERS 1, 7 (2009); *see also* Alan Robock, *Whither Geoengineering?,* 320 SCIENCE 1166, 1166 (2008). Of course, this could also have intergenerational implications. Recent research has indicated that sulfate injection schemes could delay recovery of the stratospheric ozone layer by as much as seventy years, thus impacting future generations. The Royal Soc'y, supra note 2, at 31. Some researchers have suggested that injection of engineered nanoparticles could substantially reduce the potential threat to the stratospheric ozone layer by facilitating the lofting of aerosols out of the stratosphere. David W. Keith, *Photophoretic Levitation of Engineered Aerosols for Geoengineering,* 107(38) PNAS 1628, 1630 (2010).

[16] Ocean iron fertilization (OIF) techniques seek to stimulate the production of phytoplankton through the addition of iron to ocean regions that are allegedly deficient in this micronutrient. Christine Bertram, *Ocean Iron Fertilization in the Context of the Kyoto Protocol and the Post-Kyoto Process,* 38(2) ENERGY POL'Y 1130, 1131 (2010); Philip Boyd, *Ironing Out Algal Issues in the Southern Ocean,* 305 SCIENCE 396-

biological productivity in non-fertilized regions,[17] cause widespread eutrophication and anoxia,[18] and stimulate toxic algal blooms.[19]

This article will advance the argument that one category of geoengineering approaches, SRM schemes, could also severely circumscribe the options of future generations in the context of climate change policy, as well as potentially visit catastrophic negative climatic impacts. As such, this approach would, under all but the most stringent protocols, violate the tenets of an important principle of international law, intergenerational equity. Considerations of intergenerational equity, as such, are critical in the context of the pursuit of climate justice, defined as "special problems of obligation and participation posed by climate impacts and policies for their management."[20]

In developing this argument, I will: 1) present an overview of the principle of international equity; 2) discuss the application of intergenerational equity obligations in the context of SRM climate geoengineering; and 3) discuss the implications of intergenerational equity for CDR geoengineering options.

## II. SRM GEOENGINEERING AND INTERGENERATIONAL EQUITY CONSIDERATIONS

### *A. Overview of Intergenerational Equity as a Principle of International Law*

Intergenerational equity is a "principle of distributive justice"[21] that calls for "fairness in the utilization of resources between human generations past, present and future."[22] It is ultimately grounded in the premise that human survival is a salutary goal,

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97 (2004). Phytoplankton take up carbon dioxide from seawater to carry out photosynthesis and to build up particulate organic carbon (POC). *Id.* Ultimately, part of the POC sinks to the deep ocean where it can be stored for a century or more. *Id.* The potential effectiveness of OIF remains contested. Some proponents claim that OIF could result in a substantial drawdown of atmospheric carbon dioxide concentrations. Olivier Aumont & Laurent Bopp, *Globalizing Results from Ocean In Situ Iron Fertilization Studies*, 20 GLOBAL BIOGEOCHEMICAL CYCLES 1, 1 (2006) (demonstrating that massive OIF could reduce atmospheric concentrations of carbon dioxide by between 50-107 parts per million 100 years of fertilization). However, more recent research, informed by a number of recent field experiments, is not nearly as sanguine. *See* M.J.C. Crabbe, *Modeling Effects of Geoengineering Options in Response to Climate Change and Global Warming: Implications for Coral Reefs,* 33 COMPUTATIONAL BIO. & CHEMISTRY 415, 418 (2009) (stating that OIF of 20% of world's oceans would only reduce atmospheric carbon dioxide by less or equal to 15 parts per million at expected levels of 700 parts per million in 2100 for business as usual scenarios of greenhouse gas emissions); R.S. Lampitt, *Ocean Fertilization: A Potential Means of Geoengineering?,* 366 PHIL. TRANSACTIONS ROYAL SOC'Y A 3919, 3928 (2008) (OIF could only draw down atmospheric levels of carbon dioxide by 10 parts per million).

[17] Karen N. Scott, *The Day After Tomorrow: Ocean $CO_2$ Sequestration and the Future of Climate Change,* 18 GEO. INT'L ENVTL. L. REV. 57, 95 (2005).

[18] Lampitt, *supra* note 16, at 3930.

[19] Charles G. Trick et al., *Iron Enrichment Stimulates Toxic Diatom Production in High-Nitrate, Low-Chlorophyll Areas,* PNAS EARLY EDITION (Mar. 10, 2010), at 5887, http://www.pnas.org/cgi/doi/10.1073/pnas.0910579107 (last visited May 8, 2011).

[20] Ludvig Beckman & Edward A. Page, *Perspectives on Justice, Democracy and Global Climate Change,* 17(4) ENVTL. POL. 527, 527 (2008).

[21] Brett M. Frischmann, *Some Thoughts on Shortsightedness and Intergenerational Equity,* 36 LOY. U. CHI. L.J. 457, 460 (2005); Lawrence B. Solum, *To Our Children's Children's Children: The Problems of Intergenerational Ethics,* 35 LOY. L.A. L. REV. 163, 175 (2001) ("Distributive justice is concerned with sharing the benefits and burdens of social cooperation.").

[22] G.F. Maggio, *Inter/intragenerational Equity: Current Applications under International Law for Promoting the Sustainable Development of Natural Resources,* 4 BUFF. ENVTL. L.J. 161, 163 (1997).

and in the correlated moral obligations to support human continuity by sound stewardship of the resources essential for life, as well as to ensure the dignity and well-being of Earth's inhabitants.[23] As such, it "demands that present generations should not create benefits for themselves in exchange for burdens on future generations."[24]

There are several rationales that can support an obligation of intergenerational equity. From a social contract perspective, we can view all generations as partners in an open-ended social contract that defines their rights, duties and obligations. As Burke contended, because society's objectives cannot be achieved in a single generation, it is imperative that each generation protects the interests of those to come.[25]

Another basis for imposing intergenerational obligations is grounded in the equitable notions that underpin the "original position" theory formulated by John Rawls. As Brown Weiss contends:

> In order to define what intergenerational equity then means, it is useful to view the human community as a partnership encompassing all generations, the purpose of which is to realize and protect the well-being of every generation and to conserve the planet for the use of all generations. Although all generations are members of this partnership, no generation knows in advance when it will be living, how many members it will have, nor even how many generations there will be.
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> It is appropriate to adopt the perspective of a generation which is placed somewhere on the spectrum of time, but does not know in advance where . . . . Such a generation would want to receive the planet in at least as good condition as every other generation receives it and to be able to use it for its own benefit. This requires that each generation pass on the planet in no worse condition than received and have equitable access to its resources.[26]

The notion of unjust enrichment is another rationale that has been advanced as a basis of duties toward future generations. Our generation is indebted to past generations for endowing us with the resources that ensure our well-being. In turn, it can be argued that we hold these resources in trust and have a responsibility to pass them on in no worse condition than we received them. To fail to do so would constitute a form of unjust enrichment.[27] Finally, intergenerational equity can be viewed as an extension of the

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[23] Edith Brown Weiss, *Climate Change, Intergenerational Equity and International Law: An Introductory Note,* 15 CLIMATIC CHANGE 327, 330 (1989) ("Each generation is both a trustee and a beneficiary, or a custodian and user, of the planet"); Dinah Shelton, *Intergenerational Equity, in* SOLIDARITY: A STRUCTURAL PRINCIPLE OF INTERNATIONAL LAW 131 (Rüdiger Wolfrum & Chie Kojima eds., 2010).

[24] Marlos Goes, Klaus Keller, & Nancy Tuana, *The Economics (or Lack Thereof) of Aerosol Engineering* (forthcoming 2011), *available at* http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.144.446.

[25] Edmund Burke, *Reflections on the Revolution in France* (1790), *in* 2 WORKS OF EDMUND BURKE 130-40 (1854) ("[A]s the ends of such a partnership cannot be obtained in many generations, it becomes a partnership not only between those who are living but between those who are living, those who are dead, and those who are to be born."); *see also* Robin Attfield, *Environmental Ethics and Intergenerational Equity,* 41(2) INQUIRY 207, 219 (1998).

[26] Brown Weiss, *supra* note 23, at 335.

[27] Shelton, *supra* note 23, at 132.

public trust doctrine, mandating that this generation protect the interests of future generations in the Earth and its resources.[28]

The equitable considerations that support the principle of intergenerational equity mandate that "later generations [should] not be worse off than previous generations."[29] In the context of environmental resources, this includes both the form of resource stocks and the shape of environmental problems that current generations bestow on future generations.[30] More broadly, intergenerational equity also requires that future generations be accorded freedom of choice as to their political, economic and social systems.[31]

Edith Brown Weiss outlines three basic obligations of intergenerational equity:

1. **Conservation of options**. "[E]ach generation should be required to conserve the diversity of the natural and cultural base, so that it does not unduly restrict the options available to future generations in solving their problems and satisfying their own values . . .";
2. **Conservation of quality.** "[E]ach generation should be required to maintain the quality of the planet so that it is passed on in no worse condition than that in which it was received . . .";
3. **Conservation of access.** "[E]ach generation should provide its members with equitable rights of access to the legacy of past generations and should conserve this access for future generations."[32]

These three categories of "Planetary Obligations" are further disarticulated into five duties of use: (i) the duty to conserve resources; (ii) the duty to ensure equitable use; (iii) the duty to avoid adverse impacts; (iv) the duty to prevent disasters, minimize damage, and provide emergency assistance; and (v) the duty to compensate for environmental harm.[33]

Intergenerational equity is a binding principle of international law with broad application.[34] Most pertinent in the context of climate change policy making, the United Nations Framework Convention on Climate Change (UNFCCC),[35] which has 194

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[28] Edith Brown Weiss, *Intergenerational Equity: A Legal Framework for Global Environmental Change*, *in* ENVIRONMENTAL CHANGE AND INTERNATIONAL LAW 395 (Edith Brown Weiss ed., 1992); Donna R. Christie, *Marine Reserves, The Public Trust Doctrine and Intergenerational Equity,* 19 J. LAND USE 427, 434 (2004), *available at* http://www.law.fsu.edu/journals/landuse/vol19_2/1achristie.pdf.
[29] Edith Brown Weiss, *What Obligation Does Our Generation Owe to the Next? An Approach to Global Environmental Responsibility: Our Rights and Obligations to Future Generations for the Environment,* 84 AM. J. INT'L L. 198, 200 (1990).
[30] Lars Osberg, MEANING AND MEASUREMENT IN INTERGENERATIONAL EQUITY 4 (1997), *available at* http://myweb.dal.ca/osberg/classification/book%20chapters/Meaning%20and%20Measurement%20in%20Intergenerational%20Equity/Meaning%20and%20Measurement%20in%20Intergenerational%20Equity.pdf.
[31] U.N. Educ., Sci., & Cultural Org., *Declaration on the Responsibilities of the Present Generations Towards Future Generations* (1997)*,* at art. 3, *available at* http://portal.unesco.org/en/ev.php-URL_ID=13178&URL_DO=DO_PRINTPAGE&URL_SECTION=201.html.
[32] Brown Weiss, *supra* note 29, at 201-02.
[33] Edith Brown Weiss, IN FAIRNESS TO FUTURE GENERATIONS: INTERNATIONAL LAW, COMMON PATRIMONY, AND INTERGENERATIONAL EQUITY 51-60 (1989).
[34] Maggio, *supra* note 22, at 161; Collins, *supra* note 1, at 123.
[35] U.N. Framework Convention on Climate Change [hereinafter UNFCCC], U.N. Doc. A/AC.237/18 (May 9, 1992), *reprinted in* 31 I.L.M. 849 (1992).

Parties,[36] incorporates the principle in Article 3(1), providing that "The Parties should protect the climate system for the benefit of present and future generations of humankind, on the basis of equity . . ."[37] It can also be argued that intergenerational equity is a binding principle of customary international environmental law given its incorporation in a wide array of treaties,[38] domestic and international case law,[39] domestic law,[40] and soft law instruments.[41] Moreover, the principle has been characterized as "a fundamental

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[36] UNFCCC Secretariat, *Status of Ratification of the Convention*, *available at* http://unfccc.int/essential_background/convention/status_of_ratification/items/2631.php.

[37] UNFCCC, *supra* note 35, art. 3 § 1.

[38] Amazonian Cooperation Treaty pmbl., July 3, 1978, I.L.M. 1045; Convention on Access to Information, Public Participation in Decision-Making, and Access to Justice in Environmental Matters pmbl., *adopted on* June 25, 1998, 2161 U.N.T.S. 447; Convention on Biological Diversity pmbl. para. 23, *opened for signature* June 5, 1992, 1760 U.N.T.S. 79, 31 I.L.M. 818; Convention on the Conservation of European Wildlife and Natural Habitats pmbl., *open for signature* Sept. 19, 1979, 1284 U.N.T.S. 209; Convention on the Conservation of Migratory Species of Wild Animals pmbl., *done on* June 23, 1979, 1651 U.N.T.S. 356, 19 I.L.M. 15; Convention on International Trade in Endangered Species of Wild Fauna and Flora pmbl., *done on* Mar. 3, 1973, 27 U.S.T. 1087, 993 U.N.T.S. 243; *see also* North East Atlantic Fisheries Commission, *Information on the Protection of Biodiversity and Mitigating Impact of Fisheries in the North East Atlantic* (19 Oct. 2010) (*prepared by* the NEAFC Secretariat), at 2 ("Fishing communities and societies have the right to pursue their legitimate business of establishing economic development that meets the needs of the present generation without compromising the ability of future generations to meet their needs."). It should be noted, however, that the UNFCCC is the only treaty that includes intergenerational equity considerations in non-preambular provisions. Intergenerational equity principles are also incorporated into the first paragraph of the United Nations Charter ("We the peoples of the United Nations, determined to save future generations from the scourge of war . . . ."). U.N. Charter pmbl.

[39] Maritime Delimitation in the Area between Greenland and Jan Mayen (Den. v. Nor.), 1993 I.C.J. 38, at 274 (June 14) (separate opinion of Judge Weeramantry), *available at* http://www.icj-cij.org/docket/files/78/6761.pdf; *Minors Oposa v. Sec'y of the Dept. of Env't & Natural Res.,* 33 I.L.M. 173, 185 (Phil. Sup. Ct. 1993); Legality of the Threat or Use of Nuclear Weapons (advisory op.), 1996 I.C.J. 226, 243-44 (July 8); *State of Himachal Pradesh v. Ganesh Wood Products*, A.I.R. 1996 S.C. 149, 158 (Ind. Sup. Ct. 1995), *available at* http://www.ecolex.org/server2.php/libcat/docs/COU/Full/En/COU-143787E.pdf.

[40] "The domestic Constitutions of twenty-two countries explicitly recognize the environmental interests of future generations." Collins, *supra* note 1, at 136; *see* CONST. AMEND. ON THE ENV'T CHARTER 2 (Fr.) ("[I]n order to secure sustainable development, the choices made to meet the needs of the present should not jeopardize the ability of future generations and other peoples to meet their own needs."); REGERINGSFORMEN [RF] [CONSTITUTION] 2 (Swed.) ("[P]ublic institutions shall promote sustainable development leading to a good environment for present and future generations . . . ."); BUNDESVERFASSUNG [BV] [CONSTITUTION] Apr. 18, 1999, SR 101, pmbl. (Switz.) (Swiss people and cantons are "conscious of their common achievements and their responsibility towards future generations."); CONST. pmbl. (Ukr.) (stating that Parliament is "aware of [its] responsibility before God, [its] own conscience, past, present and future generations . . . .")); CONST. pmbl. (Pol.) ("[B]equeath to future generations all that is valuable from our […] heritage . . . ."); S. AFR. CONST., 1996, art. 24 (recognizing the right of South African citizens "to have the environment protected, for the benefits of future and present generations."). *See also* J. C. Tremmel, *Establishing Intergenerational Justice in National Constitutions*, *in* HANDBOOK OF INTERGENERATIONAL JUSTICE 187-214 (J.C. Tremmel ed., 2006).

[41] *See* European Parliament, *The Charter of Fundamental Rights of the EU*, 2000/C 364/01, para. 6 (Dec. 7), *available at* http://www.ec.europa.eu/justice_home/unit/charte/index_en.html; *Draft International Covenant on Environment and Development*, I.U.C.N. Envtl. Policy & Law Paper No. 31 Rev. 2, art. 5 (2004), *available at* http://www.i-c-e-l.org/english/EPLP31EN_rev2.pdf; *Proposal for a Basic Law on Environmental Protection and the promotion of Sustainable Development*, U.N.E.P. Document Series on Environmental Law No. 1 (1993); *Goa Guidelines on Intergenerational Equity Adopted by the Advisory Committee to the United Nations University Project on International Law*, *Common Patrimony and*

principle of sustainable development,"[42] a concept that many believe has now emerged as a principle of customary law.[43]

In the next section of this article, I will assess the applicability of the principle of intergenerational equity to potential climate geoengineering options.

*B. Intergenerational Equity and SRM Geoengineering*

As indicated above, SRM geoengineering schemes seek to ameliorate potential increases in temperature associated with the buildup of greenhouse gases in the atmosphere by deflecting incoming solar radiation, or increasing the reflectivity of the atmosphere, clouds or Earth's surfaces.[44] In addition to sulfate aerosol injection,[45] the other primary SRM schemes that have been proposed are seeding marine stratiform clouds with sulfur aerosols to increase reflectivity,[46] the deployment of space-based "sunshades" to reduce incoming solar radiation inflows,[47] and the injection of huge amounts of dust particles in the equatorial plane between altitudes of 2000 and 4000 kilometers to reflect and scatter solar radiation.[48]

Proponents of SRM approaches tout their potential for offsetting the projected warming associated with a doubling or more of atmospheric levels of greenhouse gases

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*Intergenerational Equity*, 18 E.P.L. 190 (Feb. 1998), *available at* http://www.i-c-e-l.org/english/EPLP31EN_rev2.pdf; *see also* U.N. Comm. on Sustainable Dev., *Report of the Expert Group Meeting on Identification of Principles of International Law for Sustainable Development* ¶ 38 (background paper, Sept. 1995), *available at* http://www.un.org/documents/ecosoc/cn17/1996/background/ecn171996-bp3.htm.

[42] Org. for Econ. Co-operation and Dev. (OECD), *National Strategies for Sustainable Development: Good Practices in OECD Countries,* SG/SD(2005)6, ¶ 16, *reviewed in* U.N. Div. for Sustainable Dev., Expert Group Meeting on Reviewing National Sustainable Development Strategies, New York, Oct. 10-11, 2005, UNDSD/EGM/NSDS/2005/CRP, 9, *available at* http://www.un.org/esa/sustdev/natlinfo/nsds/egm/crp_9.pdf; *see also* U.N. Conference on Environment and Development, Rio de Janeiro, Brazil, June 13, 1992, *Report of the United Nations Conference on Environment,* U.N. Doc. A/CONF.151/26 (vol. 1) (Aug. 12, 1992); U.N. Env't Prog., *Final Report of the Expert Group Workshop on International Environmental Law Aiming at Sustainable Development,* UNEP/IEL/WS/3/2 (1996), 13-14, ¶ 30, 44-45.

[43] P. SANDS, PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW 254-55 (2003); Hari M. Osofsky, *Defining Sustainable Development After Earth Summit 2002,* 26 LOYOLA L.A. INT'L & COMP. L. REV. 111, 112 (2003).

[44] *See supra* note 9.

[45] *See supra* note 11 and accompanying text.

[46] Stephen Salter, Graham Sortino & John Latham, *Sea-Going Hardware for the Cloud Albedo Method of Reversing Global Warming,* 366 PHIL. TRANSACTIONS ROYAL SOC'Y A 3989, 3989 (2008). Cloud albedo enhancement geoengineering would seek to increase the number of cloud-condensation nuclei in low-level marine clouds. Large numbers of small cloud micro-droplets scatter and reflect more incoming solar radiation than larger droplets of the same total mass. T.M. Lenton & N.E. Vaughan, *The Radiative Forcing Potential of Different Climate Geoengineering Options,* 9 ATMOSPHERE, CHEMISTRY & PHYSICS 5539, 5543 (2009); The Royal Soc'y, *supra* note 2, at 27.

[47] Takanobu Kosugi, *Role of Sunshades in Space as a Climate Control System,* 67 ACTA ASTRONAUTICA 241-53 (2010); Roger Angel, *Feasibility of Cooling the Earth with a Cloud of Small Spacecraft Near the Inner Lagrange Point (L1),* 103 PNAS 17184-89 (2006). There are two major options for deployment of sunshades, boosting them into orbit around the Earth, or placing them at an optimal point between the Sun and Earth. Kosugi, *supra*, at 242.

[48] The Royal Soc'y, *supra* note 2, at 32.

from pre-industrial times.[49] However, the potential effectiveness of SRM schemes also sows the seeds of major peril for future generations. Imagine a scenario in which a single nation[50] or group of nations deploys an SRM scheme and it proves successful in abating temperature increases and other phenomena associated with climate change. Many analysts believe successful deployment of geoengineering technologies would severely undermine development of effective mitigation responses to climate change. As The Royal Society concluded:

> The very discussion of geoengineering is controversial in some quarters because of a concern that it may weaken conventional mitigation efforts, or be seen as a 'get out of jail free' card by policy makers . . . . This is referred to as the 'moral hazard' argument, a term derived from insurance, and arises where a newly-insured party is more inclined to take risky behavior than previously because compensation is available. In the context of geoengineering, the risk is that major efforts in geoengineering may lead to a reduction of effort in mitigation and/or adaptation because of a premature conviction that geoengineering has provided 'insurance' against climate change.[51]

Beyond empirical evidence of moral hazards in the context of insurance,[52] there is ample cause for concern that deployment of geoengineering technology could seriously undermine society's commitment to reducing greenhouse gas emissions and ultimately decarbonizing the world's economy. This is true for several reasons. First, while accurate cost assessments of geoengineering technologies are difficult at this protean stage, several studies have indicated that some SRM options could cost as little as one percent or less of the cost of dramatically reducing emissions,[53] exerting a potentially powerful pull away from mitigation initiatives. Moreover, because geoengineering options "leave . . . powerful actors and their interests relatively intact,"[54] they are likely to be backed by

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[49] Kosugi, *supra* note 47, at 242; Michael C. MacCracken, *On the Possible Use of Geoengineering to Moderate Specific Climate Impacts,* 4 ENVTL. RES. LETTERS 1, 4 (2009); Oliver Morton, *Great White Hope,* 458 NATURE 1097, 1098-99 (2009).

[50] The cost of many geoengineering options might be "well within the budget of almost all nations," as well as a handful of wealthy individuals. KATHARINE RICKE ET AL., UNILATERAL GEOENGINEERING: NON-TECHNICAL BRIEFING NOTES FOR A WORKSHOP AT THE COUNCIL ON FOREIGN RELATIONS 4 (2008), *available at* http://d1027732.mydomainwebhost.com/articles/articles/cfr_geoengineering.pdf; *see also* Lin, *supra* note 12, at 16.

[51] The Royal Soc'y, *supra* note 2, at 37; *see also* David W. Keith, *Geoengineering the Climate: History and Prospect,* 25 ANN. REV. ENERGY ENV'T 245, 276 (2000).

[52] Dianne Dumanoski, *Resisting the Dangerous Allure of Global Warming Technofixes,* YALE ENV'T 360, http://e360.yale.edu/feature/the_dangerous_allure_of_global_warming_technofixes/2224/ (last visited Sept. 30, 2010); H. Kunreuther, *Disaster Mitigation and Insurance: Learning from Katrina,* 605 ANNALS AM. ACAD. POL. & SOC. SCI. 208-227 (2006).

[53] Edward Parson & M. Granger Morgan, *Research on Global Sun Block Needed Now,* 463 NATURE 426, 426 (2010); Graeme Wood, *Re-Engineering the Earth,* THE ATLANTIC, July/Aug. 2009, at 70; David G. Victor et al., *The Geoengineering Option: A Last Resort Against Global Warming?,* 88(2) FOREIGN AFF. 64, 69 (2009). However, it should be emphasized that the costs of monitoring systems would likely substantially increase the cost of deploying such systems. Caldeira & Keith, *supra* note 5, at 60.

[54] Jay Michaelson, *Geoengineering: A Climate Change Manhattan Project,* 17 STAN. ENVTL. L.J. 73, 113 (1998).

influential constituencies going forward. Indeed, there are growing advocacy initiatives for geoengineering by think tanks funded by fossil fuel interests,[55] as well as support by powerful politicians like former Speaker of the House, Newt Gingrich.[56] Finally, there would likely be substantial public support for geoengineering options because they would not require fundamental changes in lifestyles.[57]

Unfortunately, while a commitment to SRM geoengineering approaches in lieu of effective mitigation responses might prove effective and politically palatable for our generation, future generations may not feel the same way because of the threat posed by the "termination" effect.[58] The termination effect refers to the potential for a huge multi-decadal pulse of warming should the use of an SRM scheme be terminated abruptly in the future due to technological failure or a decision by future policymakers. This would be a consequence of the buildup of carbon dioxide that had accrued in the atmosphere in the interim, with its suppressed warming effect, as well as the temporary suppression of climate-carbon feedbacks.[59]

The ramifications of the termination effect could be "catastrophic."[60] As one study recently concluded:

> [S]hould the engineered system later fail for technical or policy reasons, the downside is dramatic . . . . The climate suppression has only been temporary, and the now $CO_2$-loaded atmosphere quickly bites back, leading to severe and rapid climate change with rates up to 20 times the current rate of warming of ≈0.2ºC per decade . . . .[61]

As a consequence, temperatures could increase 6-10ºC in the winter in the Arctic region *within 30 years of termination of the use of SRM technology*, with northern landmasses

[55] AM. ENTER. INST. FOR PUB.POL'Y RES. EVENTS, GEOENGINEERING: A REVOLUTIONARY APPROACH TO CLIMATE CHANGE (2008), *available at* http://www.aei.org/event/1728; BJØNAR EGEDE-NISSEN & HENRY DAVID VENEMA, INTERNATIONAL INSTITUTE FOR SUSTAINABLE DEVELOPMENT, DESPERATE TIMES, DESPERATE MEASURES: ADVANCING THE GEOENGINEERING DEBATE AT THE ARCTIC COUNCIL 9 (2009), *available at* http://www.iisd.org/publications/pub.aspx?id=1162; ALAN ROBOCK, *Geoengineering Shouldn't Distract from Investing in Emissions Reduction, in* BULL. OF THE ATOMIC SCI. (2008), *available at* http://www.thebulletin.org/web-edition/roundtables/has-the-time-come-geoengineering.

[56] Newt Gingrich, *Can Geoengineering Address Concerns About Global Warming?*, http://www.newt.org/newt-direct/stop-green-pig-defeat-boxer-warner-lieberman-green-pork-bill-capping-american-jobs-and-t (last visited Jan. 20, 2011).

[57] J. ERIC BICKEL & LEE LANE, COPENHAGEN CONSENSUS CTR., AN ANALYSIS OF CLIMATE ENGINEERING AS A RESPONSE TO CLIMATE CHANGE (2009), *available at* http://fixtheclimate.com/component-1/the-solutions-new-research/climate-engineering/; John Virgoe, *International Governance of a Possible Geoengineering Intervention to Combat Climate Change,* 95 CLIMATIC CHANGE 103, 105 (2009).

[58] SCI. & TECH. COMM., THE REGULATION OF GEOENGINEERING, 2009-10, H.C. 221, at 16.

[59] H. Damon Matthews & Ken Caldeira, *Transient Climate-Carbon* 104(2) PNAS 9951 (2007).

[60] B. Govindasamy et al., *Impact of Geoengineering Schemes on the Terrestrial Biosphere,* 29(22) GEOPHYSICAL RES. LETTERS 18-1, 18-3 (2002).

[61] Peter G. Brewer, *Evaluating a Technological Fix for Climate,* 104(24) PNAS 9915, 9915 (2007); *see also* John C. Moore, Svetlana Jevrejeva, & Aslak Grinstad, *Efficacy of Geoengineering to Limit 21st Century Sea-Level Rise*, PNAS EARLY EDITION (forthcoming 2011), *available at* http://www.pnas.org/cgi/doi/10.1073/pnas.1008153107.

seeing increases of 6ºC in summer.[62] Moreover, temperatures could jump 7ºC in the tropics in 30 years.[63] Projected temperature increases after termination would occur more rapidly than during one of the most extreme and abrupt global warming events in history, the Paleocene-Eocene Thermal Maximum.[64] It is beyond contention that climatic changes of this magnitude "could trigger unimaginable ecological effects."[65] To put this rate of temperature increase in perspective, a recent study concluded that a warming rate of greater than 0.1ºC per decade could threaten most major ecosystems and decrease their ability to adapt.[66] Should temperatures increase at a rate of 0.3ºC per decade, only 30% of all impacted ecosystems and only 17% of all impacted forests would be able to adapt.[67] Moreover, temperature increases of this magnitude and rapidity would imperil many human institutions.[68]

As indicated above, a future generation would face the grave implications of the termination effect if an SRM scheme failed. This would contravene the second obligation of intergenerational equity outlined by Brown Weiss, conservation of quality, because the failure of our generation to substantially reduce its greenhouse gas emissions would result in greatly degraded planetary conditions for future generations under such a scenario.

Alternatively, even if a future generation was not compelled to forego or terminate deployment of an SRM scheme, it might deem it judicious to do so on policy or ethical grounds. For example, as indicated earlier in this article, atmospheric sulfur dioxide injection might result in adverse regional impacts on precipitation, undermining the interests of inhabitants in Asia and Africa.[69] Also, while another SRM scheme, marine cloud seeding, might substantially reduce incoming solar radiation, it could also result in sharp declines in precipitation in South America, including particularly serious impacts on the Amazon rain forest.[70]

While our generation might deem such "collateral effects" acceptable, a future generation might not, especially if regional impacts were exacerbated by other factors,

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[62] Victor Brovkin et al., *Geoengineering Climate by Stratospheric Sulfur Injections: Earth System Vulnerability to Technological Failure,* 92 CLIMATIC CHANGE 243, 254 (2009).
[63] Eli Kintisch, *Scientists Say Continued Warming Warrants Closer Look at Drastic Fixes,* 318 SCIENCE 1054, 1055 (2007).
[64] *Id.*
[65] *Id.*; *see also* Andrew Ross & H. Damon Matthews, *Climate Engineering and the Risk of Rapid Climate Change*, 4 ENVTL. RES. LETTERS 045103 (2009), *available at* http://iopscience.iop.org/1748-9326/4/4/045103 ("It seems likely that two decades of very high rates of warming would be sufficient to severely stress the adaptive capacity of many species and ecosystems, especially if preceded by some period of engineered climate stability.").
[66] A. Vliet & R. Leemans, *Rapid Species' Response to Changes in Climate Require Stringent Climate Protection Targets, in* AVOIDING DANGEROUS CLIMATE CHANGE 135, 135-41 (Hans Joachim Schellnhuber et al. eds., 2006).
[67] R. Leemans & B. Eickhout, *Another Reason for Concern: Regional and Global Impacts on Ecosystems for Different Levels of Climate Change,* 14 GLOBAL ENVTL. CHANGE—HUMAN POL'Y DIMENSIONS 219-28 (2004).
[68] Brewer, *supra* note 61, at 9915; Dumanoski, *supra* note 52; Kintisch, *supra* note 63, at 1055.
[69] *Supra* notes 11 & 13 and accompanying text.
[70] Bala Govindasamy et al., *Albedo Enhancement of Marine Clouds to Counteract Global Warming: Impacts on the Hydrological Cycle,* 6 CLIMATE DYNAMICS, DOI 10.1007/s00382-010-0868-1, 2 (2010); Andy Jones, Jim Haywood & Olivier Boucher, *Climate Impacts of Geoengineering Marine Stratocumulus Clouds,* 114 J. GEOPHYSICAL RES. D10106, at 5 (2009).

such as rising populations or declines in food production attributable to other causes, or if affected States threatened war.[71] However, leaders might feel that their hands were tied given the potentially catastrophic global implications of suspending the use of SRM technologies. Indeed, some of the proponents of geoengineering strategies even tout the threat of the rebound effect as a way to ensure "policy continuity" in the future.[72] Placing future generations on the horns of such a dilemma would violate the first obligation of intergenerational equity outlined by Brown Weiss—conservation of options—because it would severely circumscribe its ability to make policies that reflects its values and its options to address climate change.

It should also be emphasized that SRM technologies would have to be deployed for 500-1000 years unless we can find a way to remove carbon dioxide from the atmosphere.[73] As a consequence, the intergenerational implications of SRM geoengineering would extend for a breathtaking period of time, threatening the interests of tens of billions of future inhabitants of this planet.

*C. Could SRM Schemes Be Deployed in a Way That Comports with Principles of Intergenerational Equity?*

Proponents of SRM geoengineering might contend that a geoengineering governance regime could condition deployment of an SRM scheme on a scheduled reduction in greenhouse gas emissions of sufficient magnitude to ensure that future generations would not face the threat of the termination effect. Unfortunately, this approach could prove problematic for several reasons. First, it is by no means clear that any current international regime would have jurisdiction over SRM schemes. For example, the UNFCCC,[74] the most logical locus for international regulation of geoengineering, likely could not currently assert jurisdiction over SRM deployment. As provided for under Article 2, "[t]he ultimate objection of this Convention . . . is to achieve . . . *stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system*."[75] Thus, the regime focuses on controlling atmospheric levels of greenhouse gases, whereas SRM focuses on reducing the amount of solar radiation incident on the surface of the Earth. This conclusion is reinforced by the Commitments provisions of Article 4, which include the following:

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[71] *Geoengineering: Assessing the Implications of Large-Scale Climate Intervention*: *Hearing Before the H. Comm. on Sci. & Tech., Subcomm. on Energy & Env't.*, 111th Cong. (2009) (statement of Alan Robock); Kevin Bullis, *The Geoengineering Gambit,* TECH. REV., Jan. 1, 2010. One plausible scenario that would compel termination of an SRM scheme could be a threat of war by nations that might be potentially negatively impacted. David Roberts, *What Could Possibly Go Wrong: Blotting out the Sun,* POPULAR SCI., Feb. 3, 2011, http://www.popsci.com/science/article/2011-01/what-could-possibly-go-wrong-blotting-out-sun.

[72] Bickel & Lane, *supra* note 57, at 27.

[73] Dumanoski, *supra* note 52; *see also* Brovkin et al., *supra* note 13, at 255; Naomi E. Vaughan & Timothy M. Lenton, *A Review of Climate Geoengineering Proposals,* CLIMATIC CHANGE, Mar. 22, 2011 ("[A] significant fraction of the effect will need to be maintained for >1,000 years, because approximately 20% of the CO2 added to the atmosphere is only removed by natural sedimentation and weathering processes on timescales of 10,000 to 1,000,000 years.").

[74] UNFCCC, *supra* note 35.

[75] *Id.* art. 2 (emphasis added).

> (a) Develop, periodically update, publish and make available to the Conference of the Parties, in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties;
> (b) Formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to mitigate climate change by addressing anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, and measures to facilitate adequate adaptation to climate change;
> (c) Promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors, including the energy, transport, industry, agriculture, forestry and waste management sectors;
> (d) Promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems;
>
> ***
>
> 2. The developed country Parties and other Parties included in Annex I commit themselves specifically as provided for in the following:
>
> (a) Each of these Parties shall adopt national policies and take corresponding measures on the mitigation of climate change, by limiting its anthropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs. [emphasis added]

Again, the scope of obligations herein is restricted to reducing greenhouse emissions and enhancing sinks. While the Parties to the UNFCCC arguably could assert jurisdiction over CDR schemes under Articles 4(1)(d) or 4(2)(a), since their deployment could enhance carbon dioxide sinks,[76] SRM schemes would fall outside the ambit of Article 4 because these technologies would neither enhance sinks nor contribute to reduction of greenhouse gas emissions.[77] While the UNFCCC could potentially be

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[76] Under the UNFCCC, a "sink" "means any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere." *Id.* art. 1 § 8.

[77] *See also* Virgoe, *supra* note 57, at 110. The Royal Society contends that any geoengineering scheme would be subject to UNFCCC jurisdiction. The Royal Soc'y, *supra* note 2, at 41. In support of this proposition, it cites a provision of the treaty that requires the Parties to minimize "adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change." UNFCCC, *supra* note 74, art. 4(1)(f). However, as indicated above, SRM technologies could not be construed as measures to "mitigate" climate change under the UNFCCC since Article 4 restricts such measures to those that address sources or sinks. Moreover, most

amended to assert jurisdiction over SRM deployment, it is difficult to be sanguine about the prospects given the very high bar for passage of amendments to the treaty,[78] as well as the expected resistance to binding international mandates on part of many of the States that would most likely develop geoengineering systems.[79]

Second, even if there was authority under the UNFCCC to condition deployment of SRM technology on a commitment to reduce greenhouse gas emissions, it is far from clear that the political will exists to operationalize such a mandate. As indicated in the Introduction to this Article, the very impetus for geoengineering has been the abject failure of the world's major greenhouse gas emitting States to curb their emissions.[80] This is despite the fact that there is nearly universal recognition by States of the serious impacts that climate change will visit upon nations throughout the world.[81] Despite this fact, the latest "International Energy Outlook" assessment by the U.S. Energy Information Administration projects that energy-related carbon dioxide emissions may rise 43% by 2035 from 2007 levels.[82] If the world community has not been willing to make a meaningful commitment to reduce emissions in the face of a looming threat of extremely serious climatic impacts, why would it do so merely because the threat of those impacts could be reduced by deployment of geoengineering technologies?[83]

There are other regimes that might assert jurisdiction over SRM schemes; however, it is difficult to be sanguine about their prospects to protect the interests of future generations. The Convention on Prohibition of Military or any Other Hostile Use of Environmental Modification Techniques (ENMOD)[84] prohibits States from engaging "in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party."[85] The Convention's scope would encompass deployment of

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commentators and policymakers draw a distinction between geoengineering responses and adaptation responses, again rendering 4(1)(f) non-applicable. *See, e.g.*, Am. Meteorological Soc'y, *Proposals to Geoengineer Climate Require More Research, Cautious Consideration, and Appropriate Restrictions,* AMS NEWS, July 21, 2009, *available at* http://www.ametsoc.org/policy/2009geoengineeringclimate_amsstatement.html; William R. Travis, *Geo-Engineering the Climate: An Emerging Technology Assessment 1* (Env't & Soc'y Prog. at the Univ. Colo. Boulder, Working Paper No. ES2008-0002, 2008), *available at* http://www.colorado.edu/ibs/pubs/eb/es2008-0002.pdf.

78 UNFCCC, *supra* note 35, at art. 15(3) ("The Parties shall make every effort to reach agreement on any proposed amendment to the Convention by consensus. If all efforts at consensus have been exhausted, and no agreement reached, the amendment shall as a last resort be adopted by a three-fourths majority vote of the Parties present and voting at the meeting . . . .").

79 For example, China, the United States, and India have neither ratified the Kyoto Protocol nor committed themselves to binding long-term commitments.

80 *Supra* note 4 and accompanying text.

81 *See* UNFCCC, *Copenhagen Accord,* Draft Decision CP.15, FCCC/CP/2009/L.7, ¶ 1 (2009) ("[C]limate change is one of the greatest challenges of our time.").

82 U.S. ENERGY INFO. ADMIN., INTERNATIONAL ENERGY OUTLOOK 2010 – HIGHLIGHTS*, available at* http://www.eia.doe.gov/oiaf/ieo/highlights.html.

83 *See also* Chuck Greene, Bruce Monger, & Mark Huntley, *Geoengineering: The Inescapable Truth of Getting to 350,* 1(5) SOLUTIONS J. 57, 57 (2010) ("First, given a rapidly growing global population and the desire of most developing nations to achieve an improved standard of living, society currently lacks the sense of urgency and political willpower necessary to alter its energy consumption habits in the short amount of time available.").

84 May 18, 1977, 31 U.S.T. 333, 1108 U.N.T.S. 152, *reprinted in* 16 I.L.M. 88.

85 *Id.* art. I § 1.

SRM technologies, as definition of the term "environmental modification techniques" under the treaty includes any technique "for changing — through the deliberate manipulation of natural processes — the dynamics, composition or structure of the Earth, including its . . . atmosphere, or of outer space."[86] However, Article III exempts from the Convention's purview only environmental modification techniques designed for "peaceful purposes." Thus, a strong case could be made that geoengineering schemes would not be proscribed given the purposes for which they would be deployed.[87] Further, ENMOD is a treaty of limited subscription, with only 73 parties, and it does not govern attacks by a party State against a non-party State.[88]

The Convention on Biological Diversity (CBD)[89] could also be germane given the clear link between SRM deployment and potential threats to biodiversity. This could include the potential impacts of SRM schemes on the ozone layer,[90] as well as the threat that rising temperatures could pose to many species.[91] Indeed, the Parties to the CBD have already engaged on geoengineering issues in the context of ocean iron fertilization experiments, passing two resolutions calling on its members to limit such activities to small-scale scientific research conducted under a stringent environmental impact

[86] *Id.* art. II.

[87] Daniel Bodansky, *May We Engineer the Climate?,* 33 CLIMATIC CHANGE 309, 311 (1996). However, some commentators have argued that to the extent that geoengineering schemes might result in serious negative implications, their use could be construed as "hostile," prohibiting their deployment under ENMOD. Bidisha Banerjee, *ENMOD Squad,* SLATE, Sept. 23, 2010, http://www.slate.com/id/2268123/pagenum/all; *see also* William Daniel Davis, *What Does "Green" Mean?: Anthropogenic Climate Change, Geoengineering, and International Environmental Law,* 43 GA. L. REV. 901, 935 (2009); Alan Robock, *20 Reasons Why Geoengineering May Be a Bad Idea,* 64(2) BULL. ATOMIC SCI. 14, 17 (2008), *available at* http://cmapspublic3.ihmc.us/rid=1226664705437_1636398002_9066/Robock_2008_20%20reasons%20against%20geoengineering.pdf.

[88] Albert C. Lin, *Geoengineering Governance,* 8(3) ISSUES IN LEGAL SCHOLARSHIP 1, 20 (2009), *available at* http://www.bepress.com/ils/vol8/iss3/art2.

[89] Convention on Biological Diversity, June 5, 1992, 1760 U.N.T.S. 79.

[90] Ultraviolet radiation can inhibit photosynthesis in phytoplankton. U.N. Env't Programme, World Conservation Monitoring Centre, *Changing Oceans: Effects on Biodiversity, available at* http://www.unep-wcmc.org/climate/oceans/biodiv.aspx; *see also* SARA CHESIUK, CANADIAN WILDLIFE FEDERATION, OZONE LAYER 101, *available at* http://www.cwf-fcf.org/en/what-we-do/wildlife/featured-species/flora/ozone-layer-101.html. This, in turn, threatens a large number of species that depend on phytoplankton as their primary food source, including seals, whales, fish, and more than 50 species of birds in the Antarctic. PETER TERRY, SCIENCE NETWORK WESTERN AUSTRALIA, IS THE OZONE HOLE THREATENING ANTARCTIC WILDLIFE? (2006), *available at* http://www.sciencewa.net.au/topics/environment/869-is-the-ozone-hole-threatening-antarctic-wildlife.html. Increased ultraviolet radiation associated with ozone depletion may also adversely threaten other species, including amphibians and coral reef species. *See* Andrew Blaustein et al., *Ambient Ultraviolet Radiation Causes Mortality in Salamander Eggs,* 5(3) ECO. APPLICATIONS 740, 740-43 (1995); D.F. Gleason & G.M. Wellington, *Ultraviolet Radiation and Coral Bleaching,* 365 NATURE 836, 836-38 (1993); M.P. Lesser et al., *Bleaching of Coral Reef Anthozoans: Effects of Irradiance, Ultraviolet Radiation and Temperature on the Activities of Protective Enzymes against Active Oxygen,* 8 CORAL REEFS 225, 225-32 (1990); Christina Lydick, Evaluating Amphibian Abnormalities on Wildlife Refuges, *available at* http://findarticles.com/p/articles/mi_qa4444/is_1_25/ai_n52942966/.

[91] CAROLYN KOUSKY ET AL., RESPONDING TO THREATS OF CLIMATE CHANGE MEGA-CATASTROPHES 5 (2009), *available at* www.rff.org/documents/RFF-DP-09-45.pdf; Chris D. Thomas et al., *Extinction Risk from Climate Change,* 427 NATURE 145, 145 (2004).

assessment.[92] However, resolutions of the CBD are not legally binding on its Parties.[93] Moreover the Parties to the CBD have suggested that other regimes might be more appropriate for regulation of geoengineering activities.[94]

*D. Intergenerational Equity and CDR Geoengineering*

A strong argument could be made that deployment of CDR geoengineering schemes[95] would not present the same kinds of intergenerational threats posed by SRM approaches. As the Science and Technology Committee of the House of Commons in the United Kingdom observed, while SRM technologies would treat only the "symptom," i.e., global warming, CDR schemes would address the "root issue," i.e., rising levels of carbon dioxide.[96] As a consequence, the specter of abrupt climatic changes associated with a massive carbon dioxide pulse would not exist should use of such technologies be terminated by a future generation.

On the other hand, deployment of CDR technologies could still pose a moral hazard problem by reducing the current generation's commitment to decarbonizing the economy. This would pass the responsibility to address this issue to future generations to address this issue, while again compelling them to continue to deploy CDR technologies in the interim. At the very least, this would deny them the full panoply of options that the principle of intergenerational equity demands. However, given the far less serious implications of deploying technologies that don't pose the threat of a termination effect, the ethical questions associated with deploying CDR technologies, at least from an intergenerational perspective, would be far less pressing.

## III. IS GEOENGINEERING ACTUALLY A MEANS TO ACHIEVE INTERGENERATIONAL EQUITY?

Some proponents of geoengineering have suggested to me that research and/or deployment of geoengineering schemes would actually comport with principles of intergenerational equity. The contention is that geoengineering schemes could shield future generations from the potentially very serious impacts of climate change that may ensue in this century and beyond, and thus fulfill this generation's obligations to our successors. However, I believe that this presents a false dichotomy of potential policy options: either failing to take meaningful measures to reduce our greenhouse gas emissions, or using geoengineering as a bandage to cover the wound that failing to act would inflict on our successors on this planet. As Attfield observes, intergenerational

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[92] Convention on Biological Diversity, 10th Meeting of the Conference of the Parties, *Biodiversity and Climate Change,* Decision X/33 para. 8(w) (2010), *available at* http://www.cbd.int/doc/decisions/cop-10/cop-10-dec-33-en.pdf; Convention on Biological Diversity, 9th Meeting of the Conference of the Parties, *Biodiversity and Climate Change,* Decision IX/16 (2008), *available at* http://www.cbd.int/decision/cop/?id=11659. For an analysis of the decision at the 10th Conference of the Parties to the Convention on Biological Diversity, see MASAHIRO SUGIYAMA & TAISHI SUGIYAMA, INTERPRETATION OF CBD COP10 DECISION ON GEOENGINEERING (2010) (unpublished discussion paper, *available at* http://criepi.denken.or.jp/en/serc/research_re/download/10013dp.pdf).

[93] ALEXANDER PROELSS, LEGAL OPINION ON THE LEGALITY OF THE LOHAFEX MARINE RESEARCH EXPERIMENT UNDER INTERNATIONAL LAW (2009).

[94] Sugiyama & Sugiyama, *supra* note 92, at 13.

[95] *See supra* note 10.

[96] SCI. & TECH. COMM., *supra* note 58, at 14.

equity is only effectuated if future generations "receive an intact and renewable environmental and cultural heritage . . . not preempted by the squandering of resources or the bequeathing of injustices by the generations now alive."[97] This necessarily dictates that our generation maximize its efforts to mitigate greenhouse gas emissions so that our children and grandchildren are not compelled to live with a Sword of Damocles over their head.

The convenient truth is that climate change can be addressed effectively, and in a manner that will not undermine the welfare of the current generation, through an aggressive program of mitigation. One study concluded that effectuating reductions in emissions by 75-90% by 2100 would cost about 3-6% of cumulative GNP during this century, certainly by no means an insubstantial sum.[98] However, to put this commitment in perspective, a 6% reduction in GNP would still result in the world community being ten times richer in 2102 as opposed to in 2100. In accord, McKinsey & Associates and the Vattenfall Institute have identified 27 gigatons of annual potential carbon dioxide equivalent abatement consistent with stabilizing atmospheric concentrations at 450-550ppmv, at a cost of less than $40 per ton.[99] The mechanisms to achieve these goals include a massive commitment to renewable energy sources, enhanced energy efficiency, and deployment of carbon capture and storage technologies.[100]

Moreover, while many supporters of geoengineering cite the threat of passing critical climatic thresholds in the shorter term,[101] there are also alternatives that can help us buy time as we make a transition to a decarbonized world economy. For example, a recent study by the United Nations Environment Program and the World Meteorological Organization concluded that implementation of a full set of measures to reduce black carbon[102] and ozone emissions by 2030 could reduce the potential increase in global

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[97] Attfield, *supra* note 25, at 210.

[98] Christian Azar & Stephen H. Schneider, *Are the Economic Costs of Stabilizing the Atmosphere Prohibitive?,* 42(1-2) ECO. ECON. 73, 76 (2002).

[99] ERIC BEINHOCKER ET AL., MCKINSEY GLOBAL INSTITUTE THE CARBON PRODUCTIVITY CHALLENGE: CURBING CLIMATE CHANGE AND SUSTAINING ECONOMIC GROWTH 8 (2008), *available at* http://www.mckinsey.com/mgi/publications/Carbon_Productivity/index.asp.

[100] LESTER B. BROWN, PLAN B 4.0: MOBILIZING TO SAVE CIVILIZATION 109-142 (2009); SHRUTI MITTAL, CUTS CENTRE FOR INTERNATIONAL TRADE, ECONOMICS & ENVIRONMENT, TAPPING THE UNTAPPED: RENEWING THE NATION: FOCUS ON RENEWABLE SOURCES ESPECIALLY SOLAR ENERGY 1-33 (2010); David Hodas, *Imagining the Unimaginable: Reducing U.S. Greenhouse Gas Emissions by Forty Percent,* 26 VA. ENVTL. L.J. 271, 271-290 (2008); *Green Energy 'Revolution' Needed,* BBC NEWS ONLINE, June 6, 2008, http://news.bbc.co.uk/2/hi/business/7439338.stm.

[101] *See supra* notes 5 & 6 and accompanying text.

[102] Black carbon is a constituent element of the combustion product known as soot. The primary indoor source is cooking with biofuels, such as dung, wood, and crop residue. The primary outdoor sources are attributable to fossil fuel combustion (diesel and coal), open biomass burning and cooking with biofuels. Veerabhadran Ramanathan & Gregory Carmichael, *Global and Regional Climate Changes Due to Black Carbon,* 1 NATURE GEOSCI. 221, 221 (2008). Recent studies indicate that black carbon emissions are the second largest contributor to global warming, as much as 55% of the forcing associated with carbon dioxide. INST. FOR GOVERNANCE AND SUSTAINABLE DEV., REDUCING BLACK CARBON, OR SOOT, IS THE FASTEST STRATEGY FOR SLOWING CLIMATE CHANGE (2008), *available at* http://www.igsd.org/docs/BC%20Briefing%20Note%2027Mar08.pdf; JONATHAN LASH, CARNEGIE COUNCIL, BLACK CARBON AN EASY TARGET FOR CLIMATE CHANGE, INNOVATIONS (2009), *available at* http://www.policyinnovations.org/ideas/innovations/data/000084.

temperature projected for 2050 by 50%.[103] This would translate into a reduction of temperatures by 0.5° Celsius.[104] Moreover, it would yield substantial co-benefits, including the avoidance of more than 2 million premature deaths and the annual loss of 1-4% of global production of maize, rice, soybeans and wheat.[105]

## IV. CONCLUSION

As Frischmann concludes, "the present generation has mastered the art of pushing the costs of shortsighted decisions onto future generations."[106] Deployment of SRM geoengineering technologies in the future could constitute the quintessential act of generational selfishness, compelling untold future generations to "stick with the program" or face catastrophic impacts. The potential intergenerational consequences of climate geoengineering counsel strongly in favor of doubling our resolve to address an issue for which this generation is profoundly responsible.

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[103] U.N. Env't Program, Twenty-sixth Session of the Governing Council/Global Ministerial Environment Forum, Nairobi, Kenya, Feb. 21-25, 2011, *Summary for Decision Makers of the Integrated Assessment of Black Carbon and Tropospheric Ozone,* 3, U.N. Doc. UNEP/GC.26/INF/20 (Feb. 2011); *see also* Almut Arneth et al., *Clean the Air, Heat the Planet?,* 326 SCIENCE 672, 672 (2009).
[104] U.N. Env't Program, *supra* note 103, at 3.
[105] *Id.*
[106] Frischmann, *supra* note 21, at 459.