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The International Regulation of Climate Engineering: Lessons from Nuclear Power

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ABSTRACT

Proposals for climate engineering—intentional large-scale interventions in climate systems—are increasingly under consideration as potential additional responses to climate change, yet they pose risks of their own. Existing international regulation of large-scale field testing and deployment is considered inadequate. This article looks to the closest existing analogy—nuclear power—for lessons, and concludes that climate engineering research will most likely be promoted and will not be the subject of a binding multilateral agreement in the near future. Instead, climate engineering and its research will probably be internationally regulated gradually, with an initially low degree of legalisation, and through a plurality of means and institutions. This regulation is expected to proceed from norms, to non-binding and non-legal policies, and then to relatively soft multilateral agreements which emphasise procedural duties. Any eventual agreements will have trade-offs between their strength and breadth of participation. Intergovernmental institutions could play important facilitative roles. Treaties regarding liability and non-proliferation of global deployment capability should be considered.

KEYWORDS: climate engineering, climate change, geoengineering, nuclear power, international environmental law

1. INTRODUCTION

In the face of worsening forecasts for climate change and inadequate reductions of greenhouse gas emissions, intentional large-scale interventions in climate systems are now being considered as potential additional responses to reduce climate risks. Although at first glance these proposed 'climate engineering' or 'geoengineering' techniques may appear to be impractical, dangerous, and/or contrary to international environmental law, upon closer inspection some proposals may be effective in reducing the net climate risks to humans and the environment while receiving favourable consideration under international law. The movement of climate engineering discussions from the margins to the mainstream has been accompanied by the rise of a debate over the existing, and optimal, international regulation of climate engineering research and deployment.

This article looks to the international regulation of climate engineering's closest existing analogy—nuclear power—for lessons. It also aims to add a dose of realism to the climate engineering regulation discourse, which too often neglects what is actually possible in a world of sovereign states with diverse interests, capabilities, and levels of power, and too often focuses on climate engineering's risks while ignoring its potential benefits. Finally, the article maintains a distinction between climate engineering research and deployment, focusing on the more urgent question of the former while maintaining an awareness of the latter. The following section briefly introduces climate engineering, and notes that this article restricts itself to the riskier, poorly regulated climate engineering techniques. The third section presents nuclear power as an instructive case. The next section summarises the most important aspects of the international regulation of nuclear power, providing relevant observations. The final section draws appropriate inferences for the international regulation of climate engineering. It concludes that observers should be modest in their expectations of climate engineering's international regulation, particularly through binding multilateral agreements. Instead of implying that the international regulation of climate engineering and its research will be entirely lacking, it will more likely be gradual, with a low degree of legalisation, and through a plurality of means and institutions.[1] Although some may react to this with pessimism, I cautiously find the trajectory to be encouraging.

2. CLIMATE CHANGE AND CLIMATE ENGINEERING

Considered in isolation, suggestions that humans could intentionally alter the climate appear unjustified and possibly contrary to international law. However, because climate engineering is proposed as a means to counter the most dangerous aspects of anthropogenic climate change, it must be considered in that context. Industrial activities have altered the atmospheric concentrations of some 'greenhouse gases', which allow sunlight to enter the atmosphere but restrict heat from exiting it. The most important of these is carbon dioxide, whose concentration has increased in the past two centuries by roughly 40% due to processes such as burning of fossil fuels and land-use changes.[2] These increases in greenhouse gas concentrations will change the climate by warming it and altering precipitation patterns, harming humans and the environment in the process.[3] To date, there have been two leading categories of internationally coordinated efforts to reduce climate change risks: to limit and reduce

1 'Legalization' in the sense of greater obligation, precision, and/or delegation. See Kenneth Abbott and others, 'The Concept of Legalization' (2000) 54 Int'l Org 401.

2 Thomas Stocker and others (eds), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (CUP 2014) 11.

3 Christopher Field and others (eds), *Climate Change 2014: Impacts, Adaptation, and Vulnerabilities. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (CUP 2014).

greenhouse gas emissions, and to adapt society and ecosystems to a changed climate.[4] Efforts toward emissions reductions and adaptation have thus far been disappointing, and there are reasons to be pessimistic about the future. Furthermore, scientists remain uncertain as to the magnitude of climate change risks, in part because climate change is delayed by several decades relative to greenhouse gas emissions. Meanwhile, the intensity of climate change as a function of greenhouse gas concentrations and its damage to humans and the environment as a function of climate change are not perfectly known. Therefore, we are already committed to a yet unknown amount of climate change, and there is a significant chance that the damage may be much worse than the simple expected value.[5]

In response to climate change risks and the limited prospects for emissions reductions and adaptation, some scientists and other observers are increasingly discussing intentional large-scale interventions in the planet's climate systems as potential additional responses.[6] There are two distinct categories of such 'climate engineering' or 'geoengineering', the first of which would pull carbon dioxide from the atmosphere (carbon dioxide removal or negative emissions technologies). These proposals would be relatively slow, expensive, and low risk while addressing a cause of climate change. A significant exception to the low-risk character of these proposals is ocean fertilisation. In this, a nutrient would be added to the ocean, instigating an algal bloom. The algae indirectly incorporate atmospheric carbon dioxide into their bodies, some of which would sink to the deep ocean after their death, effectively sequestering the carbon. Ocean fertilisation presents risks, such as generating other greenhouse gases as by-products and depriving nearby marine areas of nutrients.

The second category of climate engineering proposals, collectively called solar radiation management (SRM), would attempt to make the planet slightly more reflective in order to compensate for the warming aspect of climate change. These would be relatively fast, inexpensive, and high risk, and only address a symptom of climate change. Under the most widely discussed technique, a reflective aerosol would be injected into the stratosphere, mimicking the global cooling effect experienced after major volcanoes. Another would involve the lower atmospheric spraying of seawater mist, which after evaporation would result in small salt particles in the air. These would act as cloud condensation nuclei, in turn making marine clouds more reflective.

The vast majority of those who research climate engineering assert that it would not be a substitute for emissions reductions or adaptation. Instead they emphasise the primacy of emissions reductions, hope that climate engineering would never be deployed, and see emissions reductions, adaptation, and climate engineering

4 These categories are enshrined in the United Nations Framework Convention on Climate Change (UNFCCC) (adopted 9 May 1992, entered into force 21 March 1994) 1771 UNTS 107, arts 4.1, 4.2.

5 That is, the probability distribution of damage is not symmetrical, but instead has a 'long tail' of low probability, high-impact damage.

6 A good non-technical introduction is John Shepherd and others, *Geoengineering the Climate: Science, Governance and Uncertainty* (The Royal Society 2009). A more recent, detailed review is Tim Lenton and Naomi Vaughan (eds), *Geoengineering Responses to Climate Change: Selected Entries from the Encyclopedia of Sustainability Science and Technology* (Springer 2013). Climate engineering received a prominent but cautious discussion in the latest report of the Intergovernmental Panel on Climate Change (IPCC). Stocker and others (eds) (n 2) SPM-21 and ss 6.5, 7.7.

(if necessary) as complementary. For example, the first 'headline message' and 'key recommendation' of a seminal report from the Royal Society are, respectively,

> The safest and most predictable method of moderating climate change is to take early and effective action to reduce emissions of greenhouse gases. No geoengineering method can provide an easy or readily acceptable alternative solution to the problem of climate change.... Parties to the UNFCCC should make increased efforts towards mitigating and adapting to climate change, and in particular to agreeing to global emissions reductions.[7]

On this view, carbon dioxide removal would decelerate and then reduce its atmospheric concentration. SRM would be a temporary means to reduce harm to humans and the environment until greenhouse gas concentrations have been reduced and/or society has adapted. Another perspective holds that climate engineering, particularly SRM, could be developed and held as something of an insurance option in case climate change turns out to be worse than expected.

The environmental and social risks of climate engineering would vary among the proposed techniques and also by the stages of their development. Some observers fear that the mere discussion of climate engineering could decrease the political willpower for emissions abatement and adaptation.[8] Researching climate engineering could lead to technological momentum and the development of influential vested interests, both of which could cause biases in favour of which technique(s), if any, are actually deployed in future. Large-scale field research and deployment may have unintended negative side effects to humans and the environment, in particular changes in precipitation. Because some effects may be at least partially known but not intended, climate engineering field research or deployment could raise questions of informed consent of those who will be impacted.[9] Deployment could pose issues of control, decision-making, and disagreement among states.[10] Some SRM methods could be inexpensive enough to be globally deployed for tens of billions of dollars, within the budget of small states as well as some non-state organisations and individuals.[11] Perhaps the greatest risk would be if, once deployed, SRM were to stop for some reason, causing the climate change that would have occurred in the absence of SRM to occur in less than a year. This very rapid rate of climate change would cause much greater damage relative to 'normal' climate change.

Because many of these risks are transboundary and/or would occur in areas beyond national jurisdiction, international environmental law is relevant for climate engineering.

7 Shepherd and others (n 6) ix.

8 Albert Lin, 'Does Geoengineering Present a Moral Hazard?' (2013) 40 Ecol LQ 673.

9 David Morrow, Robert Kopp and Michael Oppenheimer, 'Toward Ethical Norms and Institutions for Climate Engineering Research' (2009) 4 Envtl Res Lett 045106.

10 In reality, international tensions regarding climate engineering deployment may not be so strong because, according to models, the world's regions may agree more than not as to the desired intensity of climate engineering. See Katharine Ricke, Juan Moreno-Cruz and Ken Caldeira, 'Strategic Incentives for Climate Geoengineering Coalitions to Exclude Broad Participation' (2013) 8 Envtl Res Lett 014021.

11 Realistically, implementation costs, the inability to carry it out undetected, and the probability of retaliation make unilateral deployment unlikely. Scott Horton, 'Geoengineering and the Myth of Unilateralism: Pressures and Prospects for International Cooperation' (2011) 4 Stan JL Sci & Pol'y 56; Edward Parson and Lia Ernst, 'International Governance of Climate Engineering' (2013) 14 Theo Inq L 307, 332–33.

I have argued elsewhere that, on the whole, existing international environmental law leans in favour of climate engineering research as developing potential means toward reducing risks to humans and the environment.[12] One reason for this is because, even though climate engineering poses some risks, those from climate change are of a much higher order.[13] Additionally, some multilateral environmental agreements encourage science and technology, and climate engineering and its research are also consistent with principles of international environmental law including the polluter pays principle, the principle of common but differentiated responsibilities, and the precautionary principle.[14] Moreover, those agreements whose substance is most closely related to climate engineering are best interpreted as being favourable to it. Some existing multilateral environmental agreements do impose certain duties, mainly procedural ones, on states that might carry out, or be responsible for, climate engineering. These duties are part of, or roughly consistent with, the customary international law of transboundary risks. A handful of specific climate engineering activities are prohibited or curtailed.[15]

There is a consensus that existing international regulation—broadly defined—of climate engineering is inadequate. To date, the academic literature discussing this regulatory gap has been rather general in its nature, suggesting guideposts on the path toward some form of international regulation. The positions in this discourse can be generalised as varying in at least two dimensions.[16] First, some observers believe that the regulation of climate engineering and its research should be developed through existing international legal institutions.[17] The most-cited forum is the Conference of Parties to the UN Framework Convention on Climate Change (UNFCCC-COP), which could possibly work towards a new Protocol to the UNFCCC. Others argue that such forums would be unproductive and likely lead to stalemate or to premature, poorly crafted binding rules.[18] Instead, these writers often

12 Jesse Reynolds, 'Climate Engineering Field Research: The Favorable Setting of International Environmental Law' (2014) 5 Wash & Lee J Energy, Clim & Environ (forthcoming).

13 Juan Moreno-Cruz, Katharine Ricke and David Keith, 'A Simple Model to Account for Regional Inequalities in the Effectiveness of Solar Radiation Management' (2012) 110 Clim Change 649. Consider that both climate change and climate engineering may satisfy the definitions of 'pollution', 'adverse effect' or 'damage' which multilateral environmental agreements seek to reduce. More general obligations to protect the environment further support climate engineering research. For details, see Reynolds (n 12).

14 Jesse Reynolds and Floor Fleurke, 'Climate Engineering Research: A Precautionary Response to Climate Change?' (2013) Carbon Clim L Rev 101.

15 For treaty details, see Reynolds (n 12).

16 Of course, the positions are rarely at the extremes of the suggested axes and often cannot be placed on a clear, single 'location'.

17 Scott Barrett, 'The Incredible Economics of Geoengineering' (2008) 39 Envtl & Resour Econ 45, 53; Albert Lin, 'Geoengineering Governance' (2009) 8 Issues Legal Schol, 17–26; Karen Scott, 'International Law in the Anthropocene: Responding to the Geoengineering Challenge' (2013) 34 Mich J Int'l L 309, 355; Michael Zürn and Stefan Schäfer, 'The Paradox of Climate Engineering' (2013) 4 Glob Pol'y 266, 273.

18 Daniel Bodansky, 'May We Engineer the Climate?' (1996) 33 Clim Change 309, 319; David Victor, 'On the Regulation of Geoengineering' (2008) 24 Oxford Rev Econ Pol'y 322, 331–32; William Daniel Davis, 'What Does "Green" Mean?: Anthropogenic Climate Change, Geoengineering, and International Environmental Law' (2009) 43 Ga L Rev 901, 928–38; David Victor and others, 'The Geoengineering Option: A Last Resort Against Global Warming?' (2009) 88 Foreign Aff 64, 75; David Keith, Edward Parson and M Granger Morgan, 'Research on Global Sun Block Needed Now' (2010) 463 Nature 426, 427; Richard Elliot Benedick, 'Considerations on Governance for Climate Remediation Technologies: Lessons from the "Ozone Hole"' (2011) 4 Stan JL Sci Pol'y 6, 7–8; Parson and Ernst (n 11) 324.

emphasise the benefits of initially developing norms from the bottom-up,[19] coordinating scientific activities (perhaps through central institutions),[20] and a well-crafted moratorium on deployment and research projects above a certain threshold.[21] As a second dimension of variability, some scholars believe that many countries should be brought into forums for developing international regulation—whatever their nature—as early as possible,[22] whereas a counter position is that a smaller group of states would be more effective.[23]

This article is concerned chiefly with those proposed climate engineering methods that may be effective and affordable yet pose significant risks. This presently includes SRM techniques such as stratospheric aerosol injection and marine cloud brightening, although this set could change over time. Even though carbon dioxide removal by ocean fertilisation could arguably be included, it appears to now be fairly well regulated,[24] a recent incident notwithstanding.[25] Therefore, from here onward, 'climate engineering' will refer only to these relatively riskier, weakly regulated SRM methods.

19 Victor (n 18) 332–33; Davis (n 18) 941–42; Victor and others (n 18) 74; Keith, Parson and Morgan (n 18) 427; Lisa Dilling and Rachel Hauser, 'Governing Geoengineering Research: Why, When and How?' (2013) 121 Clim Change 553; M Granger Morgan, Robert R Nordhaus and Paul Gottlieb, 'Needed: Research Guidelines for Solar Radiation Management' (2013) 29 Issues Sci Tech 37, 41–43; Parson and Ernst (n 11) 324–25; Stefan Schäfer and others, 'Field Tests of Solar Climate Engineering' (2013) 3 Nature Clim Change 766.

20 Victor (n 18) 332–33; Davis (n 18) 940–44; Victor and others (n 18) 73–74; John Virgoe, 'International Governance of a Possible Geoengineering Intervention to Combat Climate Change' (2009) 95 Clim Change 103, 116–17; Keith, Parson and Morgan (n 18) 427; Benedick (n 18); Daniel Bodansky, 'Governing Climate Engineering: Scenarios for Analysis' (2011) 11–47 The Harvard Project on Climate Agreements Discussion Papers, 29; Dilling and Hauser (n 19).

21 Ralph Cicerone, 'Geoengineering: Encouraging Research and Overseeing Implementation' (2006) 77 Clim Change 221; Davis (n 18) 944–45; Morgan, Nordhaus and Gottlieb (n 19) 41–42; Edward Parson and David Keith, 'End the Deadlock on Governance of Geoengineering Research' (2013) 339 Science 1278, 1279.

22 Bodansky (n 18) 320. This implicitly also includes those who propose action through the UNFCCC (n 17), which has universal participation.

23 Victor (n 18) 332; Davis (n 18) 938–40; Benedick (n 18); Parson and Ernst (n 11) 333–34.

24 The Contracting Parties to the London Convention and London Protocol, which regulate marine dumping, developed (and continue to refine) regulations for marine geoengineering permitting only 'legitimate scientific research'. The parties have approved amendments to the London Protocol in order to make this binding. 'Resolution LC-LP.1 on the Regulation of Ocean Fertilization' (2008) in 'Report of the Thirtieth Consultative Meeting and the Third Meeting of Contracting Parties' (2008) IMO Doc LC 30/16; 'Resolution LC-LP.2 on the Assessment Framework for Scientific Research Involving Ocean Fertilization' and 'Assessment Framework for Scientific Research Involving Ocean Fertilization' in 'Report of the Thirty-Second Consultative Meeting and the Fifth Meeting of Contracting Parties' (2010) IMO Doc LC 32/13; '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' in 'Report of the Thirty-Fifth Consultative Meeting and the Eighth Meeting of Contracting Parties (2013) IMO Doc LC 35/15.

25 A 'rogue' scientist performed the largest ocean fertilization experiment to date with the purported intentions of restoring salmon and somehow selling carbon credits in order to fund the project. The Canadian government is currently investigating. See Neil Craik, Jason Blackstock and Anna-Maria Hubert, 'Regulating Geoengineering Research through Domestic Environmental Protection Frameworks: Reflections on the Recent Canadian Ocean Fertilization Case' (2013) Carbon Clim L Rev 117.

3. THE NUCLEAR POWER ANALOGY

The academic discourse discussed above has emphasised the challenging novelties of regulating climate engineering. In this, most authors have referred to previous new risky technologies only in passing and have drawn few useful lessons from them.[26] This is a missed opportunity, and I detail six reasons that nuclear power generation and its attendant risks provide the best existing case in international law from which to draw insights into the potential international regulation of climate engineering and its research. First, both nuclear power and climate engineering present transboundary risks to human health and the environment. An accident at a nuclear power installation can result in dangerous levels of radiation in other countries and non-state areas. This was most evident in the 1986 Chernobyl accident, which occurred in the Soviet Union and contaminated parts of about a dozen other countries. Similarly, large-scale climate engineering field research projects and deployment will threaten the environments of other states and non-state areas in ways that remain partially unknown. The most significant risks are changes in rainfall patterns and in sunlight characteristics due to SRM, in turn impacting ecosystems and agriculture.[27] Larger environmental changes caused by SRM are not out of the question.[28]

Second, the risks posed by nuclear power and climate engineering are ultra-hazardous, in that they carry low probabilities of very high damage.[29] To date, the vast majority of deaths due to nuclear power generation have occurred as a result of only two accidents, Chernobyl and Fukushima in 2011, which together led to dozens of direct deaths and thousands of indirect ones.[30] The risk of much greater damage, such as from larger accidents or terrorism, is uncertain. In the case of climate engineering, potentially catastrophic hazards include major changes in precipitation and light, and perhaps even alterations in major global phenomena such as the El Niño/ La Niña-Southern Oscillation.[31] These ultra-hazardous risks are difficult to manage because of the long durations between negative events. As a result, little empirical data is available, causing great uncertainty in any cost-benefit analysis.[32] Furthermore, the choice of an intergenerational discount rate has a dramatic effect

26 Eg Barrett (n 17) 51–53, Victor (n 18) 332, and Bodansky, 'Governing Climate Engineering: Scenarios for Analysis' (n 20) 24 briefly mention the European Organization for Nuclear Research and its Large Hadron Collider. Nuclear safety or weapons were brought up by Bodansky, 'May We Engineer the Climate?' (n 18) 318; Victor (n 18) 328; Virgoe (n 20) 112; Bidisha Banerjee, 'The Limitations of Geoengineering Governance in a World of Uncertainty' (2011) 4 Stan JL Sci & Pol'y 15, 32–33.

27 Simone Tilmes and others, 'The Hydrological Impact of Geoengineering in the Geoengineering Model Intercomparison Project (GeoMIP)' (2013) 18 J Geophys Res 11036; J Pongratz and others, 'Crop Yields in a Geoengineered Climate' (2012) 2 Nat Clim Change 101.

28 Peter Braesicke, Olaf Morgenstern and John Pyle, 'Might Dimming the Sun Change Atmospheric ENSO Teleconnections as We Know Them?' (2011) 12 Atmos Sci Lett 184.

29 Other ultra-hazardous activities in international law are maritime oil transportation, space activities, and activities involving hazardous substances. See Hanqin Xue, *Transboundary Damage in International Law* (CUP 2003) 19–72.

30 Chernobyl Forum, 'Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine' <http://www.iaea.org/Publications/Booklets/ss.html> 14, 16; John Ten Hoeve and Mark Jacobson, 'Worldwide Health Effects of the Fukushima Daiichi Nuclear Accident' (2012) 5 Energy Environ Sci 8743.

31 (n 27–28).

32 See eg Martin Weitzman, 'On Modeling and Interpreting the Economics of Catastrophic Climate Change' (2009) 91 Rev Econ Stat 1.

on cost and benefit estimates but is ethically ambiguous.[33] Moreover, if centuries-long trends continue, then future generations will most likely have greater capacities to adapt to negative events. Future generations will also probably have different values concerning, among other things, risk aversion, equity, and the values of biodiversity and 'undisturbed nature' versus the well-being of people. Finally, costly efforts to reduce low-probability risks that are infrequent or have not yet happened are usually politically unpopular, limiting action by political leaders in democratic states.[34]

The third basis for an analogy between nuclear power and climate engineering is that both present risk–risk tradeoffs, in which the reduction of targeted risks creates a new set of countervailing risks. Nuclear power is a substitute for the burning of fossil fuels, which causes deaths and illness in the short term and climate change in the long term. One recent study placed the benefits to date of the existing capacity of nuclear power relative to the use of fossil fuels at 1.84 million prevented air-pollution deaths and two years' worth of averted global greenhouse gas emissions.[35] In the case of climate engineering, it may be able to greatly reduce climate change risks to humans and the environment, while posing some risks of its own. These risk–risk tradeoffs are difficult to manage in that the two sets of risks may be of fundamentally different types and/or affect different populations or ecosystems.[36] Applying traditional legal norms, especially precaution, becomes very difficult under these circumstances.

Fourth, although the politics of climate engineering presently remain amorphous, they are likely to emerge in a similar pattern as that of nuclear power. Among the general population, nuclear power has been, and climate engineering probably will be, perceived as unknown, dreadful and involuntary, characteristics that are correlated with strong aversion.[37] Among political leaders, nuclear power has been, and climate engineering probably will be, developed in the context of potential dual-use

33 The discount rate is the quantification of people's preference for receiving rewards sooner rather than later (and for incurring losses later rather than sooner). This is problematic when considering subsequent generations. On one hand, intergenerational discounting amounts to transferring costs onto another population cohort (ie, the future) which lacks a voice in present decision-making processes, while those with a voice reap the benefits. On the other hand, using an intergenerational discount rate of zero also produces perverse results. For example, all but the most essential current consumption would be unjustified, and instead nearly all present resources would be invested in future generations, even though they will be wealthier than us. See Paul Portney and John Weyant (eds), *Discounting and Intergenerational Equity* (Resources for the Future 1999).

34 Although support for action against climate change is popular in the abstract, it is low when it competes with other objectives. Eg, in an American annual survey, 'dealing with global warming' has been last or second-to-last among 15–20 public policy priorities since its inclusion in 2007. The Pew Research Centre for People and the Press, Twelve Years of the Public's Top Priorities (2013) <http://www.people-press.org/interactives/top-priorities> accessed 7 November 2013.

35 Pushker Kharecha and James Hansen, 'Prevented Mortality and Greenhouse Gas Emissions from Historical and Projected Nuclear Power' (2013) 47 Environ Sci Tech 4889.

36 John Graham and Jonathan Baert Wiener, 'Confronting Risk Tradeoffs' in John D Graham and Jonathan Baert Wiener (eds), *Risk vs Risk: Tradeoffs in Protecting Health and the Environment* (Harvard UP 1995) 19–41.

37 Paul Slovic, 'Perception of Risk' (1987) 236 Science 280; Ellen Peters and Paul Slovic, 'The Role of Affect and Worldviews as Orienting Dispositions in the Perception and Acceptance of Nuclear Power' (1996) 26 J Appl Soc Psychol 1427; Adam Corner and others, 'Messing with Nature? Exploring Public Perceptions of Geoengineering in the UK' (2013) 23 Glob Envtl Change 938. See also Dan Kahan and others, 'Geoengineering and the Science Communication Environment: A Cross-Cultural Experiment' (2012) The Cultural Cognition Project Working Paper 92 <http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1981907> accessed 10 October 2013.

and highly heterogeneous state capacity. Specifically, nuclear power is internationally promoted, but can be used as a basis for nuclear weapons programmes, which the nuclear powers desire to limit to themselves.[38] Similarly, climate engineering research appears to be encouraged by existing international environmental law, and can be expected to be pursued by states.[39] And as with nuclear weapons, countries' relative power will be impacted by their acquisition of an ability to deploy large scale climate engineering. Those states with this capacity will wish to prevent inappropriately risky, premature, or militarised implementation and, will also most likely, wish to prevent its proliferation to a greater number of states in order to maintain their relatively greater power.

Fifth, scientists and technological expertise play a necessary role in the regulation of nuclear power and climate engineering. Of course, environmental law cannot be disentangled from the science on which it is based. Regulators must rely upon technical experts and their specialised knowledge due to the complex and dynamic nature of certain issues. In turn, these experts can form close-knit communities that are influential in establishing norms and shaping policy.[40] Expertise is also used as a means to establish and maintain legitimacy, particularly within regulated domains—such as nuclear power and climate engineering—that pose uncertainty and/or complexity and that cross lines between states and among international, national, quasi-public, and private institutions.[41] Indeed, '[i]n emerging areas of international law concerned with the regulation of risk, expertise based on scientific and technical knowledge is typically viewed as a plausible basis for legitimating the growing authority exercised by relevant international rules'.[42] Of course, these experts are also likely to be practitioners, and thus to the extent that they influence regulation, it partially takes on the form of self-regulation. This brings both benefits and challenges. In addition to greater knowledge and legitimacy, the inclusion of the regulated actors in the development, monitoring, and enforcement of regulation can make it more effective due to less adversarial relationships between the regulators and regulated. This is also the case when it is difficult for consumers to learn about the quality of a product before purchasing it, and when the producers' reputations are important, sensitive, and shared.[43] In the cases of

38 The peaceful development of nuclear technologies and the prevention of nuclear weapon proliferation are the foundations of international nuclear law. Statute of the International Atomic Energy Agency (opened for signatures 26 October 1956, entered into force 29 July 1957) 26 UNTS 3, arts II, III; Treaty on the Non-Proliferation of Nuclear Weapons (opened for signatures 1 July 1968, entered into force 5 March 1970) 729 UNTS 161 (Non-Proliferation Treaty) arts IV, V.

39 Text to (n 13–15).

40 Although nuclear power scientists and engineers appear to meet Haas's criteria for an epistemic community, he asserts that they enjoy less political influence because their research is expensive and thus less independent of their funding source. Peter Haas, 'Epistemic Communities' in Daniel Bodansky, Jutta Brunnée and Ellen Hey (eds), *The Oxford Handbook of International Environmental Law* (OUP 2007) 763–65.

41 Daniel Bodansky, 'The Legitimacy of International Governance: A Coming Challenge for International Environmental Law?' (1999) 93 Am J Int'l L 596, 601; Gráinne de Búrca, 'Developing Democracy Beyond the State' (2008) 36 Colum J Transnat'l L 221, 240–46.

42 Jacqueline Peel, *Science and Risk Regulation in International Law* (CUP 2010) 14.

43 Thomas Gehrig and Peter-J Jost, 'Quacks, Lemons, and Self Regulation: A Welfare Analysis' (1995) 7 J Reg Econ 309; Andrew King, Michael Lenox and Michael Barnett, 'Strategic Responses to the Reputation Commons Problem' in Andrew Hoffman and Marc Ventresca (eds), *Organizations, Policy and the Natural Environment: Institutional and Strategic Perspectives* (Stanford University Press 2002).

nuclear power and climate engineering, the 'consumers' can include the government agencies which approve and fund the activities and the voters who lend support, the 'quality of the product' includes the generated risks, 'purchasing' is done through grants or regulatory approval, and the 'producers' are energy companies or climate engineering researchers. On the other hand, the self-regulated can use their position for rent-seeking behaviour, at the expense of both the public and potential competing 'producers'. Yet regulatory regimes are rarely pure self-regulation, with a spectrum of hybrid forms and roles for the regulated actors available.

The final basis for a nuclear power–climate engineering analogy is that the regulations of the two technologies present similar problem structures. Both nuclear power and climate engineering research are, in some aspects, global public goods.[44] The former is one in that it is a substitute for the burning of fossil fuels.[45] From this, the world benefits from reductions in greenhouse gas emissions, even though the country hosting nuclear power bears the costs, including the environmental risks. Similarly, climate engineering research can increase shared knowledge of possible additional responses to climate change, while the costs are borne by few.[46] Notably, both are positive only to the extent that they reduce the negative effects of another global public 'good', greenhouse gas emissions. More specifically, the emissions-reducing aspect of nuclear power and climate engineering research are aggregate effort global public goods,[47] whose supply is a function of worldwide cumulative efforts, and both are promoted in international law.[48] Scott Barrett concludes that international cooperation—generally through multilateral agreements—is useful in the promotion of global public goods in order to coordinate efforts, share costs, tap potential where local capacity may be lacking (such as in developing countries), and overcome free-riding.[49] This international cooperation need not be global, because non-participating states do not hinder the provision of the good, although they may unjustly free-ride on its provision by others.

At the same time, nuclear power and climate engineering research each increase the likelihood of events with large negative effects: the former could lead to

44 A public good is something which is non-rivalrous and non-excludable. Its effects can be positive or negative for various people or states. See Daniel Bodansky, 'What's in a Concept? Global Public Goods, International Law, and Legitimacy' (2012) 23 Eur J Int L 651. Of course, public goods also often also confer private benefits.

45 Text to (n 35).

46 Scientific research and accessible knowledge in general are public goods. Doinique Foray, *The Economics of Knowledge* (MIT Press 2004) 113–29. Research as a public good assumes that the results are published and not subject to extensive intellectual property claims. Recently proposed norms for climate engineering research call for transparency, open publication of positive and negative results, and/or no private intellectual property. Michael MacCracken and others, *The Asilomar Conference Recommendations on Principles for Research into Climate Engineering Techniques* <http://climateresponsefund.org/> accessed 19 November 2013; Jane Long and others, *Geoengineering: A National Strategic Plan for Research on the Potential Effectiveness, Feasibility, and Consequences of Climate Remediation Technologies* <http://bipartisanpolicy.org/library/report/task-force-climate-remediation-research> accessed 19 April 2013; Steve Rayner and others, 'The Oxford Principles' (2013) 121 Clim Change 499.

47 See the distinction among single best efforts, weakest links, and aggregate efforts in Jack Hirshleifer, 'From Weakest-link to Best-shot: The Voluntary Provision of Public Goods' (1983) 41 Pub Choice 371; Scott Barrett, *Why Cooperate? The Incentive to Supply Global Public Goods* (OUP 2007).

48 (n 38); text to (n 13–15).

49 Barrett (n 47), ch 3.

accidents, terrorism, and weapons proliferation, while the latter makes inappropriately risky, premature, or militarised climate engineering deployment possible. Efforts to *prevent* these negative events are mixtures of weakest link global public goods, whose provision depends upon the state with the weakest performance, and mutual restraint, in which all states must refrain from doing something.[50] Barrett argues that international coordination is needed in these cases in order to establish standards and sometimes to share costs, but that multilateral agreements are less useful than with aggregate effort global public goods. Instead, norms, consensus and customary law can better provide incentives to those laggard states that may not otherwise have the incentives to join a multilateral agreement.[51] Notably, in the two cases here, the desire to prevent negative events is particularly acute among the advocates and practitioners of the technology. This is because the reputations of the individual actors (ie nuclear power providers or climate engineering researchers) are important and sensitive due to the controversial nature of their practice, and require a social license to operate.[52] However, the actors are relatively small in number and their identities are not clearly distinguished by members of the public. Consequently they share a reputations 'common'.[53] Since these actors are few in number, they may be able to cooperate in order to maintain their shared reputation.[54]

Of course, nuclear power and climate engineering differ in important ways. The risks of nuclear power are known, and power plants can reasonably strive for negligible harm to humans and the environment, whereas climate engineering inherently will have some unknown risks—at least initially—and will impact the environment. When nuclear accidents do occur, the negative effects are regional and of a limited type, while those from climate engineering deployment could be global and could take a wide range of forms. At the same time, the benefits of climate engineering research (and perhaps deployment) would be more clearly, and probably more widely distributed, than the benefits of nuclear power. Furthermore, nuclear power is a relatively consistent practice year-to-year, whereas climate engineering research would be more dynamic, changing in light of previous results. Relatively speaking, determining causation of damages is easier with nuclear power because of radioactive isotopes' traceability, the predictability of radioactive materials' movement and lifespan, and better knowledge of radiation's effects, while the precise impact of a climate engineering field experiment may be difficult to pinpoint. Finally, the line between promoted and proscribed applications is clearer in the case of nuclear technologies. Nevertheless, some useful insights from experience with the existing technology of nuclear power can be drawn.

50 See n 47.

51 Barrett (n 47) chs 2, 5.

52 Neil Gunningham, Robert Kagan and Dorothy Thornton, 'Social License and Environmental Protection: Why Businesses Go Beyond Compliance' (2004) 29 L & Soc Inquiry 307.

53 Consider the reactions among the public and politicians around the world to nuclear accidents such as Three Mile Island, Chernobyl, and Fukushima. Matthew Fuhrmann, 'Splitting Atoms: Why Do Countries Build Nuclear Power Plants?' (2012) 38 Int'l Interact 29.

54 King, Lenox and Barnett (n 43).

4. THE REGULATION OF NUCLEAR POWER

The international regulation of nuclear power is vast, but here, a few relevant observations will suffice. These are based primarily on international regulation concerned with reducing the risks of accidents at civilian nuclear power facilities, including both ex ante accident prevention and ex post accident response. However, the basis for these observations extends to international regulation of nuclear weapons proliferation, because nuclear power and climate engineering research are each promoted while the proliferation of nuclear weapons and the risky, premature, or militarised deployment of climate engineering are widely condemned.

It is both obvious yet noteworthy that nuclear power, perhaps the riskiest of the ultra-hazardous activities recognised under international law, is not illegal. Indeed, it is actively promoted under international law[55] and the 'research, production and use of nuclear energy for peaceful purposes' constitute an 'inalienable right' of states.[56] Instead, like other transboundary risks, nuclear power must be carried out with due diligence, which in this case includes among other things national regulation consistent with globally promulgated standards, prior assessment, notification and international peer review. This is evident in the 1994 Convention on Nuclear Safety, the first and most important binding international law regarding the safety standards of civilian nuclear power facilities.[57] Parties are obligated to 'take the appropriate steps to ensure' that general standards regarding—among other things—the siting, design, construction, and operation of nuclear installations; emergency preparation; funding for the safety of nuclear facilities; and training of staff.[58] Parties must maintain a domestic regulatory framework that establishes safety standards, issues licenses, inspects installations and enforces the regulations.[59] The Convention also calls for its parties to issue reports on their progress for peer review meetings.[60]

Second, states generally prefer to retain sovereignty, and this preference is stronger the closer an issue is to national security. This is most apparent in the case of nuclear weapons, in which states such as China, France, India, Israel and the USA have refused to join widely adopted agreements and/or have rejected the decisions of international courts when these agreements or rulings were inconsistent with their nuclear ambitions. France and China never signed the 1963 Limited Test Ban Treaty—which has 126 parties including all other known nuclear weapons powers—and subsequently continued and began testing, respectively.[61] When the International Court of Justice ruled that France's atmospheric testing in the South Pacific might violate international law and issued Interim Measures (roughly analogous to an injunction), France rejected the Court's jurisdiction and proceeded with

55 N 38.

56 Non-Proliferation Treaty (n 38) art IV.1. The UN General Assembly has also declared that the peaceful development and use of nuclear energy to be a right of all states. UN General Assembly 32/50 (1977).

57 Convention on Nuclear Safety (opened for signatures 17 June 1994, entered into force 24 October 1996) 1963 UNTS 293.

58 ibid arts 10–19.

59 ibid arts 7–8.

60 ibid arts 5, 20–22.

61 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water (opened for signatures 5 August 1963, entered into force 10 October 1963) 480 UNTS 43.

atmospheric testing.[62] The 1996 Comprehensive Nuclear Test Ban Treaty has been ratified by 159 countries, but remains not in force due to the non-participation of eight 'select' countries, six of which have nuclear weapons (China, India, Israel, North Korea, Pakistan and the USA) and one of which appears to have ambitions for them (Iran).[63] The 1968 Non-Proliferation Treaty, with 189 parties, recognised the then-five nuclear weapon states, which are the permanent members of the UN Security Council.[64] All four countries that have developed nuclear weapons since then either never ratified the treaty or withdrew from it. Notably, such withdrawals are explicitly allowed if a state 'decides that extraordinary events, related to the subject matter of this Treaty, have jeopardized the supreme interests of its country'.[65] It also commits parties with nuclear weapons to 'pursue negotiations in good faith' on agreements for complete nuclear disarmament.[66] Those five parties have essentially ignored this.

This preference is also present, albeit to a lesser degree, in the case of nuclear power, whose international regulation is soft in form and limited in substance. Three Conventions are modest and have wide participation. The Convention on Nuclear Safety relies upon soft commitments to general principles of nuclear safety, 'reaffirm[s] that responsibility for nuclear safety rests with the State', and lacks both independent monitoring for compliance and an enforcement mechanism for non-compliance.[67] The Convention on Early Notification of a Nuclear Accident requires parties to notify neighbouring and the International Atomic Energy Agency (IAEA) Member States in the event of a potentially significant transboundary release of radiation, and partially standardises the information to be shared.[68] Parties to the Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency are not obligated to provide or accept assistance but instead are obligated only to inform the IAEA of their available expertise and equipment.[69]

In contrast, the nuclear liability regimes—founded upon the Paris Convention for Western Europe and the Vienna Convention for other countries—could be potentially effective but are not adequately ratified.[70] Under these, liability is channelled to

62 Nuclear Tests cases: *Australia v France* (Interim Measures) (1973) ICJ Reports 99; *New Zealand v France* (Interim Measures) (1973) ICJ Reports 135.

63 Comprehensive Nuclear Test-Ban Treaty (opened for signatures 24 September 24 1996) 35 ILM 1439.

64 Non-Proliferation Treaty (n 38).

65 ibid art X.

66 ibid art VI. The International Court of Justice unanimously concluded that 'There exists an obligation to pursue in good faith and bring to a conclusion negotiations leading to nuclear disarmament in all its aspects under strict and effective international control.' *Legality of the Threat or Use of Nuclear Weapons*, Advisory Opinion, 8 July 1996 [1996] ICJ Rep 226.

67 Convention on Nuclear Safety (n 57). Quote is from Preamble, para iii.

68 Convention on Early Notification of a Nuclear Accident (opened for signatures 26 September 1986, entered into force 27 October 1986) 1439 UNTS 275.

69 Convention on Assistance in Case of a Nuclear Accident or Radiological Emergency (opened for signatures 26 September 1986, entered into force 26 February 1987) 1457 UNTS 133.

70 The cornerstones are the Paris Convention on Third Party Liability in the Field of Nuclear Energy (opened for signatures 29 July 1960, entered into force 1 April 1968) 956 UNTS 251 (Paris Convention); Vienna Convention on Civil Liability for Nuclear Damage (opened for signatures 21 May 1963, entered into force 12 November 1977) 1063 UNTS 265 (Vienna Convention). These are furthered by numerous supplements and protocols, some of which have minimal participation or are not yet in force. For a thorough overview, see Stephan Tromans, *Nuclear Law: The Law Applying to Nuclear Installations and Radioactive Substances in Its Historic Context* (2nd edn, Hart 2010) 166–82.

the operator of the nuclear power installation, who is solely and absolutely liable for transboundary damages.[71] Liability is limited in both time and amount. Operators are required to carry insurance up to a minimum that is stated in the treaties, but may be increased by the individual parties. If damages exceed the operator's liability, the state will provide public funds up to a second threshold. Under the Paris Convention regime, parties are collectively liable up to yet a higher amount. Legal actions are to be pursued in the courts of the party where the accident occurred. In theory, this liability regime is beneficial in a number of ways. Absolute liability allows the victims of a nuclear accident access to remedies without the burden to demonstrate fault. Furthermore, the courts need not define appropriate levels of care, which would be difficult given nuclear power's complexity. The responsibilities of the victims and the courts are further lessened by the channelling of liability to a single operator. Moreover, the nuclear industry has greater clarity and its operators are generally able to obtain insurance due to the channelling of liability to the operator and the limitations in amount and time. In reality, however, the effectiveness of the international nuclear accident liability regime is unclear. Less than half of the world's nuclear power capacity is located in a country that is a party to one of the two core treaties.[72] Furthermore, the limitations on the amount of liability are low, presently approximately 350 million euro, whereas a major nuclear accident could cost tens or hundreds of billions of euro.[73] The limitation of liability in time, generally at 10 years, also could be problematic, as some manifestations of radiation such as cancer may not occur within that time. Finally, the covered damage in the Western Europe regime is limited to people and property, not inclusive of damage to the environment or of lost economic activity. Notably, each of these shortcomings is addressed by existing conventions, protocols and supplementaries that are not yet in force or ratified only by few states with little nuclear power capacity.

From these details, we see that countries do have incentives to commit to general international safety principles and internationally coordinate information sharing and cooperation in the event of an accident. On the other hand, they lack adequate incentives for the international harmonisation of safety regulations and for strong liability measures. As a result, the regulation of nuclear power through public

71 Although demonstration of fault is not required, there are exceptions such as war, negligence of the victim, and grave natural disasters.

72 International Atomic Energy Agency, Nuclear Share of Electricity Generation in 2012 (2012) <http://www.iaea.org/PRIS/WorldStatistics/NuclearShareofElectricityGeneration.aspx> accessed 21 March 2014; Nuclear Energy Agency 'Paris Convention on Nuclear Third Party Liability: Latest Status of Ratifications or Accessions' <http://www.oecd-nea.org/law/paris-convention-ratification.html> accessed 21 March 2014; International Atomic Energy Agency, 'Vienna Convention on Civil Liability for Nuclear Damage' <http://www.iaea.org/Publications/Documents/Conventions/liability_status.pdf> accessed 21 March 2014.

73 Damages from the Chernobyl accident may have been on the order of hundreds of billions of euro. Chernobyl Forum, 'Chernobyl's Legacy: Health, Environmental and Socio-Economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine' <http://www.iaea.org/Publications/Booklets/ss.html>, 33 Ludivine Pascucci-Cahen and Momal Patrick, 'Massive Radiological Releases Profoundly Differ from Controlled Releases' Institut de Radioprotection et de Sûreté Nucléaire (French Institute for Radiological Protection and Nuclear Safety) <http://www.irsn.fr/FR/Actualites_presse/Actualites/Documents/EN_Eurosafe-2012_Massive-releases-vs-controlled-releases_Cost_IRSN-Momal.pdf> accessed 15 March 2013.

international law is soft in form and limited in substance, and will most likely remain so. This implies that countries are reluctant to make strong binding commitments on a topic as close to national security as nuclear power, and that there will generally be trade-offs between proposed agreements' strength and their breadth of participation. Indeed, given that 'states continue to resist significant intrusions upon their sovereignty in the area of nuclear safety…modest and incremental inroads into autonomous national decisionmaking may be the most effective means of creating and maintaining state commitments'.[74]

The third observation about the international regulation of nuclear power is that it extends beyond centralised public international law. Instead, there are partially overlapping systems of regulation that differ in their geographic scales, breadths of participation, means and degrees of legalisation. These includes informal and formal norms; associations of experts and of institutional practitioners; self-, co-, meta- and private regulation and soft and binding policies. These occur at the national and international scales. Specifically, the most important international vehicle for the promotion of nuclear power safety is the standards of the IAEA.[75] These standards are binding only for projects that receive assistance from the IAEA, and such projects and their facilities are subject to inspection by the IAEA. However, the standards are influential and widely adopted voluntarily. These 'health and safety standards have been a significant contribution to controlling the risks of nuclear energy [and] have resulted in a high degree of harmonization'.[76] This can be attributed to the involvement of governments, intergovernmental organisations, non-governmental organisations and experts. Furthermore, states can (and sometimes do) voluntarily request from the IAEA inspection and advice for their nuclear facilities. In addition to the IAEA, the UN Scientific Committee on the Effects of Atomic Radiation assesses the effects of exposure to ionising radiation. The International Commission on Radiological Protection, a professional society, builds upon that work and issues recommendations as to how to reduce exposure. These recommendations are often influential in formulating IAEA standards.[77] The Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD), the private industry group World Association of Nuclear Operators, the US-initiated International Framework for Nuclear Energy Cooperation (until recently called the Global Nuclear Energy Partnership) and the World Institute for Nuclear Security reinforce the work of the IAEA in developing nuclear power and ensuring its safety. Their activities are further supported by the promulgation of norms, both informal and more explicit, such as those of the Nuclear Power Plant Exporters.[78]

Fourth, experts and expertise are essential in the regulation of nuclear power, not only because of nuclear power's technical character. A relatively small professional

74 Monica Washington, 'The Practice of Peer Review in the International Nuclear Safety Regime' (1997) 72 NYU L Rev 430, 440, 465.

75 Statute of the IAEA (n 38) arts III.6, XI, XII.

76 Patricia Birnie, Alan Boyle and Catherine Redgwell, *International Law and the Environment* (3rd edn, OUP 2009) 496.

77 ibid 44.

78 Nuclear Power Plant Exporters, 'Principles of Conduct' (2013) <http://nuclearprinciples.org/> accessed 5 May 2013.

cohort such as nuclear engineers and technicians are unlikely to readily accept detailed binding regulations developed by actors who are perceived to be outsiders. Moreover, the promulgation of, and adherence to, technical standards are not enough. Instead, as the experience in the USA after the 1979 Three Mile Island accident revealed, an appropriate culture among experts is necessary, something which can only be achieved with their cooperation.[79] In that case, an industry group—the Institute of Nuclear Power Operations—was formed in order to foster 'communitarian regulation,' which is 'well-defined industry morality that is backed by enough communal pressure to institutionalize responsibility among its members'.[80] Joseph Rees asserts that this organisation was successful because the accident was due to institutional failures, not to hardware or inadequate regulations, and because the nuclear power industry recognised itself as a community of shared fate due to its reputation 'commons'.[81] This is not to say that an activity as risky as nuclear power should be left to self-regulation, but instead to emphasise the need to integrate regulated experts as part of the regulatory process, particularly in technical cases.

Finally, the development of regulation, especially binding multilateral agreements, takes time. This is all the more the case in a dynamic technical field such as nuclear power, in which little is known during its infancy but more becomes known as research progresses. Furthermore, law is based on norms. Although some norms are general, within a new domain these must be refined gradually and emerge somewhat organically. The Convention on Nuclear Safety, arguably the most important multilateral agreement on the topic, was opened for signatures 52 years after the first nuclear reaction and 40 years after the first nuclear power installation. Even the rapid development of international environmental law from 1972 to 1992 was based on norms that initially developed decades earlier.[82]

5. LESSONS FOR CLIMATE ENGINEERING

We can now draw some lessons for the potential international regulation of climate engineering and its research. These will be based on several reasonable assumptions about the behaviour of states and about climate engineering. Regarding the former, I assume that states identify and pursue their self-interests, and will coordinate and cooperate among themselves when it is beneficial to them. In short, this is a

79 The US government's investigation of the accident, as well as other investigations, attributed the root cause to the institutional culture within the nuclear industry. John Kemeney and others, *The Need for Change, the Legacy of TMI: Report of the President's Commission on the Accident at Three Mile Island* (US Government Printing Office 1979); Hyman Rickover, 'An Assessment of the GPU Nuclear Corporation Organization and Senior Management and Its Competence to Operate TMI-l' (1983) <http://archives.dickinson.edu/sites/all/files/files_document/Rickover_Assessment.pdf> accessed 21 March 2014. '[I]f one all-important lesson attaches to the TMI accident, the accident examinations tell us, it mainly concerns…nuclear power's institutional arrangements.' Jospeh Rees, *Hostages of Each Other: The Transformation of Nuclear Safety Since Three Mile Island* (University of Chicago Press 1994) 12.

80 Rees, ibid 87.

81 ibid.

82 Eg Convention between the United States and Other Powers Providing for the Preservation and Protection of Fur Seals (opened for signatures 7 July 1911, entered into force 14 December 1911) 104 BFSP 175; *Trail Smelter Arbitration Tribunal (US v Canada)* (1939) 33 AJIL 182 & (1941) 35 AJIL 684; International Court of Justice, 'Corfu Channel Case (UK v. Albania)' (1949) ICJ Rep 4.

rationalist approach to international relations and to the resulting development of international law.[83] Further, because the climate significantly impacts a variety of state interests, climate change and climate engineering will be seen by states as matters of self-interest and even national security.[84] They will consequently act strongly in order to retain sovereignty in these areas and to maximise their net gains. Regarding climate engineering, I assume that it holds significant potential to reduce climate risks to humans and the environment, although it also poses risks of its own. Thus, climate engineering research should be pursued. Indeed, this has been the conclusion of a number of expert bodies,[85] and national governments are beginning to earmark funds for climate engineering research.[86] Finally, climate engineering should be appropriately internationally regulated in order to manage its transboundary risks. This is essentially the unanimous opinion of those who advocate for consideration of, and research into, climate engineering.[87]

I will first describe what is unlikely, and then what is likely, to occur. Note that one could make a wider range of observations, predictions, and recommendations regarding the international regulation of climate engineering. I limit myself here to those that can be inferred from the experience of nuclear power.

Climate engineering is not and will not be internationally prohibited, despite the desires of some.[88] In fact, its research is, and will continue to be, promoted, both internationally and domestically.[89] Moreover, climate engineering will not be the subject of a binding global agreement or protocol to an existing agreement, at least anytime in the near future, for several reasons. To the extent that climate change threatens state interests, climate engineering may offer an opportunity to reduce those threats. Those states with the capacity to research climate engineering or to deploy it—which will be the relatively powerful ones—as well as those states which are especially vulnerable to climate change will resist and not participate in proposed

83 See Andrew Guzman, *How International Law Works: A Rational Choice Theory* (OUP 2008).

84 See Daniel Moran (ed), *Climate Change and National Security: A Country-level Analysis* (Georgetown University Press 2011); Michael Link and others, 'Possible Implications of Climate Engineering for Peace and Security' (2013) 94 Bull Am Meteorol Soc ES13.

85 Innovation, Universities, Science and Skills Committee, *Engineering: Turning Ideas into Reality* (HC 2008-09, 50-I); Shepherd and others (n 6); Pamela Matson and others, *Advancing the Science of Climate Change* (National Academies Press 2010); Wilfried Rickels and others, *Large-Scale Intentional Interventions into the Climate System? Assessing the Climate Engineering Debate* <http://www.kiel-earth-institute.de/scoping-report-climate-engineering.html> accessed 14 November 2013; Jane Long and others (n 46); Nationalen Komitee für Global Change Forschung, der DFG Senatskommission für Ozeanographie, and der DFG Senatskommission Zukunftsaufgaben der Geowissenschaften, *Forschungsfragen einer gesellschaftlichen Herausforderung* <http://www.dfg.de/download/pdf/dfg_im_profil/reden_stellungnahmen/2012/stellungnahme_climate_engineering_120403.pdf> accessed 14 November 2013.

86 Engineering and Physical Sciences Research Council, *Climate Geoengineering Sandpit* <http://www.epsrc.ac.uk/funding/calls/2009/Pages/climategeoengsandpit.aspx> accessed 14 November 2013; Deutsche Forschungsgemeinschaft, *DFG-Schwerpunktprogramm 'Climate Engineering: Risks, Challenges, Opportunities?' (SPP 1689)* <http://www.dfg.de/Foerderung/info_wissenschaft/archiv/2012/info_wissenschaft_12_22/index.html> accessed 14 November 2013.

87 Eg the reports in (n 85) call for regulation.

88 Gerd Winter, 'Climate Engineering and International Law: Last Resort or the End of Humanity?' (2011) 20 RECIEL 277, 288.

89 Reynolds (n 12); n 86. Other countries and the EU have also publicly funded climate engineering research.

restrictive multilateral climate engineering agreements.[90] This is similar to the case of nuclear power, which internationally is regulated only weakly, as it provides material benefits to states—especially the powerful ones—who prefer to retain sovereignty over an issue so closely related to national security.[91] Furthermore, too much about climate engineering and its research remains uncertain: what it precisely may be, what forms it may take, what benefits and risks it may entail, how these effects and risks would be distributed, how reversible it would be, what states wish to get out of it, and what they wish to avoid. Any detailed or restrictive language would thus have unforeseeable consequences.[92] Uncertainty may be gradually reduced, of course. Recall that decades passed between the development of nuclear power and the passage and ratification of the Convention on Nuclear Safety, and climate engineering is at this moment arguably more uncertain than nuclear power was in the 1950s. The topic also remains too controversial. This is partially due to the lingering uncertainty, but also because it runs contrary both to the current 'dominant paradigm' in international climate debates of emissions reduction and adaptation, and to the underlying logic of many actors who advocate for action to reduce climate risks.[93] As a result, few of them have anything to gain—and much to lose—by proposing a new international law regime for climate engineering. Finally, after the flurry of multilateral environmental agreements of the 1990s, the international community has a generally low appetite for new treaties.

Instead, as with nuclear power, climate engineering research is likely to be internationally promoted and regulated gradually with a low degree of legalisation—at least initially—through a plurality of means and institutions.[94] As a first step, norms regarding, for example, transparency and the role of intellectual property must be developed.[95] This process will require significant time and a wide range of relevant actors, including experts such as climate engineering researchers.[96] While some of this discourse may occur within existing international legal forums such as the UNFCCC-COP

90 Of course, this could change if research indicates that climate engineering would increase risks more than decrease them and/or that many countries (or a few powerful ones) would be put at serious risk.

91 Text to (n 55–74).

92 Consider the often negative reaction against the statements from the Conference of Parties to the Convention on Biological Diversity (CBD-COP), eg Intergovernmental Oceanographic Commission Ad Hoc Consultative Group on Ocean Fertilization, 'Statement of the IOC Ad Hoc Consultative Group on Ocean Fertilization' in *Report on the IMO London Convention Scientific Group Meeting on Ocean Fertilization (IOC/INF-1247)* (UNESCO 2008).

93 The climate debates have been used as a vehicle for two other agendas, besides reducing risks to humans and the environment. The 'greener' environmental groups seek to reduce the overall footprint of humanity on the natural world. Others see action against climate risks as a means to international retributive justice. Climate engineering would not further either of these two agendas. See Gareth Davies, 'The Psychological Costs of Geoengineering: Why It May Be Hard to Accept Even If it Works' in Wil Burns and Andrew Strauss (eds), *Climate Change Geoengineering: Philosophical Perspectives, Legal Issues, and Governance Frameworks* (CUP 2012) 71–77.

94 Consider the roles of and interactions among various institutions in the case of nuclear power and its safety. Text to (n 75–78).

95 This is already occurring. Text to (n 106–108).

96 This is not to imply that the roles of experts and expertise in law are simple. Indeed, there is a large literature on their sometimes problematic relationship. For differing perspectives, see Sheila Jasanoff, *Science at the Bar: Law, Science, and Technology in America* (Harvard University Press 1997); Roger Pielke, Jr, *The Honest Broker: Making Sense of Science in Policy and Politics* (CUP 2007).

and the Intergovernmental Panel on Climate Change, other sites with less prior commitment to the 'dominant paradigm' of emissions reduction and adaption, and greater opportunity for candour will also be necessary. After some time, these norms will lay the foundation for soft policy among non-legal institutions, such as national and international scientific societies. Once significant climate engineering field testing begins, it may then be in States' interest to coordinate their climate engineering activities, formally and informally, to establish and clarify standards, minimise interference among projects, distribute costs, build capacity, combat free-riding in research efforts and prevent misuse. This would be not unlike the IAEA's three pillars: safety and security, fostering technology and preventing proliferation.[97] A key question at this juncture—if not sooner—will be whether to place a moratorium on large-scale field research and deployment, and if so, by whom and how.

Once norms and soft policies are in place, and once field activities have reached a scale that they may pose transboundary risks, there will then be a larger role for the development of international law, broadly defined. Considering the low level of legalisation of existing international law governing nuclear power, resulting documents concerning climate engineering will likely be—even then—non-binding guidelines and relatively soft multilateral agreements.[98] These will be dominated by procedural duties such as prior assessment, notification, monitoring, information sharing, public access to information, consultation and coordination of responses to negative events. Meanwhile, states could at that time develop, monitor and enforce more detailed domestic regulations. Liability for damages will be controversial. Generally speaking, a liability regime similar to that for nuclear accidents may be beneficial, at least in theory.[99] This could involve strict, limited liability with channelling to the state instead of the 'operator' (due to researchers' relatively smaller budgets) and with pooling of liability among those states active in research (due to the very large potential damages and to the public good character of climate engineering research). However, proving causation in a climate liability claim would be very challenging.

When and if some states gain the capability for the deployment of large-scale climate engineering methods, they will wish to limit such ability to themselves. Although this might give a first impression of brute power aggrandisement, it may be beneficial to have a smaller number of countries that can intervene in the global climate.[100] This would minimise conflicts among States and interference among climate engineering projects, assuming that decisions to affect the global climate are taken in a

97 The functions of the Agency were originally provided in Statute of the IAEA (n 38) art III.A but then expanded, particularly through the Non-Proliferation Treaty (n 38) and the Convention on Nuclear Safety (n 57).

98 Some may argue that the 2010 decision on climate engineering by the CBD-COP runs counter to my analysis. However, it uses strongly qualified language and is non-binding. Report of the Tenth Meeting of the Conference of Parties to the Convention on Biological Diversity' UN Doc UNEP/CBD/COP/27 (2010) X/33/8(w). See also Secretariat of the Convention on Biological Diversity, *Geoengineering in Relation to the Convention on Biological Diversity: Technical and Regulatory Matters* (CBD Technical Series No 66, Secretariat of the Convention on Biological Diversity 2012), 6, which calls the decision 'a non-binding normative framework'.

99 Text to (n 70–73).

100 Consider the analogy with nuclear weapons. A world in which only a few countries have nuclear weapons is more stable and less likely to experience nuclear warfare than one in which most countries have them.

transparent and inclusive manner. Thus, a non-proliferation agreement—binding or possibly less formal—could be roughly analogous to the Nuclear Non-Proliferation Treaty.[101] Under this, those parties with climate engineering capabilities would pledge to share knowledge with non-capable parties and to include them in research activities, while not sharing knowledge and research activities with non-participating states. In turn, all parties would agree to limit climate engineering capabilities to a small number of States and to abide by certain research standards.

In this regulation of large-scale climate engineering field experiments and deployment, one or more institutions similar to the IAEA and the others involved in overseeing nuclear power could play several important facilitative roles.[102] Such institutions could further research norms and guidelines by, for example, translating them into detailed best practices and assisting with their implementation among researches and through national legislation. They could also help coordinate climate engineering activities, minimising the conflicts among field tests. This could include fairly distributing costs and fostering research capacity, particularly in developing countries. Moreover, an international institution could provide a site where a moratorium on large-scale field experiments and deployment could be developed and modified as appropriate. Finally, institutions could promulgate and help implement multilateral agreements regarding the above-listed procedural duties, liability and non-proliferation. For example, they could provide forums for information sharing and access, adjudicate liability claims and verify non-proliferation.

Although the rules regarding when climate engineering deployment would be permitted is already a matter of much interest, it may be wise to delay formal discussions on this. Such debates could unnecessarily increase international tensions and cloud understandings of climate engineering, while details are still emerging regarding climate change risks, states' ability to reduce these risks through emissions reductions and adaptation, the nature and potential of climate engineering, and what society desires out of climate engineering. Although one could imagine climate engineering becoming a source of polarised debate and tension among countries, this is not as probable as some authors suggest.[103] In fact, current models indicate that countries may more strongly agree on whether and to what degree climate engineering should be deployed than how much they may disagree over the details.[104] Furthermore, if a final lesson from nuclear *weapons* may be drawn, international norms may develop which can prevent misuse in cases where explicit multilateral agreements are impossible to reach—even in the *realpolitik* world of national security.[105]

101 Non-Proliferation Treaty (n 38).

102 Banerjee (n 26) also suggests looking at the IAEA as an example.

103 Eg David Victor, 'On the Regulation of Geoengineering' (2008) 24 O Rev Env Pol'y 322.

104 See Ricke, Moreno-Cruz and Caldeira (n 10).

105 Nuclear weapons have never been used outside of the arguably exceptional case of World War II. There is a strong international norm against the first-strike use of nuclear weapons, especially against a non-nuclear state. This has been maintained for decades despite the fact that in several instances it would have been advantageous for states to use them. However, it is improbable that the nuclear weapon states would commit to such a norm in a binding treaty or UN Security Council resolution. See Thomas Schelling, 'An Astonishing Sixty Years: The Legacy of Hiroshima', Nobel Prize Lecture, 8 December 2005, available at <http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2005/schelling-lecture.html> accessed 11 October 2013.

6. CONCLUSION

The initial steps on the trajectory described in the last section are already occurring. In recent years, at least three different ad hoc expert bodies have produced norms to guide climate engineering research, with significant agreement among their products.[106] International institutions are cautiously dipping their toes into the potentially treacherous waters of examining climate engineering.[107] Leading researchers are now discussing prohibitions on climate engineering patents and a moratorium on large-scale field research and deployment.[108] This is not to say that concerned participants in the climate engineering regulation discourse should become complacent. Quite the contrary, all voices, ranging from active practitioners to strident opponents, must be fully engaged in order to better shape one of the most challenging international regulatory developments of this era. This engagement will be more productive if the participants are aware of the range of likely rational behaviour of sovereign states with diverse interests, capabilities and levels of power, as evidenced by the instructive case of nuclear power.

106 MacCracken and others (n 46); Jane Long and others (n 46); Rayner and others (n 46). See also Solar Radiation Management Governance Initiative, 'Solar radiation management: the governance of research' <http://www.srmgi.org/report/> accessed 19 April 2013.

107 Eg Stocker and others (n 2).

108 Anne Mulkern, 'Researcher: Ban Patents on Geoengineering Technology' (*ClimateWire*, 2012) available at <http://www.scientificamerican.com/article.cfm?id=researcher-ban-patents-on-geoengineering-technology> accessed 10 May 2012; Parson and Keith (n 21).