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Geoengineering: rights, risks and ethics

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This article discusses arguments that manipulating the Earth's climate may provoke unforeseen, unintended and uncontrollable consequences that threaten human rights. The risks arise from both main types of geoengineering: solar radiation management (SRM) techniques and carbon dioxide removal (CDR). SRM creates particular risks because it is difficult to test on a wide scale and may not be capable of being recalled after deployment. Adequate, enforceable governance structures do not currently exist to assess and regulate the risks of climate engineering, not least whether such technologies can be terminated in the absence of significant emissions reductions. This article is divided into six sections. After the opening introductory section, section 2 discusses the links between climate change and human rights. It briefly outlines the range of rights, including procedural rights, that might be violated by geoengineering. This is followed, in section 3, by an evaluation of the risks of SRM and CDR. The fourth section discusses debates on the ethics of geoengineering. Section 5 critiques hubristic faith in technological solutions. The final section examines the governance of geoengineering and the extent to which international environmental law and human rights law might be used to regulate the research and deployment of geoengineering.

Keywords: *geoengineering, solar radiation management, carbon dioxide removal, human rights, moral hazard, risk*

1 INTRODUCTION

Geoengineering is the 'deliberate, large-scale manipulation of the planetary environment in order to counteract anthropogenic climate change'.[1] The term refers to a diverse range of techniques commonly divided into solar radiation management (SRM) techniques and carbon dioxide removal (CDR). SRM techniques are designed to reflect sunlight back into space through the injection of sulphate particles into the stratosphere (to simulate volcanic eruptions – the so-called Pinatubo effect), marine cloud brightening, space-based mirrors, terrestrial and ocean surface whitening options, while CDR deploys methods such as carbon capture and storage.[2] This article examines arguments that manipulating the Earth's climate in this way may provoke unforeseen, unintended and uncontrollable consequences that threaten human rights, and argues that adequate enforceable governance structures do not currently exist to

1. Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty* (The Royal Society, London 2009).
2. Geoengineering is commonly described as a complement to adaptation and mitigation (Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty* (The Royal Society, London 2009) 57, but Heyward argues that CDR and SRM 'should be regarded as two parts of a five-part continuum of responses to climate change'. C Heyward, 'Situating and Abandoning Geoengineering: A Typology of Five Responses to Dangerous Climate Change' (2013) 46 PS: Political Science & Politics 23 at 23.

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assess and regulate the risks of climate engineering, not least whether such technologies can be terminated in the absence of significant emissions reductions.

It is unsurprising that geoengineering should seem, for some, to present an attractive technological response to climate warming. Concentrations of CO_2 have passed the symbolic level of 400 ppm. June 2016 was the fourteenth consecutive month of record heat for land and oceans, and the three hundred and seventy-eighth consecutive month with temperatures above the twentieth-century average.[3] In James Hansen's words, we are facing a planetary emergency that increases human rights violations and risks for growing numbers of vulnerable people today and in future generations.[4] It seems clear that the inexorable rise of greenhouse gas (GHG) emissions will lead to growing calls for climate engineering. The key question is whether such technologies will increase the threats to human rights or provide a means of protecting them.

In the following section I describe the threats that climate change poses to a range of human rights, including the right to life and the right to food, considering the argument that a safe environment is a basic human right and taking into account the importance of procedural rights, as well as pointing briefly towards the implications of geoengineering for such rights. In sections 3 and 4, I examine the risks and ethics of geoengineering. Section 5 contains an analysis of the dangers of hoping that scientific innovation will enable us to escape the worst effects of climate change and, if not, that it will provide a viable alternative in the form of geoengineering. In section 6, I briefly examine the effectiveness of relevant international environmental law principles such as the precautionary principle.[5] I conclude that the risks of wide-scale geoengineering currently outweigh its potential benefits, and that renewable technologies that reduce greenhouse gas emissions are the safest and most ethical way of addressing the impacts of climate change.

2 THE IMPACTS OF CLIMATE CHANGE ON HUMAN RIGHTS: JUSTICE, RIGHTS AND GEOENGINEERING

It is well established that the impacts of anthropogenic global warming will affect everyone on Earth, but that those least responsible for the problem will suffer most, especially those in the global South, due to geographical location, the legacies of underdevelopment, greater reliance on sensitive sectors such as agriculture, and a relative lack of adaptive resources. Climate change – as is also well established now – threatens a wide range of human rights, including the rights to food, health, property, the benefits of culture, and to family life.

3. World Meteorological Organization, 'Global Climate Breaks New Records January to June 2016' <http://public.wmo.int/en/media/press-release/global-climate-breaks-new-records-january-june-2016> accessed 11 August 2016.
4. J Hansen, 'Tipping Point' in E Fearn (ed), *State of the Wild 2008–2009* (Island Press, Washington, DC 2008); H Shue, *Climate Justice: Vulnerability and Protection* (Oxford University Press, Oxford 2014). For a technical perspective on risk, see IM Mintzer, 'Living in a Warming World' in IM Mintzer (ed), *Confronting Climate Change: Risks, Implications and Responses* (Cambridge University Press, Cambridge 1992) 1–13.
5. The relevant law is extensively discussed elsewhere, for example in J Reynolds, 'Climate Engineering Field Research: The Favorable Setting of International Environmental Law' (2014) 5(2) Washington & Lee Journal of Energy, Climate and Environment 417.

The future prospects for human rights are relatively grim in the light of the range of risks and forms of precarity associated with climate change. The fifth IPCC assessment report, for example, warns that anthropogenic climate change will have 'severe, pervasive and irreversible' impacts.[6] The report expresses very high confidence that injuries, diseases and deaths will increase due to more intense heatwaves and fires, and suggests with a high degree of confidence that under-nutrition will result from diminished food production in poor regions of the world. The right to health, the report notes, will increasingly be threatened by food-, water- and vector-borne diseases.[7] The right to private and family life and the right to culture will be affected as increasing warming puts ecosystems at risk of abrupt and irreversible changes which will slow economic growth and poverty reduction, erode food security and trigger new poverty traps, particularly in urban areas and emerging hunger hotspots.[8] The right to food will be threatened by the breakdown of food systems due to warming, drought, flooding, and desertification.[9] All aspects of food security are likely to be affected, not least access to food.[10] Rural livelihoods and income will be undermined by insufficient access to drinking and irrigation water and by reduced agricultural productivity, especially for farmers and pastoralists with minimal capital in semi-arid regions. In Africa 'between 75 million and 250 million people are projected to be exposed to increased water stress' by 2020.[11] The IPCC also predicts that hundreds of millions of people will be displaced by land loss from coastal and inland flooding, which will increase the risks of death, injury, severe ill-health and disrupted livelihoods in low-lying coastal zones and small island developing states due to storm surges and rising sea levels.[12] Richardson et al. estimate that a one metre rise in sea levels will eliminate the small island developing states and that '10% of the global population – over 650 million people – will be directly impacted by a sea-level rise of between 0.5 m and 1.0 m, which now may represent a best-case scenario'.[13]

The IPCC is far from being an isolated voice concerning the implications of climate change for human rights. Indeed, the sense of threat is pervasive – particularly in the most affected communities. In 2007, for example, the Association of Small Island States (AOSIS), representing countries threatened by inundation from rising sea levels, expressed growing concern that climate change threatens the full enjoyment of human rights, including *inter alia* the rights to life, to take part in cultural life, to use and enjoy property, to an adequate standard of living, to food, and to

6. IPCC, *Climate Change 2014: Synthesis Report – Longer Report* (Intergovernmental Panel on Climate Change, Geneva 2014). On the relationship between climate change and human rights see S Adelman, 'Rethinking Human Rights: The Impact of Climate Change on the Dominant Discourse' in S Humphreys (ed), *Human Rights and Climate Change* (Cambridge University Press, Cambridge 2010) and 'Environmental Rights: Climate Justice and Human Rights' in G DiGiacomo (ed), *Human Rights* (University of Toronto Press, Toronto 2016).
7. Unless otherwise indicated, these data are from ML Parry et al., *Climate Change 2007: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, Cambridge 2007).
8. Ibid 399.
9. Ibid 283–4.
10. Ibid 13, 297–8, 435, 490.
11. Ibid 41.
12. Ibid 41, 327, 343, 365.
13. K Richardson, W Steffen and D Liverman (eds), *Climate Change: Global Risks, Challenges and Decisions* (Cambridge University Press, Cambridge 2011) 66.

the highest attainable standard of physical and mental health. AOSIS adopted the Malé Declaration, which asserts 'the fundamental right to an environment capable of supporting human society and the full enjoyment of human rights',[14] but clearly, operationalizing such rights remains an unresolved challenge – and declarations alone achieve little beyond a claim for human rights responses. Whether geoengineering is a meaningful response to such challenges, or simply further endangers such rights, is a pressing question – and lies at the heart of this article (and will be discussed more fully below).

Quite apart from its direct effects on a range of human rights, climate change also creates risks of social and political unrest and armed conflicts that further undermine human rights.[15] By threatening the right to peace and security, climate change indirectly increases 'risks from violent conflict in the form of civil war, inter-group violence, and violent protests by exacerbating well-established drivers of these conflicts such as poverty and economic shocks'.[16] While further assessment of the relationship between human rights and geoengineering must await further analysis (below), it is relatively clear that geoengineering would be unlikely to reduce the risk of such conflict. In fact, geoengineering arguably increases the risk of conflict because it is extremely unlikely that an attempt by one country to control its climate can be contained within its borders without affecting that of other countries or that a single state or bloc will be allowed to control a 'global thermostat'.[17] The prospect of conflict in such situations is clear. The US National Academy of Sciences has expressed 'serious concern … that such an action could be unilaterally undertaken by a nation or smaller entity for their own benefit without international sanction and regardless of international consequences'.[18]

Despite the clear threat that climate change presents to human rights, the UN High Commissioner for Human Rights has somewhat bizarrely concluded that although climate change threatens the enjoyment of a many human rights, it does not necessarily *violate* them – presumably a conclusion asserted at the behest of states resisting a clear link that might form the basis of liability.[19] In the light of this assertion, it is worth

14. Malé Declaration on Human Dimension of Global Climate Change <http://www.ciel.org/Publications/Male_Declaration_Nov07.pdf> accessed 16 August 2016.
15. SH Schneider, 'Geo-engineering: Could We or Should We Make it Work?' in B Launder and M Thompson (eds), *Geo-Engineering Climate Change: Environmental Necessity or Pandora's Box?* (Cambridge University Press, Cambridge 2010) 7. See also the papers in the Special Issue: Climate and Security: Evidence, Emerging Risks, and a New Agenda of (2014) Climatic Change 123(1).
16. US Department of Defense, Report on National Security Implications of Climate Related Risks and a Changing Climate <http://archive.defense.gov/pubs/150724-congressional-report-on-national-implications-of-climate-change.pdf?source=govdelivery> accessed 17 September 2015, at 3.
17. See WW Kellogg and SH Schneider, 'Climate Stabilization: For Better or for Worse?' (1974) 186(4170) Science 1163; S Barrett, 'The Incredible Economics of Geoengineering' (2008) 39(1) Environmental and Resource Economics 45–54 at 41; A Maas and I Comardicea, 'Climate Gambit: Engineering Climate Security Risks?' in GD Dabelko et al. (eds), *Backdraft: The Conflict Potential of Climate Change Adaptation and Mitigation* (Woodrow Wilson International Center for Scholars, Washington 2013) 37.
18. National Research Council of the National Academies, *Climate Intervention: Reflecting Sunlight to Cool Earth* (National Academies Press, Washington, DC 2015) ix–x.
19. OHCHR, Report of the Office of the United Nations High Commissioner for Human Rights on the Relationship Between Climate Change and Human Rights, UN Doc. A/HRC/10/61 (15 January 2009).

revisiting the clear links established in international law between human rights and the environment – a link also necessarily germane to an analysis of the relationship between human rights and geoengineering.

The first clear articulation of the link between human rights and the environment came in the 1972 Stockholm Declaration on the Human Environment.[20] The preamble recognizes that a healthy environment is necessary for the enjoyment of human rights and Principle 1 states that human beings have 'the fundamental right to freedom, equality and adequate conditions of life, in an environment of a quality that permits a life of dignity and well-being, and … [humanity] bears a solemn responsibility to protect and improve the environment for present and future generations'. In 1990, the UN General Assembly declared 'that all individuals are entitled to live in an environment adequate for their health and well-being'.[21] The right to a clean and healthy environment is also recognized in a majority of national constitutions, but is not always justiciable, and enforcement is patchy.[22] It is clear that in normative terms, at least, there is a growing assertion of a broad right to a clean and healthy environment. Indeed, Burns Weston and David Bollier argue that environmental rights are derivatives of the rights to life and health and procedural rights, as well as being autonomous entitlements.[23] The right to a clean and healthy environment is the centrepiece of their rights-based paradigm of green governance because in their view it is the only way that individuals and civil society can address climate change at the international level. This right is conceptually and normatively linked to a basic right to a stable climate. Steve Vanderheiden contends that:

> The right to an adequate environment is intended to encompass a broad range of anthropocentric duties of environmental protection, and the right to climatic stability appears to be an obvious corollary of such a right. While climate change is only one of many ongoing threats to the maintenance of an adequate environment, it must be regarded as among the most serious threats. Therefore, the duty to maintain climatic stability, or to refrain from excessive GHG emissions, is a necessary but insufficient condition for meeting the general obligation to maintain an adequate environment …[24]

The normative pressure for the clear recognition of a global right to a healthy environment is growing. Indeed, John Knox, the UN Special Rapporteur on Human Rights and the Environment, argues that the absence of a global right to a healthy environment appears increasingly anomalous in light of its increasing prevalence in national and regional regimes:[25]

20. Declaration of the United Nations Conference on the Human Environment, UN Doc. A/Conf.48/14/Rev. 1(1973); 11 ILM 1416 (1972).
21. UN General Assembly Resolution on the need to ensure a healthy environment for the well-being of individuals, A/RES/45/94, 14 December 1990. See also see Human Rights Council (HRC) Resolution 7/23, Human rights and climate change, UN Doc. A/HRC/RES/7/23 (28 March 2008) and HRC Resolution 18/22, UN Doc. A/HRC/18/L.26/Rev.1 (28 September 2011).
22. LJ Kotzé, *Global Environmental Constitutionalism in the Anthropocene* (Hart, Portland 2016); J May and E Daly, *Global Environmental Constitutionalism* (Cambridge University Press, Cambridge 2015).
23. BH Weston and D Bollier, *Green Governance: Ecological Survival, Human Rights, and the Law of the Commons* (Cambridge University Press, Cambridge 2014) 33.
24. S Vanderheiden, *Atmospheric Justice: A Political Theory of Climate Change* (Oxford University Press, Oxford 2008) 241–2.
25. JH Knox, 'Human Rights Principles and Climate Change' in KR Gray, R Tarasofsky and CP Carlarne (eds), *The Oxford Handbook of International Climate Change Law* (Oxford University Press, Oxford 2014).

> [N]o global agreement sets out an explicit right to a healthy (or satisfactory, safe or sustainable) environment. Were the Universal Declaration to be drafted today, it is easy to imagine that it would include a right recognized in so many national constitutions and regional agreements. At the same time, it must be acknowledged that the United Nations has not taken advantage of subsequent opportunities to recognize a human right to a healthy environment.[26]

Central to the recognition of environmental human rights – and important for the purposes of the present reflection – is a strong emphasis upon participation. Knox identifies a range of human rights 'whose free exercise makes policies more transparent, better informed and more responsive', including rights to freedom of expression and association, to receive information and participate in decision-making processes, and rights to legal remedies.[27]

The importance of public participation in matters of environmental risk is increasingly recognized in international law, and some writers argue that consent is one of the most important ethical issues in climate engineering.[28] The Aarhus Convention is the foremost multilateral environmental agreement outlining the obligations of states towards their citizens and promotes the rule of law by enabling citizens to enforce their rights and to have access to participatory decision-making. The Convention unambiguously states that 'every person has the right to live in an environment adequate to his or her health and well-being',[29] and contains provisions designed to facilitate public participation in decisions affecting the environment. The Convention does not stipulate who must be consulted or the appropriate form that consultation should take. Nor does it require mandatory environmental impact assessments for every research project that carries an environmental risk. Furthermore, the Convention exempts research, development and testing 'unless they would be likely to cause a significant adverse effect on environment or health'. Yet, despite these characteristics, and although the Aarhus Convention is not yet internationally embraced despite its powerful regional influence in Europe, it nonetheless offers a persuasive model for the centrality of public participation in environmental matters – and for such participation to be firmly linked to the exercise of human-rights-based concerns and interests. It is now generally widely accepted that states should incorporate procedural safeguards when making decisions about environmental harms likely to undermine the enjoyment of human rights – such safeguards as environmental impact assessments,

26. OHCHR Report of the Independent Expert on the Issue of Human Rights Obligations Relating to the Enjoyment of Safe, Clean, Healthy and Sustainable Environment: Mapping Report, UN Doc. A/HRC/25/53 (2013), para 14.
27. Rights to freedom of expression, freedom of peaceful assembly and association, participation in government and effective remedies for violations of rights are recognized in the Universal Declaration (arts 7, 8, 19, 20 and 21) and the International Covenant on Civil and Political Rights (arts 2, 19, 21, 22 and 25).
28. A Corner and N Pidgeon, 'Geoengineering the Climate: The Social and Ethical Implications' (2010) 52(1) Environment 24; C Preston, 'The Extraordinary Ethics of Solar Radiation Management' in C Preston (ed), *The Ethics of Solar Radiation Management* (Lexington Books, Lanham, MD 2012).
29. The United Nations Economic Commission for Europe (UNECE) Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (25 June 1998). The Convention is a European instrument but is open to ratification by other states which are willing to bring their legislation into conformity with it.

the full and informed participation of those affected, and effective remedies for non-compliance.[30]

Information, participation and consent are therefore central to the operationalization of environmental human rights – and present, it is suggested, a particular challenge in the context of large-scale geoengineering projects. There is particularly good reason to question the validity of consent in contexts – such as geoengineering – where there are likely to be important power disparities and differing levels of agency. Gardiner, for example, maintains that geoengineering that has the consent of the most vulnerable may be morally better than deployment without consultation, but that such consent is likely to be severely restricted and given under duress. In his view, agreement from the desperate cannot justify geoengineering if it violates the human rights of those 'consenting' or those of others – and this includes the right 'not to be subject to domination by another power'. Obtaining approval in this manner would be an act of profound subjugation because:[31]

> To exert control over the planetary system is to determine the basic life prospects of humans within that system, including the parameters against which they pursue their conceptions of the good, generate their ideals, and even conceive of their identities. In addition, it marks a further milestone in humanity's evolving (most would say 'deteriorating') relationship to nonhuman nature.[32]

A further difficulty in relation to participation in this context is that future generations cannot be consulted about their views concerning survival on a devastated planet. It will therefore be difficult to construct processes to secure meaningful and inclusive consent for climate engineering that are democratic and legitimate.[33] Such lack of participatory inclusion presents a particularly serious human-rights-based objection to geoengineering. Simon Caney convincingly argues that human rights are moral thresholds that should not be traded off against other putative advantages.[34] Human rights are not substitutable for other goods or values and cannot easily be remedied when they are violated. Human rights have such broad public appeal and legitimacy that Burns Weston and David Bollier argue – in the environmental rights context – that they trump other legal obligations.[35]

Given the meta-ethical power of human rights, and the centrality of participatory rights to the exercise of meaningful environmental human rights, it is strange that more attention has not been paid to them in the context of addressing climate change. Stephen Humphreys, for example, considers it puzzling that so little attention has been paid to human rights despite the IPCC's warnings.[36] A range of initiatives

30. OHCHR (n 26).
31. SM Gardiner, 'The Desperation Argument for Geoengineering' (2013) 46(1) PS: Political Science & Politics 28, 31.
32. Ibid 29.
33. See PH Wong, 'Consenting to Geoengineering' (2016) 29(2) Philosophy & Technology 173 and DR Morrow, RE Kopp and M Oppenheimer, 'Toward Ethical Norms and Institutions for Climate Engineering Research' (2009) 4(4) Environmental Research Letters.
34. S Caney, 'Climate Change, Human Rights, and Moral Thresholds' in SM Gardiner, S Caney, D Jamieson and H Shue (eds), *Climate Ethics: Essential Readings* (Oxford University Press, Oxford 2010).
35. BH Weston and D Bollier, *Green Governance: Ecological Survival, Human Rights, and the Law of the Commons* (Cambridge University Press, Cambridge 2014).
36. S Humphreys, *Human Rights and Climate Change* (Cambridge University Press, Cambridge 2010) 2.

has taken up the challenge. The 2005 petition from the Canadian Inuit to the Inter-American Commission on Human Rights amply demonstrated the difficulties involved in overcoming the legal hurdles of standing and causation for alleged violations of human rights arising from the effects of climate change,[37] while itself signalling a change in the level of attention paid to human rights claims and arguments in the context of climate change. The failure of the UN Framework Convention on Climate Change (UNFCCC) to negotiate a viable framework for reducing emissions has also led to an increase in attempts to establish state and corporate liability for climate-related human rights violations. On the eve of the negotiations that produced the Paris Agreement in December 2015, the Philippines Human Rights Commission agreed to hear a petition from several non-governmental organizations (NGOs) against 47 'carbon majors', including oil, cement and mining companies, for their role in contributing to climate-related damage in the country, and issued a formal complaint in September 2016. Yet, despite these initiatives, human-rights-based approaches still require further development and recognition. The fact that the Paris Agreement refers to human rights only in the preamble reflects the low priority the UNFCCC has given to human rights[38] – leaving the impact of human-rights-based considerations in the context of geoengineering a topic very much open to further analysis.

3 THE RISKS OF GEOENGINEERING

As noted above, geoengineering is the 'deliberate, large-scale manipulation of the planetary environment in order to counteract anthropogenic climate change'.[39] The term, as was also noted above, refers to a diverse range of techniques commonly divided into solar radiation management (SRM) techniques designed to reflect sunlight back into space through the injection of sulphate particles into the stratosphere (to simulate volcanic eruptions, the so-called Pinatubo effect), marine cloud brightening, space-based mirrors, and terrestrial and ocean surface whitening options, and carbon dioxide removal (CDR) methods such as carbon capture and storage.[40]

The IPCC currently believes that SRM has numerous side effects, risks and shortcomings, but that some methods 'if practicable, could substantially offset a global temperature rise and partially offset some other impacts of global warming', but

37. The Inuit petition to the Inter-American Commission on Human Rights contended that climate change is undermining *inter alia* their rights to life and health, fundamental rights to residence and movement, the inviolability of the home, and the right to subsistence. Petition to the Inter-American Commission on Human Rights Seeking Relief from Violations Resulting from Global Warming Caused by Acts and Omissions of the United States (7 December, 2005) <http://earthjustice.org/sites/default/files/library/legal_docs/summary-of-inuit-petition-to-inter-american-council-on-human-rights.pdf> accessed 16 August 2016.
38. UNFCCC, Paris Agreement, 12 December 2015, FCCC/CP/2015/L.9/Rev.1.
39. Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty* (The Royal Society, London 2009).
40. Geoengineering is commonly described as a complement to adaptation and mitigation (Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty* (The Royal Society, London 2009) 57, but Heyward argues CDR and SRM 'should be regarded as two parts of a five-part continuum of responses to climate change', C Heyward, 'Situating and Abandoning Geoengineering: A Typology of Five Responses to Dangerous Climate Change' (2013) 46 PS: Political Science & Politics 23 at 23.

compensation for the climate change caused by greenhouse gases (GHGs) is not clear.[41] SRM is usually considered a stopgap measure 'to shave the top of the curve'.[42] The Royal Society describes SRM as fast and cheap, but also uncertain, and prone to unintended side effects that it may not be possible to unwind.[43] SRM is also technically more difficult than CDR (which can be perceived to be less risky than SRM) – and SRM merely aims to *offset* some of the effects of GHG emissions without reducing them, while CDR addresses the *cause* of climate change. SRM is seen as being risky because climate manipulation may provoke irreversible consequences: it is not possible to be certain how the biosphere will respond to forced interventions.[44] Anxieties over risk include concerns that stratospheric sulphate injection (SSI) might lead to feedback processes that increase acid rain and exacerbate ocean acidification, reduce global rainfall (which may in turn become more acidic) or increase flooding and intensify extreme weather events.[45] The Royal Society views the injection of sulphate aerosols into the stratosphere (SSI) as more promising than space-based SRM such as mirrors orbiting the Earth, but has argued that significant research and development is 'required to identify and evaluate potential impacts on the hydrological cycle, stratospheric ozone and on the biosphere prior to deployment'.[46] SRM has, additionally, little chance of success unless it is accompanied by substantial reduction of GHGs.[47]

Like SRM, CDR carries substantial risks. For example, bioenergy with carbon capture and storage (BECCS) could require diverting huge amounts of arable land from food production, consume significant amounts of water and energy supplies, and lead to severe soil degradation and to land grabs in developing countries. Ocean iron fertilization might sequester insignificant amounts of carbon dioxide but have devastating effects on ocean ecosystems.[48] There are also limits on how quickly carbon can be

41. O Boucher et al., 'Clouds and Aerosols' in TF Stocker et al. (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* (Cambridge University Press, Cambridge 2013) 7.
42. CJ Preston, 'Climate Engineering and the Cessation Requirement: The Ethics of a Life-cycle' (2016) 25(1) Environmental Values 91, 92; M Zürn and S Schäfer, 'The Paradox of Climate Engineering' (2013) 4(3) Global Policy 266.
43. C Hamilton, *Earthmasters: The Dawn of the Age of Climate Engineering* (Yale University Press, New Haven 2013) 115–16.
44. On the risks of geoengineering in general, see WCG Burns and JA Flegal, 'Climate Geoengineering and the Role of Public Deliberation: A Comment on the US National Academy of Sciences' Recommendations on Public Participation' (2015) 5(2–4) Climate Law 252; K Caldeira, G Bala and L Cao, 'The Science of Geoengineering' (2013) 41 The Annual Review of Earth and Planetary Sciences 231.
45. Royal Society (n 39) 36. See Y Chang and A Posch, 'The Wickedness and Complexity of Decision Making in Geoengineering' (2014) 5(2) Challenges 390. For an evaluation of the risks of SSI see National Research Council of the National Academies, *Climate Intervention: Reflecting Sunlight to Cool Earth* (National Academies Press, Washington, DC 2015). On the regional effects of geoengineering see A Robock et al., 'Regional Climate Responses to Geoengineering with Tropical and Arctic SO_2 Injections' (2008) 113(15) Journal of Geophysical Research: Atmospheres.
46. Royal Society (n 39) 36. SSI could endanger recovery of the ozone layer; PJ Rasch et al., 'An Overview of Geoengineering of Climate Using Stratospheric Sulphate Aerosols' (2008) 366 Philosophical Transactions of the Royal Society 4007, 4027.
47. Preston (n 28).
48. Burns and Flegal (n 44); SK Rose et al., 'Bioenergy in Energy Transformation and Climate Management' (2014) 123(3–4) Climatic Change 477.

taken out of the atmosphere.[49] Large-scale CDR may also have significant ecological impacts. Safe geological sequestration methods for storing carbon dioxide are not yet available and it is uncertain whether sufficient underground storage is available.[50]

Added to these elements of risk and uncertainty is the fact that it is unlikely that any climate engineering technology can be deployed on a scale sufficient to prevent the average global temperature from increasing by more than 2 degrees Celsius from preindustrial levels. Even if geoengineering technologies were to prove successful, it would take decades – if not centuries – for the carbon dioxide already emitted to be reabsorbed. Since it is not clear that geoengineering projects can be adequately tested in laboratories or in large-scale field trials, scientists are forced to rely on models that are intrinsically uncertain.

One of the main risks of geoengineering is the problem of termination. Preston argues that there is little or no possibility of cessation unless the technologies are accompanied by mitigation and adaptation, and even then it would take substantial amounts of time for carbon already emitted to be reabsorbed. This could result in technological lock in, especially since sudden withdrawal of SRM could lead to rapid and unmanageable warming – and signal a fundamental weakness in the SRM strategy more generally: 'For a technology without a cessation strategy, these risks and burdens promise continually diminishing returns'.[51] In Preston's view, on this basis CDR is preferable to SRM, not because it is more benign or natural, but because it offers the possibility of termination if it is accompanied by substantial emissions reductions.[52] If, however, CDR failed to sufficiently reduce emissions, there might be calls for it to operate alongside SRM, a scenario in which the risks would multiply the threats. Preston believes that it is possible to envisage a viable short-term climate engineering intervention but argues that 'SRM alone has no obvious cessation strategy [and] does not solve the climate change problem'. There are numerous technical, ecological and material constraints on the potential of CDR, but it is preferable because under the right circumstances it can meet the cessation requirement. Even so, 'the social and political conditions required for CDR with a genuine cessation strategy are not yet here and, if they were ever met, would be extremely challenging to maintain over time'.[53] Accordingly, Preston concludes that:

> there are reasons to be seriously sceptical about whether we are now, or will ever be, in a position to commence climate engineering with any confidence that it could be eventually withdrawn. If the global community is not willing to create the conditions under which climate engineering would cease, then it seems there are two equally stark options. Either we never allow climate engineering to start in the first place, or we abandon the idea of climate engineering having a cessation requirement. In the latter case, climate engineering would be viewed as an ongoing, possibly perpetual, defence against rising temperatures.[54]

This lack of certainty over cessation further complicates, moreover, the centrally important issue of consent. To secure consent, the benefits of a technology must outweigh its risks; it must provide an effective remedy to the problem it aims to solve; it

49. M Tavoni and R Socolow 'Modeling Meets Science and Technology: An Introduction to a Special Issue on Negative Emissions' (2013) 118(1) Climatic Change 1.
50. Ibid.
51. Preston (n 28) 96.
52. Ibid 99.
53. Ibid 102.
54. Ibid 103.

must be containable and reversible; and it must avoid the creation of moral hazards, protect human rights and minimize harm to future generations. Yet assessing the risks of climate change and geoengineering in order to inform consent is complicated, not least because such assessment requires synthesizing information from the natural and social sciences: Securing consent about complex problems and technologies necessarily involves ethical, political and philosophical considerations that outweigh economic cost-benefit analyses and quantitative risk assessments.[55] Cost-benefit analyses and quantitative risk assessments are ethically problematic when applied to risks that cannot be reduced to monetary values – such as human rights violations, the loss of one's homeland and culture, or the production of irreversible effects on the environment and/or climate, and so forth. Cost-benefit analysis is essentially utilitarian. It 'has only a partial and contingent commitment to the basic interests and entitlements of the most vulnerable'.[56]

Yet, as Boyd et al. rightly argue, social science is as important as natural science in evaluating risk, and factors such as betrayal aversion and risk equity are two factors that demonstrate why ignoring public opinion is undemocratic and inappropriate.[57] '[S]ubjective views and value judgments heavily influence how individuals perceive both the risks of climate change and the potential benefits and costs of risk management options'.[58] Obtaining legitimate democratic consent will always, therefore, be a complex matter in such cases – and the evaluation of risk will play a centrally important, and inherently contestable and uncertain role in the generation of consent.

These uncertainties can be further multiplied by the complexity of the problem itself: objections to geoengineering arise from concerns that it 'entails "messing with" a complex, poorly understood system'.[59] Disagreements are likely to be rife, moreover. In 2012, a British project to test sulphur injection into the atmosphere was abandoned after a public outcry, ostensibly due to difficulties with a patent application,[60] but proponents counter that it is not certain that geoengineering would be any more unpredictable or risky than climate change and that potentially negative side effects do not pose ethical dilemmas any more profound than does the continued use of fossil fuels.

Notwithstanding that argument, it is clear that the risks of geoengineering remain unacceptably high. In 2014, a team of researchers compared five geoengineering methods and concluded that all were both relatively ineffective and carried potentially severe side effects. For example, reflecting the sun's rays into space would alter rainfall patterns while reforesting deserts could change wind patterns and possibly reduce

55. See Gardiner's critique of cost-benefit analysis in SM Gardiner, 'Is "Arming the Future" with Geoengineering Really the Lesser Evil? Some Doubts about the Ethics of Intentionally Manipulating the Climate System' in Gardiner, Caney, Jamieson and Shue (n 34) 287–8.
56. Caney (n 34).
57. W Boyd, D Kysar and JJ Rachlinski, 'Law, Environment, and the "Nondismal" Social Sciences' Cornell Law Faculty Publications Paper 643 (2013) <http://scholarship.law.cornell.edu/facpub/643> accessed 9 February 2016.
58. PAT Higgins and JV Steinbuck, 'A Conceptual Tool for Climate Change Risk Assessment' (2014) 18(1) Earth Interactions 2.
59. DW Keith, 'Geoengineering the Climate: History and Prospect' (2000) 25 Annual Review of Energy and the Environment 245 at 277.
60. N Pidgeon, K Parkhill, A Corner and N Vaughan, 'Deliberating Stratospheric Aerosols for Climate Geoengineering and the Spice Project' (2013) 3(5) Nature Climate Change 451. For an extended discussion see J Stilgoe, *Experiment Earth: Responsible Innovation in Geoengineering* (Routledge, Abingdon 2015).

tree growth in other regions. Two of the five methods considered could not be safely stopped, though less dramatic changes would result if the other methods were discontinued. The researchers argued that such interventions are likely to lead to chaos in complex and not fully understood weather systems, and that the most that can be expected is an 8 per cent reduction in temperature, even if such intervention strategies are widely deployed.[61] Barrett et al. conclude that when the use of plausible SRM scenarios 'is politically feasible, geoengineering may not be effective; and that, when its use might be effective, its deployment may not be politically feasible'.[62] They argue that the insuperable problem confronting its proponents is that geoengineering is difficult to model and that it is unwise to deploy uncertain technologies that cannot be recalled.[63] As Naomi Klein puts it, climate engineering 'may cause the earth to go wild in ways we cannot imagine, making geoengineering not the final engineering frontier, another triumph to commemorate on the walls of the Royal Society, but the last tragic act in [the] centuries-long fairy tale of control'.[64] The safest way to avoid the risk that countries will become addicted to geoengineering is to reduce GHG emissions.[65]

Returning to the complexity of gaining legitimate consent, and following the work of Ulrich Beck and others, it is clear that risk evaluation is no longer to be regarded as a technical matter best left to scientists or economists but is infinitely more complex and demanding. Risk is[66]

> now established as a complex multi-dimensional psychological construct and a form of social discourse. Reframing risk as a complex and multi-dimensional social construct involves paying attention to the wider context of individuals' beliefs, attitudes, perceptions, judgements and feelings, alongside significant questions of ethics and political governance.[67]

It is to the question of ethics that we now turn – a consideration central to reflection upon the relationship between geoengineering and human rights.

61. DP Keller, EY Feng and A Oschlies, 'Potential Climate Engineering Effectiveness and Side Effects during a High Carbon Dioxide-emission Scenario' (2014) 5 Nature Communications, Article number 3304. The methods modelled were reflecting sunlight from space, adding vast quantities of lime or iron filings to the oceans, pumping deep cold nutrient-rich waters to the surface of oceans, and irrigating vast areas of the north African and Australian deserts to grow millions of trees.
62. S Barrett et al., 'Climate Engineering Reconsidered' (2014) 4 Nature Climate Change 527 at 529.
63. Stilgoe (n 60) 171 notes that 'research using models is at an early stage'. Many geoengineering scientists advance the opposite argument, that because models are unreliable, the only alternative is to gradually escalate small-scale field trials and ratchet up their deployment as more knowledge is gained, but this makes the problematic assumption that geoengineering will in fact be deployed.
64. N Klein, *This Changes Everything: Capitalism vs the Climate* (Allen Lane, London 2014) 267.
65. J Pongratz, L Cao, K Caldeira and DB Lobell, 'Crop Yields in a Geoengineered Climate' (2012) 2(2) Nature Climate Change 101; Barrett et al. (n 62).
66. U Beck, *Risk Society: Toward a New Modernity* (Sage, London 1992); D Lupton (ed), *Risk and Sociocultural Theory: New Directions and Perspectives* (Cambridge University Press, Cambridge 1999).
67. M Cotton, *Ethics and Technology Assessment: A Participatory Approach* (Springer, London 2014) 6.

4 THE ETHICS OF GEOENGINEERING

Paul Crutzen's cautious suggestion in 2006 that SRM should be considered as a legitimate means of reducing the impacts of climate change ignited a fierce ethical debate.[68] On one side of the debate are those who fear that geoengineering will threaten rather than protect human rights. On the other are those who argue that geoengineering may be the only means available to protect human rights in the absence of substantial emissions reductions and locked-in climate change. In this latter perspective, geoengineering constitutes a form of insurance against climate change that we would be negligent and unethical to spurn, especially if it is only a stopgap measure. Geoengineering may, on this view, be a lesser evil than climate change, but, as Gardiner points out, may nonetheless still be so deeply harming that it should be treated as a 'marring evil'.[69]

Ethically, there is a strong case for arguing that it would be preferable to seek a long-term solution rather than having to choose between climate change and geoengineering. Gardiner rightly argues that 'to push the most vulnerable to the point where they feel forced to accept pronounced subjugation to those who have made them desperate is a morally horrifying prospect which we have strong ethical reason to avoid'[70] and that the burden of proof is therefore on those who support geoengineering.[71]

A common ethical objection to geoengineering is that it creates a moral hazard by fostering false hopes that science will produce a 'get-out-of-jail-free' card that reduces the incentives to cut emissions and benefits free riders who continue to emit fossil fuels in the expectation that climate change is containable.[72] In other words, that geoengineering encourages us to gamble with humanity's future. An example of such moral hazard is Russia's call for geoengineering to be included in the 2013 IPCC report as a means of legitimizing Russia's desire to exploit oil and gas reserves in the Arctic.[73]

The notion of moral hazard, unsurprisingly, also generates disagreement. The question of moral hazard is not clear cut. For David Keith, a strong proponent of geoengineering:

> The root problem is simple: Would mere knowledge of a geoengineering method that was demonstrably low in cost and risk weaken the political will to mitigate anthropogenic climate forcing? Knowledge of geoengineering has been characterized as an insurance strategy; in analogy with the moral hazard posed by collective insurance schemes, which

68. P Crutzen, 'Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?' (2006) 77(3–4) Climatic Change 211.
69. SM Gardiner, 'Is "Arming the Future" with Geoengineering Really the Lesser Evil? Some Doubts about the Ethics of Intentionally Manipulating the Climate System' in Gardiner, Caney, Jamieson and Shue (n 34).
70. Gardiner (n 55) and Gardiner (n 31) 28.
71. Gardiner (n 55) 285.
72. Corner and Pidgeon (n 28) 30–31; Royal Society (n 39) at 37. On moral hazard, see Hamilton (n 43) 166–73. For a succinct survey of arguments for and against geoengineering see J Anshelm and A Hansson, 'Battling Promethean Dreams and Trojan Horses: Revealing the Critical Discourses of Geoengineering' (2014) 2 Energy Research & Social Science 135.
73. M Lukacs, S Goldenberg and A Vaughn, 'Russia Urges UN Climate Report to Include Geoengineering', The Guardian 19 September 2013 <http://www.theguardian.com/environment/2013/sep/19/russia-un-climate-report-geoengineering> last accessed 8 September 2015. In 2009, a Russian scientist conducted an experiment in which particles from a helicopter were sprayed to assess how much sunlight was blocked by the aerosol plume. This may violate the 2010 moratorium on geoengineering projects under the Biodiversity Convention.

> encourage behaviour that is individually advantageous but not socially optimal, we may ascribe an analogous hazard to geoengineering if it encourages suboptimal investment in mitigation.[74]

Lin, on the other hand, strongly asserts that geoengineering will undermine existing climate policies, whereas Bunzl somewhat blithely regards the risk of moral hazard as minimal and 'far-fetched since, at least among policy makers, nobody believes that geoengineering offers anything but a relatively short stopgap to buy time for other action'.[75] Meanwhile, experimental work suggests that awareness of the risks of geoengineering may lead individuals to become more concerned about climate change, and thus result in a stronger focus on mitigation strategies. (In the United Kingdom, for example, there is a strong preference for mitigation over geoengineering).[76]

Contestations concerning moral hazard and the on-going complexities surrounding the ethics of consent suggest that participatory human rights concerns will remain fundamentally unsatisfied. The difficulties of obtaining genuine, informed democratic consent are intensified, furthermore, by a tendency for geoengineering to be framed somewhat deterministically – a framing that disguises, to some extent, geoengineering's controversial nature and the high degree of speculation involved in assessing its prospects of success.

5 FIXES, FETISHISM AND HUBRIS

Jack Stilgoe writes that geoengineering has 'acquired a deterministic frame, based on the assumption that it is "cheap" and "easy". It has become 'naturalised … [and] treated as a thing in the world to be understood rather than a highly controversial, highly speculative set of technological fix proposals'.[77] The naturalization of geoengineering can be 'read' as being a form of technological fetishism. Technological fetishism is the belief that technology is the solution to every problem and that all unforeseen side effects and unintended consequences will be solved by future innovations. In this context, such technological fetishism is exemplified by the unjustifiable faith that unproven technologies such as SRM will save humanity. Clive Hamilton describes geoengineering as a dream that intuitively appeals to:

> a powerful strand of Western technological thinking and conservative politicking that sees no ethical or other obstacle to total domination of the planet. It is a Promethean urge named after the Greek titan who gave to humans the tools of technological mastery. Promethean plans have always met resistance from those who share a deep mistrust of human

74. Keith (n 59) 276.
75. AC Lin, 'Does Geoengineering Present a Moral Hazard' (2013) 40 Ecology Law Quarterly 673; M Bunzl, 'Researching Geoengineering: Should Not or Could Not?' (2009) 4(4) Environmental Research Letters 045104 2.
76. A Corner and N Pidgeon, 'Geoengineering, Climate Change Scepticism and the "Moral Hazard" Argument: An Experimental Study of UK Public Perceptions' Philosophical Transactions of the Royal Society A 372.2031 (2014): 20140063.
77. J Stilgoe, 'Geoengineering as Collective Experimentation' 2016 22(3) Science and Engineering Ethics 851 <http://link.springer.com/article/10.1007%2Fs11948-015-9646-0#> last accessed 14 August 2016.

> technological overreach, those who heed the warning that Nemesis waits in the shadows to punish Hubris.[78]

Such hubris has led humanity to transgressing three planetary environmental boundaries – biodiversity loss, climate change and the nitrogen cycle – and is threatening six others.[79] And the risk is that geoengineering is a merely predictable extension of the hubristic mastery that has led to climate warming. With this in mind, Jeff Kiehl writes that those who are most responsible for climate change 'would be taking on the *ultimate state of hubris* to believe we can control Earth. We (the industrially developed world) would essentially be telling the (rest of the) world *not to worry* about our insatiable use of energy'.[80] Rather than 'addressing the real root of the crisis, the dominant response is to avoid all questions about the nature of our society, and to turn to technological fixes or market mechanisms of one sort or another'.[81] Surveying past attempts to control the environment, James Fleming observes that 'Control of weather and climate is a perennial issue rooted in hubris and tragedy; it is a pathological issue, illustrating what can go wrong in science; and it is a pressing public policy issue with widespread social implications'.[82] Sheila Jasanoff distinguishes 'technologies of humility' that obviate the need for climate engineering from 'technologies of hubris' that emerge from the belief that human problems can be solved through science and technology.

> [Technologies of humility] compel us to reflect on the sources of ambiguity, indeterminacy and complexity. Humility instructs us to think harder about how to reframe problems so that their ethical dimensions are brought to light, which new facts to seek and when to resist asking science for clarification. Humility directs us to alleviate known causes of people's vulnerability to harm, to pay attention to the distribution of risks and benefits, and to reflect on the social factors that promote or discourage learning.[83]

David Harvey defines fetishism as 'the habit humans have of endowing real or imagined objects or entities with self-contained, mysterious, and even magical powers to move and shape the world in distinctive ways'.[84] In his view, the 'whole political-economic structure of power relations is suffused with a certain level of technological fetishism which can become self-sustaining'[85] because many technologies 'depend

78. Hamilton (n 43) 18. In Greek mythology, Prometheus stole fire from the gods to elevate humanity to a divine level and was punished for his hubris. Contrasting Prometheus with Soteria, the goddess of safety, preservation and deliverance from harm, Hamilton advocates a mentality of precaution and humility.
79. J Rockström et al., 'Planetary Boundaries: Exploring the Safe Operating Space for Humanity' (2009) 14(2) Ecology and Society 32; and JB Foster, B Clark and R York, *The Ecological Rift: Capitalism's War on the Earth* (Monthly Review Press, New York 2010).
80. J Kiehl, 'Geoengineering Climate Change: Treating the Symptom over the Cause?' (2006) 77 Climatic Change 227 at 228, my emphases.
81. JB Foster, 'Why Ecological Revolution?' in L King and DMC Auriffeille (eds), *Environmental Sociology: From Analysis to Action* (Rowman & Littlefield, Lanham, MD 2005) 40.
82. JR Fleming, *Fixing the Sky: The Checkered History of Weather and Climate Control* (Columbia University Press, New York 2010) 3.
83. S Jasanoff, 'Technologies of Humility' (2007) 450(33) Nature; S Jasanoff, 'Technologies of Humility: Citizen Participation in Governing Science' (2003) 41 Minerva 223.
84. D Harvey, 'The Fetish of Technology: Causes and Consequences' (2013) 13 Macalaster International Article 7 DigitalCommons@Macalester College <http://digitalcommons.macalester.edu/macintl/vol13/iss1/7> last accessed 11 August 2016, 3.
85. Ibid 5.

crucially upon hierarchically organized expertise and strong centralization of decision making, so that they are antagonistic to democratization as well as to individual autonomy. They depend fundamentally upon the cult of the expert. They foreclose on certain possibilities while they open up others'.[86]

How then, can geoengineering be governed in a manner reflecting full awareness of its many complex implications? Can it be governed in ways that honour human rights? Or is it inherently positioned against human rights and likely to increase the risk of their violation? We have already seen that the central human rights concern of participation and consent is very difficult to satisfy in relation to geoengineering for a range of reasons. What, though, of related and broader considerations?

6 GOVERNING GEOENGINEERING

An important factor to consider when considering geoengineering and its governance is its intimacy with the interests of the powerful. Earlier in this article, I emphasized the fact that climate change effects are most felt by the vulnerable populations least responsible for their production – a disparity with profound human rights implications. Climate engineering research capabilities are concentrated in developed countries with the greatest historical responsibility for GHG emissions.[87] Mike Hulme relatedly contends that debates about climate engineering are disproportionately influenced by a small geoclique of predominantly North American and British male scientists that aims to depoliticize climate engineering. This, it should be noted, is a naturalization strategy entirely familiar to critiques of the power of the global North in the genesis of the climate crisis. It is essential, in the light of the predictable patterns of power disparity associated with climate change and the promotion of geoengineering, that this geoclique's 'can-do' attitude should 'give way to the "should we" questions raised through ethical, moral and political reflection'.[88] Indeed, Klein wonders whether the readiness of supporters of geoengineering to gloss over the risks of geoengineering and in some cases 'to ignore them entirely has something to do with who appears to be most vulnerable. After all, if … injecting sulfur into the stratosphere would cause widespread drought and famine in North America and Germany, as opposed to the Sahel and India, is it likely that this Plan B would be receiving such serious consideration?'[89] The argument is an important one, especially in the light of the climate justice disparities noted by the IPCC (see above) and other observers of the uneven nature of climate impacts upon populations and their human rights.

Geoengineering cannot be responsibly addressed without taking into account these patterns of power disparity. Hulme, for example, argues that the 'idea that global temperature is a suitable object of governance and one through which the well-being of humanity can be secured is a delusion' because it assumes the possibility of a non-existent global community with similar interests and values. Such a 'global community' is a figment of the imagination, particularly viewed from the perspective of the Least Developed Nations vulnerable to climate impacts.

86. Ibid 23–4.
87. M Hulme, *Can Science Fix Climate Change? A Case against Climate Engineering* (Polity Press, Cambridge 2014) 54.
88. Ibid 133–4. See also Hamilton (n 43) and Klein (n 64).
89. Klein (n 64) 275.

In reality, then, deciding whether geoengineering research should be subject to a moratorium raises extremely complex issues of governance and procedural justice. Because wide-scale deployment of SRM potentially affects everyone, failure to secure international approval would be unjust. It follows that long-term solutions to climate change must be as inclusive, democratic and transparent as possible – yet the difficulty of obtaining genuine consent and participation in relation to geoengineering is abundantly clear: the tension between expert technocratic evaluation and democratic deliberative decision making is often further compounded by the difficulties in establishing fora in which informed individuals are to participate on an equal basis and freely give consent. While this is true of all significant transboundary risks, the deeply uncertain and possibly irreversible effects of SRM suggest that it ought to be regarded as illegitimate in the absence of the widest possible degree of participation. Yet this is difficult to achieve. Participation has, in any case, a long track-record in relation to uneven power: historically, non-state actors such as women, social movements and NGOs have been excluded from effective participation. Inclusive participation is crucial if geoengineering is legitimately to satisfy environmental human rights standards. As Cotton argues:

> The direct inclusion of individuals in the political and ethical discussion of technology implementation remains important because the implicit consent involved in technocratic decision-making or national and regional voting … is insufficient to legitimately expose individuals to additional or elevated risks, costs and other burdens that may result without informed consent. Inclusive participation is required so that consent can be obtained explicitly and transparently from those affected, improving the procedural fairness of all manner of decision-making processes and hence improving the democratic validity of a range of possible policy outcomes.[90]

It is difficult to see how geoengineering, at present, can satisfy the ethical requirement of full participatory inclusion for affected communities. What then, of the status of environmental modification itself?

The only treaty that unambiguously regulates international attempts to control the climate is the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD), which is the only binding treaty that covers intentional attempts to control climate.[91] Article 1 prohibits the use of environmental modification techniques for military or other hostile purposes. However, ENMOD does not prohibit research and Article 3.1 states that the Convention 'shall not hinder the use of environmental modification techniques for peaceful purposes'. Reynolds, who believes that international environmental law is generally favourable to geoengineering, albeit more by default than design, suggests that it will be difficult to enforce a complaint under the Convention.[92]

Sands et al. identify seven general rules and principles of international environmental law that enjoy broad if not universal support and are frequently endorsed by state practice.[93] These comprise the responsibility not to cause transboundary

90. Cotton (n 67) 19.
91. Reynolds (n 5) 441–3; D Bodansky, 'The Who, What, and Wherefore of Geoengineering Governance' (2013) 121(3) Climatic Change 539.
92. Reynolds (n 5) 442–3. He argues at 482 that the UNFCCC may be read as favourable and that 'ENMOD and the UNEP Provisions for Weather Modification each encourage the development of peaceful climate engineering'.
93. P Sands, J Peel, A Fabra and R MacKenzie, *Principles of International Environmental Law* (Cambridge University Press, Cambridge 2015) 187.

environmental damage; the principle of preventive action; the principle of co-operation; the polluter pays principle; sustainable development; the precautionary principle; and the principle of common but differentiated responsibility.[94] The authors point out that it is difficult to establish which principle takes precedence in the absence of clear judicial authority and in the light of conflicting interpretations of state practice. On face value, the precautionary principle would seem to be clearly applicable to geoengineering but there is no consensus on its meaning and enforceability.[95] Principle 15 in the Rio Declaration on Environment and Development states: 'In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation'.[96] Bodansky argues in relation to the precautionary principle and geoengineering that 'failure to take action could also result in irreversible and catastrophic harm due to global warming, so it is unclear which way the principle cuts'.[97] It seems then, that not only is the science unclear (with uncertain and troubling levels of potential risk), but the law is also uncertain.

When the science is unclear and the law is uncertain, ethics and politics carry greater weight. As the Royal Society report argued, 'the acceptability of geoengineering will be determined as much by social, legal and political factors, as by scientific and technical factors'.[98] The reach of the precautionary principle concerning geoengineering projects, in the face of such factors, is unclear. For example, the United Kingdom (UK) House of Commons Science and Technology Committee concluded that the application of the precautionary principle should have limited application in the UK because strict application might limit British research without preventing other actors from violating common rules.[99] The Committee considered the five Oxford Principles: geoengineering should be regulated as a public good, there should be public participation in decisions about research and deployment and full disclosure and open publication of the results of any intervention, independent assessment of possible impacts, and governance structures should be in place prior to deployment.[100] The Committee called for a set of principles to guide international regimes on geoengineering techniques and for the groundwork for regulatory arrangements to begin.[101]

Such a set of principles would be a useful contribution to geoengineering governance. All in all, the current state of the law suggests that it is at this time impossible to prohibit geoengineering research, but that it is difficult for those who wish to implement its results to escape surveillance. Stilgoe believes that collective experimentation

94. A rights-based approach to climate change should in principle reinforce the precautionary principle.
95. Bodle argues that its status in the UNFCCC is ambiguous at best. R Bodle, 'Geoengineering and International Law: The Search for Common Legal Ground' (2010) 46(2) Tulsa Law Review 305 at 311. See also J Virgoe, 'International Governance of a Possible Geoengineering Intervention to Combat Climate Change' (2009) 95(1–2) Climatic Change 103 at 111.
96. UN Doc. A/CONF.151/26 (vol I) / 31 ILM 874 (14 June 1992). See also Article 3.3 of the UNFCCC.
97. Bodansky (n 91) 542.
98. Royal Society (n 39) 50.
99. House of Commons, *Science and Technology Committee: The Regulation of Geoengineering, Fifth Report of Session 2009–10* (The Stationery Office, London 2010).
100. S Rayner, C Heyward, T Kruger, N Pidgeon, C Redgwell and J Savulescu, 'The Oxford Principles' (2013) 121(3) Climatic Change 499.
101. House of Commons (n 99) 3.

is an appropriate mode for the governance of geoengineering.[102] Humphreys argues that the diversity of geoengineering techniques makes it difficult to justify a blanket prohibition. Minimally, it is clear that a comprehensive regulatory framework that promotes transparency and accountability would do much to secure consent and legitimacy, subject to the complexities and difficulties concerning consent and participation, noted above, being satisfactorily faced and dealt with. Collective experimentation, however, cannot possibly provide a normatively satisfying mode for the governance of geoengineering unless and until full account is taken of environmental human rights – and of the absolute centrality to their realization of genuine, inclusive participation for vulnerable and affected communities.

7 CONCLUSION

Hulme describes climate change as a wicked problem that science cannot and should not try to fix.[103] Science, as this discussion has intimated, offers limited solutions, meaning that the only way forward is to deal with the social, political, economic and ethical issues that have created the problem and arise as a result of it. As Harvey argues, it is 'abundantly clear that there will be no major transformation in our relation to nature without changes in social relations, in *mentalités*, and in ways of sustaining material life, as well as in the hardware, software, and organizational forms of technologies'.[104] More fundamentally, as Gardiner asks, 'if the problem is social and political, why isn't the solution social and political as well?'[105]

There are very strong reasons to argue that we need to fix our attitudes rather than attempting to fix the planet through the application of technologies carrying high levels of potential risk, a minimal chance of reducing climate-driven international conflict and high levels of genuine complexity related to consent, participation and inclusion. The question of risk remains unanswered – and decisively important. Meanwhile, Henry Shue argues that delaying the transition to renewable technologies is an inexcusable wrong because it will subject our children and future generations to:

> risks of unknowable probability but of enormous possible magnitude, including radical change in the very conditions of life, human and non-human, on this planet. It is vital not to make the mistaken assumption that if the size of a risk is unknown, the risk must be small – as if it could be unknown only if it were too small to see … The imposition of such risks – of unknown (not necessarily small) probability and large magnitude – seems to me to be an inexcusable wrong.[106]

102. Stilgoe (n 77).
103. Hulme (n 87) 119 borrows the term from Horst Rittel, who used it to describe public policy concerns that defy rational and optimal solutions. This brings to mind Boaventura de Sousa Santos's assertion that we live in an era of strong questions and weak answers <http://www.ces.uc.pt/myces/UserFiles/livros/278_If%20God%20were%20a%20Human%20Rights%20Activist_LawSocialJustice_09.pdf> last accessed 16 August 2014.
104. Harvey (n 84) 14.
105. SM Gardiner, 'Some Early Ethics of Geoengineering the Climate: A Commentary on the Values of the Royal Society Report' (2011) 20(2) Environmental Values 163 at 173. Gardiner (n 55) argues that political inertia increases support for geoengineering.
106. Shue (n 4) 215.

Klein correctly argues that geoengineering is 'the ultimate expression of a desire to avoid doing the hard work of reducing emissions'.[107] Even a strong proponent like David Keith accepts that geoengineering 'is a technical fix, kluge, or end-of-pipe solution. Rather than attacking the problems caused by fossil fuel combustion at their source, geoengineering aims to add new technology to counter their side effects'.[108] But in Hulme's view, the dream of a global thermostat in the sky is undesirable, ungovernable and unattainable, and stratospheric aerosol injection 'is the wrong sort of solution to the wrong sort of problem. Human-induced climate change is not the sort of problem that lends itself to technological end-of-pipe solutions'.[109] It is worrying that despite these concerns, and despite the clear human-rights-related risks, geoengineering is increasingly touted as a safe solution to climate change.[110]

In short, anthropogenic climate change began with the extraction of coal through the use of technologies. Many technologies are safe, and enhance human well-being and the protection of human rights – but the lesson of global warming is that we should be extremely wary of gambling on a Faustian pact with geoengineering. Resisting the siren calls of unproven geoengineering methods is not Luddite, because it is clear that increasingly cheap renewable energy makes it possible to reduce emissions and to decarbonize the global economy by the middle of the century. Prudence dictates caution and the prevention of harm. Respect for environmental human rights indicates the central role of participation and the guarantee of genuine inclusion in the construction of community consent, while legitimate consent demands a cautious response to both risk and technological hubris alike. Mitigation is both prudent and ethically preferable at this juncture.

107. Interview with Naomi Klein, 'Green Groups May Be More Damaging than Climate Change Deniers' <https://earthfirstnews.wordpress.com/2013/09/05/naomi-klein-green-groups-may-be-more-damaging-than-climate-change-deniers/> accessed 16 August 2016.
108. Keith (n 59) 277.
109. Hulme (n 87) 118.
110. O Morton, *The Planet Remade: How Geoengineering Could Change the World* (Princeton University Press, Princeton, NJ 2016).