

The Governance of Geoengineering: An Emerging Challenge for International and Domestic Legal Systems?

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Abstract

Scientists propose developing geoengineering as an alternative means for responding to the risks of anthropogenic climate change. Discussions are growing amongst academics, stakeholders and policymakers as to how geoengineering might be best governed. An underlying assumption stemming from scientific literature is that greater scientific research on geoengineering technologies is needed to focus and progress discussions on governance and that law will play at best a peripheral role. This article challenges this assumption by considering how legal research can constructively contribute to the governance of geoengineering, regardless of further scientific developments. This article is a précis for an upcoming special edition of this Journal. As such, it provides an overview of proposed geoengineering technologies and introduces key legal issues they raise. Further legal research is needed to better understand the potential of existing legal frameworks to contribute to future geoengineering governance and to bolster the normativity of law in broader discussions on geoengineering governance.

1 Introduction

The term 'geoengineering' refers to a host of recent proposals for humans to deliberately manipulate the climate system on a large scale in order to counteract anthropogenic climate change.¹ One prominent class of proposed geoengineering technologies, carbon dioxide removal (CDR), seeks to lessen the risk or severity of climate change impacts by drawing down the level of carbon dioxide in the atmosphere.² Ocean iron fertilization (OIF) is an example of CDR that would involve scientists intentionally stimulating algal growth in the ocean to draw down carbon dioxide from the atmosphere through the process of photosynthesis. Another prominent class of proposed geoengineering technologies, commonly referred to as solar radiation management (SRM), seeks to reduce rising global temperatures associated with climate change by reflecting

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⁴ The Royal Society, 'Geoengineering the climate: science, governance and uncertainty' (Full Report, The Royal Society, September 2009) 1 ('*Royal Society Report*').

⁵ See *ibid* 9.

some portion of incoming solar radiation (i.e. sunlight) away from the Earth.³ The most discussed SRM proposal, stratospheric aerosol injection (SAI), would mimic the cooling effect of a large volcanic eruption by creating a fine layer of particles in the stratosphere to reflect away a proportion of incoming solar radiation.

Interest in geoengineering has grown concurrently with the slow progress in global action to mitigate greenhouse gas emissions. Despite twenty years of negotiations under the *United Nations Framework Convention on Climate Change* ('UNFCCC') scientific assessment based on current policy projections indicates that the Earth is currently on track for a 3.6-4.2⁰ C rise in average surface temperature above pre-industrial levels.⁴ This is well beyond the objective in the *Copenhagen Accord* and *Cancun Agreements* of limiting global warming to no more than a 2⁰ C increase in global average surface temperature above pre-industrial levels.⁵ Proponents of geoengineering argue that such technologies should be developed and made ready for implementation as an 'emergency' option, in the event that the current pattern of global efforts to reduce greenhouse gas emissions continues and humanity fails to significantly minimise the negative impacts of climate change.⁶ Geoengineering proponents argue that such action can complement mitigation and adaptation strategies.⁷ Many geoengineering technologies are currently at an early stage of development,⁸ while others (such as OIF and SAI) are now capable of field-testing.⁹ In a recent series of reports, the

³ See *ibid* 23.

⁴ *United Nations Framework Convention on Climate Change*, opened for signature 9 May 1992, 1771 UNTS 107 (entered into force 21 March 1994) ('UNFCCC').

⁵ Climate Action Tracker, *Effect of current pledges and policies on global temperatures* (2015) Climate Action Tracker <<http://climateactiontracker.org/global.html>>.

⁶ *Copenhagen Accord*, 15th sess, Agenda item 9, FCCC/CP/2009/L.7, (18 December 2009); *Report of the Conference of the Parties on Its Seventeenth Session, Addendum, Part Two: Action Taken by the Conference of the Parties at Its Seventeenth Session*, Decision 1/CP.17: Establishment of an Ad Hoc Working Group on the Durban Platform for Enhanced Action, 19th sess, 10th plen mtg, UN Doc FCCC/CP/2011/9/Add.1 (15 March 2011).

⁷ See, eg, Paul J Crutzen, 'Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?' (2006) 77(3-4) *Climatic Change* 211. For further discussion of the way in which geoengineering is framed in the literature as a potential 'emergency' response to climate change see Nils Markusson et al, 'In case of emergency press here': framing geoengineering as a response to dangerous climate change' (2014) 5(2) *Wiley Interdisciplinary Reviews: Climate Change* 281.

⁸ See, eg, David Keith, *A Case for Climate Engineering* (The MIT Press, 2013) 15-17.

⁹ For example, proposals to reflect solar radiation by placing giant mirrors into outer space are theoretical and have not yet been developed.

¹⁰ Scientists have performed field-tests of OIF. For example, in 2009, scientists conducted the LOHAFEX OIF experiment in the Southern Ocean. See S Schäfer et al, 'The European Transdisciplinary Assessment of Climate Engineering (EuTRACE): Removing Greenhouse Gases from the Atmosphere and Reflecting Sunlight away from Earth' (Report, EuTRACE, 2015) 63-4 <<http://www.eutrace.org/>> ('*EuTRACE Report*'). SAI experiments have not been conducted in the stratosphere. The only field experiment was conducted in 2009 by Russian scientists at ground-level. See Yu A. Izrael et al, 'Field experiment on studying solar radiation passing through aerosol layers' (2009) 34(5) *Russian Meteorology and Hydrology* 265. In 2012, scientists in the UK had planned to field-test a delivery system for SAI. However, these plans were

National Research Council of the US National Academy of Sciences (NRC)¹⁰ has declared several geoengineering proposals to be technically feasible.¹¹ Hence, small-scale field-testing (and even full-scale deployment) of geoengineering technologies are distinct possibilities in the short-to-medium term. However, geoengineering proposals raise important environmental and social risks that challenge its viability as an alternative response to climate change.

The NRC reports reinforce a common argument found in geoengineering literature, which emanates largely from the natural sciences. Namely, that further scientific research is needed to improve understanding of the feasibility, potential benefits and risks associated with different geoengineering techniques¹² and this will also be the key driver for decision-making and design of governance mechanisms.¹³ For instance, David Keith, a climate scientist and leading geoengineering proponent, suggests that small scale-field testing of SAI will 'provide a better platform than mere theory on which to anchor debates about the governance of geoengineering'.¹⁴ This literature implicitly adopts an

cancelled in part because of a potential conflict of interest between some of the SPICE members and existing patents. See Daniel Cressey, 'Cancelled project spurs debate over geoengineering patents' 485(7399) *Nature* 429. In the United States, a group of scientists advocate field-testing SRM in the stratosphere on a small scale in the near future. See, David W. Keith, Edward Parson and M. Granger Morgan, 'Research on global sun block needed now' (2010) 463(7280) *Nature* 426.

¹⁰ The National Academy of Sciences is a non-profit society in the United States. Its members are high-profile scientists and engineers and its purpose is 'the furtherance of science and technology and to their use for general welfare.' The NRC was organised by the National Academy of Sciences, with the goal of furthering public knowledge on scientific issues and advising the United States Federal Government. See National Research Council, *Climate Intervention: Reflecting Sunlight to Cool the Earth* (The National Academies Press, 2015) Preliminary pages <<http://www.nap.edu/catalog/18988/climate-intervention-reflecting-sunlight-to-cool-earth>> ('NRC SRM Report').

¹² Ibid 139. National Research Council, *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration* (The National Academies Press, 2015) 104 <<http://www.nap.edu/catalog/18805/climate-intervention-carbon-dioxide-removal-and-reliable-sequestration>> ('NRC CDR Report'). This report declares mineral weathering techniques to be technically feasible. However, the report suggests that the cost and scale of implementation may not be economically feasible.

¹³ NRC SRM Report, above n 11, 184–5; Ibid 107. See also David W. Keith and Douglas G. MacMartin, 'A temporary, moderate and responsive scenario for solar geoengineering' (2015) 5(3) *Nature Climate Change* 201.

¹⁴ NRC SRM Report, above n 11, 185. This recommendation is specifically made with regards to SRM. See also NRC CDR Report, above n 12, 107–9. This report states that the cost and scalability of CDR is likely to drive decision-making with regards to deployment at 109. It recommends further research to assess these characteristics at 107. For a critique of this argument, see Clive Hamilton, *Geoengineering: Governance Before Research Please* (22 September 2013) CliveHamilton.com <<http://clivehamilton.com/geoengineering-governance-before-research-please/>>. See also Mike Hulme, *Can Science Fix Climate Change?* (Polity Press, 2014) 64. Hulme suggests that this argument is often used to 'side-step' questions as to whether SAI would ever be deployed.

¹⁵ Keith, above n 8, 84.

understanding of 'governance' (which we share) that encompasses the rules, decision-making procedures and knowledge generating activities of both state and non-state actors.¹⁶ Scientific understanding of various geoengineering options may assist policy and decision-making by reducing scientific uncertainty over the likely impacts and side effects of geoengineering. It may also highlight the technologies most in need of immediate regulation or oversight. However, it does not necessarily follow that further scientific research is needed in order to progress and resolve questions regarding the governance of geoengineering. Indeed, strong arguments can be made that geoengineering governance should be developed *before* scientific research progresses further. Hamilton argues that geoengineering has such inherent wide scale social and political risks that governance research must precede further scientific research.¹⁷ He claims that it is impossible to conduct 'pure' scientific research on geoengineering (i.e. the pursuit of knowledge) without also triggering these inherent social and political risks. In light of this, Hamilton suggests that it is important for research on geoengineering governance to come first.¹⁸ In other words, it is necessary for governance to develop to actively inform scientific research and policy decisions over whether to engage in geoengineering, and if so on what terms.

Research on geoengineering governance is expansive and scattered across writings in various disciplines and sub-disciplines.¹⁹ Conversations regarding the

¹⁶ Following Oran R Young, *Global Governance: Drawing on Insights from Environmental Experience* (MIT Press, 1997) 3–4, governance arises in situations where members of a social group are interdependent in the sense that the actions of an individual member impinge on the welfare of others. This interdependence leads to the necessity for interactive decision-making through the establishment and operation of social institutions. Young draws on a classic definition of governance from Douglas C North, *Institutions, Institutional Change and Economic Performance* (Cambridge University Press, 1990). That is, governance is 'sets of rules, decision making procedures, and programmatic activities that serve to define social practices and to guide the interactions of those participating in these practices.': Young above n 16, 4. We consider this concept of governance is particularly apt in the context of geoengineering as the actions of one state in attempting geoengineering, may have widespread and damaging effects on others.

¹⁷ Hamilton, *Governance Before Research*, above n 14. Two key social/political risks identified by Hamilton are technological lock-in and the 'moral-hazard' argument. These risks are explained in greater detail below in Section 2.1.

¹⁸ Ibid.

¹⁹ For examples of research in the field of philosophy and ethics see eg, Christopher J. Preston, 'Ethics and geoengineering: reviewing the moral issues raised by solar radiation management and carbon dioxide removal' (2013) 4(1) *Wiley Interdisciplinary Reviews: Climate Change* 23; Stephen M Gardiner, 'Is "Arming the Future" with Geoengineering Really the Lesser Evil? Some Doubts about the Ethics of Intentionally Manipulating the Climate System' in Stephen Gardiner, Simon Caney and Dale Jamieson (eds), *Climate Ethics: Essential Readings* (Oxford University Press, USA, 2010) 284. For examples of research in the fields of international relations and international politics see Ian D Lloyd and Michael Oppenheimer, 'On the design of an international governance framework for geoengineering' (2014) 14(2) *Global Environmental Politics* 45; Joshua B Horton, 'Geoengineering and the Myth of Unilateralism: Pressures and Prospects for International Cooperation' (2011) IV *Stanford Journal of Law, Science and Policy* 56. For examples of research in the field of international law see Karen N Scott, 'International Law in the Anthropocene: Responding to the Geoengineering

object and form of governance are currently fragmented across these writings.²⁰ A key practical question for academics, scientists and citizens interested in geoengineering is: *What research in the social sciences, humanities, and related disciplines such as law, can contribute to discussions on geoengineering governance and assist policy and decision-making?*

There have been some early attempts within legal scholarship to contribute to debates on the governance of geoengineering.²¹ This literature has focused on international law and how it might apply to the use of geoengineering. It suggests that there are significant gaps that may limit the capacity of existing international law principles to respond to key governance challenges raised by geoengineering. However, a counter argument emerging from the legal literature is that existing international law regimes and principles can nevertheless contribute to geoengineering governance discussions. Existing rules and institutions – both national and international – will govern certain aspects of geoengineering, such as rules relating to transboundary harm (between states) and national legislation on environmental impact assessment. Where there are no applicable formal legal rules, underlying principles of law can help shape new governance institutions.²² Therefore, researching legal mechanisms can constructively contribute to broader discussions of geoengineering governance, regardless of scientific developments in the field.

The primary purpose of this article is to provide a précis of the legal issues surrounding geoengineering that will act as a foundation for a later special edition of this journal. Since geoengineering is a relatively new technology, many

Challenge' (2013) 34 *Michigan Journal of International Law* 309; Albert C Lin, 'International Legal Regimes and Principles Relevant to Geoengineering' in Wil C G Burns and Andrew L Strauss (eds), *Climate Change Geoengineering—Philosophical Perspectives, Legal Issues, and Governance Frameworks* (Cambridge University Press, 2013) 182.

²⁰ A primary example is whether geoengineering research should be governed separately from deployment. For an overview of arguments in favour of governing geoengineering research separately from deployment, see Lisa Dilling and Rachel Hauser, 'Governing geoengineering research: why, when and how?' (2013) 121(3) *Climatic Change* 553. For a critique of governing research separately from deployment, see Hulme, above n 14, 69–70. Another example are arguments for small-scale field-testing to be governed separately from large-scale field-testing. See Edward A Parson and David W Keith, 'End the Deadlock on Governance of Geoengineering Research' (2013) 339(6125) *Science* 1278. A further example is whether scientists ought to self-regulate the research of geoengineering, or whether formal 'top-down' governance mechanisms are preferable. For arguments in favour of self-governance by scientists see, Parson and Keith at 9. For arguments in favour of the design of a formal international governance regime, see eg, Lloyd and Oppenheimer, above n 19.

²¹ See eg, Daniel Bodansky, 'May we engineer the climate?' (1996) 33(3) *Climatic Change* 309; Ralph Bodle, 'Geoengineering and International Law: The Search for Common Legal Ground' (2010–2011) 46 *Tulsa Law Review* 305; Lin, above n 19; Scott, above n 19.

²² See Anna-Maria Hubert and David Reichwein, 'An Exploration of a Code of Conduct for Responsible Scientific Research involving Geoengineering' (Working Paper, Institute for Advanced Sustainability Studies, May 2015) 6
<<http://publications.iasspotsdam.de/pubman/faces/viewItemOverviewPage.jsp?itemId=escidoc:1092905>> .

legal scholars may not be familiar with the risks of geoengineering or the legal issues that it raises. This article therefore provides a detailed overview of the historical development of geoengineering and the environmental and social risks that are associated with geoengineering proposals, in order to provide the necessary context for considering the legal and governance issues that flow from these risks. It is beyond the scope of this article to engage in detailed analysis of these issues. Rather, we aim to map the state of legal research relating to geoengineering and identify future research directions, thereby stimulating new legal scholarship on this topic.

Following this introduction, this article proceeds as follows. Section two provides an overview of proposed geoengineering technologies and explains how geoengineering has developed as an issue on the international agenda. Section three examines the current state of legal literature on geoengineering. Section four outlines key governance issues emerging from current geoengineering proposals. Finally, section five considers how further research on legal norms and mechanisms can constructively contribute to discussions on the governance of geoengineering.

2 The Development of Geoengineering

This section outlines the historical development of geoengineering and explains the technology behind two key case studies in order to lay the foundation for discussion of governance concerns in section four.²³ Ocean Iron Fertilization (OIF) and Stratospheric Aerosol Injection (SAI) provide concrete examples of Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM) geoengineering respectively, are widely discussed in geoengineering literature, and raise numerous legal issues. They are therefore useful examples for exploring how legal research might help shape broader geoengineering governance discussions.

2.1 The Historical Development of Geoengineering

Recent proposals for geoengineering to address climate change are not the first time that humans have proposed to manipulate the atmosphere for human ends. Weather refers to the day-to-day changes in the atmosphere (ie wind, temperature and rain), whereas the climate is the long-term average of weather.²⁴ Shortly after the end of the Second World War (WWII), scientists in the United States developed weather modification technologies that aimed to influence the weather at a local scale over a short period of time. Examples included: enhancing

²³ We refer readers to three recent reports which provide a comprehensive analysis of other CDR and SRM geoengineering proposals beyond the case studies in this article: *NRC SRM Report*, above n 11; *NRC CDR Report*, above n 12; *EuTRACE Report*, above n 10.

²⁴ See Intergovernmental Panel on Climate Change, *Climate Change 2007: Working Group 1: The Physical Science Basis, Frequently Asked Question 1.2 What is the Relationship between Climate Change and Weather?* Intergovernmental Panel on Climate Change <https://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1-2.html>.

the amount of rain or snow produced by naturally formed clouds ('cloud seeding');²⁵ dispersing cloud or fog;²⁶ and reducing the severity of hurricanes by seeding the eye wall of the hurricane with silver iodide.²⁷ Historian James Fleming identifies two historical periods of heightened human interest in weather modification.²⁸ In the first period, during the mid-19th century to the early 20th century in the United States, so-called 'pluiculturalists' attempted to precipitate rainfall using large fires and explosions.²⁹ The second period of interest began just after WWII when scientist Vincent Schaefer was working on a project for the United States' corporation General Electric aimed at better understanding the formation of ice on aircraft during flight.³⁰ As part of this project, Schaefer discovered how to make a cloud of ice crystals by placing dry ice into a freezer.³¹ In 1947 General Electric was awarded a military contract by the United States government to research cloud seeding,³² Schaefer's discovery had triggered a new era in weather modification research.

The United States' interest in developing weather modification technologies included investigating its potential to be used as weapon during the Cold War. An infamous example of the military use of weather modification technology occurred during the Vietnam War, when the United States Air Force used cloud seeding technologies to cause flooding of the 'Ho Chi Minh trail' and thereby impede North Vietnamese troop movements.³³

²⁵ A recent example of cloud seeding to increase precipitation is in Kosciuszko National Park, Australia, where hydroelectric company Snowy Hydro conducted 'cloud seeding' in an attempt to increase the amount of snowfall produced by clouds during the winter ski season. See Scott Hannaford, 'Concerns persist over long-term impact of cloud seeding in Kosciuszko', *Sydney Morning Herald* (online) 27 March 2015 <<http://www.smh.com.au/technology/sci-tech/concerns-persist-over-longterm-impact-of-cloud-seeding-in-kosciuszko-20150327-13tj6c.html>>.

²⁶ An example of weather modification (cloud seeding) for the purpose of dispersing clouds or fog was during the 2008 Beijing Olympics in China. See Clifford Coonan, 'How Beijing used rockets to keep opening ceremony dry', *The Independent* (online), 11 August 2008 <<http://www.independent.co.uk/sport/olympics/how-beijing-used-rockets-to-keep-opening-ceremony-dry-890294.html>>.

²⁷ H E Willoughby et al, 'Project Stormfury: A Scientific Chronicle 1962-1983' (1985) 66(5) *Bulletin American Meteorological Society* 505, 505-6. From 1962 to 1983, the United States government funded project 'Stormfury'. One of the goals of project Stormfury was to develop the means to modify hurricanes in order to reduce their intensity, at 505.

²⁸ James Rodger Fleming, 'The pathological history of weather and climate modification: Three cycles of promise and hype' (2006) 37(1) *Historical Studies in the Physical and Biological Sciences* 3, 3.

²⁹ *Ibid* 4-8.

³⁰ Chunglin Kwa, 'The Rise and Fall of Weather Modification: Changes in American Attitudes Toward Technology, Nature, and Science' in Clark A Miller and Paul N Edwards (eds), *Changing the Atmosphere: Expert Knowledge and Environmental Governance* (The MIT Press, 2001) 135, 137.

³¹ Fleming, above n 28, 8-9.

³² Kwa, above n 30, 137. This program was called 'Project Cirrus'.

³³ See Jack Anderson, 'Air Force turns Rainmaker in Laos', *The Washington Post*, (Washington DC), 18 March 1971, F7. See also Louise A. Purrett, 'Weather Modification

It was in the context of heightened risk of military use of weather modification techniques that the United States and the Soviet Union took the lead in negotiating the 1976 *Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques* ('ENMOD Convention').³⁵ Despite having used weather modification technologies during the Vietnam War, in 1973 the United States Senate passed a resolution requesting the United States government negotiate an international agreement to prohibit further hostile use of weather modification technologies.³⁶ At the 1974 Moscow Summit meeting of leaders, the United States and the Soviet Union entered into bilateral talks regarding the regulation of environmental modification techniques for military purposes.³⁷ In 1974, the Soviet Union introduced to the UN General Assembly the issue of a new treaty to govern weather modification for military and hostile purposes and proposed the first draft convention.³⁸ UN General Assembly Resolution 3264 (XXIX) referred the drafting of a convention to the Conference of the Committee on Disarmament (CCD).³⁹ In 1975, the United States and the Soviet Union separately submitted identical draft conventions to CCD.⁴⁰ Like the 1959

as a Future Weapon' (1972) 101(16) *Science News* 254; Fleming, above n 28, 13. According to Kwa, the United States Department of Defense spent USD\$21.6 million on weather modification along the Ho Chi Minh trail. See Kwa, above n 30, 157.

³⁴ *Convention on the Prohibition of Military or Other Hostile Use of Environmental Modification Techniques*, opened for signature 10 December 1976, 1108 UNTS 151 (entered into force 5 October 1978) ('ENMOD Convention').

³⁵ See United Nations, *The United Nations and Disarmament 1970-1975*, (United Nations Publication, 1976) ('*United Nations and Disarmament*') 191–9. For contemporaneous discussion of the need for a treaty to regulate weather modification for military purposes, see J W Samuels, 'International Control of Weather Modification Activities: Peril or Policy?' in Ludwik A Teclaff and Albert E Utton (eds), *International Environmental Law* (Praeger Publishers, 1974) 199. See also Fleming, above n 28, 14. Fleming suggests that the negotiation of the *ENMOD Convention* was triggered by the United States' use of cloud seeding along the Ho Chi Minh trail, which became public knowledge in 1971.

³⁶ A resolution expressing the sense of the Senate that the United States Government should seek the agreement of other governments to a proposed treaty prohibiting the use of any environmental or geophysical modification activity as a weapon of war, or the carrying out of any research or experimentation directed thereto, S Res 71, 93rd Congress (1973).

³⁷ *United Nations and Disarmament*, above n 35, 191.

³⁸ *Ibid* 192–4; *Prohibition of action to influence the environment and climate for military and other purposes incompatible with the maintenance of international peace and security, human wellbeing and health*, GA Res 326, UN GAOR, 29th sess, 2039th plen mtg, UN Doc A/Res/29/3264 (9 December 1974) annex ('GA Res 3264').

³⁹ GA Res 3264, UN Doc A/Res/29/3264, above n 38.

⁴⁰ *United Nations and Disarmament*, above n 35, 199. See also *Report of the Conference of the Committee on Disarmament Volume 1*, UN GAOR, 31st sess, Supp No 27, UN Doc A/31/27 (1976) annex 1. The draft convention submitted by the Soviet Union was number CCD/471. The draft convention submitted by the United States was CCD/472.

*Antarctic Treaty*⁴¹, the *ENMOD Convention* was a rare product US and Soviet cooperation during the Cold War period.

The *ENMOD Convention* was negotiated in order to protect humanity from the dangers of using weather and environmental modification technologies as a weapon.⁴² Article I contains the purpose or object of the treaty and indicates that the parties to the *ENMOD Convention* are prohibited from engaging in environmental modification techniques for *military or other hostile purposes*. Environmental modification techniques are defined in Article II as 'any technique for changing – through the deliberate manipulation of natural processes – the dynamics, composition or structure of the earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space.'⁴³ This definition of 'environmental modification techniques' is arguably wide enough to include weather modification attempts at a local scale, as well as attempts to manipulate the atmosphere on a larger scale (i.e. through geoengineering techniques such as SAI).⁴⁴ However, the preamble to the *ENMOD Convention* clearly distinguishes the 'hostile' use of environmental modification techniques from non-military uses, recognising that:

... the use of environmental modification techniques for peaceful purposes could improve the interrelationship of man and nature and contribute to the preservation and improvement of the environment for the benefit of present and future generations.

The *ENMOD Convention* therefore does not prohibit the use of environmental modification techniques (even geoengineering efforts such as SAI) if carried out for non-hostile (i.e. 'peaceful') purposes. However, the term 'military or any other hostile use' [authors' emphasis] is not defined within the *ENMOD Convention*.⁴⁵ This term therefore remains open to interpretation, raising the question of whether 'hostile use' could be interpreted in such a way as to enable the *ENMOD Convention* to play a more active role in geoengineering governance.⁴⁶

The 1978 entry into force of the *ENMOD Convention* coincided with a decline in interest in the development of weather modification technologies. Kwa attributes the decline of United States interest in weather modification to a wider shift in the public attitude towards the environmental protection and concerns that weather modification technologies could have long-term negative impacts on the

⁴¹ *The Antarctic Treaty*, opened for signature 1 December 1959 42 UNTS 72 (entered into force 23 June 1961).

⁴² See *ENMOD Convention*, above n 34, preamble.

⁴³ *Ibid* art II.

⁴⁴ See Bodle, above n 21, 312.

⁴⁵ For a critique of this issue, see Jozef Goldblat, 'The Environmental Warfare Convention: How Meaningful Is It?' (1977) 6(4) *Ambio* 216.

⁴⁶ But see Bodle, above n 21, 312. Bodle states that armed conflict and peaceful purposes are 'clearly distinguished' under the *ENMOD Convention*. Given this distinction, Bodle argues that environmental modification techniques would need to be deployed during an armed conflict in order for their use to be classified as 'hostile'.

climate.⁴⁷ The United States signed the *ENMOD Convention* in 1977 and ratified it in 1980.⁴⁸ Fleming notes that by 1979 US Federal funding for weather modification technologies had declined significantly,⁴⁹ suggesting that the entry into force of the *ENMOD Convention* and the decline in interest in weather modification was more than coincidental.

During the early 1990s, scientific concern regarding anthropogenic climate change triggered fresh consideration of using technology to manipulate the atmosphere. A prominent early example is the 1992 report produced by the United States Committee on Science, Engineering and Public Policy (COSEPUP) *Policy Implications of Greenhouse Warming*.⁵⁰ Unlike earlier attempts at weather modification, involving human manipulation of the atmosphere at a sub-national or local scale, these new proposals to engage in 'geoengineering' suggested manipulating the atmosphere to influence the climate system at a global scale. It is this 'up-scaling' of deliberate human interference with the atmosphere in the context of climate change that distinguishes current geoengineering proposals from the earlier practice of weather modification.⁵¹

Prior to 2006, the idea of developing geoengineering technologies to counteract human induced climate change was not a prominent topic in mainstream research.⁵² Geoengineering literature speaks of an unofficial 'taboo' in scientific circles until this time, about openly discussing and researching geoengineering.⁵³ According to Hamilton, climate scientists were wary of engaging in geoengineering research because it could not be separated from the political risk that research and discussion of geoengineering could weaken resolve within the international community to drastically curb greenhouse gas (GHG) emissions.⁵⁴ Countries may instead take the short term 'easy option' of experimenting with geoengineering, rather than seriously reducing national GHG emissions. Another political risk is what Hamilton describes as 'technological lock-in' or 'path dependency'. That is, if research into geoengineering gains enough

⁴⁷ Kwa, above n 30, 162–3.

⁴⁸ The USSR ratified the *ENMOD Convention* on 30 May 1978. The United States ratified the *ENMOD Convention* on 17 January 1980. For a list of state signatories and ratifications, see United Nations Treaty Collection, *United Nations Treaty Series Online Collection* <<https://treaties.un.org/Pages/UNTSONline.aspx?id=1>>.

⁴⁹ Fleming, above n 28, 15–16.

⁵⁰ Committee on Science, Engineering and Public Policy (COSEPUP), *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Basis* (National Academy Press, 1991) 433–62.

⁵¹ Whilst there has been earlier practices of weather modification, none of these practices have been known to have had transboundary consequences so as to contribute to customary international law. It was the potential use of weather modification as a weapon against other states, rather than its scale, that triggered international concern and led to the negotiation of the *ENMOD Convention*.

⁵² The 1991 COSEPUP report is an early exception. See *ibid*.

⁵³ See, eg, Albert C Lin, 'Does Geoengineering Present a Moral Hazard?' (2013) 40 *Ecology Law Quarterly* 673, 690; Keith, above n 8, 92.

⁵⁴ Hamilton, *Governance Before Research*, above n 14. See also Clive Hamilton, *Earthmasters: Playing God with the Climate* (Allen & Unwin, 2013) 15–16.

momentum, geoengineering proposals may become 'normalised' in discussions of appropriate global and national responses to climate change, thereby causing stakeholders and decision makers to downplay or become more accepting of the relevant, potentially significant, environmental risks.⁵⁵ These political risks and the legal issues arising from them are discussed further in section four.

The taboo against discussing and researching geoengineering research was broken in 2006. In that year, Paul Crutzen, an atmospheric chemist and joint winner of the 1995 Nobel Prize in Chemistry for his work on the formation and decomposition of ozone⁵⁶, published an editorial essay on proposals to develop SAI geoengineering.⁵⁷ In this seminal work, Crutzen argued that the best course of action for responding to climate change is to reduce global greenhouse gas emissions, but such efforts to date have been 'grossly unsuccessful'.⁵⁸ As an alternative, Crutzen advocated further scientific research on the potential for minimising climate change impacts by placing aerosols in the stratosphere to reflect incoming sunlight and thereby reduce global temperatures.⁵⁹ Crutzen's prominent status in the atmospheric science community meant that this article sparked strong debate amongst social and physical scientists on the consideration of geoengineering.⁶⁰

Since Crutzen's article, public consideration of the research and potential use of geoengineering has gathered further momentum. In 2009, the UK's leading scientific research and advisory body, The Royal Society⁶¹ released a report assessing different geoengineering proposals and relevant governance and ethical issues ('*Royal Society Report*').⁶² This report provides a scientific review of proposed geoengineering techniques and the potential role they might play in responding to climate change.⁶³ The *Royal Society Report* was initiated in response to growing scientific interest in geoengineering, stating that '[c]oncerns with the lack of progress of the political processes [to address climate change] have led to increasing interest in geoengineering approaches.'⁶⁴ In 2010, the UK House of Commons Scientific and Technology Committee also released a report examining the regulation of geoengineering, the main aim of which was to examine whether there was a need to regulate geoengineering at an international level, and how

⁵⁵ Ibid.

⁵⁶ Nobelprize.org, *Paul J. Crutzen- Facts* Nobelprize.org <http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1995/crutzen-facts.html>.

⁵⁷ Crutzen, above n 7.

⁵⁸ Ibid 212.

⁵⁹ Ibid 212, 217.

⁶⁰ See, eg, Mark G Lawrence, 'The Geoengineering Dilemma: To Speak or not to Speak' (2006) 77(3-4) *Climatic Change* 245; Ralph J Cicerone, 'Geoengineering: encouraging research and overseeing implementation' (2006) 77(3) *Climatic Change* 221.

⁶¹ See The Royal Society, *About us*, The Royal Society <<https://royalsociety.org/about-us/>>.

⁶² *Royal Society Report*, above n 1.

⁶³ Ibid 1.

⁶⁴ Ibid.

such international regulation might be achieved.⁶⁵ This report was coordinated with the United States House of Representatives Science and Technology Committee, in part because of the potentially global repercussions of geoengineering.⁶⁶

In 2009 and 2010, the United States House of Representatives Science and Technology Committee held a series of Hearings on geoengineering science and governance.⁶⁷ The Chairman, Bart Gordon, explained the reason for these hearings as follows:

... this issue is too important for us to keep our heads in the sand. We must get ahead of geoengineering before it gets ahead of us, or worse, before we find ourselves in a climate emergency with inadequate information as to the full range of options. As Chairman of the Committee of jurisdiction, I feel a responsibility to begin a public dialogue and develop a record on geoengineering.⁶⁸

This statement preceded the 2009 Fifteenth Conference of the Parties (COP) to the *UNFCCC* in Copenhagen.⁶⁹ Gordon's justification for the hearings nevertheless suggests that policymakers were already concerned that international efforts to mitigate climate change might not prevent a future 'climate emergency'. The modest outcome on emission reduction at the *UNFCCC* Copenhagen COP 15 meeting reinforced such concerns.

Interest in geoengineering has continued to grow since the Copenhagen COP. Reports on geoengineering were published in 2011 by the Keil Earth Institute in Germany⁷⁰ and in 2013 by the Congressional Research Service in the United States⁷¹. In 2013 Geoengineering was included (for the first time) in the Intergovernmental Panel on Climate Change's (IPCC) 5th Assessment Working Group 1 Report.⁷² The Report provided a description of SRM and CDR

⁶⁵ Science and Technology Committee, UK House of Commons, *The Regulation of Geoengineering: Fifth Report of Session 2009-2010* (2010) ('UK House of Commons Report') 9.

⁶⁶ Ibid 1.

⁶⁷ Geoengineering: Parts I, II, and III, Hearing before the Committee on Science and Technology, House of Representatives, One Hundred Eleventh Congress, 1st and 2nd session (5 November 2009; 4 Feb 2010; 18 March 2010) <<http://www.gpo.gov/fdsys/pkg/CHRG-111hrg53007/pdf/CHRG-111hrg53007.pdf>> ('Geoengineering Hearings before Committee on Science and Technology').

⁶⁸ Ibid 12.

⁶⁹ Gordon stated that the hearing had 'nothing to do with the pending negotiations in Copenhagen'. Ibid 11.

⁷⁰ W Rickels et al, 'Large-Scale Intentional Interventions into the Climate System? Assessing the Climate Engineering Debate' (Scoping Report, conducted on behalf of the German Federal Ministry of Education and Research (BMBF), Kiel Earth Institute, 2011).

⁷¹ Kelsi Bracmort and Richard Lattanzio, 'Geoengineering: Governance and Technology Policy' (CRS Report, Congressional Research Service, 26 November 2013).

⁷² Intergovernmental Panel on Climate Change, 'Summary for Policymakers' in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth*

geoengineering proposals, but undertook no evaluation or assessment of their feasibility, likely efficacy or desirability.

In 2014, the first international transdisciplinary conference on geoengineering was held in Berlin, Germany.⁷³ This conference brought together over 350 participants including academics, policymakers and non-governmental organisations to discuss geoengineering research and establish an international dialogue on the future development and governance of geoengineering.⁷⁴ The conference was established in light of significant developments in geoengineering research that had taken place in the five years since the 2009 *Royal Society Report*.⁷⁵ This conference included panels on international law and governance, which acknowledged the existence of potentially applicable international law rules and regimes, and the possible utility of domestic law in regulating geoengineering.⁷⁶ A small group of researchers introduced a draft set of principles (the “Berlin Declaration”) for the voluntary self-governance of SRM geoengineering research by scientists.⁷⁷ However, these principles were not accepted by conference participants and sparked heated debate on the governance of geoengineering.⁷⁸ The reaction of the conference participants to these principles demonstrated that transparency and democratic inclusion are likely to be important elements in the successful negotiation of any future geoengineering governance mechanisms.⁷⁹ Most recently, in 2015, the NRC in the United States released two detailed reports on CDR and SRM.⁸⁰ Further in 2015, the European Transdisciplinary Assessment of Climate Engineering, funded by the European Union’s Seventh Framework Programme for research, technological development and demonstration, released its final assessment report on climate engineering (*EuTRACE Report*).⁸¹

The above pattern of inquiries and reports shows ongoing engagement with the possibilities of geoengineering across the Royal Society, academia, IPCC, United

Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge University Press, 2013) 29
<http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf>
(‘AR5 Working Group 1 Report Summary for Policymakers’).

⁷³ See Institute for Advanced Sustainability Studies, *Climate Engineering Conference 2014: Critical Global Discussions, Conference Report* (2014) Institute for Advanced Sustainability Studies <<http://www.ce-conference.org/>> (‘CEC14 Conference Report’).

⁷⁴ Ibid 6.

⁷⁵ Ibid.

⁷⁶ Ibid 25–6.

⁷⁷ Ibid 29. The statement is available at: Draft Statements, *Climate Engineering Conference 2014* <<http://ce-conference.org/draft-statements>>.

⁷⁸ See Andy Parker, Oliver Morton and George Collins, *Reflecting on the “Berlin Declaration”* (16 July 2015) Forum for Climate Engineering Assessment <<http://dcgeoconsortium.org/2015/07/16/reflecting-on-the-berlin-declaration-andy-parker-with-oliver-morton-and-george-collins/>>.

⁷⁹ Ibid; *CEC14 Conference Report*, above n 73, 29–30.

⁸⁰ *NRC SRM Report*, above n 11; *NRC CDR Report*, above n 12.

⁸¹ *EuTRACE Report*, above n 10.

States National Research Council and EuTRACE. This shows that geoengineering proposals are no longer a ‘fringe’ idea in the international community. Rather, geoengineering proposals are growing in prominence as a possible alternative human response to climate change. Geoengineering technologies give rise to environmental and social risks that require management by international law and governance. In order to better understand geoengineering and its attendant risks, the following sections examine in detail the two most prominent proposed technologies – ocean iron fertilization and stratospheric aerosol injection - that were raised in the Introduction.

2.2 Carbon Dioxide Removal (CDR)

CDR technologies are proposed to address the “cause” of climate change, being the increased concentration of GHGs in the atmosphere.⁸² The Earth’s temperature (and hence climate) is determined by three elements: (1) incoming solar radiation energy from the sun; (2) the Earth’s ‘albedo’ or reflectivity; and (3) the ‘greenhouse’ effect produced by GHGs in the atmosphere.⁸³ Burch and Harris describe these elements as forming the Earth’s “energy budget”, as each element influences ‘how much energy enters and leaves the climate system.’⁸⁴ To put it simply, incoming solar radiation enters the Earth’s atmosphere, where an amount is absorbed by the Earth’s surface and some emitted into the atmosphere as infrared radiation.⁸⁵ Some of this infrared radiation escapes back out into space with the residual trapped in the atmosphere by GHGs.⁸⁶ It is this “energy budget” that has kept the Earth’s surface and atmospheric temperatures at a level that are consistent for human flourishing over the last several thousand years.

However, human activities such as the burning of fossil fuels, have over the last 200 years significantly increased the concentration of greenhouse gases in the atmosphere thereby trapping more outgoing infrared radiation and thereby disturbing the Earth’s energy budget. The IPCC’s 5th Assessment Report states that human activities have caused the Earth’s atmospheric concentration of GHGs (ie carbon dioxide, methane and nitrous oxide) to increase to their highest levels in 800,000 years.⁸⁷ In the words of the IPCC, it is ‘extremely likely’ that the increased level of GHGs in the atmosphere is the dominant cause of climate change.⁸⁸ The

⁸² *Royal Society Report*, above n 1, ix.

⁸³ Sarah L Burch and Sara E Harris, *Understanding Climate Change: Science, Policy and Practice* (University of Toronto Press, 2014) 51.

⁸⁴ *Ibid* 51.

⁸⁵ *Ibid* 53. Burch and Harris note that approximately 30% of incoming solar radiation is reflected by clouds, dust and aerosols in the atmosphere.

⁸⁶ *Ibid* 54.

⁸⁷ *AR5 Working Group 1 Report Summary for Policymakers*, above n 72, 4. According to the AR5 Working Group I Summary for Policymakers the atmospheric concentration of these GHGs in 2011 were as follows: carbon dioxide was 40% higher than pre-industrial levels at 391 parts per million (ppm); methane was 150% higher than pre-industrial levels at 1803 parts per billion (ppb); and nitrous oxide was 20% higher than pre-industrial levels at 324 ppb: at 11.

⁸⁸ Intergovernmental Panel on Climate Change, ‘Summary for Policymakers’ in *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth*

increase in carbon dioxide emissions from fossil fuel combustion is of particular concern to scientists. Approximately 80% of the total increase in GHG emissions from 1970-2010 came from fossil fuel combustion and industrial processes.⁸⁹ In May 2013, the Mauna Loa observatory in Hawaii recorded atmospheric carbon dioxide levels over 400 ppm for the first time.⁹⁰

The aim of CDR is to address the 'disturbance' of the increased concentration of greenhouse gases by removing carbon dioxide directly from the atmosphere (ie direct air capture) and storing it for a sufficiently long period to influence the global energy budget.⁹¹ In its 2009 report, the Royal Society describe the purpose of CDR as follows:

[b]y removing greenhouse gases from the atmosphere it would, in principle, be possible to reduce the speed at which the planet is warming, and in theory, to remove greenhouses gases to the point where global warming would stop and the climate would start to cool. In addition, by reducing the increase in CO₂ concentrations these methods mitigate other direct and deleterious consequences, such as ocean acidification.⁹²

There are numerous CDR techniques that are proposed to capture and store carbon dioxide in the land or in the oceans. Examples of proposed land-based CDR techniques include: afforestation and reforestation;⁹³ bioenergy with carbon capture and storage;⁹⁴ and direct air capture and sequestration.⁹⁵ Examples of proposed ocean-based CDR include: Ocean Iron Fertilization (OIF) and ocean upwelling/downwelling.⁹⁶ This article focuses on OIF as it is a prominently discussed CDR technology and is already subject to putative regulatory efforts in

Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014) 4 <<http://www.ipcc.ch/report/ar5/syr/>> ('AR5 Synthesis Report Summary for Policymakers').

⁸⁹ Ibid 5.

⁹⁰ National Ocean and Atmospheric Administration (NOAA), *Carbon Dioxide at NOAA's Mauna Loa Observatory reaches new milestone: Tops 400 ppm* (10 May 2013) <<http://research.noaa.gov/News/NewsArchive/LatestNews/TabId/684/ArtMID/1768/ArticleID/10061/Carbon-Dioxide-at-NOAA%E2%80%99s-Mauna-Loa-Observatory-reaches-new-milestone-Tops-400-ppm.aspx>>.

⁹¹ See *Royal Society Report*, above n 1, 9.

⁹² Ibid.

⁹³ See *NRC CDR Report*, above n 12, 39. Afforestation and reforestation are proposals to restore deforested land in order to create a land-based carbon sink. According to the *Royal Society Report*, afforestation and reforestation are not traditionally identified as 'geoengineering'. See *Royal Society Report*, above n 1, 10.

⁹⁴ See *NRC CDR Report*, above n 12, 63. According to the *NRC CDR Report*, biomass (ie vegetation) draws carbon dioxide from the atmosphere through photosynthesis. The concept behind this form of CDR is to use biomass to produce energy/electricity. The carbon dioxide released in this process would be captured at source to prevent it from entering the atmosphere.

⁹⁵ See *NRC CDR Report*, above n 12, 67. These are proposals to chemically "scrub" (i.e. remove) carbon dioxide directly from ambient air and store it.

⁹⁶ See *Royal Society Report* above n 1, 19

international treaty law. The 1996 *Protocol to the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter* ('London Protocol')⁹⁷ recently passed an amendment prohibiting the field-testing and deployment of marine geoengineering technologies, including OIF, unless they are specifically listed as an exception.⁹⁸ OIF therefore provides a useful case study to consider how international law might be developed to respond to the risks of other geoengineering technologies.

OIF is proposed by scientists to enhance the ocean's "biological pump", being its natural capacity to draw carbon dioxide from the atmosphere at surface level and transfer it to the bottom of the ocean.⁹⁹ Phytoplankton (a type of microscopic algae¹⁰⁰) in the surface layers of the ocean draw CO₂ directly from the atmosphere through photosynthesis and convert it into biomass.¹⁰¹ When the plankton dies, that biomass sinks to the ocean floor and remains there, taking the embodied carbon dioxide with it.¹⁰² According to the *Royal Society Report*: 'This 'biological pump' exerts an important control on the CO₂ concentration of surface water, which in turn strongly influences the CO₂ concentration in the atmosphere.'¹⁰³ The growth of phytoplankton, and hence the oceans' capacity to draw CO₂ from the atmosphere, is determined by the level of nutrients in the water, such as nitrate and iron.¹⁰⁴ Scientists therefore propose adding nutrients to parts of the ocean to enhance phytoplankton growth, especially to areas in which phytoplankton growth is low.¹⁰⁵ The *EuTRACE Report* states that scientists propose OIF in parts of the North Pacific, the Equatorial Pacific, and the Southern Ocean because insufficient levels of soluble iron are limiting phytoplankton growth.¹⁰⁶

At least nine OIF field-tests have been carried out since 1993,¹⁰⁷ mostly to understand changes in ocean productivity and atmospheric CO₂ concentrations

⁹⁷ 1996 *Protocol to the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, opened for signature 7 November 1996, [2006] ATS 11 (entered into force 24 March 2006) ('London Protocol').

⁹⁸ *Resolution LP.4(8): On the Amendment to the London Protocol to Regulate the Placement of Matter for Ocean Fertilization and other Marine Geoengineering Activities*, LC 35/15 (adopted 18 October 2013) <<https://www.gov.uk/government/publications/ms-amendment-to-1996-london-protocol-to-regulate-marine-geoengineering>> ('Resolution LP.4(8)').

⁹⁹ *Royal Society Report*, above n 1, 16–17. See also R S Lampitt et al, 'Ocean fertilization: a potential means of geoengineering?' (2008) 366(1882) *Phil. Trans. R. Soc. A* 3919, 3912–20.

¹⁰⁰ See National Ocean Service, *What are Phytoplankton?* <<http://oceanservice.noaa.gov/facts/phyto.html>>.

¹⁰¹ *EuTRACE Report*, above n 10, 34; *Royal Society Report*, above n 1, 16–17.

¹⁰² *EuTRACE Report*, above n 10, 34; *Royal Society Report*, above n 1, 16–17.

¹⁰³ *Royal Society Report* above n 1, 17.

¹⁰⁴ *EuTRACE Report*, above n 10, 34; *Ibid* 17.

¹⁰⁵ *EuTRACE Report*, above n 10, 34; *Royal Society Report* above n 1, 17

¹⁰⁶ *EuTRACE Report*, above n 10, 34.

¹⁰⁷ A recent example are the LOHAFEX experiments that were conducted in 2009 in the Southern Ocean. For a description see *ibid*, 63–4.

over glacial-interglacial cycles.¹⁰⁸ These experiments have demonstrated that it is possible to stimulate the growth of phytoplankton using OIF.¹⁰⁹ However, the growth of phytoplankton does not necessarily mean that OIF would effectively address climate change, so it remains unclear whether OIF would be an effective geoengineering technique. Lampitt et al highlight that in order for OIF to be effective at addressing climate change, CO₂ not only needs to be removed from the atmosphere must also must be sequestered into the depths of the ocean and remain 'out of contact with the atmosphere for periods in excess of a century'.¹¹⁰ Even though some field experiments resulted in phytoplankton growth, scientists do not know the extent to which this result impacted on the oceans' biological pump.¹¹¹ According to Buesseler et al, '[t]he efficacy by which OIF sequesters atmospheric CO₂ to the deep sea remains poorly constrained'.¹¹² They point out that the majority of OIF field experiments were not conducted for purpose of assessing of OIF as a potential geoengineering technique.¹¹³ According to Strong et al: '[t]he original goal of iron fertilization experiments was to answer fundamental questions about how iron and carbon are used and cycled in marine ecosystems.'¹¹⁴ It is therefore questionable whether OIF could be adapted successfully as a geoengineering strategy.

Scientists are also concerned that OIF could negatively impact on marine ecosystems. One concern is the effect that increased levels of phytoplankton might have on marine ecosystems and biodiversity.¹¹⁵ Strong et al emphasise this characteristic of OIF, stating that '[e]cological disruption is the very mechanism by which iron fertilization would sequester carbon.'¹¹⁶ Lampitt et al suggest that OIF could cause eutrophication (an excess of macronutrients), which in turn might reduce oxygen levels, cause harmful algal blooms and lower biological diversity.¹¹⁷ Scientists are also concerned that OIF could starve parts of the ocean of oxygen, causing areas to become 'anoxic' and/or increase the size of already anoxic areas.¹¹⁸ It is predicted that low levels of oxygen would, in turn, negatively affect marine organisms.¹¹⁹ Other potential negative impacts include the release of

¹⁰⁸ Peter Strutton, 'Mixing iron into the north Pacific stirs geo-engineering controversy', *The Conversation* (online) 8 November 2012 <<https://theconversation.com/mixing-iron-into-the-north-pacific-stirs-geo-engineering-controversy-10490>>.

¹⁰⁹ *EuTRACE Report*, above n 10, 34.

¹¹⁰ Lampitt et al, above n 99, 3922.

¹¹¹ *EuTRACE Report*, above n 10, 34

¹¹² Ken O Buesseler et al, 'Ocean Iron Fertilization- Moving Forward in a Sea of Uncertainty' (2008) 319(5860) *Science* 162, 162.

¹¹³ *Ibid.*

¹¹⁴ Aaron Strong et al, 'Ocean fertilization: time to move on. (2009) 461(7262) *Nature* 347.

¹¹⁵ See, eg, *ibid* 347.

¹¹⁶ *Ibid* 347.

¹¹⁷ Lampitt et al, above n 99, 3930.

¹¹⁸ *Royal Society Report*, above n 1, 17-18; Strong et al, above n 114, 347, 348.

¹¹⁹ Strong et al, above n 114, 347; Lampitt et al, above n 99, 3930.

nitrous oxide (a GHG) into the atmosphere¹²⁰ and changes to the oceans' pH level and macronutrient distribution¹²¹. Strong et al suggest that it is difficult to assess accurately how OIF will impact on the oceans, because the side effects of OIF would depend on the scale at which it is deployed.¹²²

A further issue is the cost and timeliness of OIF as a potential geoengineering strategy. In this respect, OIF appears to reflect the general characteristics of other proposed CDR techniques. That is, in comparison to some proposed Solar Radiation Management (SRM) techniques (such as Stratospheric Aerosol Injection), CDR strategies are generally considered to be expensive and slow to influence climate change.¹²³ According to the *EuTRACE Report*, '[m]ost techniques for removing greenhouse gases, if applied at scales sufficient to significantly impact the global atmospheric CO₂ burden, would involve sizeable industrial development'.¹²⁴ Zeebe and Archer estimate that if 20% of the world's surface ocean were fertilized 15 times per year until year 2100, it would only reduce atmospheric CO₂ by about 15 ppmv, based on an expected level of 700 ppmv for business-as-usual scenarios. That is, it would only reduce atmospheric CO₂ by 0.2%.¹²⁵ The *EuTRACE Report* does not provide cost-estimates for OIF. The *Royal Society Report* suggests that OIF would not be as cost-effective as other geoengineering methods such as SAI.¹²⁶ However, the possibility that OIF could be used to generate carbon credits has made OIF attractive to private companies wishing to generate carbon credits for trading purposes.¹²⁷

The prospect of private companies engaging in OIF triggered several developments in international law. According to Ginzkey and Frost, proposed OIF activities by United States Company Planktos Incorporated triggered the Contracting Parties to the *London Convention* and the *London Protocol* to consider

¹²⁰ *EuTRACE Report*, above n 10, 127.

¹²¹ Lampitt et al, above n 99, 3931–2;

¹²² Strong et al, above n 114, 347.

¹²³ See, eg, *EuTRACE Report*, above n 10, 127; *Royal Society Report*, above n 1, x.

¹²⁴ *EuTRACE Report*, above n 10, 37.

¹²⁵ R. E. Zeebe and D. Archer (2005), 'Feasibility of ocean fertilization and its impact on future atmospheric CO₂ levels' (2005) 32(9) *L09703 Geophysical Research Letters* 1, 1.

¹²⁶ *Royal Society Report*, above n 1, 17. This report assessed the affordability of OIF as 'medium', whereas it assessed the affordability of SAI as 'high': at 31.

¹²⁷ A prominent example is United States based company Planktos Incorporated. See, Rachel Courtland, 'Planktos dead in the water', *Nature* (online) 15 February 2008 <<http://www.nature.com/news/2008/080215/full/news.2008.604.html>>. See also *Royal Society Report*, above n 1, 5. This report does not endorse these suggestions. It merely notes that some organisations have suggested that OIF (and other CDR methods) could be used to generate carbon credits under the Kyoto Protocol. See also Buesseler et al, above n 112, 162. Buesseler et al argue that carbon credits for OIF should not be issued until it can be demonstrated that OIF effectively removes and sequesters CO₂.

the international regulation of OIF.¹²⁹ In 2008¹²⁹ and 2010¹³⁰, the Contracting Parties to the *London Convention* and *London Protocol* passed non-binding resolutions that encouraged the development of an effective control and regulatory mechanism for ocean fertilization activities.¹³¹ Similarly, in 2008¹³² and 2010,¹³³ state parties to the *Convention on Biological Diversity*¹³⁴ also adopted non-binding decisions with regard to ocean fertilization and geoengineering respectively. However, the most significant development in international law to date is resolution LP.4(8) which was adopted in 2013 to amend the *London Protocol* to enable it to regulate marine geoengineering activities.¹³⁵

Resolution LP.4(8) amends the *London Protocol* to include a definition of marine geoengineering under article 1(5)*bis*. Marine geoengineering activities are regulated under Article 6*bis* in conjunction with two new annexes (4 & 5).¹³⁶ Article 6*bis* (1) states:

Contracting Parties shall not allow the placement of matter into the sea from vessels, aircraft, platforms or other man-made structures at sea for marine

¹²⁸ See Harald Ginzkey and Robyn Frost, 'Marine Geo-Engineering: Legally Binding Regulation under the London Protocol' (2014) 2 *Carbon and Climate Law Review* 82, 83.

¹²⁹ *Resolution LC-LP 1(2008) on the Regulation of Ocean Fertilization*, LC30/16 (adopted 31 October 2008) <[http://www.imo.org/blast/blastDataHelper.asp?data_id=24337&filename=LC-LP1\(30\).pdf](http://www.imo.org/blast/blastDataHelper.asp?data_id=24337&filename=LC-LP1(30).pdf)>. This Resolution recognised that ocean fertilization activities fall within the scope of the *London Convention* and *Protocol*: at [1]. Contracting Parties also agreed that ocean fertilization activities for purposes other than 'legitimate scientific research' should not be conducted, due to the limited understanding of these technologies: at [8]. See also *ibid*, 83. Ginzkey and Frost note that this resolution closely follows decision IX/16 under the *Convention on Biological Diversity*.

¹³⁰ *Resolution LC-LP.2 (2010) on the Assessment Framework for Scientific Research Involving Ocean Fertilization*, LC 32/15 (adopted 13 October 2010). Under this resolution, the Contracting Parties adopted a non-binding framework to evaluate whether a proposed ocean fertilization activity constitutes a 'legitimate scientific activity': at 2 [1].

¹³¹ For an historical overview of the regulation of marine geoengineering under the *London Convention* and *London Protocol* see Ginzkey and Frost, above n 128. See also International Maritime Organization, *Marine Geoengineering* <<http://www.imo.org/en/OurWork/Environment/LCLP/EmergingIssues/geoengineering/Pages/default.aspx>>.

¹³² *Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Ninth Meeting, IX/16 Biodiversity and climate change, C. Ocean Fertilization, 9th mtg, Agenda Item 4.5, UNEP/CBD/COP/DEC/IX/16 (9 October 2008)* <<https://www.cbd.int/doc/decisions/cop-09/cop-09-dec-16-en.pdf>>.

¹³³ *Decision adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting x/33, Biodiversity and Climate Change, 10th mtg, Agenda Item 5.6, UNEP/CBD/COP/DEC/X/33 (29 October 2010) paragraph 8(w) ('Decision X/33')*. See also, Scott, above n 19, 332. Scott notes that this decision is sometimes referred to as a moratorium on geoengineering, however, this is incorrect because it is non-binding.

¹³⁴ *Convention on Biological Diversity*, opened for signature 5 June 1992, 1760 UNTS 79 (entered into force 29 December 1993) ('*CBD*').

¹³⁵ *Resolution LP.4(8)*, above n 98.

¹³⁶ See also Ginzkey and Frost, above n 128, 86.

geoengineering activities listed in Annex 4, unless the listing provides that the activity or the sub-category of an activity may be authorized under a permit.

Article 6bis (2), establishes the procedure and standards which states must follow when it comes to issuing permits. These are the first legally binding international laws specifically related to geoengineering.¹³⁷ Although the moratorium is not yet in force, Ginzky and Frost claim that these amendments may nevertheless act as a 'precedent for the regulation of other climate engineering technologies.'¹³⁸ Further research regarding the content of these amendments, the way in which they have been incorporated into the *London Protocol* as an existing multilateral environmental agreement, and the process by which they were negotiated by the Contracting Parties could therefore inform the development of international law to regulate other proposed geoengineering technologies.

2.3 Solar Radiation Management (SRM)

Whereas CDR is proposed to address the cause of climate change, by reducing levels of GHG in the atmosphere, SRM is being proposed to address the effects.¹³⁹ That is, the aim of SRM is to directly target rising global mean surface temperatures associated with climate change. Once again, it is useful to think in terms of the Earth's 'energy budget': scientists propose SRM to address the imbalance in the Earth's energy budget by limiting the amount of incoming solar radiation to compensate for the increased absorption of infrared radiation in the atmosphere.¹⁴⁰ Instead of allowing more energy to escape the atmosphere, SRM would reduce the amount of energy entering in the first place.

Proposed SRM technologies aim to reduce the amount of incoming solar radiation by enhancing the reflectivity ('albedo') of the earth.¹⁴¹ An early proposal, mentioned in the 1991 *COSEPUP* report, was to increase the amount of solar radiation reflected away from the Earth by placing giant mirrors into outer space to orbit the earth at strategic locations.¹⁴² Another proposal is to increase the brightness of naturally-formed ocean clouds so that they reflect more sunlight.¹⁴³ However, this section will examine stratospheric aerosol injection (SAI), as it is the most prominently discussed proposal.

SAI is a type of SRM designed to mimic the injection of particles into the stratosphere that occurs with large volcanic eruptions.¹⁴⁴ Scientist propose

¹³⁷ Ibid 82.

¹³⁸ Ibid 82.

¹³⁹ *Royal Society Report*, above n 1, ix.

¹⁴⁰ Ibid 23.

¹⁴¹ See *ibid*.

¹⁴² *COSEPUP*, above n 50, 448

¹⁴³ See *EuTRACE Report*, above n 10, 44-6.

¹⁴⁴ Ibid 22.

creating a fine layer of a minute aerosol particles in the stratosphere.¹⁴⁵ The particles would be created in the stratosphere using modified weather balloons or jet aircraft.¹⁴⁶ Unlike the troposphere (the lowest layer of the atmosphere in which we experience weather) the stratosphere is relatively stable with little convection (upwards and downwards movement of air).¹⁴⁷ Scientists suggest that particles could therefore remain suspended in the stratosphere for 12 months or more.¹⁴⁸ Once in the stratosphere, these particles would create a fine reflective layer intended to block a percentage of incoming solar radiation.¹⁴⁹

SAI is one of the most prominent geoengineering proposals due to its perceived affordability, short-term feasibility and likely effectiveness in reducing temperatures.¹⁵⁰ According to the *Royal Society Report*, development of SAI appears feasible in the near future and is likely to be highly effective in reducing global temperatures.¹⁵¹ Although scientists are yet to field-test SAI in the stratosphere, they are confident it will have a cooling effect from observing a similar phenomenon from the volcanic eruption of Mt Pinatubo in the Philippines.¹⁵² SAI promises to reduce global temperatures within 12 months, making it suitable as an emergency response to climate change.¹⁵³ SAI also appears to be affordable, potentially costing as little as US\$1 billion per annum.¹⁵⁴ These perceived benefits of SAI, however, must be weighed against the significant uncertainty and potential environmental and associated social risks inherent in these proposals.

Scientists are uncertain about how SAI will affect the global climate system and the precise nature and magnitude of undesirable side effects it could have at regional and global scales.¹⁵⁵ It is thought that SAI will produce both 'winners and losers': some states and/or regions may benefit whereas others may suffer

¹⁴⁵ *Royal Society Report*, above n 1, 29. According to this report, the most prominent proposal is to use sulphate aerosols.

¹⁴⁶ See *ibid* 32.

¹⁴⁷ Burch and Harris, above n 83, 40-1.

¹⁴⁸ *Royal Society Report*, above n 1, 29. Particles in the troposphere would only stay suspended for a short period of time (days or weeks) before being rained out. See Burch and Harris, above n 83, 40-1.

¹⁴⁹ See, eg, *Royal Society Report*, above n 1, 29; *NRC SRM Report*, above n 11, 66-7. The NRC Report notes that aerosols naturally exist in the stratosphere: SAI would increase the amount of aerosols in the stratosphere.

¹⁵⁰ See *EuTRACE Report*, above n 10, 22.

¹⁵¹ *Royal Society Report*, above n 1, 31.

¹⁵² Crutzen, above n 7, 212.

¹⁵³ *Royal Society Report*, above n 1, 31.

¹⁵⁴ See Scott Barrett, 'The incredible economics of geoengineering' (2008) 39(1) *Environmental and Resource Economics* 45, 49. For a more recent summary of cost estimates see *EuTRACE Report*, above n 10, 42.

¹⁵⁵ See, *Royal Society Report*, above n 1, 12, 31, 34. This report states that further research and development is needed to 'assess uncertainties about effectiveness and undesired side effects' of SRM.

detrimental side effects.¹⁵⁶ For example, based on climate modelling and observations following large volcanic eruptions, some scientists suggest that SAI risks altering regional precipitation and changing the patterns of the Asian and African monsoons.¹⁵⁷ As the *Royal Society Report* notes, this could adversely affect regional food security.¹⁵⁸ SAI could also delay the recovery of, or even further deplete, the stratospheric ozone layer.¹⁵⁹ The changes to precipitation and sunlight (intensity and scattering of light) may affect ecosystems and biological processes such as photosynthesis.¹⁶⁰ It could also increase surface acid deposition, in the form of acid rain.¹⁶¹ The *EuTRACE Report* and *NRC SRM Report* recognise that SAI could have unforeseen side effects that can only be identified after the technology has been deployed.¹⁶²

A further risk associated with SAI (and other SRM proposals more generally) is the so-called 'termination problem'.¹⁶³ If SAI were commenced, then stopped, this would decrease the Earth's reflectivity, allowing more solar radiation to enter the atmosphere. Scientists fear that if SAI is implemented but the atmospheric concentration of GHGs remains high, stopping SAI could cause global temperature to increase rapidly, creating far more serious problems.¹⁶⁴ While SAI might lower global temperatures and reduce some of the impacts associated with climate change, the termination problem means that deploying SAI could nevertheless introduce a new risk of triggering a rapid increase in global

¹⁵⁶ See Scott Barrett et al, 'Climate engineering reconsidered' (2014) 4(7) *Nature Clim. Change* 527, 528 figure 1.

¹⁵⁷ See Alan Robock, 'Stratospheric Aerosol Geoengineering' in Roy Harrison and Ron Hester (eds), *Geoengineering of the Climate System* (The Royal Society of Chemistry, 2014) 162, 174–5; *Royal Society Report*, above n 1, 31. See also *NRC SRM Report*, above n 9, 84–5.

¹⁵⁸ *Royal Society Report*, above n 1, 31.

¹⁵⁹ See, eg, *NRC SRM Report*, above n 11, 86; P Heckendorn et al, 'The impact of geoengineering aerosols on stratospheric temperature and ozone' (2009) 4(4) *Environmental Research Letters* 045108; Robock, 'Stratospheric Aerosol Geoengineering', above n 157, 167–8.

¹⁶⁰ *NRC SRM Report*, above n 11, 94. This report indicates that SAI could have negative and positive effects in this regard.

¹⁶¹ *NRC SRM Report*, above n 11, 94. However, it is thought that the contribution of SAI to acid rain/snow would be minimal compared to current industrial pollution. See also Intergovernmental Panel on Climate Change, *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2013) <http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf> ('AR5 Working Group 1 Report') chapter 7, 634.

¹⁶² *EuTRACE Report*, above n 10, 44; *NRC SRM Report*, above n 11, 95.

¹⁶³ *Royal Society Report*, above n 1, 24.

¹⁶⁴ See *ibid* 24. See also Victor Brovkin et al, 'Geoengineering climate by stratospheric sulfur injections: Earth system vulnerability to technological failure' (2009) 92(3–4) *Climatic Change* 243.

temperatures in its own right.¹⁶⁵ Additionally, because SAI does not address the level of GHG in the atmosphere, scientists are concerned that other impacts associated with high CO₂ concentrations, especially ocean acidification, would persist.¹⁶⁶

SAI has not been field-tested in the stratosphere. In 2009, a team of Russian scientists tested aerosols at ground level to study their reflective characteristics.¹⁶⁷ Research has otherwise been confined to laboratory testing and climate modelling. The Geoengineering Model Intercomparison Project (GeoMIP) is a leading example of climate modelling research on geoengineering. GeoMIP is an ongoing research initiative using climate models to investigate the impacts of solar geoengineering methods (SAI and cloud brightening) on climate patterns.¹⁶⁸ The *NRC SRM Report* draws heavily on the research of GeoMIP to date and recommends scientists undertake more varied and detailed climate modelling research in addition to GeoMIP, to better assess the uncertainties and different outcomes from various models.¹⁶⁹ However, there are some scientists who argue that the utility of climate modelling for researching the risks and benefits of SRM/SAI is limited. Keith, Duren and MacMartin suggest that while improved modelling might reduce uncertainty, it cannot eliminate it and that field-testing may be necessary to 'bridge the gaps between models.'¹⁷⁰

Suggestions to field-test SAI are highly controversial and the topic of much debate in geoengineering literature.¹⁷¹ There is concern that even on a small scale, field-testing might create a 'slippery slope' that would eventually lead to full-scale deployment.¹⁷² Robock et al argue that SAI cannot be effectively field-tested unless it is on a scale comparable to full-scale deployment.¹⁷³ They claim that field-tests would have to be large and conducted for a long time, in order to distinguish the impacts of the experiment from natural variations in these systems.¹⁷⁴ In 2011, a proposal in the UK to field-test a delivery system for SAI known as the 'SPICE'

¹⁶⁵ J. G. Shepherd, 'Geoengineering the climate: an overview and update' (2012) 370 *Phil. Trans. R. Soc. A* 4166, 4107.

¹⁶⁶ Alan Robock, '20 reasons why geoengineering may be a bad idea' (2008) 64(2) *Bulletin of the Atomic Scientists* 14, 15.

¹⁶⁷ Izrael et al, above n 10.

¹⁶⁸ Ben Kravitz et al, 'An overview of the Geoengineering Model Intercomparison Project (GeoMIP)' (2013) 118(23) *Journal of Geophysical Research: Atmospheres* 13.

¹⁶⁹ *NRC SRM Report*, above n 11, 126.

¹⁷⁰ David W. Keith, Riley Duren and Douglas G. MacMartin, 'Field experiments on solar geoengineering: report of a workshop exploring a representative research portfolio' (2014) 372 *Phil. Trans. R. Soc. A* 2, 4-5.

¹⁷¹ See eg, Alan Robock et al, 'A Test for Geoengineering?' (2010) 327(5965) *Science* 530; Hulme, above n 14, 60-8;

¹⁷² Solar Radiation Governance Initiative, 'Solar radiation management: the governance of research' (Report, Solar Radiation Governance Initiative, 2011) 21 <<http://www.srmgi.org/report/>> ('*SRMGI Report*').

¹⁷³ Robock et al, above n 171, 530.

¹⁷⁴ *Ibid* 531.

project triggered significant public concern over geoengineering.¹⁷⁵ The *EuTRACE Report* also suggests that a number of social issues flow from proposals to field-test geoengineering technologies, such as the SPICE project.¹⁷⁶ These issues include transparency, public participation and stakeholder engagement in decisions over the location, duration, scale and form of such tests.¹⁷⁷

It is against the backdrop of the historical use of weather modification techniques and emergent CDR and SRM technologies that literature on the governance of geoengineering has emerged. The possibilities of state and/or non-state actors engaging in attempts in geoengineering has created concerns (in academic and scientific circles) about governance of the environmental and social risks involved. For example: Who should decide if and/or when to use geoengineering? What principles should inform such decisions? What recourse should the international community and/or individual states have if a state (or group of states) attempts geoengineering and causes harm to their territory or the global commons? Whilst these concerns have stimulated preliminary research across a number of disciplines, the following section examines how they have been addressed in existing legal scholarship.

3 Existing Legal Research on Geoengineering

The proposition that law has an important role to play in the governance of geoengineering is not unique to this article. Indeed, there is a growing body of scholarship focusing on law and geoengineering. Legal scholars have long recognised that geoengineering proposals do not exist in a legal vacuum – a range of existing rules and principles may apply.¹⁷⁸ Geoengineering is intended to have global impacts on the climate system. Technologies such as Ocean Iron Fertilization (OIF) and Stratospheric Aerosol Injection (SAI) would operate in global commons areas (the high seas and/or the atmosphere) and risk transboundary impacts to the territory of other states. As such, legal research has largely focused on how existing international law rules, principles and treaty regimes might respond to different geoengineering technologies.¹⁷⁹ Comparatively little legal research has been published on domestic law.¹⁸⁰

¹⁷⁵ See Camila Ruz, 'Scientists criticise handling of pilot project to 'geoengineer' climate', *The Guardian* (online) 17 November 2011 <<http://www.theguardian.com/environment/2011/nov/17/scientists-criticise-project-geoengineer-climate>>.

¹⁷⁶ *EuTRACE Report*, above n 10, 129–30.

¹⁷⁷ *Ibid* 130.

¹⁷⁸ For an early example, see Bodansky, above n 21. See also Hubert and Reichwein, above n 22, 6.

¹⁷⁹ See, eg, Lin, above n 19; Scott, above n 19.

¹⁸⁰ Notable exceptions are Chiara Armeni and Catherine Redgwell, 'Geoengineering Under National Law: A Case Study of Germany' (Working Paper No 024, Climate Geoengineering Governance Working Paper Series, 9 March 2015) <<http://www.geoengineering-governance-research.org/perch/resources/workingpaper24armeniredgwellgermany-1.pdf>>.

Research on international law and geoengineering ranges from general overview pieces to more focused studies examining how law might apply to a particular geoengineering technique. Broad surveys highlight various hard and soft international legal norms that are potentially relevant to the implementation of different geoengineering technologies.¹⁸¹ More detailed legal analysis considers how specific rules or principles might be interpreted in the context of geoengineering, including the issue of international liability for transboundary harm from geoengineering¹⁸² and how the precautionary principle might be interpreted to apply to geoengineering proposals.¹⁸³

On the whole, this scholarship has demonstrated that there are some significant gaps in international law limiting its capacity to manage geoengineering technologies. There is no international treaty that specifically governs all proposed geoengineering technologies. The only binding international agreement to specifically address geoengineering is the *London Protocol* that, as explained above in section 2.2 has been amended to regulate marine geoengineering activities such as OIF.¹⁸⁴ This amendment does not address land based Carbon Dioxide Removal (CDR) or Solar Radiation Management (SRM) proposals. Similarly, as discussed in section 2.1 the accepted view amongst international law scholars is that the *ENMOD Convention* is unlikely to apply to geoengineering activities, unless they are conducted for a military or hostile purpose (a highly unlikely scenario).¹⁸⁵ Therefore, SRM and land-based CDR proposals may fall outside the scope of existing treaty regimes.

Furthermore, the application of relevant principles of customary international law to geoengineering is uncertain. For example, the International Court of Justice has confirmed that states have a duty under customary international law to prevent significant transboundary harm to the territory of other states and to the environment of the global commons.¹⁸⁶ However, some legal scholars doubt whether this duty would directly influence the decision of states to undertake

Chiara Armeni and Catherine Redgwell, 'Geoengineering Under National Law: A Case Study of the United Kingdom' (Working Paper No 023, Climate Geoengineering Governance Working Paper Series, 9 March 2015) < <http://geoengineering-governance-research.org/perch/resources/workingpaper23armeniredgwelltheukcombine.pdf>>.

¹⁸¹ See, eg, Lin, above n 19.

¹⁸² See, eg, Barbara Saxler, Jule Siegfried and Alexander Proelss, 'International liability for transboundary damage arising from stratospheric aerosol injections' (2015) 7(1) *Law, Innovation and Technology* 112; Kerry Brent, Jeffrey McGee and Amy Maguire, 'Does the 'No-Harm' Rule Have a Role in Preventing Transboundary Harm and Harm to the Global Atmospheric Commons from Geoengineering?' (2015) 5(1) *Climate Law* 35.

¹⁸³ See, eg, Jesse L Reynolds and Floor Fleurke, 'Climate Engineering Research: A Precautionary Response to Climate Change?' (2013) (2) *Carbon and Climate Law Review* 101.

¹⁸⁴ *Resolution LP.4(8)*, above n 98.

¹⁸⁵ Bodle, above n 21, 312.

¹⁸⁶ *Legality of the Threat or Use of Nuclear Weapons (Advisory Opinion)* [1996] ICJ Rep 226, 227-8; *Case Concerning the Gabčíkovo-Nagymaros Project (Hungary v Slovakia)* (Merits) [1997] ICJ Rep 7, 41.

geoengineering because the legal content of this duty lacks clarity and it is questionable whether it could be successfully enforced by an international court or tribunal.¹⁸⁷ Additionally, the customary law rules regarding state responsibility and liability for transboundary harm may not respond to geoengineering. Saxler, Siegfried and Proelss suggest that international law does not have an adequate liability mechanism to provide 'effective and equitable compensation' in the event of transboundary harm resulting from SAI.¹⁸⁸ These examples indicate that, in its current form, there are significant doubts about the capacity of existing rules of international law to adequately manage the geoengineering technologies currently being proposed.

However, the study of existing international (and domestic) law rules and institutions is still important to the future governance of geoengineering. For example, Bodansky suggests that existing international environmental law rules can provide a 'general frame of reference' that can inform decision-making regarding geoengineering, despite the fact that they are unlikely to constrain the actions of states.¹⁸⁹ Bodle suggests that even though the *ENMOD Convention* does not directly apply to geoengineering, it contains definitions and provisions that could inform future geoengineering governance arrangements.¹⁹⁰ Similarly, although Saxler, Siegfried and Proelss suggest that it might be difficult to hold states liable under existing international law for SAI, they recognise that 'international law offers some valuable approaches concerning the framing of a future SAI liability regime'.¹⁹¹ These examples suggest that researching international law can still benefit broader governance discussions on geoengineering.

This article argues that greater legal analysis is needed to bolster the normativity of law in this area, by developing a set of principles concerning the scope of permissible research, development and implementation of geoengineering.¹⁹² This is especially important given suggestions that institutional and governance considerations should simply respond reactively to technological drivers, such as

¹⁸⁷ For a review of these arguments see Brent, McGee and Maguire, above n 182, 50-3.

¹⁸⁸ Saxler, Siegfried and Proelss, above n 182, 146. This conclusion is drawn specifically in relation to SAI. However, at page 114 the authors note that their conclusions may also be relevant to other SRM techniques.

¹⁸⁹ Bodansky, above n 21, 313.

¹⁹⁰ Bodle, above n 21, 312. For example, Bodle suggests that the definition of 'deliberate environmental modification' and the criteria for determining 'widespread, long-lasting or severe effects' from weather modification technology could be useful in the context of geoengineering. He also suggests that the dispute resolution procedure under the *ENMOD* convention is worth considering in the context of geoengineering.

¹⁹¹ Saxler, Siegfried and Proelss, above n 182, 146. They suggest that researching liability regimes for other ultra-hazardous activities in international law might provide 'valuable guidance' for the design of a future liability regime for SAI: at 113.

¹⁹² For a draft example of such a framework for the governance of geoengineering research, see Hubert and Reichwein, above n 22.

small-scale field-testing or deployment,¹⁹³ rather than delineate the circumstances in which technologies should be developed or used at all.

There is remarkably little current research addressing geoengineering from a national or domestic law perspective. Only a few key reports have touched on the issue of domestic law. For example, the *EuTRACE Report* considers geoengineering in the context of EU law.¹⁹⁴ Bracmort and Lattanzio in their report *Geoengineering: Governance and Technology Policy* for the United States Congressional Research Service briefly highlight current United States policies that may apply to geoengineering.¹⁹⁵ Armeni and Redgwell examine how domestic law in Germany and the UK may apply to geoengineering.¹⁹⁶ However, these analyses are limited to only four jurisdictions, and further legal research is needed to understand how domestic legal systems might respond to geoengineering and the potential of these systems to influence global governance.

Having briefly surveyed the current state of legal scholarship relating to geoengineering, the next section explores some of the key governance debates that arise before outlining how further research of national and international legal rules and principles can inform and direct future governance discussions.

4 Challenges for Geoengineering Law and Governance

There is wide agreement in geoengineering literature that governance mechanisms are needed to regulate the deployment of geoengineering. However, beyond the fact that governance is needed before full-scale deployment, there is little consensus as to what the purpose of governance ought to be and the form it might take. As mentioned above in section three, there is a growing body of legal scholarship focussing on how existing legal rules, principles and regimes might respond to geoengineering and increasing recognition that legal rules and principles can help shape future geoengineering governance. This potential is not widely recognised beyond legal literature.

Geoengineering poses a number of significant challenges for international and domestic law. Some of these challenges relate to geoengineering as a broad concept; other challenges relate to specific geoengineering proposals. Rather than presume to provide a comprehensive assessment of *all* law and governance issues for *all* geoengineering proposals, this section seeks to expedite the conversation of geoengineering within the legal academy by setting into a legal context some of the more prominent issues raised in geoengineering literature

¹⁹³ See, eg, Jane C S Long, 'A Prognosis, and Perhaps a Plan, for Geoengineering Governance' (2013) (3) *Carbon and Climate Law Review* 177. Long suggests that cooperation on climate intervention by states on a local or regional scale might lead to the development of governance norms for geoengineering on a global scale.

¹⁹⁴ *EuTRACE Report*, above n 10, 90-3.

¹⁹⁵ Bracmort and Lattanzio, above n 71, 24-5.

¹⁹⁶ Armeni and Redgwell, *A Case Study of Germany*, above n 180; Armeni and Redgwell, *A Case Study of the UK*, above n 180.

dealing with: uncertainty and distributive justice issues, liability and responsibility, unilateral actions and moral hazard. It highlights these issues with a view to demonstrating the diversity of law and governance issues associated with geoengineering, and the complexity of broader geoengineering governance discussions.

4.1 Uncertainty and Distributive Justice

The most prominent issue common to CDR and SRM geoengineering proposals is how to address the uncertainty and risks associated with different geoengineering methods. For example, as noted above CDR and SRM proposals may have significant environmental impacts, including transboundary environmental impacts and impacts on global commons areas (the marine environment of the high seas and the atmosphere). Additionally, as noted above, scientists suggest that the impacts of some geoengineering technologies are unlikely to be uniform. That is, geoengineering will produce different impacts on different parts of the world, benefitting some states and/or regions more than others. According to the Solar Radiation Management Governance Initiative ‘SRM research could constitute a cheap fix to a problem created by developed countries, while further transferring environmental risk to the poorest countries and the most vulnerable people.’¹⁹⁷ It is beyond the scope of this article to examine critiques of distributive justice in legal and non-legal literature. However, we recognise that a significant challenge for law and governance is not only how to manage risk, but also how to address potential inequality which may result from large-scale attempts at geoengineering.

4.2 Liability and Responsibility

Connected to the issue of managing environmental risks are questions about responsibility, liability and compensation in the event that geoengineering field-testing or deployment causes damage. Horton, Parker and Keith suggest that a liability mechanism will be necessary in order to get widespread international support if geoengineering is to be attempted.¹⁹⁸ However, there are key questions which need to be considered regarding the design and operation of future liability mechanisms. These include: who should be liable for harm caused by geoengineering?; if compensation is to be paid, to whom should it be paid?; should all geoengineering activities attract liability or compensation?; and, what types of harms should attract liability?¹⁹⁹

¹⁹⁷ SRMGI Report, above n 172, 21.

¹⁹⁸ Joshua B Horton, Andrew Parker and David Keith, ‘Solar Geoengineering and the Problem of Liability’ (2013) *Geoengineering Our Climate? Working Papers and Opinion Articles* 2 <<http://geoengineeringourclimate.com/tag/solar-radiation-management/>>.

¹⁹⁹ See *EuTRACE Report*, above n 10, 132.

4.3 Unilateralism

The relative affordability and feasibility of geoengineering techniques such as SAI raises the possibility of 'unilateral' geoengineering. That is, an individual state, small coalition of states, or even a private actor (ie company or wealthy individual) might attempt geoengineering without consensus from the wider international community.²⁰⁰ Horton argues against assumptions that states might be tempted to unilaterally attempt SAI geoengineering²⁰¹ and that unilateral geoengineering might be less attractive for state actors than initially assumed. He argues that there are a number of technical and political impediments that, when viewed collectively, outweigh the 'benefit' states might gain from unilaterally attempting SAI.²⁰² However, in 2012, an incident occurred which suggests that concern regarding unilateral geoengineering is not unfounded. In August 2012, a Canadian fishing community – the Haida Salmon Restoration Corporation (HSRC) – conducted an unauthorised ocean fertilization experiment off the coast of Canada.²⁰³ While this experiment was directed towards restoring salmon numbers rather than to influence atmospheric conditions, this incident fuelled existing fear that geoengineering might be used without the consent of the global community to 'hijack' the Earth's climate.²⁰⁴ The potential for unilateral geoengineering has prompted suggestions that other states might engage in 'counter-geoengineering'. Namely, states might attempt to modify the climate to compensate for the changes 'to regional and national meteorological disruptions' caused by the geoengineering activities of other states.²⁰⁵ Unilateral geoengineering could therefore lead to tension between states and threaten international peace and security.²⁰⁶ The *Royal Society Report* also suggest that if geoengineering was conducted unilaterally, this could prevent global consensus on international climate policy from being reached.²⁰⁷ In addition to destabilising international peace and security, therefore, it is possible that unilateral geoengineering might also destabilise international efforts at climate change

²⁰⁰ See David Victor, 'On the regulation of geoengineering' (2008) 24(2) *Oxford Review of Economic Policy* 322, 324. See also John Virgoe, 'International governance of a possible geoengineering intervention to combat climate change' (2009) 95(1-2) *Climatic Change* 103, 115-6.

²⁰¹ See Horton, above n 19.

²⁰² Ibid 59.

²⁰³ Jeff Tollefson 'Ocean fertilization project off Canada sparks furore' 490 *Nature* 458 (online 25 October 2012)
<http://www.nature.com/polopoly_fs/1.11631!/menu/main/topColumns/topLeftColumn/pdf/490458a.pdf>.

²⁰⁴ See John Vidal, 'Rogue geoengineering could 'hijack' world's climate' *The Guardian* (online) 9 January 2013
<<http://www.theguardian.com/environment/2013/jan/08/geoengineering-hijack-world-climate>>.

²⁰⁵ William Daniel Davis, 'What Does "Green" Mean?: Anthropogenic Climate Change, Geoengineering, and International Environmental Law' (2009) 43 *Georgia Law Review* 901, 906-7.

²⁰⁶ See, eg, Virgoe, above n 200, 115.

²⁰⁷ *Royal Society Report*, above n 1, 40

mitigation and adaptation. This raises the question of whether a moratorium or ban ought to be established for geoengineering.²⁰⁸

4.4 Impacts on Progress to Reduce Emissions

The potential for geoengineering to detract from efforts at mitigation and adaptation is often referred to as a 'moral hazard'. Lin describes the moral hazard argument as follows: 'Just as insurance can encourage insureds to assume greater risk, the prospect of geoengineering the Earth in response to climate change might exacerbate the very behaviours contributing to climate change.'²⁰⁹ In other words, despite the inherent risks and limitations associated with different proposals, geoengineering might provide the technical means by which human society can maintain a carbon-intensive economic base. In constructing his argument, Lin draws parallels between geoengineering and climate change adaptation; once also considered taboo for fear of detracting from mitigation efforts, adaptation now plays a crucial role in mainstream climate change policy.²¹⁰ Lin points out that, like adaptation, geoengineering might promise to be a useful short-term strategy, but it does not present a permanent solution to climate change.²¹¹

Not all commentators are convinced that the risk of creating a moral hazard is a 'deal breaker' for the development of geoengineering. It can be argued that, given the lack of progress to date in reducing global GHG emissions, it is important to 'keep as many options open as possible'.²¹² Keith argues that the potential for geoengineering to change behaviour on climate change mitigation is not a valid argument against the research and development of geoengineering²¹³ because geoengineering might still play an important role in reducing the risk of climate change.²¹⁴ He suggests that geoengineering does not fit the definition of a 'moral hazard' (at least, not in the narrow, insurance-based understanding of the term). Instead, Keith suggests that the term 'risk compensation' more accurately describes the potential of geoengineering to alter the behaviour of actors with regard to climate change.²¹⁵ Not all commentators are as easily convinced as Keith that the potential utility of geoengineering justifies creating the potential for geoengineering to significantly detract from mitigation efforts. According to the recent *EuTRACE Report*, moral hazard remains a key argument against the research and development of geoengineering.²¹⁶

²⁰⁸ Efforts towards establishing a moratorium have been made under the *Convention on Biological Diversity*. See *Decision X/33*, above n 133.

²⁰⁹ Lin, 'Moral Hazard', above n 53, 674.

²¹⁰ *Ibid* 679.

²¹¹ *Ibid* 681.

²¹² Preston, above n 19, 25.

²¹³ Keith, above n 8, 130-3.

²¹⁴ *Ibid* 132.

²¹⁵ *Ibid* 128-9.

²¹⁶ *EuTRACE Report*, above n 10, 135.

4.5 Factors Unique to Specific Geoengineering Technologies

In addition to challenges of risk management, inequality, liability, unilateral actors and moral hazard, different geoengineering technologies present unique governance challenges. It has been argued that CDR and SRM present different governance challenges and therefore ought to be governed separately. For example, the large scale and cost of CDR would likely mean that multiple state and/or non-state actors would need to cooperate in order for CDR to be implemented successfully. For these reasons, Parson and Ernst liken the governance challenges of CDR to those associated with climate change mitigation, of 'motivating costly efforts toward a globally shared risk-management goal, coordinating efforts to limit aggregate costs, monitoring performance and results to learn how to do it well, and building confidence that costly efforts are being reciprocated.'²¹⁷ On the other hand, SRM is characterised as being 'fast, cheap and imperfect'.²¹⁸ Parson and Ernst argue that these characteristics create separate governance challenges.²¹⁹

5 Mapping a Research Agenda on Geoengineering Governance

This brief overview of governance challenges highlights that there are differing opinions on the existence and/or importance of certain issues. Given these differences, it is unsurprising that there is no uniform understanding in geoengineering literature as to what issues ought to be the subject of governance mechanisms. Similarly, there is no clear understanding of what form such a governance mechanism ought to take. Ideas range from moratoria²²⁰ and legally enforceable international agreements,²²¹ to informal codes of conduct amongst scientists and other relevant stakeholders.²²² Research into the science of geoengineering may be able to reduce uncertainty regarding the utility of geoengineering in reducing the risk of climate change impact and resolve some uncertainty regarding the likely impacts and side effects of different geoengineering methods. Beyond this, however, undertaking further research and development of geoengineering is unlikely to contribute substantially to the formulation of appropriate governance arrangements. Indeed, it may actually add momentum to these technologies that becomes hard to resist. What is

²¹⁷ Edward A Parson and Lia N Ernst, 'International Governance of Climate Engineering' (2013) 14 *Theoretical Inquiries in Law* 307, 313.

²¹⁸ Ibid 317.

²¹⁹ Ibid 317-318.

²²⁰ See, eg, *Decision X/33*, above n 133.

²²¹ See eg, Scott, above n 19, 355. Scott advocates that states negotiate a protocol to the UNFCCC for geoengineering.

²²² See, eg, Asilomar Scientific Organising Committee, 'The Asilomar Conference Recommendations on Principles for Research into Climate Engineering Techniques' (Conference Report, Asilomar Scientific Organising Committee, November 2010) <<http://www.climate.org/PDF/AsilomarConferenceReport.pdf>> ('Asilomar Principles'); Steve Rayner et al, 'The Oxford Principles' in *The Regulation of Geoengineering*, House of Commons, Science and Technology Committee, Fifth Report of Session 2009-2010 (2010) Ev42-Ev44 ('Oxford Principles').

needed, therefore, is a concerted research effort from legal and governance perspectives, examining the shape, mandate, and operating model of future governance regimes. These potential lines of inquiry are numerous, but at least four broad issues deserve closer attention.

Firstly, legal research can help to prioritise issues, by demonstrating what aspects of geoengineering are effectively governed by existing international or national regimes, and those that fall into a legal lacuna. The interaction of geoengineering with the current international climate regime, especially the potential for geoengineering to create moral hazard and undermine global emissions reduction commitments demands careful evaluation. More broadly, scholarship addressing the capacity of international law to protect the global commons should be extended to address issues arising specifically from geoengineering field-testing and implementation. Similarly, further work is needed looking into the scope, operation and – importantly – the limitations of existing liability mechanisms in light of the specific challenges posed by geoengineering.

Secondly, the coverage (or otherwise) of domestic laws has received scant attention to date, and demands far more research. To what extent do geoengineering activities trigger national government approval and environmental impact assessment requirements, for example through territorial and extra-territorial operation of legislation such as the United States *National Environmental Policy Act of 1969*, or the Australian *Environment Protection and Biodiversity Conservation Act 1999* (Cth)? How should such environmental impact assessment processes account for the spatial and temporal distribution of impacts from such technologies, and are existing mechanisms sufficient to require such consideration? The way in which domestic regimes have addressed other novel technologies that pose new and uncertain risks may also offer valuable lessons for the regulation and governance of geoengineering. While none of these seeks to manipulate or affect global commons or shared resources in the same way as geoengineering, the processes for public participation and risk assessment incorporated into regimes governing, for example, cloning and biotech industries may be capable of adaptation. Similarly, lessons may be learned from the failures or inadequacies of such frameworks, for example in relation to liability issues. These matters require theoretical and doctrinal analysis of the architecture and underpinning principles of domestic regimes, as well as empirical investigation of regime implementation and effectiveness.

Thirdly, the formulation, operation and enforcement of overarching environmental legal principles also requires further study. Principles such as the precautionary principle and intergenerational equity set out the existing parameters within which geoengineering governance can operate, both domestically and internationally. It is unlikely that any new governance mechanism would be created that conflicts with these principles, so scholarship that seeks to improve policy-makers' understanding of these principles, examining their potential application as well as their limitations would also enhance future governance negotiations.

Fourthly, the application of international law and domestic law to geoengineering scenarios raises a number of questions about how established theories of procedural and distributive justice should guide further development

of the law. Further work at the intersection of law and political theory is necessary to provide lawyers with cogent arguments as to how the law should be developed to shape governance of these technologies.

6 Conclusion

Expert reports, including the *Royal Society Report*²²³ and the recent NRC reports²²⁴, maintain that the reduction of GHG emissions remains the best strategy for reducing the impacts of anthropogenic climate change. However, the past 10 years has seen interest in geoengineering research and development increase steadily.²²⁵ Concern over what form the governance of geoengineering might take has emerged alongside scientific interest. While many governance issues have been revealed and explored in existing research, limited progress has been made towards managing and/or resolving these issues or translating the conclusions of this research into workable proposals for institutional and legal arrangements.

This article has provided a précis of issues for a future special edition of this Journal on law and geoengineering. The purpose of this article was therefore to introduce key issues in order to act as a catalyst for further discussion regarding the intersection of law, governance and geoengineering. It challenges suggestions made in scientific literature that greater scientific research on geoengineering is required for progress to be made regarding the governance of geoengineering. We suggest instead that, far from being a servant to scientific progress on this contentious suite of technologies, legal and governance arrangements must precede, and thereby shape the scope and dimensions of further progress. Such research can help to prioritise geoengineering governance issues by: (i) identifying existing gaps in international law that need to be addressed; (ii) exploring the potential role of domestic law; (iii) investigating the role of overarching environmental law principles (such as precaution); and (iv) sharpening the focus upon normative issues by drawing on the intersections between law and ethics/political theory. It is hoped that the ideas and issues raised in this article will stimulate further legal research on geoengineering, and thereby contribute to development of a governance regime for these emergent – and highly risky – technologies.

²²³ *Royal Society Report*, above n 1, 54. The report states that '[i]t is clear that geoengineering must not divert resources from climate change mitigation or adaptation.'

²²⁴ *NRC SRM Report*, above n 11, 3. This is the first recommendation of the reports.

²²⁵ See Section 2.1 above.