Geoengineering a Future for Humankind: Some Technical and Ethical Considerations

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The term "geoengineering" relates to the various strategies and techniques aimed at containing and, in some cases, reversing the effects of anthropogenic and other forms of environmental degradation. These strategies and techniques range from the fairly innocuous to the highly scientifically and politically controversial. Given the transboundary effect of environmental degradation and the urgency that this creates, the concerted efforts of the international community are indispensable to usefully enlist whatever benefits geoengineering is capable of offering. However, serious obstacles stand in the way of the international community acting in unison. This paper seeks to outline the various contentious issues regarding geoengineering that arise in relation to its ethical, technological, political, and trade-related legal dimensions. Along with State actors, it is likely that this field of activity would be highly reliant on market mechanisms to deliver the technological solutions and capital investment that are necessary. Clear rules in relation to how these strategies and techniques ought to be governed are in urgent need. Rules should not be limited to the governance aspects, but should also provide for the commercial use of geoengineering.

I. Introduction

Geoengineering relates to the manipulation of the natural habitat – including the marine environment – in order to somehow abate or counteract the effects of natural and anthropogenic climate change and global warming. Geoengineering also relates to the various strategies and techniques aimed at containing and, in some cases, reversing the effects of anthropogenic and other forms of environmental degradation. These strategies and techniques range from the fairly innocuous to the highly scientifically and politically controversial.[1] Given the transboundary effect of environmental degradation and the urgency that this creates, the concerted efforts of the international community are indispensable to usefully enlist whatever benefits geoengineering is capable of offering. However, serious obstacles that will be discussed later stand in the way of the international community acting in unison.

Geoengineering is no new phenomenon – humans have manipulated their habitats throughout the various stages of civilization and development, according to the means that have historically been

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1 See the views of Jason Blackstock, "Researchers Can't Regulate Climate Engineering Alone", 486 *Nature* (2012) (arguing that "political interests, not scientists or investors, will be the biggest influence on technologies to counter climate change").

at their disposal.[2] Geoengineering-related activities range from the wholly innocuous – for instance, the whitening of roof tops – to the near apocalyptic – for instance, the use of cloud-seeding by the United States during the Vietnam War.[3] Geoengineering-related potential solutions to environmental degradation may include, amongst other things, the injection of sulphur particles into specific layers of the atmosphere to deflect solar radiation, manipulating the behavior of clouds, including their formation and their capacity for rainfall, the depositing of iron in the oceans to encourage the proliferation of algae to sequester excess carbon dioxide,[4] forest proliferation (e.g., afforestation and reforestation) for similar purposes, and so on.

Any carbon emitted today will stay in the atmosphere, warming the Earth for years to come, unless techniques are applied to remove it from the atmosphere. Techniques to counter or cancel the effects of human-induced climate change are bracketed under the term geoengineering, which entails manipulating the Earth-climate system on a large scale.[5] Despite the fact that there are several technological solutions to tackle climate change mitigation in the future, this paper will only focus on geoengineering. Although geoengineering refers to numerous methods of offsetting climate change, including the removal of GHGs from the atmosphere, it is most commonly applied to an approach known as Shortwave Radiation Management (SRM).[6] SRM involves altering the Earth's reflectivity or albedo,[7] in order to change the levels of solar radiation that the Earth absorbs, thereby balancing the warming effect of GHGs on the Earth's infrared radiation to space. Geoengineering is financially feasible, developing countries could contribute to it, and it is an alternative to GHG emissions limits.

Geoengineering is currently in the spotlight as the issue of climate change gains urgency, the science for dealing with it has advanced,[8] global temperatures have increased,[9] the U.S. has stalled on enforcing limitations on domestic GHG emissions,[10] international negotiations regarding binding obligations have not succeeded,[11] and prevent-

2 William Burns argues that the notion of climatic geoengineering has been around at least since the 1830s, when American meteorologist James Pollard Espy suggested that "lighting huge fires could stimulate convective updrafts and alter the intensity and frequency of precipitation." See William Burns, "Geoengineering the Climate: An Overview of Solar Radiation Management Options", 46 *Tulsa Law Review* (2011), at 283.

3 Spencer C. Tucker (ed.), The Encyclopedia of the Vietnam War: A Political, Social, and Military History, 2nd ed. (Oxford: Oxford University Press, 2011), at 981, where the following passage appears underneath the header "Popeye, Operation": "A cloud-seeding project undertaken by the US military in the Democratic Republic of Vietnam, Cambodia, and Laos from 1967 and 1972 … [which] sought to extend the monsoon season over North Vietnam by seeding clouds with silver iodine … Critics … identified cloud-seeding as a contributing cause of devastating 1971 floods in much of North Vietnam."

4 Luigi *Provasoli, John J. A. McLaughlin and Michael Droop, "The Development of Artificial Media for Marine Algae", 25(4)* Archives of Microbiology *(1957), 392; Oilgae,* Oilgae Comprehensive Report. Energy from Algae: Products, Market, Processes and Strategies *(Tamilnadu, India: Oilgae, 2011)*.

5 The Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty* (London: The Royal Society, 2009). William D. Davis, "What does 'Green' Mean? Anthropogenic Climate Change, Geoengineering, and International Environmental Law", 43 *Georgia Law Review* (2009).

6 This term refers to the management of radiation which is located in the visible and near-visible segment of the electromagnetic spectrum (approximately 0.4 to 4.0 μm in wavelength). This is distinguished from longwave radiation. See National Snow and Ice Data Center, available on the Internet at <http://nsidc.org/arcticmet/glossary/short_wave_radiation.html> (last accessed on 11 September 2012).

7 "Albedo is the fraction of solar energy (shortwave radiation) reflected from the Earth back into space. It is a measure of the reflectivity of the earth's surface. Ice, especially with snow on top of it, has a high albedo: most sunlight hitting the surface bounces back towards space. Water is much more absorbent and less reflective. So, if there is a lot of water, more solar radiation is absorbed by the ocean than when ice dominates." See <http://www.esr.org/outreach/glossary/albedo.html> (last accessed on 11 September 2012). See also Global Climate & Energy Project Stanford, *An Assessment of Solar Energy Conversion Technologies and Research Opportunities* (Stanford: GC&EP, 2006); David Keith, *Photophoretic Levitation of Engineered Aerosols for Geoengineering* (Washington, DC: Proceedings of the National Academy of Sciences of the United States of America, 2010); Paul Crutzen, "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?", 77 *Climatic Change* (2006), pp. 211 *et sqq*.

8 Philomene Verlaan, "Geo-engineering, The Law of the Sea, and Climate Change", 3 *The Carbon and Climate Law Review* (2009), 446.; Elke Weber and Paul Stern, "Public Understanding of Climate Change in the United States", 66 *American Psychologist* (2011), pp. 315 *et sqq*.

9 Harriet Townsend, "The Climate Change Bill", 4 *Journal of Planning and Environmental Law* (2008), 450; Mark Stallworthy, "Sustainability, Coastal Erosion and Climate Change: An Environmental Justice Analysis", 18 *Journal of Environmental Law* (2006), pp. 357 *et sqq*.

10 David Campbell, "The US States Are at it Again: Is that Reasonable?", 5 *The Carbon and Climate Law Review* (2011), 113; World Watch Institute, "IPCC Chief Challenges Obama to Further Cut U.S. Emission Targets", 2011, available on the Internet at <http://www.worldwatch.org/node/5991> (last accessed on 11 September 2012).

11 Arvind Subramanian, "Climate Change Justice", 10(2) *World Trade Review* (2011), pp. 277 *et sqq*; Lavanya Rajamani, "The Making and Unmaking of the Copenhagen Accord", 59(3) *International and Comparative Law Quarterly* (2010), 824.

ing a significant future rise in global temperatures seems unlikely.[12] Advocates for geoengineering make no claims to its being a comprehensive solution towards climate change, forestalling criticism that it is merely a way to avoid reducing fossil fuel dependence.[13] Instead, they present it as a means by which to slow warming and prevent "dangerous anthropogenic interference,"[14] while exploring the commercial potential of low-carbon energy alternatives,[15] or as an option to turn to in case of a climate emergency, such as a catastrophically rapid rise in sea levels resulting from the unforeseen breakdown of an ice sheet. Along with State actors, it is likely that geoengineering would be highly reliant on market mechanisms to deliver the technological solutions and capital investment that are necessary. Clear rules in relation to how these strategies and techniques ought to be governed are in urgent need. Rules should not be limited to the governance aspects, but should also provide for the commercial use of geoengineering.

The paper explores the complex challenges that geoengineering poses to the international community, including the limitations and controversies that surround geoengineering. The paper opens by analyzing the ethical, technological, and political considerations of geoengineering. The final part of this paper explores the legal considerations of geoengineering for international trade.

II. Limitations and controversies

Although geoengineering is receiving growing attention as a possible means by which to offset human-induced climate change, as of now its options are flawed, with an insufficient understanding of the required scientific dimension. Moreover, the options lack comprehensive risk assessment, and are uncertain when it comes to effectiveness.[16]

Post-emission GHGs are already being sequestered, for example through reforestation of previously stripped areas and also by planting new forests.[17] While the UNFCCC and the Kyoto Protocol allow and encourage these techniques,[18] including the REDD-plus initiative,[19] they have faced controversy, as some have seen them as a way to avoid reducing fossil fuel dependence. They have also received criticism for depending on ecologically-damaging monoculture planting, and posing a risk to the rights of indigenous people and people in developing countries in order to solve an issue that is mainly of importance to developed countries.[20]

12 Oliver Morton, "Is this What it Takes to Save the World?", 447 *Nature* (2007), 132; Oliver Morton, "Great White Hope", 458 *Nature* (2009), pp. 1097 *et sqq*.

13 Gwynne Dyer, *Climate Wars: The Fight for Survival as the World Overheats* (Oxford: Oneworld, 2010); David Keith, "Engineering the Planet" in Stephen Schneider, Armin Rosencranz, Michael Mastrandrea and Kristin Kuntz-Duriseti (eds.), *Climate Change Science & Policy* (Washington, DC: Island Press, 2010); Jeff Goodell, "Geoengineering the Planet: The Possibilities and the Pitfalls", Yale Environment 360, 21 October 2009, available on the Internet at <http://e360.yale.edu/content/feature.msp?id=2201> (last accessed on 11 September 2012).

14 Article 2 of the UNFCCC.

15 For example hydro electricity, solar, wind or geothermal energy, biofuel, and ethanol. An example of commercialized hydro electricity is seen in the Juneau Hydropower company; Josh Carmody and Duncan Ritchie, *Investing in Clean Energy and Low Carbon Alternatives in Asia* (Manila: Asian Development Bank, 2007); HM Government, *Carbon Plan* (London: DECC, 2011).

16 See for instance David Victor *et al*., "The Geoengineering Option: A Last Resort Against Global Warming?", 88 *Foreign Affairs* (2009), pp. 64 *et sqq*; Michael Specter, "The Climate Fixers: Is There a Technological Solution to Global Warming?", The New Yorker, 14 May 2012; Christopher Borick and Barry Rabe, "Americans Cool on Geoengineering Approaches to Addressing Climate Change", 47 *Issues in Governance Studies* (2012).

17 Max Bronstein, "Readily Deployable Approaches to Geoengineering: Cool Materials & Aggressive Reforestation", 10 *Sustainable Development Law and Policy* (2010), pp. 44 *et sqq*.

18 Article 2.1(a)(ii) of the Kyoto Protocol.

19 The REDD-plus initiative derives from Reducing Emissions from Deforestation and Forest Degradation. It is a series of actions which are created to make use of financial incentives to assist in reducing the emissions of GHGs resulting from deforestation and forest degradation. Its central aim is to reduce GHGs. However, it has cumulative effects as it can also preserve biodiversity and aid in alleviating poverty. REDD-plus has significant implications which are directed towards local peoples. Chiara Armeni, "The Copenhagen Accord and Beyond", 12 *Environmental Law Review* (2010), 132; Peter Oniemola, "Climate Change Law and Developing Countries: Legal and Policy Challenges for the World Economy", 13 *Environmental Law Review* (2011), pp. 76 *et sqq*.

20 Bischöfliches Hilfswerk Misereor, *Appetite for Land: Large-Scale Foreign Investment in Land* (Aachen, Germany: Bischöfliches Hilfswerk Misereor e.V., 2010); World Bank, *The Cost to Developing Countries of Adapting to Climate Change* (Washington, DC: IBRD, 2010); Sophie Theriault, "The Food Security of the Inuit in Times of Change: Alleviating the Tension between Conserving Biodiversity and Access to Food", 2 *Journal of Human Rights and the Environment* (2011), pp. 136 *et sqq*; Lyal Sunga, "Does Climate Change Kill People in Darfur?" 2 *Journal of Human Rights and Environment* (2011), pp. 64 *et sqq*; Michael Pollan, *The Botany of Desire: A Plant's-Eye View of the World* (Random House, 2001).

One of the more controversial techniques for GHG-recapturing involves increasing algae blooms at the ocean surface. The idea is that eventually the algae will die and sink, and remove carbon from the atmosphere for hundreds of years.[21] However, the results of experimentation thus far have been ambiguous;[22] there is uncertainty as to whether a significant portion of the algae even sunk, or re-oxidized into atmospheric CO_2.[23] Moreover, experiments received criticism[24] for potentially harming marine ecosystems.[25] In fact, in 2008, the parties to the Convention on Biological Diversity[26] called for a ban on all except for small-scale marine fertilization experiments.[27] In 2010, the Conference of the Parties to the Convention on Biological Diversity adopted non-binding language that expanded the ban to include geoengineering in general.[28]

Other ways to remove GHG emissions are being explored. These have been the subject of debate for their expense, rather than for any risk they may pose to the environment.[29] One of these, perhaps the most important, is looking at ways to capture atmospheric CO_2,[30] with air being filtered through a global network of very large structures fitted with machinery to absorb CO_2, which is eventually directed to underground storage reservoirs,[31] in much the same way as is planned for pre-emission capture from power plants. In terms of concerns regarding leaks and groundwater pollution, there is no difference between such proposals and pre-emission carbon capture and storage techniques. Other capture techniques are even less concrete and give rise to other environmental repercussions.[32]

III. Considerations around geoengineering

Shortwave Radiation Management (SRM) is accepted as the least expensive method of manipulating the climate after reforestation.[33] It also avoids the land-use issues of reforestation. Moreover, implementing SRM could be fairly quick, and it could be conducted in a way that rapidly reduces global mean temperature (which not even the fastest imaginable system of GHG emissions reductions

21 See generally Peter Davies, "Global Warming and the Kyoto Protocol", 47(2) *The International and Comparative Law Quarterly* (1998), pp. 446 *et sqq*; Michael Boddington, "Agriculture and the Rural Economy: Times of Change", *Journal of Planning and Environment Law* (1988), pp. 1 *et sqq*.

22 Eli Kintisch, *Hack the Planet: Science's Best Hope—or Worst Nightmare—for Averting Climate Catastrophe* (Hoboken, N.J.: Wiley, 2010) (who suggests that conservatives embracing radical solutions such as large-scale ocean algae blooms are simply trying to block profit-threatening regulation and alternative energy development). See also Scott Weiner, "The Uncertain Future for Biodiesel: A Case for Biofuel Subsidisation Reform", 4 *International Energy Law Review* (2011), pp. 171 *et sqq*; Les Lo Baugh and William Troutman, "Assessing the Challenges of Geologic Carbon Capture and Sequestration: A California Guide to the Cost of Reducing CO_2 Emissions", 8 *International Energy Law Review* (2009), pp. 293 *et sqq*.

23 Susse Wegeberg and Claus Felby, *Algae Biomass for Bioenergy in Denmark: Biological/Technical Challenges and Opportunities* (Copenhagen: University of Copenhagen, 2010); Catie Ryan, *Cultivating Clean Energy: The Promise of Algae Biofuels* (Washington, DC: Natural Resources Defense Council, 2009).

24 Criticism has been received from several sources. Business Green, "Scientists Warn against Ocean Fertilisation Projects", Business Green, 13 November 2007; Mario Sengco, *A Fatal Attraction for Harmful Algae* (Woods Hole, Mass.: Oceanus, 2005); Quirin Schiermeier, "Ocean Fertilization Experiment Draws Fire", Nature News, 9 January 2009.

25 Hugh Rossi, "The Consequences of the Green Issue and the European Dimension", *Joint Planning Law Conference* (1990), 17; Vanessa Edwards, "Waste Water", 22(1) *Journal of Environmental Law* (2010), pp. 153 *et sqq*; Richard Macrory, "ECJ Ruling on Eutrophication Spells New Shake Up for Sewage Treatment", 358 *ENDS Report* (2004), pp. 65 *et sqq*.

26 See Conference of the Parties to the Convention on Biological Diversity, ninth meeting, decision IX/16 (Biodiversity and climate change). See also Secretariat of the Convention on Biological Diversity, "Scientific Synthesis of the Impacts of Ocean Fertilization on Marine Biodiversity" (Montreal: Technical Series No. 45, 2009).

27 Rosemary Rayfuse, Mark G. Lawrence and Kristina M. Gjerde, "Ocean Fertilisation and Climate Change: The Need to Regulate Emerging High Seas Uses", 23 *International Journal of Marine and Coastal Law* (2008), pp. 297–326.

28 Convention on Biological Diversity, Nairobi, 22 May 1992, in force 29 December, 1993, 31 *International Legal Materials* (1992), pp. 818 *et sqq*.

29 Nicola Jones, "Sucking it Up", 458 *Nature* (2009), pp. 1094 *et sqq*.

30 Thomas Kerr, "Legal and Regulatory Developments: The Path Forward to Advance Carbon Dioxide Capture and Storage as a Climate Change Solution", 11/12 *International Energy Law and Taxation Review* (2007), pp. 232 *et sqq*; American Physical Society, *Direct Air Capture of CO_2 with Chemicals: A Technology Assessment for the APS Panel on Public Affairs* (College Park, Md.: American Physical Society, 2001); Viktoria Nikulshina, Christophe Gebald and Aldo Steinfel, "CO_2 Capture from Atmospheric Air via Consecutive CaO-carbonation and $CaCo_3$-Calcination Cycles in a Fluidized-bed Solar Reactor", 146 *Chemical Engineering Journal* (2009), pp. 244 *et sqq*.

31 Jan Martin Nordbotten, Michael Celia and Stefan Bachu, "Injection and Storage of CO_2 in Deep Saline Aquifers: Analytical Solution for CO_2 Plume Evolution During Injection", 58 *Transportation in Porous Media* (2005), pp. 339 *et sqq*.

32 Ke Liu, Chunshan Song and Velu Subramani, *Hydrogen and Syngas Production and Purification Technologies* (Hoboken, N.J.: Wiley, 2010).

33 "Carbon Capture and Storage: A Shiny New Pipe Dream," The Economist, 12 May 2012.

could achieve).[34] However, options for SRM have given rise to a variety of questions regarding morals, technology, governance, and certain legal aspects of international trade.[35]

1. Moral and policy concerns

In supporting geoengineering and advocating for moving ahead with it, three main arguments take the lead: it will enable us to buy time, it will help us respond to a climate emergency and, in financial terms, it may be the most feasible option.[36] On the other hand, there are several ethical dilemmas that arise: it may encourage us to turn a blind eye to our moral duties; governments may take advantage of progress with geoengineering to lessen their climate change mitigation efforts; those biased towards geoengineering may emerge as an important force, wielding influence over decision-making; and attempting to regulate the Earth's great natural processes is playing God, which is dangerous and invites retribution. Moreover, as a technological solution, geoengineering may worsen the situation by covering up the social and political reasons behind the climate crisis.[37]

Another ethical concern with SRM addresses the matter of experimentation: the only completely safe experiments are those carried out with climate models (if anything, their only harm is to divert resources from other areas). It would be an unparalleled experiment to try geoengineering through large-scale – or even global-level – testing. This has never been done. Perhaps the closest such case would be atmospheric nuclear weapons testing;[38] however the goal in that experiment was to test the bombs, not the environmental repercussions they would have.[39]

This kind of wide-scale experimenting brings to light several important questions: What would be the approval process? Regarding those placed at risk, how could permission be gained? What would be the maximum timeframe and how would one determine the threshold of harm that would be the cut-off point? If people suffer adverse affects, who would be responsible for their compensation? These questions apply to the full-scale deployment and governance of geoengineering, not only to its testing phase.[40] As its impact would be global, who would have the authority to decide whether to launch it?[41]

A couple of other ethical concerns have been brought to light regarding moral dangers: 1) if geoengineering is implemented, would it reduce the pressure on governments to lower GHG emissions, and inadvertently result in unbridled usage of fossil fuels? (This in spite of the fact that its original purpose would be to provide a few degrees of flexibility to the warming limit while other technology is being explored); and 2) there is a risk that even just exploring this technology may lead to the emergence of an expert or commercial constituency that would exert an influence over ethical and policy decisions in favor of adopting the technology.

Lastly, a significant policy issue is that, once launched, SRM's offsetting or masking of warming

34 Burns, "Geoengineering the Climate", *supra*, note 2, at p. 283.

35 ETC Group, *Geopiracy: The Case Against Geoengineering* (Salt Lake City, Ut.: ETC Group, 2010); Alan Robock, "Whither Geoengineering?" 320 *Atmospheric Science* (2008), 1166; Nidhi Srivastava, "Geoengineering and Law: A Case Study of Carbon Capture and Storage in the European Union", 20 *European Energy and Environmental Law Review* (2011), pp. 187 *et sqq*; Steve Rayner, "Climate Geoengineering Governance", 20 *Jahrbuch Ökologie* (2011); Gareth Davies, "Framing the Social, Political, and Environmental Risks and Benefits of Geoengineering: Balancing the Hard-to-Imagine against the Hard-to-Measure", 46 *Tulsa Law Review* (2011), pp. 261 *et sqq*.

36 Clive Hamilton, "Ethical Anxieties about Geoengineering: Moral Hazard, Slippery Slope and Playing God", Paper presented at a conference of the Australian Academy of Science, Canberra, 27 September 2011 (unpublished).

37 Ibid. See also Adam Heal, "Managing Plan B: the Security Challenges of Geoengineering", 11 *Harvard Kennedy School Review* (2011), pp. 47 *et sqq*; Clive Hamilton, "The Philosophy of Geoengineering", Contribution to the IMPLICC Symposium "The Atmospheric Science and Economics of Climate Engineering via Aerosol Injection", Mainz, 14-16 May 2012.

38 Iain Scobbie, "Discontinuance in the International Court: The Enigma of the Nuclear Tests Cases", 41 *International and Comparative Law Quarterly* (1992), pp. 808 *et sqq*; Lisa Tabassi, "The Nuclear Test Ban: *Lex Lata* or *de Lege Ferenda*?", 14 *Journal of Conflict and Security Law* (2009), pp. 309 *et sqq*.

39 For further details on this matter, see David Morrow *et al.*, "Political Legitimacy in Decisions About Experiments in Solar Radiation Management," in William Burns and Andrew Strauss (eds.), *Geoengineering the Climate: Law, Ethics, and Policy Considerations* (Cambridge: Cambridge University Press, forthcoming).

40 Catherine Redgwell, "Geoengineering the Climate: Technological Solutions to Mitigation – Failure or Continuing Carbon Addiction?", 5 *Carbon and Climate Law Review* (2011), pp. 178 *et sqq*.

41 David Morrow *et al.*, "Toward Ethical Norms and Institutions for Climate Engineering Research", 4 *Environmental Research Letters* (2009), pp. 1 *et sqq*.

must be maintained indefinitely (or at least until GHG concentrations begin to fall). This is because without a continuous supply of particles in the atmosphere, aerosol masking the greenhouse forcing would decline in a few years, exposing the underlying increase in temperature and resulting in a very rapid warming that populations would not be ready to adapt to.[42] It is therefore inadvisable to embark upon SRM without being certain that it would be continued as long as necessary.

2. Technology

In terms of implementing SRM, the method most widely discussed involves proliferating the stratosphere with aerosol sulfate particles.[43] The particles would scatter and reflect sunlight, thereby lowering the amount of incoming radiation.[44] Other SRM techniques being explored include increasing sulfate particles in the troposphere,[45] which would create more clouds and therefore also reflect sunlight, and launching vehicles into space that would serve as mirrors to do the same.[46] All three methods would reduce sunlight available to living organisms, and also present various environmental and economic problems. In other respects, the three methods significantly differ. For example, the proposal regarding tropospheric particles raises concerns about air pollution and its impact would not be uniform around the globe. The mirror option is likely to be enormously costly.[47] Stratospheric particles may have an adverse effect on the ozone layer,[48] although this is the option that has earned the highest degree of interest.[49]

Stratospheric SRM aims at increasing aerosol levels in the stratosphere by projecting rockets holding containers of sulfur-dioxide.[50] When released at high altitude, the sulfur dioxide eventually condenses into the aerosol particles. A thin, natural sulfate layer already exists in the stratosphere, which is enhanced from time to time by large volcanic eruptions. Such eruptions actually reduce global mean temperatures for a year or two until the particles are washed away. The SRM proposal aims at continually maintaining this layer through ongoing projection of sulfur into the stratosphere. The repercussions of this approach on the environment, apart from those mentioned earlier, include a slight increase in acid rain and an uncertain amount of increased air pollution from rocket exhaust. Neither is likely to eliminate the proposal. Moreover, the cost, approximated at US$10-100 billion/year to offset warming through 2030,[51] would be far less than

42 Rob Swart, Natasha Marinova, Stefan Bakker and Xander van Tilburg, *Policy Options to Respond to Rapid Climate Change* (Wageningen: Alterra, 2009); Pedro Llanillo, Phil Jones and Roland von Glasow, "The Influence of Stratospheric Sulphate Aerosol Deployment on the Surface Air Temperature and the Risk of an Abrupt Global Warming", 1 *Atmosphere* (2010), pp. 62 *et sqq*.

43 Sulfur aerosols exist naturally in a layer of the Earth's atmosphere that is known as the stratosphere. The aerosols are comprised of a combination of sulphuric acid and water. When they are present in high levels, they create a cooling effect by assisting in reflecting sunlight. The concept discussed here would involve a forced or 'artificial' increase in the number of aerosols which, in turn, would have the positive effects mentioned above and assist with the global warming problem. See James Friend, "Properties of the Stratospheric Aerosol", Tellus XVIII (1966), pp. 465 *et sqq*.

44 Parliamentary Office of Science and Technology, Geo-Engineering Research No. 327 (2009).

45 Barbara *Finlayson-Pitts and James Pitts, Chemistry of the Upper and Lower Atmosphere:* Theory, Experiments, and Applications *(Waltham, Mass.: Academic Press, 2000)*; Jim Haywood, V. Ramaswamy and Brian Soden, "Tropospheric Aerosol Climate Forcing in Clear Sky *Satellite Observations over the Oceans", 283* Science *(1999), pp. 1299* et sqq.

46 Roger Angel, "Feasibility of Cooling the Earth with a Cloud of Small Spacecraft near the Inner Lagrange Point (L1)", 103 Proceedings of the National Academy of Sciences (2006), 17184; James Early, "Space-Based Solar Shield to Offset Greenhouse Effect", 42 *British Interplanetary Society* (1989), 567; Walter Seifritz, "Mirrors to Halt Global Warming?", 340 Nature (1989), 603.

47 Paul Crutzen, "Cooling the Earth's Surface by Stratospheric Sulphur Injections", 20 *Jahrbuch Ökologie* (2011).

48 Peter Morrisette, "The Evolution of Policy Responses to Stratospheric Ozone Depletion", 29 *Natural Resources Journal* (1989), 793; David Fahey, *Twenty Questions and Answers About the Ozone Layer: 2006 Update* (Washington, DC: US Global Change Research Program, 2007), 167; Sari Kovats, Bettina Menne, Anthony McMichael and Colin Soskolne (eds.), *Climate Change and Stratospheric Ozone Depletion: Early Effects on our Health in Europe* (Copenhagen: WHO Regional Publications, 2000).

49 Alan Carlin, "Implementation & Utilization of Geoengineering for Global Climate Change Control", 7(2) Sustainable Development Law & Policy (2007), 56; Karen Parkhill and Nick Pidgeon, Public Engagement on Geoengineering Research: Preliminary Report on the SPICE Deliberative Workshops, Understanding Risk Working Paper 11-01 (Cardiff: Cardiff University, 2011).

50 Stuart *Wolpert, "No Quick or Easy Technological Fix for Climate Change, Researchers Say",* UCLA Sustainability, 17 December 2008, available on the Internet at <http://www.sustain.ucla.edu/cap/article.asp?parentid=1849> (last accessed on 11 September 2012); BBC, "Creating a 'Sulphur Screen'", 20 February 2007, available on the Internet at <http://news.bbc.co.uk/1/hi/programmes/6369971.stm> (last accessed on 11 September 2012).

51 "Generating the Funding Needed for Mitigation and Adaptation", in The World Bank, *World Development Report 2010: Development and Climate Change* (Washington, DC: IBRD, 2010), at 257.

the cost of the GHG emissions reductions required to achieve the same results for global mean temperature.[52]

There has been much scientific opposition to SRM, on the grounds that: 1) current model simulations show that, while it is possible to effectively offset all human-induced warming, it means a drop in monsoon rains throughout the tropics,[53] posing a potential risk to agriculture in several developing countries;[54] and 2) at the regional level, climate projections are far from certain and are expected to stay that way for some time to come. This means there is a chance for unanticipated consequences to arise.[55] Also, the only way to know if a certain technology is feasible is by conducting large-scale experiments over an extended time period until the results are clear, thereby subjecting populations to potentially adverse or even catastrophic effects for at least several years.[56]

3. Governance

In the same way as other matters involving multilateral environmental agreements (MEAs),[57] geoengineering gives rise to challenges such as dealing with risks of action versus inaction when faced with ambiguous scientific knowledge,[58] the complexity of designing regulatory approaches,[59] the need for cooperation among nations versus the costs of developing such arrangements,[60] and their sometimes limited effectiveness.[61] However, geoengineering has two possibly unique characteristics: 1) the need to take into account a governance system for its experimental phase; and 2) the risk that a country could unilaterally decide to tackle climate change through geoengineering, ignoring the possible misgivings of other States.[62] To that end, it may be placed within Ian Lloyd's moniker of a collective "non-action" problem:[63] how to ensure a safe and

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52 See Nicola Jones, "Sucking it Up", 458 *Nature* (2009), 1094 (arguing that taking CO_2 out of the air is simple, but may cost a lot of money).

53 George Boer, Gregory Flato and David Ramsden, "A Transient Climate Change Simulation with Greenhouse Gas and Aerosol Forcing: Projected Climate to the Twenty-First Century", 16 *Climate Dynamics* (2000), 427; Stephen Cox, Wei-Chyung Wang and Stephen Schwartz, "Climate Response to Radiative Forcings by Sulfate Aerosols and Greenhouse Gases", 22(18) *Geophysical Research Letters* (1995), 2509; Chia Chou, J. David Neelin, Ulrike Lohmann and Johann Feichter, "Local and Remote Impacts of Aerosol Climate Forcing on Tropical Precipitation", 18 *Journal of Climate* (2005), 4621.

54 Jemma Gornall et al., "Implications of Climate Change for Agricultural Productivity in the Early Twenty-First Century", 365(1554) Philosophical Transactions of the Royal Society B (2010), 2973; Bryson Bates et al. (eds.), Climate Change and Water (Geneva: IPCC Technical Paper VI, 2008); Suhas Wani, Johan Rockström and Theib Oweis (eds.), *Rainfed Agriculture: Unlocking the Potential* (Wallingford: CABI, 2009).

55 Hiram *Levy II, Drew Shindell, Alice Gilliland, Larry Horowitz, and Daniel Schwarzkopf, M. (eds.),* Climate Projections Based on Emissions Scenarios for Long-Lived and Short-Lived Radiatively Active Gases and Aerosols *(Washington, DC: U.S. Climate Change Science Program, 2008); Ed* Sarachik, "The Application of Climate Information", 5(2) Consequences *(1999)*; Martin Weitzman, *The Extreme Uncertainty of Extreme Climate Change: An Overview and Some Implications* (Cambridge, Mass.: PSU, 2009).

56 Michael Specter, "The Climate Fixers: Is there a Technological Solution to Global Warming?" *The New Yorker*, 14 May 2012; "Human Consequences and Responses" in Paul Stern, Oran Young and Daniel Druckman (eds.), *Global Environmental Change: Understanding the Human Dimensions* (Washington, DC: National Academy Press, 1992); Anthony McMichael et al. (eds.), *Climate Change and Human Health: Risks and Responses* (Geneva: World Health Organization, 2003); Kevin Trenberth, Kathleen Miller, Linda Mearns and Steven Rhodes, *Effects of Changing Climate on Weather and Human Activities* (Mill Valley, Ca.: University Science Books, 2000); Rafael Leal-Arcas, "Geoengineering the Climate: An Overview", 10 *Oil, Gas & Energy Law Intelligence* (2012), 1.

57 Jutta Brunée, "Coping with Consent: Law-Making under Multilateral Environmental Agreements", 15 *Leiden Journal of International Law* (2002), 1.

58 Kelsi Bracmort, Richard Lattanzio and Emily Barbour, *Geoengineering: Governance and Technology Policy* (Washington, DC: Congressional Research Service, 2011); Redgwell, "Geoengineering the Climate", supra, note 40, at 178; Royal Society, *Geoengineering the Climate: Science, Governance and* Uncertainty (London: Royal Society, 2009); Katherine Ricke, M. Granger Morgan, Jay Apt et al., *Unilateral Geoengineering* (Council on Foreign Relations, 2008).

59 House of Commons Science and Technology Committee, *The Regulation of Geoengineering,* Fifth Report of Session 2009–10, chapter 4 (2010); Bidisha Banerjee, "The Limitations of Geoengineering Governance in a World of Uncertainty", *Stanford Journal of Law, Science & Policy* (2011).

60 Jay Michaelson, "Geoengineering: A Climate Change Manhattan Project", 17 *Stanford Environmental Law Journal* (1998); National Research Council of the National Academies, *Geological and Geotechnical Engineering in the New Millennium: Opportunities for Research and Technological Innovation* (Washington, DC: National Academies Press, 2006); Robert Lempert and Don Prosnitz, *Governing Geoengineering Research: A Political and Technical Vulnerability Analysis of Potential Near-Term Options* (Santa Monica, Ca.: RAND, 2011).

61 Scott Barrett, "The Incredible Economics of Geoengineering", 39 *Environmental and Resource Economics* (2008), *45; John* Virgoe, "International Governance of a Possible Geoengineering Intervention to Combat Climate Change", 95(1–2) *Climatic Change* (2009), 103.

62 Daniel Bodansky, "The Legitimacy of International Governance: A Coming Challenge for International Environmental Law?", 93 *American Journal of International Law* (1999), 596.

63 See Ian Lloyd and Michael Oppenheimer, "On the Design of an International Governance Framework for Geoengineering", 20 April 2011, at 3 (unpublished paper, on file with author).

educative testing phase, while adjusting incentives so that no State will act single-handedly (as long as these two conditions are not in total opposition to each other).

Moreover, it is in a context of vastly different interests that these new issues arise; a situation similar to the very climate problem. This makes it even more difficult to attain any sort of concurrence. For instance, small island States may be in favor of any steps that lower global mean temperature because, if successful, such steps would ultimately stem the sea level rise that threatens to submerge them.[64] India, however, might oppose any action that affects the monsoon.[65] In the case of the U.S. and China, they might, under some circumstances, support geoengineering so as to not have to reduce fossil fuel consumption.[66] On the other hand, a possible threat to rainfall patterns may be of concern to China.[67] As for Russia, it has, at times, seemed complacent about global warming (at least up to a point).[68] The EU, for its part, may perceive geoengineering as a threat to its age-old attempts to create a global GHG emissions reduction framework.[69]

a. Moving forward

There are three basic views regarding the most suitable way to move ahead. According to David Victor, at this point there is no benefit to aiming for any sort of joint international framework.[70] Were a new, inclusive platform to be built, or a current forum like the UNFCCC to be utilized, countries' varying interests would cause an impasse in the best case scenario, and in the worst case, lead to a complete ban on all testing.[71] A country that had the inclination and resources to experiment with, or implement geoengineering, would proceed regardless of the agreement. Creating mechanisms to make sure of all parties' involvement would be as ineffective as they have been under Kyoto. On the contrary, Victor advises a bottom-up approach through decentralized cooperation,[72] possibly evolving into a full regime over a long period of time.[73] However, this does not satisfactorily address the ethical concerns that Morrow *et al.* have expressed.[74]

Another view acknowledges that while no current agreement has the capacity to address geoengineering, the UNFCCC could be updated to include geoengineering as a basic element of strategies to reduce GHG emissions and adapt to climate change.[75] Such an updated agreement could encompass both the research and implementation stages. The benefit of this approach is that the regime already exists and has universal participation. Adaptation funds – which already exist, if only partially funded – could provide a basis for designing other arrangements, such how to compensate States for damages that may occur either during experimentation or implementation. However, since these proposals were first put forth, the limitations of the UNFCCC, apart from the ones Victor points out, have become more apparent. Part of the same interplay that has stalled GHG emissions reduction negotiations at the UNFCCC would rear its head in the

64 Robert *Nicholls and Nobuo Mimura, "Regional Issues Raised by Sea-Level Rise and their Policy Implications", 11* Climate Research *(1998), 5; James Lewis, "The Vulnerability of Small Island States to Sea Level Rise: The Need for Holistic Strategies", 14* Disasters *(1990), 241.*

65 Kirsten Zickfeld, Brigitte Knopf, Vladimir Petoukhov and Hans-Joachim Schellnhuber, "Is the Indian Summer Monsoon Stable against Global Change?", 32 *Geophysical Research Letters* (2005); Muni Krishna Kailasam and Sai Ramalingeswara Rao, "Impact of Global Warming on Tropical Cyclones and Monsoons", in Stuart A. Harris (ed.), *Global Warming* (Rijeka: InTech, 2010).

66 Mark Kinver, "Public Supports Geo-Engineering Ideas, Study Suggests", BBC, 24 October 2011.

67 Anders Levermann, Jacob Schewe, Vladimir Petoukhov et al., *Basic Mechanism for Abrupt Monsoon Transitions* (Washington, DC: PNAS, 2009); Yali Zhu, Huijun Wang, Wen Zhou et al., "Recent Changes in the Summer Precipitation Pattern in East China and the Background Circulation", 36 *Climate Dynamics* (2010), 1463; Joint Global Change Research Institute and Battelle Memorial Institute, *China: Impact of Climate Change to 2030* (Washington, DC: National Intelligence Council, 2009).

68 Artyom Liss, "Global Warming Leaves Russians Cold", BBC, 24 September 2007; Pew Research, *Global Warming Seen as a Major Problem around the World. Less Concern in the U.S., China and Russia* (Washington, DC: Pew Research Publications, 2009).

69 Kornelis Blok, N. Höhne, A. Torvanger et al., *Towards a Post-2012 Climate Change Regime* (Brussels: DG Environment, 2005).

70 David Victor, "On the Regulation of Geoengineering", 24(2) *Oxford Review of Economic Policy* (2008), 322.

71 Jeff Tollefson, "Geoengineering Faces Ban", 468 *Nature* (2010), 13.

72 David Victor, "On the Regulation of Geoengineering", 24(2) *Oxford Review of Economic Policy* (2008), 332.

73 Anne-Marie Slaughter, *A New World Order* (Princeton, N.J.: Princeton University Press, 2004).

74 David Morrow, Robert E. Kobb and Michael Oppenheimer, "Toward Ethical Norms and Institutions for Climate Engineering Research", 4 *Environmental Research Letters* (2009), 1.

75 John Virgoe, "International Governance of a Possible Geoengineering Intervention to Combat Climate Change", 95 *Climate Change* (2009), 103; Barrett, "Economics of Geoengineering", *supra*, note 61, at 45.

case of geoengineering, and moreover, a single party would have the ability to cripple the process. It is difficult to envision a solution to such a scenario.

The third approach suggests a more streamlined negotiation, with only a few highly interested parties taking part, or taking the lead, such as the Antarctic Treaty[76] (but unlike the Nuclear Non-proliferation Treaty (NPT)[77]) regime.[78] The idea behind this proposal is that involving countries prior to their developing a definite interest in a specific outcome, or where only a handful of States envisions making use of such technology, it would be possible to build a regime that could at least deal with the experimentation stage, and hopefully, further.

With the UNFCCC process competing with the MEF, the G-20, and other negotiation venues,[79] the international community should develop proposals to engage the UNFCCC on geoengineering, specifically SRM. Three plausible positions appear to emerge: First, the UNFCCC may provide an appropriate venue for the development of geoengineering as a sub-regime to climate change. Why? Because all the necessary mechanisms, including for compensation, already exist. A second, and opposite, position is that the UNFCCC has all the characteristics which would doom any attempt to manage geoengineering. Therefore, a smaller group of countries, limited to those which are likely to implement geoengineering, could develop a more effective approach through venues such as the MEF or the G-20, which could promote the development of a regime of ongoing cooperation. A final position is that it is not the right time for either developing a new regime or for raising such a controversial issue within the already delicate UNFCCC process. Instead, there should be collaborations among experts and scientists so that they can determine the nature of appropriate experiments and implementation mechanisms. Current institutions are equipped to handle any unforeseen risks that may arise in the short term, the way the Convention on Biological Diversity addressed marine iron fertilization.

4. Legal considerations relating to international trade

Literature exists in relation to the ethical, logistical, and political complexities of geoengineering strategies; however, there is a real dearth of writings in relation to the legal implications of geoengineering on international trade. This is far from surprising given that the crucial aspects of geoengineering, *viz.,* its governance, have yet to be addressed and settled by the international community. This section is based on the review of existing literature on geoengineering that engages the question of international trade. It attempts to present and outline the principal considerations that appear to arise in this literature, along with proffering insights on how geoengineering might engage the existing multilateral trading system. Most points below are indirect to the nexus of geoengineering *vis-à-vis* international trade. However, they have been included as a means of contributing to a fuller understanding of, and having a broader picture of, the nexus of the international legal aspects and implications of geoengineering and international trade.

This section refers to the *prima facie* prohibition of the commercial use – including for the purposes of trade – of certain geoengineering techniques; to the potential extraneous capacity of geoengineering to cure trade anomalies; and to the capacity of the existing multilateral trade system to encourage buy-in, and therefore, legitimize and facilitate a future global governance regime for geoengineering.

a. Geoengineering and the environment as public goods

Geoengineering, in the main, is highly controversial. The utility it may be able to provide, and the field of the commons it seeks to remedy, is considered a 'public good.' The United Kingdom House of Commons Science & Technology Committee (the STC) recommended to the UK Government that "geoengineering ... be regarded as a 'public

76 Antarctic Treaty, Washington, DC, 1 December 1959, in force 23 June 1961, 19 *International Legal Materials* (1980), 860.

77 Treaty on the Non-Proliferation of Nuclear Weapons, New York, N.Y., 1 July 1968, in force 5 March 1970, 7 *International Legal Materials* (1968), 8809.

78 Lloyd and Oppenheimer, "International Governance Framework", supra, note 63, at 3.

79 For further elaboration on this point, see Rafael Leal-Arcas, "Top-down versus Bottom-up Approaches for Climate Change Negotiations: An Analysis", 6(4) *The IUP Journal of Governance and Public Policy* (2011), 7.

good'."[80] The potential repercussions on trade, including international trade, in tradeable geoengineering-related techniques and technologies are that, once the utility they provide is considered a 'public good,' it is more likely that these would become subject to more extensive regulation, which might potentially affect, amongst other things, the appeal of this potential field of the market to investors.

b. Geoengineering and its multiple uses

The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD)[81] was cited in evidence given to the STC. The treaty prohibits the use of the environment in hostile circumstances – as may have possibly happened between the parties to the Cold War, and by the United States against North Vietnam during the Vietnam War – and supports "the use of weather modification for peaceful purposes."[82] The ENMOD covers a number of environmental phenomena, including climate change, and contains provisions in relation to technologies that may have a dual-purpose[83] by, for instance, providing a genuine environmental benefit on the one hand, and, on the other, potentially being used for acts of aggression, or hostility. Examples include the benign use of 'cloud-seeding' to contain or restrain rain fall, and its more malevolent use to cause, amongst other things, drought and crop failure that invariably pose threats to food, and, consequently, to human security. The impact therefore that the above may have on trade – including international trade – is that geoengineering-related commodities capable of having a dual use may, on their face, engage the provisions of ENMOD, and may, hence, be subject to a further layer of regulation or even prohibition.

c. The current prohibition on the commercial exploitation of geoengineering

The Kyoto Protocol has been lauded as a breakthrough international environmental agreement as it, amongst other things, engages the private sector as part of the solution to environmental degradation through market-based emissions trading mechanisms. It functions on the logic of a closed totality of permissible emissions – the level of which is set by some central or regional authority which also issues credits to emitters – that ought not be exceeded. Unused credits may then be traded to permit an emitter to essentially purchase polluting rights. In that sense, emissions trading mechanisms focus on containing, though at best, on discouraging, GHG emissions. Geoengineering, on the other hand, if successful, provides a pressure valve that creates a real danger that business may continue emitting as usual.

Geoengineering may create further opportunities for the emissions trading market. William Davis suggests that ocean iron fertilization has been proposed or has actually been undertaken by several companies in order to sell carbon offset credits in the emissions trading market.[84] Currently, these

80 See UK House of Commons Science and Technology Committee, *The Regulation of Geoengineering Fifth Report of Session 2009/10 of the UK House of Commons Science & Technology Committee*, at 29. Furthermore, the Science and Technology Commitment (the STC) also recommended multilateral action, ideally through the UN, to achieve as wide participation as possible. This is justified on the basis that allowing one or a few States to unilaterally act may be placing the remaining international community in a dependence relationship whilst providing a perilous advantage to the former. The STC acknowledges the limitations of a multilateral top-down approach; however, it considers the accruing benefits to outweigh such limitations.

81 Adopted 10 December 1976, in force 5 October 1978, 1108 UNTS 151 / [1984] ATS 22.

82 See ENMOD Article 3.1, which states that: "1. The provisions of this Convention shall not hinder the use of environmental modification techniques for peaceful purposes and shall be without prejudice to the generally recognised principles and applicable rules of international law concerning such use.
2. The States Parties to this Convention undertake to facilitate, and have the right to participate in, the fullest possible exchange of scientific and technological information on the use of environmental modification techniques for peaceful purposes."

83 The following passage is contained within the UK House of Commons Science and Technology Committee, *The Regulation of Geoengineering,* Fifth Report of Session 2009/10 of the UK House of Commons' Science & Technology Committee, at Ev. 32 of the "Evidence" Section (see Memorandum submitted by Dr James Lee): "The treaty references assisting other countries in transferring technology related to the development of harmful or hostile ENMOD techniques. This implies the trade of materials, equipment, technology, or expertise. Export technology treaties cover materials that may have military application as dual-use technologies. The ENMOD Treaty suggests that exports of cloud seeding technologies may as well fall into such categories."

84 William Davis, "What does "Green" Mean? Anthropogenic Climate Change, Geoengineering, and International Environmental Law", 43 *Georgia Law Review* (2009), at 932. Davis refers to Planktos – one of such companies – as having planned to engage in six ocean iron fertilization projects for commercial purposes between 2007 and 2009. See also Till Markus and Harald Ginzky, "Regulating Climate Engineering: Paradigmatic Aspects of the Regulation of Ocean Fertilization", 4 *Carbon and Climate Law Review* (2011), 477.

practices may be in conflict with existing international agreements. Davis cites, for example: the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention),[85] which, amongst other things, regulates the deliberate disposal of waste and other matters at sea by its contracting parties; and the 1996 Protocol to the London Convention,[86] which places a general prohibition on ocean dumping except for safe waste.[87] In 2007, the Scientific Groups of the London Convention (and of its Protocol) expressed their concern about such activities. This resulted in the adoption by the parties to the London Convention and its Protocol of the 'Statement of Concern' of the Scientific Group and in a clarification by the parties that the London Convention and its Protocol extended to ocean fertilization. They also stated that, given the current scientific uncertainty around these activities, large-scale operations were currently not justified.[88]

Returning briefly to the ENMOD prohibition on the military and other hostile use of the environment, and to the possibility that this may extend to the commercial use of the environment, as suggested by Davis and Rayfus, this may amount to a *prima facie* prohibition of the commercial use of geoengineering, including trade in related goods and services. That said, it should be acknowledged that geoengineering is not a homogenous assortment of practices. Setting aside their efficacy, whilst SRM – involving the injection of potentially toxic compounds into the stratosphere to deflect solar radiation away from Earth in order to cool its temperature – may potentially fall within the ambit of, *inter alia,* this prohibition, it may be that iron fertilization, involving the dumping of large iron sulphur compounds into water bodies, may be permitted under some other aspect of international law.

For instance, the London Protocol[89] to the London Convention prohibits all dumping[90] and obligates parties to individually and collectively protect and preserve the marine environment from all sources of pollution and take effective measures to generally abate pollution caused by dumping of wastes or other matter in the sea.[91] To that end, they shall take a precautionary approach where it is likely that the marine environment would be harmed even in the absence of conclusive evidence to prove causality.[92] They should also ensure that those authorized in their jurisdictions to handle waste who, consequently, cause maritime pollution be made to compensate the harm caused.[93] Furthermore, in their efforts to implement the provisions of the 1996 London Protocol, parties are prohibited from transferring "damage or likelihood of damage from one part of the environment to another or to transform one type of pollution into another."[94] Moreover, the 1996 London Protocol restricts all dumping[95] except for those relating to a permitted list[96] that includes "inert, inorganic geological material; organic material of natural origin; and CO_2 streams from CO_2 capture processes." In that respect, the 1996 London Protocol could potentially create scope for parties to it to permit certain geoengineering methods without prohibiting *per se* the commercial use of such methods, including trade in related goods and services. In relation to

85 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention), London, 29 December 1972, in force 30 August 1975, 11 *International Legal Materials* (1972), 1294.

86 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Protocol), London, 7 November 1996, in force 24 March 2006, 36 *International Legal Materials* (1997), 1.

87 For an analysis of the London Convention, see Melissa Eick, "A Navigational System for Uncharted Waters: The London Convention and London Protocol's Assessment Framework on Ocean Iron Fertilization," 46 *Tulsa Law Review* (2011), 351.

88 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 and its 1996 Protocol, "Statement of Concern regarding Iron Fertilisation of the Oceans to Sequester CO_2", (13 July 2007) TF/5.01 LC-LP.1/CIRC.14, (at p. 1), which states that: "Large-scale fertilization of ocean waters using micro-nutrients such as iron to stimulate phytoplankton growth in order to sequester carbon dioxide is the subject of recent commercial interest. The Scientific Groups of the London Convention and the London Protocol took the view that knowledge about the effectiveness and potential environmental impacts of ocean iron fertilization currently was insufficient to justify large-scale operations".

89 Supra, note 86; in 1996, Parties adopted this Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter; it entered into force in 2006 and is meant to eventually replace the 1972 Convention.

90 See London Protocol, *supra*, note 86, Article 4; save for a list of permissible discharges (in Annex I to the 1996 London Protocol).

91 London Protocol, *supra*, note 86, Article 2.

92 London Protocol, *supra*, note 86, Article 3.1.

93 London Protocol, *supra*, note 86, Article 3.2.

94 London Protocol, *supra*, note 86, Article 3.3.

95 London Protocol, *supra*, note 86, Article 4.

96 London Protocol, *supra*, note 86, Annex 1.

the permitted dumping of CO_2 into the sea, it could be argued, *a fortiori,* that the dumping of "inert inorganic matter" such as iron sulphur compounds – incidentally, arguably also permitted under the Protocol – to abate damage caused by CO_2 dumping may be permissible.

What is more, the 1996 London Protocol contains exceptions[97] that allow a party in exceptional circumstances to pollute beyond the scope afforded to it by the permitted list. Specifically, it refers to *force majeure* instances, including to avert danger to human life if dumping at sea appears to be the only way of averting the threat in a way that the resultant damage from such dumping will be less than would otherwise occur. In that sense, it reflects the notion of proportionality. The effect of this is to potentially permit the deployment of a geoengineering method such as iron fertilization – which involves the dumping of iron sulphur particles into the sea – in order to avert a greater calamity, e.g. further degradation of the atmosphere by CO_2 emissions. This, however, may present problems in satisfying the element of urgency that the exception contains. Naturally, the above interplay between the 1996 London Protocol and the ENMOD is relevant to States that are parties to both instruments.[98]

In 2008, the Conference of the Parties to the 1992 Convention on Biological Diversity[99] (CBD) issued a statement in which they requested contracting parties, and urged other governments, to preclude ocean fertilization activities on the basis of the precautionary principle, given the inadequacy of scientific knowledge.[100] Small-scale scientific research studies within coastal waters were to be permitted – albeit strictly controlled and not for the purposes of "generating and selling carbon offsets or any other commercial purposes"[101] – on the basis of advancing scientific understanding. Davis suggests therefore that the current international regulatory framework, including the international obligations that attach to the CBD,[102] does not accommodate the deployment of these activities between its parties for commercial purposes, including trade.[103]

Davis further concludes that geoengineering – including its trade aspects – is likely to be passionately opposed and restricted by the international community. This is mainly due to: the great difficulties in getting universal support for the global governance of geoengineering; the potentially catastrophic transboundary side-effects of geoengineering; and to the acute political and legal complexities it seems to engage.[104]

Rosemary Rayfuse *et al.* had initially articulated the points espoused by Davis in his article: that the London Convention and its Protocol, along with the CBD, place their parties under a duty to prohibit the commercial use of ocean fertilization[105] on their territory.[106] Whilst these instruments do not extend to non-parties, the 1982 United Nations Convention on the Law of the Sea (Law of the Sea Convention,

97 London Protocol, *supra*, note 86, Article 8: "The provisions of articles 4.1 and 5 shall not apply *when it is necessary to secure the safety of human life* or of vessels, aircraft, platforms or other man-made structures at sea in cases of force majeure caused by stress of weather, or *in any case which constitutes a danger to human life* or a real threat to vessels, aircraft, platforms or other man-made structures at sea, *if dumping* or incineration *at sea appears to be the only way of averting the threat and if there is every probability that the damage consequent upon such dumping* or incineration *at sea will be less than would otherwise occur.* Such dumping or incineration at sea shall be conducted so as to minimize the likelihood of damage to human or marine life and shall be reported forthwith to the Organization." (emphasis added).

98 In relation to the 1972 London Convention, there are 87 parties to it, of which 42 have signed and ratified its 1996 London Protocol. In relation to ENMOD, although it has 76 parties, it has been signed by 48, and ratified by 20.

99 Convention on Biological Diversity, Nairobi, 22 May 1992, in force 29 December, 1993, 31 *International Legal Materials* (1992), 818.

100 Decision IX/16, Section C (May 2008). See on the Internet <www.cbd.int/climate/geoengineering> (last accessed on 11 September 2012) for more information about the positions of the parties to the CBD in relation to geoengineering.

101 Decision IX/16, Section C (May 2008).

102 See <www.cbd.int/convention/parties/list> (last accessed on 22 August 2012) for a list of parties (there are 193 parties, of which 168 are signatories, of which circa 130 have ratified the CBD).

103 William D. Davis, "What does 'Green' Mean? Anthropogenic Climate Change, Geoengineering, and International Environmental Law", 43 *Georgia Law Review* (2009), at 935.

104 *Ibid.*, at 946.

105 Ocean fertilization is a geoengineering technique that involves artificial dramatic increases of iron in the marine environment targeted at triggering a proliferation of algae capable of sequestering excess CO_2 in ocean depths. This is a highly controversial technique given the potentially catastrophic consequences of resultant ocean acidification. See on the Internet: <unesdoc.unesco.org/images/0019/001906/190674e.pdf> (last accessed on 11 September 2012) for a UNESCO-endorsed account of geoengineering for the purposes of policymakers.

106 Rosemary Rayfuse, Mark G. Lawrence and Kristina M. Gjerde, "Ocean Fertilisation and Climate Change: The Need to Regulate Emerging High Seas Uses", 23 *International Journal of Marine & Coastal Law* (2008), 297.

or UNCLOS)[107] requires parties to it to ensure that activities taking place in their jurisdictions or under their control do not cause extra-territorial damage.

UNCLOS places an express duty on parties to it, in their efforts to manage the pollution of the marine environment, not to transfer damage or hazards from one area to another, or to transform one type of pollution into another. It also mandates parties to prevent, reduce, and control pollution of the marine environment caused by technologies under their jurisdiction or control.[108] Geoengineering activities – particularly ocean fertilization (a controversial and potentially harmful technique) – may be curing one ill whilst causing another. The CBD contains similar prohibitions in relation to potentially harmful processes or activities. An activity such as ocean fertilization, which – amongst other things, sequesters CO_2 in the marine environment, by increasing iron concentrations and by leading to threatening levels of ocean acidification – may constitute *prima facie* harmful pollution for the purposes of biodiversity.

The potential trade implications of these provisions may be that the generation of emission trading credits through these technologies – basically, the very likely harming of the marine environment in order to transfer through market-allocation whatever benefit elsewhere, chiefly to existing polluters – may amount to an activity highly likely to be prohibited under UNCLOS and the CBD vis-à-vis parties to these international agreements.[109]

Returning to the question of the potential prohibition of the commercial use of geoengineering under the CBD mentioned above, Victor Galaz alludes to the confusion around what is prohibited.[110] For instance, if it is that "large-scale"[111] projects are prohibited, then, foreseeably, setting the exact scope of this term may be highly contentious between nation-States that have disparate interests linked to the exploration/deployment of geoengineering. Given this confusion, the commercial use of geoengineering may take root in the absence of consent.

Furthermore, Galaz alludes to how carbon capture and storage technologies are not always considered geoengineering. Let us assume that commercial deployment of geonengineering is prohibited under CBD. Here, the potential trade implications, again, may turn on semantics. Proponents, along with those capitalizing on such technologies, would lobby for these interventions to be considered, the more benign, *recycling*, rather than as geoengineering in order to evade the prohibition.

d. Unsanctioned geoengineering activity and potential trade sanctions

The interplay between geoengineering and trade may also arise within the context of trade sanctions. There are legitimate concerns about the deployment of geoengineering strategies with little regard to the collective needs of the international community. There is also the heightened risk that unilateral action may be taken, and that policy decision-making on the governance of geoengineering may become monopolized by a handful of actors such as economically stronger States, and, perhaps more worryingly, to private companies whose priorities, if not interests, diverge from those of State actors.[112] In connection to this, Victor links geoengineering and potential trade sanctions levied against rogue States to encourage compliance with the interests of

107 United Nations Convention on the Law of the Sea, Montego Bay, 10 December 1982, in force 16 November 1994, 1833 *United Nations Treaty Series* (1994), 396. UNCLOS has been ratified by in excess of 160 States. It is unfortunate that the United States – the main proponent of UNCLOS – is not a signatory. However, it is encouraging to note that, amongst many others, European Union Member States, Brazil, China, India, and Russia have ratified UNCLOS.

108 Articles 195 and 196 of UNCLOS.

109 Pearce suggests that the wording of the ban is vague and contradictory as to whether it covers all instances of geoengineering or just those that negatively impact on biodiversity. See Fred Pearce, "UN 'Ban on Geoengineering' May Not Be What It Seems", 208 *New Scientist* (2010), 1.

110 Victor Galaz, "Geoengineering, Governance, and Social-Ecological Systems: Critical Issues and Joint Research Needs", 17 *Ecology and Society* (2012), 24.

111 See Decision adopted by the Conference of the Parties to the CBD at its 10th meeting on "Biodiversity and Climate Change", UN Doc. UNEP/CBD/COP/DEC/X/33, where it is stated that: "Without prejudice to future deliberations on the definition of geoengineering activities, understanding that any technologies that deliberately reduce solar insolation or increase carbon sequestration from the atmosphere on a large scale that may affect biodiversity (excluding carbon capture and storage from fossil fuels when it captures carbon dioxide before it is released into the atmosphere) should be considered as forms of geoengineering which are relevant to [this] Convention … until a more precise definition can be developed" (at 5, footnote 2).

112 For a summary of some geopolitical-related concerns, cf., David Victor, "On the Regulation of Geoengineering", 24(2) *Oxford Review of Economic Policy* (2008), 322.

the international community. He concedes, however, that these are likely to be ineffective "[as] they rarely work except when focused on small and vulnerable countries, which are the nations that are perhaps least likely to pursue unilateral geoengineering."[113]

e. Less controversial geoengineering modalities

There are modalities of geoengineering that are politically less complex or controversial. These are explored at some length by Bronstein.[114] For instance, reforesting for the specific purpose of maximizing a CO_2-capturing surface area is a means of geoengineering that does not place climate change solutions within the keep or gift of a few, invariably developed, world powers. Another example is the maximization of surface area that deflects solar radiation. This is as simple as painting rooftops in colors better able to reflect radiation, thus contributing towards global cooling of stabilization.[115] The trade implications are also generally minimal. However, the significance of these modalities to trade is that the existing legal norms on international trade – for instance, within the WTO membership – are capable of accommodating an increase in trade flows without an apparent need for adaptation or differentiation.

f. Of the existing multilateral trade system

A regime specific to trade in geoengineering-related goods and services does not currently exist. This is also the case for the great majority of tradeables. A risk is that, should this field of trade remain relatively unregulated, the formation of private developer lobbies might gradually acquire undue levels of influence over public policy. Victor *et al.* caution against this eventuality.[116] Although, Victor *et al.* appreciate that States seem to prioritize their economic development needs, when these are in conflict with their international obligations in relation to the environment (e.g., taking meaningful steps to contain their emission levels), they urge governments to collectively take geoengineering seriously to ensure that international norms be created to govern the use – including the trade – of geoengineering.[117] Clearly, the development of rules on trade in such tradeables could cure against this risk.

Geoengineering related-tradeable commodities already exist in the form of, amongst other things, carbon emission credits.[118] Arguably, the existing multilateral trade system can accommodate this field of trade to an extent. Unsurprisingly, the application of the existing WTO legal norms would be highly specific and variegated to the type of tradeable commodity in question, be it a service or a good. The WTO system is designed to ensure market access in an even-handed manner, irrespective of the trading partner or of whether the tradeables are produced abroad or domestically. It is also based on the incremental liberalization of trade through periodic multilateral negotiations focused on the further reduction, and, ultimately, removal, of as many barriers to cross-border trade as may be feasible by an international community of States fiercely protective of their capacity to prioritize their own policy needs.

Geoengineering-related tradeables may engage GATT provisions[119] (and their GATS equivalents) in relation to, amongst other things: the general prohibition on quantitative restrictions on trade flows

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113 *Ibid.*, at 334.

114 Max Bronstein, "Readily Deployable Approaches to Geoengineering: Cool Materials & Aggressive Reforestation", 10 *Sustainable Development Law & Policy* (2010), pp. 44 *et sqq*, at p. 44.

115 It is noteworthy that just one square meter of white roof top can offset up to 63 kg of CO_2, Ibid., 45.

116 See the following passage in David Victor, M. Granger Morgan, Jay Apt et al., "The Geoengineering Option: A Last Resort Against Global Warming?", 88 *Foreign Affairs* (2009), 72: "Although governments are the most likely actors, some geoengineering options are cheap enough to be deployed by wealthy and capable individuals or corporations. Although it may sound like the stuff of a future James Bond movie, private-sector geoengineers might very well attempt to deploy affordable geoengineering schemes on their own. And even if governments manage to keep freelance geoengineers in check, the private sector could emerge as a potent force by becoming an interest group that pushes for deployment or drives the direction of geoengineering research and assessment. Already, private companies are running experiments on ocean fertilization in the hope of sequestering carbon dioxide and earning credits that they could trade in carbon markets".

117 *Ibid.*, at 64.

118 Currently, private companies are running experiments related to geoengineering – namely, the sequestration of emissions via ocean fertilization in the hope of sequestering CO_2 – that would earn them credits tradable in carbon markets. In this respect, these credits constitute tradable energy – and more specifically, geoengineering-related – commodities with an economic value.

119 General Agreement on Tariffs and Trade (GATT 1994), Marrakesh, 15 April 1994, in force 1 January 1995, 33 *International Legal Materials* (1994), 1153.

(GATT Article XI); to defenses to trade-restrictive measures (GATT Article XX); and to the measures that a WTO Member may take to protect the health of its population and ecosystem (for instance, the provisions contained within the Agreement on the Application of Sanitary and Phytosanitary Measures).

A consideration on how trade in geoengineering-related tradeables may engage WTO norms, suggests that it is possible for, say, an international trade transaction in large deposits of specific minerals necessary for the deployment of market-facilitated large-scale geoengineering strategies to engage all of the above provisions. For instance, foreseeably, a State may want to restrict the quantity of a particular commodity that may be imported or exported within its jurisdiction, citing, with good cause, a variety of justifications for taking such trade restrictive measures (for instance, the dispute between China and other WTO members before the WTO).[120]

The WTO system engages the majority of economies that are also affiliated to the United Nations, and therefore, the majority of the international community. There are universal jurisprudential tools – including customary and treaty-based international law – deployed by the judicial agency to resolve issues of interpretation of concurrent and competing international legal obligations. Although the WTO is a treaty-based system founded on the initial consent/opting-in of its Members, this does not provide the basis for its Members to suspend their other legal obligations *inter se*. The section below explores jurisprudential tools to resolve tension between concurrent and conflicting legal obligations.

Furthermore, the multilateral trade system may interplay with geoengineering in a less obvious way: through its co-option as a means to encourage States to buy into a global governance regime for geoengineering. According to Adam Heal, the multilateral trade system may aid this through its established mechanisms that promote compromise and offer compensation/benefits to keep parties engaging *inter se* through that system as an established venue for inter-State negotiations.[121]

A further angle to briefly consider is the interplay of geoengineering and the multilateral trade agreements. Below is an analysis of the various WTO agreements and their relation with geonengineering:

I. GATT Article V – Freedom of transit

Under GATT Article V, WTO Members are obligated to indiscriminately afford freedom of transit to goods originating from the territories of other WTO Members that are destined for consumption in other markets. Such movement of goods is considered to be traffic in transit.[122] This traffic should be facilitated through the most convenient routes for international transit.[123] That said, WTO Members may channel such traffic through pre-designated ports so long as this does not introduce unnecessary delays or restrictions.[124] Article V does not contain exceptions to this obligation. In that respect, the general exceptions to WTO rules as contained in GATT Article XX potentially extend to Article V violations, so long as such violations are not motivated by protectionism, are in any other way capricious and are non-discriminatory in nature, thus satisfying the requirements of the chapeau of GATT Article XX.

Foreseeably, a situation may arise where a WTO Member X, say, concerned with the potential transboundary effect of geoengineering being deployed in foreign territories, prohibits transit through its territory of traffic containing goods, originating from WTO Member Y, that it reasonably suspects to be linked to the deployment of geoengineering elsewhere. This would certainly present a *prima facie* violation of GATT Article V.

Under GATT Article XX, two potentially relevant grounds exist in relation to the protection of the health of life of humans, animals, and plants[125] as well as to the conservation of exhaustible natural resources.[126] However, applying GATT Article XX grounds to the example given above is complicated by the extraterritorial aspects of the trade-restrictive measure (i.e., the Article V violation) on the part of

120 WT/DS394 *China — Measures Related to the Exportation of Various Raw Materials*.

121 Adam Heal, "Managing Plan B: the Security Challenges of Geoengineering", 11 *Kennedy School Review* (2011), 51.

122 Article V:1 GATT.

123 Article V:2 GATT.

124 Article V:3 GATT prohibits the levying of customs' duties and transit duties, but permits incidental charges that are proportionate to the service rendered or administrative cost involved in facilitating this transit. Delays and restrictions are also prohibited, save for cases where the traffic in question has not complied with local custom laws and regulations.

125 GATT Article XX(b).

126 GATT Article XX(g).

WTO Member X. Presumably, the offending party may seek to argue that it considered this violation necessary to protect human, animal, and plant health or life in light of the conceivable transboundary effects of geoengineering on the environment and human population of its territory. Plausibly, such argument would appear stronger if the deployment were to take place in territories that are adjacent to the territory of WTO Member X.

Depending on what the potential transboundary consequences of the geoengineering activity may be, WTO Member X could further seek to justify its violation of Article V on the basis that it is necessary to conserve an exhaustible natural resource along the lines of the U.S. claim in *United States – Standards for Reformulated and Conventional Gasoline*.[127] In that case, the Appellate Body upheld the panel's earlier findings that a potentially depletable resource, such as clean air or clean water, may be considered an exhaustible natural resource for the purposes of GATT Article XX.[128]

By structuring its arguments along the above lines, WTO Member X would be highlighting the strong territorial aspects of its trade-restrictive measure. This could potentially displace what appears to be a general WTO prohibition on unilateral actions that have extraterritorial effects. In relation to this prohibition, one should take into account:

– the first GATT *United States – Restrictions on Imports of Tuna* case,[129] where the panel had concluded that GATT rules do not allow Members to restrict trade in order to enforce their own domestic laws extraterritorially, even if that is for purposes under GATT Article XX; and
– the *United States – Import Prohibitions of Certain Shrimp and Shrimp Products* case,[130] where the WTO Appellate Body made several references to instances – including Principle 12 of the Rio Declaration on Environment and Development – where WTO Members express their commitment to refrain from taking unilateral action to deal with environmental challenges outside their territories.

ii. GATS

In terms of geoengineering, CO_2 may be sequestered through, *inter alia,* reforestation, and ocean fertilization with iron particles. Any potential commercial use of these processes could lead to intra-WTO trade in related services. In relation to intra-WTO trade in services, the General Agreement on Trade in Services (GATS)[131] applies. Trade in services, by the very nature of its subject matter, is less liberalized than trade in goods under the GATT. GATS Article II mandates that whatever liberalization exists should be afforded without discrimination across the WTO membership.

Similarly to the GATT, the GATS contains general exceptions – albeit fewer – (Article XIV) for WTO Members to balance their other objectives. In relation to trade in geoengineering-related services, the most ostensibly relevant ground appears to be Article XIV(b) in relation to the protection of human, animal, and plant life or health. There has yet to be any dispute lodged with the WTO Dispute Settlement Body in relation to this provision.[132]

iii. Geoengineering implications for IPRs within the trade context

No discussion regarding the geoengineering implications on international trade law should sensibly omit to comment on the potential intellectual property rights (IPRs) implications. IPR protection is a key aspect of international trade law. In May 2012, it was reported that the SPICE (Stratospheric Particle Injection for Climate Engineering) project[133] was called off due to "concerns over a perceived conflict of interest with some of the researchers."[134] Apparently, two scientists involved had not been transparent about having previously submitted patents for technology associated to the SPICE project.[135] It would have involved the injection of 150

127 WT/DS2/9, 20 May 1996.

128 The U.S. was unsuccessful in that case as it had failed to satisfy the conditions in the *chapeau* of Article XX that the measure be non-discriminatory.

129 *United States – Restrictions on Imports of Tuna* (GATT Panel Report, DS21/R, 3 September 1991, unadopted, BISD 39S/155).

130 DS58/AB/R, 12 October 1998, (at pp. 67 onwards).

131 General Agreement on Trade in Services (GATS), Marrakesh, 15 April 1994, in force 1 January 1995, 33 *International Legal Materials* (1994), 1167.

132 See the breakdown of WTO cases engaging the GATS along the lines of the provisions, available on the Internet at: <www.wto.org/english/tratop_e/dispu_e/dispu_agreements_index_e.htm?id=A8#selected_agreement> (last accessed on 11 September 2012).

133 The Stratospheric Particle Injection for Climate Engineering project is a joint endeavor between the universities of Bristol, Cambridge, Edinburgh and Oxford.

134 Erin Hale, "Geoengineering Experiment Cancelled Due to Perceived Conflict of Interest", The Guardian, 16 May 2012.

135 *Ibid*.

liters of H2O through using a 1 km hose attached to a weather balloon.[136]

Although this item does not concern a patent dispute that hinders trade, it does bring to the fore the relationship between geoengineering and IPRs. Foreseeably, potential trade in geoengineering-related goods and services would be highly sensitive, given that the public-goods character of climate change mitigation and adaptation efforts could potentially be hampered by considerations around the protection of private interests. In relation to intra-WTO trade and trade engaging WIPO[137] Members, IPRs are protected globally to the extent provided by the rules of those organizations.

In relation to the WTO, the Agreement on Trade-related Aspects of Intellectual Property Rights (TRIPS)[138] applies the WTO core principles to intra-WTO IPRs protection. For instance, Article 3 obligates WTO Members to afford protection to foreign patent-holders that is equal to that of domestic rights-holders. Article 4 obligates Members to not discriminate between WTO Members in protecting the IPRs of foreign rights-holders. Furthermore, Article 2 defers to the agreements that the WIPO administers to ensure that any potential tensions between WIPO-related obligations and TRIPS are resolved in a manner that enhances, rather than subtracts from, the former.

Article 8 appears most relevant to the protection of IPRs potentially associated to geoengineering. It allows members some scope to balance IPRs protection against other objectives – "public health and nutrition, to promote the public interest in sectors of vital importance to their socio-economic and technological development"[139] – and against their interest in preventing "the abuse of intellectual property rights by right holders or the resort to practices which unreasonably restrain trade or adversely affect the international transfer of technology"[140] so long as this is done in a *bona fide* and non-discriminatory manner.[141] The public good that, arguably, prospective geoengineering tradables and processes confer on society could potentially activate the grounds contained within Article 8 to afford less protection to geoengineering-related IPRs. There may be analogies with the treatment of trade in pharmaceuticals under WTO rules (including its IPRs aspects under the TRIPS).

Furthermore, Article 27 of the TRIPS Agreement may come to bear to the protection of IPRs associated to prospective geoengineering tradables and processes. It requires that patents be available for any technological invention that is new, involves an inventive step and is capable of industrial application. Its paragraph 2, however, permits a WTO Member to exclude certain inventions relating to 'the prevention within their territory of the commercial exploitation of which is necessary to protect *ordre public* or morality, including to protect human, animal or plant life or health or to avoid serious prejudice to the environment.' This provision may come to bear in a situation where a WTO Member has serious misgivings about the human, animal or plant life or health and the environmental implications of a geoengineering product or process for which it has been approached to provide IPRs protection. Articles 27.2 may allow for it to withhold protection.

Additionally, paragraph 3 permits WTO Members to exclude, *inter alia*, "plants and animals, other than micro-organisms, and essentially biological processes for the production of plants or animals, other than non-biological and microbiological processes." Given that some geoengineering processes –

136 *Ibid*. See also "Don't Dismiss Geoengineering – We May Need it One Day", The Guardian, 17 May 2012.

137 The World Intellectual Property Organization (WIPO) is the United Nations agency for the governance of IPRs across its 185-strong membership. It was set up under the 1967 Convention Establishing the World Intellectual Property Organization in order to: "Promote the protection of intellectual property throughout the world through cooperation amongst States, and, where appropriate, in collaboration with any other international organization" and to "ensure administrative cooperation amongst the Unions" (see Article 3 of the Convention). The "Unions" refers to the patchwork of pre-existing organizations/institutions set up under a number of international legal agreements that had hitherto been connected to inter-state IPR protection across various industries (see Article 2 of the Convention). In that sense, the WIPO could be understood, firstly, as consolidating and, secondly, as developing global governance of IPRs protection. Also, for a list of international legal agreements administered by WIPO, see <www.wipo.int/treaties/en> (last accessed on 11 September 2012).

138 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), Marrakesh, 15 April 1994, in force 1 January 1995, 33 *International Legal Materials* (1994), 1197.

139 See TRIPS, supra, note 138, Article 8.1, subject to any such measures being consistent with the provisions of TRIPS.

140 See TRIPS, supra, note 138, Article 8.2, subject to such measures being consistent with the provisions of TRIPS.

141 See TRIPS, supra, note 138, Articles 3 and 4 TRIPS.

e.g., iron ocean fertilization, which relies on the interplay between organic and inorganic matter, namely iron particles and plankton – may engage microbiological processes or the use of micro-organisms, Article 27.3 may come to bear to a request to extend IPRs protection to such processes.[142]

Moreover, the UK House of Commons Science and Technology Select Committee (STC) recommended to the UK Government that it adopt a set of currently non-binding principles in relation to the governance of geoengineering.[143] These principles are known as the "Oxford Principles."[144] Principle 1, entitled *Geoengineering to be regulated as a public good*, stipulates that:

> "While the involvement of the private sector in the delivery of a geoengineering technique should not be prohibited, and may indeed be encouraged to ensure that deployment of a suitable technique can be effected in a timely and efficient manner, regulation of such techniques should be undertaken in the public interest by the appropriate bodies at the state and/or international levels." [145]

The UK Government, in its response,[146] welcomed these principles as a good basis upon which to build. However, in relation to principle 1, notably, it felt the need to assert that IPRs should be sufficiently protected to ensure that investment be not "deterred." What is more, it went as far as to state that "without private investment, some geoengineering techniques will never be developed,"[147] thus exposing perhaps the inability or unwillingness of the State to fund research in such potentially beneficial methods. This may point towards a prospectively more pro-market/trade-friendly attitude towards certain geoengineering processes in the UK and elsewhere.

iv. SPS Agreement

Daniel Mason refers to a potentially positive outcome of a particular form of geoengineering, namely solar radiation management.[148] If deployed successfully – all other things being equal – solar radiation management may potentially lower temperatures by 2 degrees Celsius; this, combined with current levels of CO_2, could lead to higher crop yields.[149] However, this would require the release of 1 to 5 million tons of sulphur dioxide into the stratosphere annually, which could well have toxic effects on human, animal and plant life and health.

Firstly, this has ostensible incidental trade implications in that it may well result in increases in trade volumes of food-related and chemical commodities. Such potential increases in trade volumes do not, on their own strength, appear to have trade law implications, given that the existing multilateral trade system and norms can accommodate trade-volume fluctuations without any need for modifications.

Secondly, the potentially noxious aspects of chemical commodities may have substantive trade law implications in relation to intra-WTO trade. In *US – Asbestos*,[150] the Appellate Body held that *bona fide* non-discriminatory trade-restrictive measures connected to asbestos could be justified on grounds contained within the Agreement on the Application of Sanitary and Phytosanitary

142 The wording of Article 27.3 mandates that this provision be reviewed four years post-adoption (i.e., 1999). It was most recently considered in 2008. For an account of the review outcome, see on the Internet <www.wto.org/english/tratop_e/trips_e/art27_3b_background_e.htm> (last accessed on 11 September 2012).

143 See UK House of Commons Science & Technology Committee, *The Regulation of Geoengineering Fifth Report of Session 2009/10 of the UK House of Commons Science & Technology Committee*, at 29.

144 See on the Internet: <www.geoengineering.ox.ac.uk/oxford-principles/history> (last accessed on 11 September 2012).

145 See principle 1, at UK House of Commons Science & Technology Committee, *The Regulation of Geoengineering, Fifth Report of Session 2009/10 of the UK House of Commons Science & Technology Committee*, 29.

146 See Secretary of State for Energy and Climate Change, *Government Response to the House of Commons Science and Technology Committee 5th Report of Session 2009–10: The Regulation of Geoengineering* (London: Secretary of State for Energy and Climate Change, 2010).

147 *Ibid.*, at 5.

148 Daniel Mason, "Geoengineering: Quick Climate Fix or Dangerous Meddling?", Public Service Europe, 2 March 2012.

149 Do note, however, that the ETC Group, in its criticism of some potential SMR-related experiments, points to its potential food-security implications. For example, injecting sulphur particles into the stratosphere to replicate the effects of volcanoes into deflect solar radiation and thus reduce the temperature of the earth, could throw up all sorts of consequences such as "to disrupt rainfall particularly in tropical and subtropical regions – potentially threatening the food supplies of billions of people." See Martin Lukacs, "US geoengineers to spray sun-reflecting chemicals from balloon," The Guardian, 17 July 2012.

150 *European Communities – Measures Affecting Asbestos and Asbestos-containing Products* report of the AB (12 March 2001) (WT/DS135/AB/R) (at paras. 167 and 178).

Measures (SPS Agreement).[151] Presumably, the importation of large volumes of substances such as sulphur dioxide may trigger trade-restrictive measures on the part of an importing WTO Member that subsequently seeks to justify its measures, *inter alia*, on the SPS Agreement. In reality, however, geoengineering activity within the territory of a particular State is highly likely to be taking place with the endorsement of that State. Consequently, it unlikely that such a State would then proceed to restrict imports of such commodities in the vein that France sought to restrict imports of asbestos-containing goods. In that respect, it seems unlikely that a WTO complaint would arise. That said, is it plausible for such trade to engage the SPS Agreement on the basis of the potential harmful effects of trade flows connected to the deployment of geoengineering.

v. SCM Agreement

Arguably, the implications of geoengineering, as it currently stands for subsidies-related WTO law, seem modest. This is based on the fact that geoengineering is not sufficiently developed commercially, neither domestically nor globally, for it to be considered a competitive industry/sector. Had it been, and had, say, a WTO Member provided subsidies that singled out that sector in order to encourage exports or the consumption of domestically produced goods and services, then such subsidies may well be in violation of WTO rules. Subsidies at the pre-competitive development stage of an industry seem to be non-actionable.[152]

g. Remedying trade anomalies

Scott Barrett comes to the potential benefits of geoengineering from a slightly parallax angle, namely in relation to how geoengineering may cure against the ills of "trade leakage" that may arise when GHG emissions reduction measures are taken by national governments.[153] Trade leakage takes place when a country reduces its GHG emissions to self- or externally-imposed levels, thereby forcing production costs up and leading to expanded output abroad, along with associated emissions.[154] In that sense, that country has lost trade as a consequence of taking steps to reduce its GHG emissions. In reality, it has lost trade whilst GHG emissions have increased elsewhere, that is to say, where that production has now migrated. Within that context, and observed from a global standpoint, GHG emissions reduction is a false victory.

Barrett too considers efforts to mitigate, retard, and/or avert global warming and climate change to be global "public goods."[155] He considers that supplying this global good through efforts to reduce GHG emissions alone is vulnerable to free-riding by State actors, given that "too few countries are likely to participate in such an effort [and that] those that do participate are likely to reduce their emissions by too little, and even their efforts may be overwhelmed by trade leakage."[156]

This line of argument seems to support the increased use of geoengineering strategies as part of a comprehensive set of solutions to climate change that is superior to reliance on GHG emissions reduction alone. Accordingly, the trade-related implications may be that geoengineering strategies – when replacing solutions focused on GHG emissions reduction – may be one way to avert trade anomalies, such as 'trade leakage', and to avoid their cost to the economy of States that have hitherto taken measures to reduce their GHG emissions.

h. Interpreting concurrent and conflicting legal obligations

As discussed above, Rayfuse and Davis argue that, under current international legal agreements, the commercial use of – and therefore, *a fortiori*, the

151 Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement), Marrakesh, 15 April 1994, in force 1 January 1995, 1867 *United Nations Treaty Series* (1999), 493.

152 See Agreement on Subsidies and Countervailing Measures (SCM Agreement), Marrakesh, 15 April 1994, in force 1 January 1995, 1867 *United Nations Treaty Series* (1999), 14, Article 8.2.

153 Barrett, "Economics of Geoengineering", *supra*, note 61, No. 1.

154 According to Barrett, "there are two aspects to trade leakage – the first is essentially a shift in comparative advantage. The second is a change in the price of traded fossil fuels. As countries reduce their demand for traded fossil fuels, prices will fall, causing other countries to increase their consumption." See Scott Barrett, paper prepared for the session on *Cross-cutting Issues: Competitiveness and Trade* (Washington, DC: Pew Center on Global Climate Change and Royal Institute of International Affairs Conference on Innovative Policy Solutions to Global Climate Change, 2000). Accordingly, the increased take-up of geoengineering solutions is likely to diminish the political will necessary globally for meaningful global efforts to curb emissions. Consequently, demand for fossil fuels is likely to remain high with whatever impact that may have on international market prices. In that sense, trade flows in traditional sources of energy are unlikely to be negatively affected.

155 Barrett, "Economics of Geoengineering", *supra*, note 61, at 53.

156 *Ibid.*

trade of – certain geoengineering techniques/activities in the jurisdiction or control of relevant parties would almost certainly be in breach of their specific obligations.[157] This view is also supported by the Action Group on Erosion, Technology and Concentration (ETC Group).[158] Given the potential transboundary effect of geoengineering, its deployment may come to impact the current set of rights and obligations of States that may lead to efforts to resolve arising disputes, amongst other things, through judicial means. There is interplay between the various rights and obligations, and jurisprudential tools have been developed to deal with the tensions that may arise, what with the worryingly increasing fragmentation of international law.

International legal agreements are creatures of international law and, according to McNair, as such they must be: "applied and interpreted against the background of the general principles of international law."[159] However wide their subject-matter, all international legal agreements are predicated for their existence and operation on being part of the international law system. As such, they must be applied and interpreted against the background of the general principles of international law. That position aptly captures the essence of systemic integration in the interpretation of inter-State legal obligations according to which obligations must be understood and discharged in a manner that is sympathetic to the entire normative framework that governs inter-State relations.

The principle of systemic integration in the interpretation of legal obligations goes some way towards curing against the problematic fragmentation of international law. This principle is reflected in Article 31:3(c) of the 1969 Vienna Convention on the Law of Treaties,[160] which is a legal instrument that is binding on its parties, and largely reflective of mirror norms that exist in customary law and, therefore, highly suggestive of the types of norms that bind non-parties to it. The Vienna Convention inducts other rules of international law that may be at play between the parties in question in the interpretation of treaty obligations. The net effect of this is that it is possible for rules contained in other areas of international law to come to bear on a question of interpretation of, say, the rights and duties of WTO Members, or of parties to a bilateral or multilateral investment treaty pursuant to which trade, and other activities, in relation to geoengineering is taking place.[161]

In relation to trade disputes, this principle, alongside Article 31:3(c), was deployed by the WTO Dispute Settlement Body in the *US – Shrimp/Turtle*[162] and *EC – Beef Hormones*[163] cases. In these cases, the Appellate Body took a synthetic approach by drawing from other sources on international obligations such as the 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)[164] and by also referring to the WTO Understanding on Rules and Procedures for the Settlement of Disputes (the DSU) which authorizes

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157 William D. Davis, "What Does Green Mean? Anthropogenic Climate Change, Geoengineering, and International Environmental Law", 43 *Georgia Law Review* (2009), at 934-938; Rosemary Rayfuse, Mark G. Lawrence and Kristina M. Gjerde, "Ocean Fertilisation and Climate Change: The Need to Regulate Emerging High Seas Uses", 23 *International Journal of Marine & Coastal Law* (2008), pp. 297–326.

158 See Appendix I *("Selection of International Treaties that Could be Violated by Geoengineering Experiments")* of "Geopiracy: the Case Against Geoengineering", 41-42, ETC Group, for a list of international agreements possibly breached by the commercial use of geoengineering.

159 Baron Arnold Duncan McNair, *The Law of Treaties* (Oxford: OUP Oxford, 1961), at 466 (as cited by McLachlan in Campbell McLachlan, "The Principle of Systemic Integration and Article 31(3)(c) of the Vienna Convention", 54 International and Comparative Law Quarterly (2005), at 280.

160 Vienna Convention on the Law of Treaties, Vienna, 23 May 1969, in force 27 January 1980, *International Legal Materials* (1969), 679.

161 Cf., the 1996 International Court of Justice (ICJ) *Oil Platforms (Islamic Republic of Iran v. United States of America)* case where Article 31:3(c) was deployed by ICJ to bridge the provisions of a 'Friendship, Navigation, and Commerce Treaty' between the parties with customary legal norms on the use of force.

162 The *United States — Import Prohibition of Certain Shrimp and Shrimp Products* – report of the WTO Appellate Body (12 October 1998) WT/DS58/AB/R. In this case, the Appellate Body – and the Panel before it – had to grapple with the obligations of the United States vis-à-vis the WTO community and how these were conditioned by the other international legal obligations of the United States in relation to the environment.

163 *European Communities — Measures Concerning Meat and Meat Products (Hormones)* – report of the Appellate Body (16 January 1998) WT/DS-26/AB/R. In this case, the Appellate Body had to examine other areas outside world trade law, including customary international law, to determine for its purposes whether the 'precautionary principle' – cited by the European Communities in defense of its trade restrictive measure – was an established rule of customary international law.

164 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), Washington DC, 3 March 1973, in force 1 July 1975, 12 *International Legal Materials* (1973), 1085.

the Dispute Settlement Body to rely on "customary rules of interpretation of public international law."[165]

IV. Conclusion

Whilst there has been scholarly literature on the political, ethical, and technological complexities of geoengineering, there appears to have been no exploration of the international trade implications of geoengineering. This is unsurprising, given that the most crucial aspects of geoengineering – chiefly, in relation to its global governance – have yet to be decided by the international community. Given their scale and complexity, geoengineering strategies are likely to engage a multitude of State and non-State actors to deliver whatever solutions may be scientifically and commercially possible.

It is equally most likely that, despite the pressing necessity for concerted efforts on the part of State actors, there would be a heightened, if not central, role for the market to deliver the formidable capital investments and technological solutions necessary. A functional and profitable market relies on an environment where unpredictability and risk are minimized. This requires clear and functional rules that are consistently applied. A comprehensive global governance regime, therefore, ought not to limit itself only to providing definitive decision-making mechanisms; rather it should also articulate comprehensive regulatory frameworks, including clear rules, for the commercial use of geoengineering techniques and their trade aspects.

165 Understanding on Rules and Procedures Governing the Settlement of Disputes (DSU), Marrakesh, 15 April 1994, in force 1 January 1995, 33 *International Legal Materials* (1994), 1226.