Geoengineering: Ethics, Risks and Rights

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Abstract: Geoengineering technologies generate intense ethical debates about the risks that manipulating the Earth's climate will provoke unforeseen, unintended and uncontrollable consequences that threaten human rights. This article focuses on the advantages and risks of solar radiation management techniques (also known as albedo management), which are difficult to test on a wide scale and may not be capable of being recalled after deployment. Adequate governance structures do not currently exist to assess and regulate the risks of climate engineering, and SRM technologies have not been clearly shown to be safe. SRM raises significant ethical problems which lead me to conclude that we need to fix our attitudes rather than the planet, eschew technological hubris, and accept that the safest technological solution is renewable energy.

Keywords: Geoengineering; solar radiation management; human rights; risk, ethics; governance

1. Introduction

The widely accepted definition of geoengineering is the 'deliberate, large-scale manipulation of the planetary environment in order to counteract anthropogenic climate change.'[1] The term refers to diverse techniques commonly divided into two groups. Solar radiation management (SRM) techniques are designed to reduce solar radiation reaching the Earth's surface by injecting sulphate particles into the stratosphere-the so-called Pinatubo effect that that aims to simulate the effects of volcanic eruptions. SRM is often claimed to be cheap to develop and easy to deploy, with positive short-term but dangerous long-term effects. The Royal Society viewed SRM as fast and cheap, but uncertain and prone to unintended side effects that may

[1] Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty* (The Royal Society, London 2009) 1.

not be able to be unwound.[2] Carbon dioxide removal (CDR) techniques such as carbon capture and storage and ocean fertilisation remove CO_2 from the atmosphere.[3] CDR is expensive and time-consuming to develop, but safe and effective in the long-term.

The main contention in this article is that SRM technologies in their current forms pose insuperable ethical and governance questions because it is unclear that their benefits outweigh their risks and, therefore, that unforeseen and unintended consequences of their deployment are likely to threaten the human rights of current and future generations. Once implemented, SRM may be uncontainable and irreversible. I argue that SRM creates a moral hazard and is likely to have a disproportionately negative effects on climate sensitive regions of the global South with low adaptive capacities.

The paper is divided into six sections. Following this introductory section, I briefly outline the threat that climate change poses to a range of human rights including fundamental rights such as the rights to life and to food. I evaluate the risks of SRM in section 3 and address the ethics of geoengineering and the dangers arising from an overweening faith in technological solutions in section 4. The fifth section examines some of the difficulties in developing a governance regime for geoengineering, the relevance of principles of international environmental law such as the precautionary principle, and importance of procedural rights in decisions about the possible deployment of geoengineering.[4]. In the concluding section I argue that the risks of SRM outweigh its potential benefits and that the safest and most ethical way to address climate change is through the use of renewable technologies that are known to be safe and effective in reducing emissions.

Climate manipulation may be irreversible consequences because scientists cannot be certain how the biosphere will respond to forced interventions. These include concerns that SSI

[2] On unintended side effects, see Clive Hamilton, *Earthmasters: The Dawn of the Age of Climate Engineering* (Yale University Press, New Haven 2013) 115-16.
[3] Geoengineering is regularly described as a complement to adaptation and mitigation (Royal Society n 1 57), but Heyward argues that it should not be conceived as a third category but that CDR and SRM should instead 'be regarded as two parts of a five-part continuum of responses to climate change.' Clare Heyward, 'Situating and Abandoning Geoengineering: A Typology of Five Responses to Dangerous Climate Change' (2013) *PS: Political Science & Politics* 46 23, 23. Geoengineering is also referred to as climate engineering and I use the terms interchangeably.
[4] I limit my discussion to the precautionary and no-harm principles. For an extensive examination of other applicable international law see J Reynolds 'Climate Engineering Field Research: The Favorable Setting of International Environmental Law' (2014) *Washington & Lee Journal of Energy, Climate and Environment* 5 417.

could lead to feedback processes that increase '"acid rain" and exacerbate ocean acidification.'[5] The 2009 Royal Society report regarded stratospheric sulfate injection (SSI) as more promising than space-based SRM methods but 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.'[6] I focus on SRM in general and SSI in particular because their consequences are more uncertain than CDR and thus give rise to the more profound ethical dilemmas. Like albedo reflection techniques, SSI may be relatively straightforward in technological terms but carries (foreseeable) risks that sulphates might slow or reverse the recovery of the ozone layer and reduce global rainfall (which may become more acidic) while increasing flooding and intensifying extreme weather events.[7] SRM is technically more difficult than CDR and merely *offsets* some effects of greenhouse gas (GHG) emissions, whereas the latter is both less risky and addresses the *cause* of climate change. CDR is generally considered to be relatively benign but will be extremely expensive to deploy on a scale sufficient to prevent average global temperature from increasing by more than targets in article 2 of the Paris Agreement.[8] If successful, geoengineering will take decades to reduce atmospheric CO_2 to safe levels. Like other SRM technologies, SSI is highly speculative. Because it cannot be adequately be tested in laboratories or large-scale field trials, scientists are forced to rely on models that are intrinsically uncertain.[9] As such, it raises complex issues of justice, ethics, liability, accountability and governance.

[5] Royal Society n 1 36; Y Chang and A Posch 'The Wickedness and Complexity of Decision Making in Geoengineering' (2014) *Challenges* 5(2), 390.
[6] Royal Society, n 1 36. Space-based techniques include placing mirrors in space to deflect incoming radiation; other SRM methods include cloud brightening and painting roofs white to reflect sunlight.
[7] 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). See also 'The Hidden Dangers of Geoengineering', *Scientific American*, 3 October 2008 <http://www.scientificamerican.com/article/the-hidden-dangers-of-geoengineering/> (last accessed 15 September 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) *Journal of Geophysical Research: Atmospheres* 113, D16101. Robock has expressed concerns at the CIA's interest in geoengineering: 'The CIA asked me about controlling the climate – this is why we should worry', The *Guardian*, 17 February 2015 <http://www.theguardian.com/commentisfree/2015/feb/17/cia-controlling-climate-geoengineering-climate-change> accessed 18 February 2015.
[8] On the limitations of CDR, see E Kintisch, 'Can Sucking CO_2 Out of the Atmosphere Really Work?' <https://www.technologyreview.com/s/531346/can-sucking-co2-out-of-the-atmosphere-really-work/> accessed 29 March 2016. Under article 2, parties aim to hold 'the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels.' Small island developing states have long insisted that the latter figure is a prerequisite for their survival. Article 4.1 is similarly vague, stating that 'In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible.' *Paris Agreement* (FCCC/CP/2015/L.9/Rev.1, 12 December 2015).
[9] Stilgoe notes that 'research using models is at an early stage.' J Stilgoe *Experiment Earth: Responsible Innovation in Geoengineering* (Routledge, Abingdon 2015) 171.

The Intergovernmental Panel on Climate Change (IPCC) finds that GHG emissions have reached dangerous levels and its work clearly indicates that we are facing a planetary emergency which increasingly threatens the human rights of current and future generations.[10] In 2015, driven by climate change and a strong El Niño, global average surface temperature records were broken by the strikingly wide margin of 0.76°C above the average between 1961 and 1990. Ocean heat down to 700m and 2000m also broke all previous records. The World Meteorological Organization's (WMO) 2014 figures put CO_2 levels at 397.7 ppm, 43 per cent higher than pre-industrial levels and on the brink of breaking through the symbolic level of 400 ppm.[11] Sea level, measured by both traditional tide gauges and satellites, was also the highest on record.[12] As WMO Secretary-General Petteri Taalas observes, 'We have reached for the first time the threshold of 1°C above pre-industrial temperatures. It is a sobering moment in the history of our planet.'[13]

2. Climate Change and Human Rights

The impacts of anthropogenic global warming affect everyone but those least responsible for GHG emissions, the poor and vulnerable, invariably suffer most-especially those in the global South due to underdevelopment, low adaptive capacities and greater reliance on climate sensitive sectors such as agriculture. Non-human species are profoundly affected by human activity.[14] Climate change affects a wide range of human rights, not least those of the inhabitants of small island states at risk of inundation. In 2007, the Association of Small Island States (AOSIS), which represents small island states threatened with inundation from rising sea levels, expressed alarm 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 the highest attainable standard of

[10] On the science, see IPCC, *Climate Change 2014: Synthesis Report - Longer Report* (Intergovernmental Panel on Climate Change, Geneva 2014. On the threat to human rights, see H Shue, *Climate Justice: Vulnerability and Protection* (OUP, Oxford 2014).
[11] The latest available at the time of writing.
[12] M Slezak 'Global warming taking place at an 'alarming rate', UN climate body warns', *The Guardian* 16 March 2016 <http://www.theguardian.com/environment/2016/mar/21/global-warming-taking-place-at-an-alarming-rate-un-climate-body-warns> accessed 25 March 2016.
[13] '2015 is hottest year on record' <http://public.wmo.int/en/media/press-release/2015-hottest-year-record> accessed 25 March 2016.
[14] More than half of all species (52 per cent) were lost between 1970 and 2010: WWF, *Living Planet Report 2014. Species and spaces, people and places* (WWF International, Gland, Switzerland 2014) 8.

physical and mental health. AOSIS adopted the Malé Declaration on [the] Human Dimension of Global Climate Change which asserts ‘the fundamental right to an environment capable of supporting human society and the full enjoyment of human rights.’[15]

Richardson et al. estimate that a one metre sea level rise will eliminate the lowest islands and ‘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.’[16] Amongst the human rights that will be threatened are the rights to life, food, health, property, the benefits of culture, to family life and their rights to use and enjoy the lands they have traditionally occupied.[17] The fifth IPCC assessment report warns that the impacts of anthropogenic global warming will be ‘severe, pervasive and irreversible.’[18] The IPCC predicts that injuries, diseases and deaths will increase due to more intense heatwaves and fires, and under-nutrition will result from diminished food production in poor regions of the world. The right to health will increasingly be threatened by food- and water- and vector-borne diseases.[19]

The right to private and family life and the right to culture will be affected as increasing warming puts some ecosystems at risk of abrupt and irreversible changes that will reduce economic growth and poverty reduction, erode food security and trigger new poverty traps, particularly in urban areas and hunger hotspots. The IPCC predicts with high confidence that hundreds of millions of people will be displaced by land loss from coastal and inland

[15] Male’ Declaration on the Human Dimension of Global Climate Change, 14 November 2007 <http://www.ciel.org/Publications/Male_Declaration_Nov07.pdf> accessed 17 March 2016.
[16] K Richardson, W Steffen and D Liverman (eds), *Climate Change: Global Risks, Challenges and Decisions* (CUP, Cambridge 2011), 66.
[17] The 2005 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, 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 2 February 2015. On the first day of COP 21 in Paris, the Philippines Commission on Human Rights agreed to hear a petition claiming that the world’s 50 oil majors have violated the human rights of Filipino’s-and by extension, all of humanity <http://www.greenpeace.org/seasia/ph/PageFiles/105904/Climate-Change-and-Human-Rights-Complaint.pdf> accessed 26 March 2016.
[18] IPCC n 10 14. For an extended discussion of 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* (CUP, Cambridge 2010) and S Adelman ‘Human Rights and Climate Change’ in G Digiacomo (ed), *Human Rights: Current Issues and Controversies* (University of Toronto Press, Toronto 2016).
[19] M L. 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* (CUP, Cambridge 2007).

flooding with a concomitant increase of 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.[20]

The right to food will be threatened by the breakdown of food systems due to warming, drought, flooding, and desertification. All aspects of food security are likely to be affected, not least access to food. Rural livelihoods and income will be undermined by insufficient access to water for drinking and irrigation, and 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.[21]

Somewhat bizarrely, in 2009 the first international body to address the relationship between human rights and climate change, the Office of the UN High Commissioner for Human Rights, decided that although climate change threatens a wide range of human rights it does not necessarily violate them. The OCHCR nonetheless concluded that human rights law imposes obligations on states in relation to climate change, including an obligation of international cooperation.[22]

3. Geoengineering and Risk

To secure public consent, the benefits of a technology must outweigh its risks.[23] It must provide an effective remedy to the problem it aims to solve, be controllable, containable and, if necessary, reversible, avoid creating a moral hazard[24], and protect the human rights of current and future generations. Boyd et al. argue that social science is as important as natural

[20] Ibid.
[21] M L Parry n 19 13.
[22] OHCHR, *Report of the Office of the United Nations High Commissioner for Human Rights on the Relationship Between Climate Change and Human Rights*, U.N. Doc. A/HRC/10/61 (15 January 2009). J Knox, (2009) 'Linking Human Rights and Climate Change at the United Nations' *Harvard Environmental Law Review* 33 477.
[23] See the chapters in I M. Mintzer (ed.), *Confronting Climate Change: Risks, Implications and Responses* (CUP, Cambridge 1992).
[24] An economic term referring to the possibility that people will take greater risks if they are insured, leaving insurers with more and larger claims than anticipated. The UK House of Commons Science and Technology Committee recommended limiting the application of the precautionary principle on the basis that applying it might limit British research without preventing other actors from violating common rules. House of Commons, *Science and Technology Committee: The Regulation of Geoengineering, Fifth report of session 2009-10* (The Stationery Office, London 2010).

science in evaluating risk, and that factors such as betrayal aversion and risk equity are two factors that demonstrate why ignoring public opinion is undemocratic and inappropriate.[25] In addition, 'subjective 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.'[26]

Climate change creates risks of social and political unrest and armed conflicts that undermine human rights.[27] It threatens the right to peace and security and 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.'[28] Geoengineering increases the risk of conflict because of the danger that the effects of an attempt by one or more countries to manipulate their climate will not be limited to a locality or region without affecting that of other countries. For this reason, attempts by a single state or bloc to deploy a 'global thermostat' may be regarded as an hostile act.[29] In 2015, the US National Academy of Sciences 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.'[30]

[25] W Boyd, D Kysar and J J Rachlinski, 'Law, Environment, and the "Nondismal" Social Sciences', *Cornell Law Faculty Publications* (2012) Paper 643 <http://scholarship.law.cornell.edu/facpub/643> accessed 9 February 2015. Betrayal aversion leads people to take risks less willingly when the agent of uncertainty is another person rather than nature.
[26] P A T Higgins and J V Steinbuck, 'A Conceptual Tool for Climate Change Risk Assessment' (2014) *Earth Interactions* 18 1, 2.
[27] S H 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?* (CUP, Cambridge, 2010), 7. See also G Dyer, *Climate Wars: The Fight for Survival as the World Overheats* (Oneworld, Oxford 2010) and the papers in F Gemenne et al, (2014) *Climatic Change* 123(1) Special Issue: Climate and Security: Evidence, Emerging Risks, and a New Agenda. Evidence suggests that drought exacerbated by global warming is a contributory factor in the Syrian civil war that erupted in 2011. C P. Kelley et al., 'Climate change in the Fertile Crescent and implications of the recent Syrian drought' (2015) *Proceedings of the National Academy of Sciences.* 112(11) 3241.
[28] The World Economic Forum regards the failure of climate change mitigation and adaptation as the biggest global risk: WEF, *The Global Risks Report 2016* (Geneva: WEF, 2016) and the Pentagon anticipates that 'Global climate change will have wide ranging implications for US national security interests over the foreseeable future because it will aggravate existing problems - such poverty, social tensions, environmental degradation, ineffectual leadership, and weak political institutions – that threaten political stability in a number of countries.' 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.
[29] See W W Kellogg and S H Schneider, 'Climate stabilization: for better or for worse?' (1974) *Science* 186:4170 1163-1172; S Barrett, 'The incredible economics of geoengineering', (2008) *Environmental and Resource Economics* 39(1) 45-54, 41; A Maas and I Comardicea, 'Climate Gambit: Engineering Climate Security Risks?' in G D Dabelko et al. (eds) *Backdraft: The Conflict Potential of Climate Change Adaptation and Mitigation* (Woodrow Wilson International Center for Scholars, Washington, DC 2013) 37.
[30] National Research Council of the National Academies, n 7 ix-x.

Objections to climate engineering arise from concerns that it 'entails "messing with" a complex, poorly understood system'[31] and creates unacceptable levels of uncertainty and risk.[32] In 2012, a British project to test sulphur injection into the atmosphere was abandoned, ostensibly due to difficulties with a patent application.[33] Proponents of geoengineering counter that the Anthropocene is the result of unprecedented manipulation of the climate through greenhouse gas emissions that will require further inventions necessary if and when mitigation is conclusively demonstrated to have failed.[34] They argue that it is not clear that geoengineering is more unpredictable or risky, and that potentially negative side-effects are not more ethically problematic than the continued use of fossil fuels.[35]

In 2014, a team of researchers compared five proposed methods of climate engineering and concluded that all were 'relatively ineffective' and might have 'potentially severe side effects.' Reflecting the sun's rays into space would alter rainfall patterns, while reforesting deserts could change wind patterns and possibly reduce tree growth in other regions. They concluded that two of the five methods considered could not be safely stopped, and that 'if solar radiation management or ocean upwelling is discontinued then rapid warming occurs. If the other methods are discontinued, less dramatic changes occur.' The researchers expressed concern that such interventions may lead to chaos in complex and not fully understood weather systems resulting in catastrophe, and that they would achieve a maximum reduction in temperature of 8 per cent even if they are widely deployed.[36] In other words, SRM

[31] D W Keith, 'Geoengineering the climate: History and prospect' (2000) *Annual Review of Energy and the Environment 25* 245, 277.
[32] 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) *Energy Research & Social Science*. 2 135.
[33] N Pidgeon et al., 'Deliberating Stratospheric Aerosols for Climate Geoengineering and the Spice Project' (2013) *Nature Climate Change*. 3(5) 451. See also the E-PEACE Eastern Pacific Emitted Aerosol Cloud Experiment <http://aerosols.ucsd.edu/E_PEACE.html> accessed 15 September 2014. For an extended discussion of the SPICE project see Stilgoe n 9.
[34] For an evaluation of the risks of geoengineering see K Caldeira et al., 'The Science of Geoengineering' (2013) *The Annual Review of Earth and Planetary Sciences* 41 231.
[35] The IPCC believes that although SRM has numerous side effects, risks and shortcomings, some methods, 'if practicable, could substantially offset a global temperature rise and partially offset some other impacts of global warming, but the compensation for the climate change caused by GHGs would be imprecise.' O Boucher et al., 'Clouds and Aerosols' in T. F. Stocker et al., *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, Cambridge 2013), 7.
[36] D P Keller et al., 'Potential climate engineering effectiveness and side effects during a high carbon dioxide-emission scenario' (2014) *Nature Communications* 5, Article 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

potentially creates severs termination risks because it produces a cooling effect without reducing the overall amount of CO_2 in the atmosphere, meaning that warming will resume if it is discontinued-and might be greater than if SRM had not been implemented. 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 this centuries-long fairy tale of control.'[37] It is difficult to disagree with the conclusion of Barrett et al. that plausible SRM scenarios suggest that 'when its use is politically feasible, geoengineering may not be effective; and that, when its use might be effective, its deployment may not be politically feasible.'[38] They argue that the insuperable problem confronting advocates of geoengineering is that it is difficult to model and risky to deploy uncertain technologies that may be reversible. Considering the possibility that geoengineering may increase global crop yields, Pongratz et al. provide a typical formulation of the dilemma: 'although SRM may allow beneficial effects of CO_2 fertilization at a comparatively low level of climate change, the potential for such approaches to reduce the overall risks is still far from established. The safest option to reduce the climate risks to global food security may be to reduce emissions of greenhouse gases.'[39] SRM may be impossible to halt because of the dangers of unleashing suppressed heating in a short period. Some defenders of geoengineering appear willing to gamble that failure to reduce GHG concentrations in the atmosphere will push humanity to a tipping point at which the risk of doing nothing exceeds the hazards of doing something and generates irresistible pressure to manipulate the climate, leading states to become addicted to geoengineering.[40]

Ferraro et al. applied a simple, risk-based framework to two climate model geoengineering simulations designed to counterbalance surface warming produced by a quadrupling of carbon dioxide concentrations, one using a layer of sulphate aerosol in the lower stratosphere, the other a reduction in total solar irradiance. Assuming that 'the goal of geoengineering is

waters to the surface of oceans, and irrigating vast areas of the north African and Australian deserts to grow millions of trees.

[37] N Klein, *This Changes Everything: Capitalism vs the Climate* (Allen Lane, London 2014) 267.
[38] S Barrett et al., 'Climate Engineering Reconsidered' (2014) *Nature Climate Change* 4 527, 529.
[39] J. Pongratz et al., 'Crop Yields in a Geoengineered Climate' (2012) *Nature Climate Change* 2(2) 101.
[40] Barrett et al., n 38.

the reduction of the risk of exceeding a given climate threshold in a given year' and that 'geoengineering may be considered successful if this risk is reduced.,'[41] they found that:

> In the solar dimming simulation, 10% of the Earth's surface area, containing 10% of its population and 11% of its gross domestic product, experiences greater risk of substantial precipitation changes under geoengineering than under enhanced carbon dioxide concentrations. In the aerosol geoengineering simulation the increased risk of substantial precipitation change is experienced by 42% of Earth's surface area, containing 36% of its population and 60% of its gross domestic product.[42]

The authors concluded that 'the treatment itself carries risks, and substantial parts of the world (whether measured by area, population or economic activity) experience greater risk when the geoengineering treatment is applied than when the effects of CO2 on their climate are unabated.'[43]

Balancing the putative advantages of SRM against the risks of unchecked GHG emissions relies on scientific inputs that can never produce definitive answers due to intrinsic uncertainties in both climate science and SRM techniques. Bioethical debates on human fertilisation and embryology suggest that securing consent about complex problems and technologies involves ethical, political and philosophical considerations that outweigh economic cost-benefit analyses and quantitative risk assessments.[44] Both methods are ethically problematic when applied to risks that should not be valued only in monetary terms such as the loss of one's homeland and culture. As Stern makes clear, conventional economics does not inadequately to address the needs of future generations and catastrophic risks resulting in non-substitutable loss and damage.[45] Cost-benefit analysis discounts future costs and benefits to current values and tends to favour contemporary action over deferred

[41] Ferraro, Angus J., Andrew J. Charlton-Perez, and Eleanor J. Highwood. 2014. 'A risk-based framework for assessing the effectiveness of stratospheric aerosol geoengineering', *PloS one* 9(2): e88849, 1-6, 4. The authors warn that these results are 'from a single climate model of intermediate complexity [and therefore may not be] a good measure of the potential real-world impacts of stratospheric aerosol geoengineering,' 4-5.
[42] Ibid. 1.
[43] Ibid. 6.
[44] Beauchamp and Childress adumbrate four principles that should inform bioethics: autonomy, beneficence, avoiding and justice in the distribution of benefits and burdens. T L Beauchamp and J F Childress *Principles of Biomedical Ethics* (OUP, Oxford 2001). See Gardiner's critique of cost-benefit analyses in S M Gardiner, 'Is "Arming the Future" Really the Lesser Evil? Some Doubts about the Ethics of Intentionally Manipulating the Climate System' in S M Gardiner et al., (eds), *Climate Ethics: Essential Readings* (OUP, Oxford 2010) 287-88.
[45] N Stern, 'The economics of climate change' (2008) *American Economic Review* 98 1.

benefits. It is essentially utilitarian and 'has only a partial and contingent commitment to the basic interests and entitlements of the most vulnerable.'[46] Klinke and Renn argue that the intrinsic uncertainties of albedo modification make risk-benefit analysis an inappropriate basis for deciding whether research should be encouraged.[47] Quantitative environmental risk assessment is ostensibly neutral and objective but masks the value-laden premises in which risks are framed. The reduction of:

> complex causalities to individual 'risk factors' plays down the distributive effects of risk, emphasizes what is known about an issue at the expense of what is not known, and tends to privilege physical and biological sciences over social sciences. The very concept of risk, moreover, implies the possibility of management, and hence tacitly favours moving ahead with new activities under controls that experts consider suitably protective.[48]

A third approach is comparative risk analysis, which combines three principles: environmental policy making must be technocratic rather than political, environmental risks should be measured in terms of potential losses, for example of habitats and ecosystems, and risks should be reduced to a common metric.[49]

Following the work of Ulrich Beck and others, risk evaluation is no longer regarded as a technical matter best left to scientists or economists.[50] Cotton argues that 'Risk is now established as a complex multi-dimensional psychological construct and a form of social discourse. [This] involves paying attention to the wider context of individuals' beliefs, attitudes, perceptions, judgements and feelings, alongside significant questions of ethics and political governance.'[51] How the risks posed by geoengineering are perceived in public discourse will greatly influence ethical and political responses.

[46] S Caney, 'Climate Change, Human Rights, and Moral Thresholds' in Gardiner et al. n 44.
[47] A Klinke and O Renn, 'A New Approach to Risk Evaluation and Management: Risk-Based, Precaution-Based and Discourse-Based Strategies' (2002) 22 *Risk Analysis* 1071, 1072.
[48] S Jasanoff, 'Science and environmental citizenship' in P Dauverge (ed) *Global Environmental Politics* (Edward Elgar, Cheltenham 2005) 365, 371.
[49] D T Hornstein, 'Reclaiming Environmental Law: A Normative Critique of Comparative Analysis' (1992) 92 *Columbia Law Review* 562.
[50] U Beck, Ulrich, *Risk Society: Toward a New Modernity* (Sage, London 1992); D Lupton (ed). *Risk and Sociocultural Theory: New Directions and Perspectives* CUP, Cambridge 1999).
[51] M Cotton, *Ethics and Technology Assessment: A Participatory Approach* (Springer, London 2014), 6.

4. The Ethics of Geoengineering

Nobel chemistry laureate Paul Crutzen's cautious suggestion in 2006 that SRM should be considered a legitimate way to reduce the impacts of climate change ignited a fierce ethical debate that shows no signs of abating.[52] On one side of the debate are those who fear that climate engineering may unleash unforeseeable risks, exacerbate the effects of rising sea levels, intensify ocean acidification and lead to significant alterations in seasonal and spatial patterns of precipitation resulting in droughts, desertification and flooding that threaten human rights. In the opposing camp are those who argue that geoengineering may be the only means available to protect human rights if the Paris Agreement does not succeed limiting dangerous anthropogenic warming. On this basis, they argue that geoengineering research should be viewed as a form of insurance against climate change which would be negligent and unethical to spurn, even if it is only a stopgap measure that buys time for mitigation to succeed.

Geoengineering may be a lesser evil than climate change but as Stephen Gardiner points out, it may nonetheless be so deeply harming that it should be treated as a 'marring evil.'[53] We may accept that supporters do not regard SRM as an alternative to emissions reductions while maintaining that it is ethically dubious to rely on hopeful claims of future success rather than effective mitigation strategies based upon energy conservation and renewable technologies. As Gardiner argues, to avoid being confronted with a choice of nightmares, the most rational approach should be the pursuit of a viable long-term solution.[54] He argues that 'there is something morally problematic about geoengineering proposals' and that the burden of proof is therefore on those who support geoengineering.[55] Gardiner cogently argues that pushing '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.'[56]

[52] P Crutzen, 'Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?' (2006) *Climatic Change* 77(3-4) 211.
[53] Gardiner n 44.
[54] Gardiner, n 44 and S M Gardiner, 'The Desperation Argument for Geoengineering' (2013) *Ps: Political Science & Politics* 46(1) 28.
[55] Gardiner, n 44 at 285.
[56] Gardiner (2013) n 54 28.

A common objection to SRM is that it constitutes a moral hazard because it creates false hopes that science will produce a technological silver bullet that reduces incentives to cut emissions and benefits free riders who continue to use fossil fuels in the expectation that climate change is containable in a gamble with humanity's future.[57]. For David Keith, a strong proponent of geoengineering:[58]

> 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 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.[59]

An example of moral hazard is Russia's call for geoengineering to be included in the 2013 IPCC report, perhaps in search of legitimacy for its desire to exploit oil and gas reserves in the Arctic and an attempt to divert attention away from its continuing heavy dependence on fossil fuels.[60]

Jack Stilgoe acknowledges that despite uncertainties about its effectiveness and desirability, geoengineering has 'acquired a deterministic frame, based on the assumption that it is "cheap" and "easy"' and has thus 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.'[61] Klein wonders whether the readiness of supporters of geoengineering to gloss over the risks and in some cases:

[57] A Corner and N Pidgeon, 'Geoengineering the Climate: The Social and Ethical Implications' (2010) *Environment* (*52*) 24, 30-31; Royal Society n 1 37. On moral hazard, see Hamilton n 2 166-73.
[58] Keith n 31 276.
[59] Ibid.
[60] '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> 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.
[61] J Stilgoe, 'Geoengineering as Collective Experimentation' (2015) *Science and Engineering Ethics* DOI 10.1007/s11948-015-9646-0.

> 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?[62]

Resorting to SRM may perpetuate and exacerbate historical injustices should the global North take 'on the ultimate state of hubris to believe we can control Earth' while telling those most at risk from climate change not be concerned by the developed world's seemingly insatiable appetite for fossil fuels.[63]

Technological fetishism is the belief that technology provides a solution to every problem and occurs when cognitive dissonance about threats such as climate change results in unjustifiable leaps of faith that unproven technologies will save humanity from itself. David Harvey argues that the 'whole political-economic structure of power relations is suffused with a certain level of technological fetishism which can become self-sustaining.'[64] In Greek mythology, Prometheus stole fire from the gods to elevate humanity to a divine level and was punished for his hubris. 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 technological overreach, those who heed the warning that Nemesis waits in the shadows to punish Hubris.[65]

[62] Klein n 37 275.

[63] J Kiehl, 'Geoengineering Climate Change: Treating the Symptom over the Cause?' (2006) *Climatic Change* 77 227. On climate injustice and developing countries, see S Adelman 'Climate justice, loss and damage and compensation for small island developing states' (2016) *Journal of Human Rights and the Environment* 7(1) 32–53 and the other articles in this special issue on climate justice.

[64] D Harvey, 'The Fetish of Technology: Causes and Consequences' (2003) McAlaster International Vol. 13. DigitalCommons@Macalester College (2003) <http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CCMQFjAA&url=http%3A%2F%2Fdigitalcommons.macalester.edu%2Fcgi%2Fviewcontent.cgi%3Farticle%3D1411%26context%3Dmacintl&ei=an4RVMX1HISp7AbPhoCYDQ&usg=AFQjCNFKw4s90wzhCj4op-GAs6ySbVlwNA&bvm=bv.74894050,d.ZGU> accessed 11 September 2014 at 5.

[65] Hamilton n 2 18. Contrasting Prometheus with Soteria, the goddess of safety, preservation and deliverance from harm, Hamilton advocates a mentality of precaution and humility.

Technological hubris is the belief that technological limitations, unforeseen side effects and unintended consequences can be solved by future innovations. It is often associated with climate sceptics who insist that renewable technologies are unreliable and more expensive than fossil fuels despite abundant evidence to the contrary.[66]

Harvey notes that "Many technologies depend 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."[67] Mike Hulme contends that debates about climate engineering are disproportionately influenced by a small geoclique of predominantly North American and British male scientists through landmark publications such as the 2009 Royal Society report.[68] In his view, the geoclique aims to depoliticise climate engineering, making it imperative that its 'can-do' attitude should 'give way to the "should we" questions raised through ethical, moral and political reflection.'[69] Technological hubris has induced humanity to transgress four planetary of nine planetary boundaries: climate change, loss of biosphere integrity, land-system change, and altered biogeochemical cycles (phosphorus and nitrogen).[70] Foster observes that 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.'[71]

Since we know that renewable technologies can solve the problem if they are deployed early enough and on a sufficiently wide scale, we can agree with Sheila Jasanoff that wisdom and precaution should impel us towards technologies of humility that obviate the need for climate

[66] Research by the International Energy Agency indicates that the cost of producing electricity from renewable sources has dropped and significantly narrowed the gap with heavily subsidised power generated from fossil fuels. International Energy Agency and OECD Nuclear Energy Agency, *Projected Costs of Generating Electricity* (Nuclear Energy Agency, Paris 2015).
[67] Harvey n 64 23-24.
[68] See Hamilton, n 2 ch 4 and Klein n 37 ch 8.
[69] M Hulme, *Can Science Fix Climate Change?: A Case against Climate Engineering* (Polity Press, Cambridge 2014) 133-34.
[70] J Rockström et al., 'Planetary boundaries: Exploring the safe operating space for humanity' (2009) *Ecology and Society*. 14(2) 32. See also J B Foster, B Clark and R York, *The Ecological Rift: Capitalism's War on the Earth* (Monthly Review Press, New York 2010).
[71] J B Foster, 'Why Ecological Revolution?' in L King and Deborah M C Auriffeille (eds). *Environmental Sociology: From Analysis to Action* (Rowman & Littlefield, Lanham, MD 2005) 40.

engineering.[72] Humility might prevent the illegitimate use of technologies for which consent has not been obtained from people whose rights may be severely affected if they are deployed.

5. Climate Rights, Procedural Rights and the Governance of Geoengineering

Deciding whether geoengineering should be encouraged or subject to a moratorium raises complex issues of governance and procedural justice. In light of unforeseen or unintended consequences that might affect everyone, failure to secure the widest possible level of consent would be unjust. Hulme 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 a non-existent global community with similar interests and values.[73] The tension between technocratic evaluation and deliberative democracy is compounded by the difficulties in establishing fora in which informed individuals can participate on an equal basis and freely consent, including those whose participation has been limited such as women. 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.[74]

Steve Vanderheiden argues that the right to a stable climate is a basic human right: '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

[72] S Jasanoff, 'Technologies of Humility: Citizen Participation in Governing Science' (2003) *Minerva* 41 223. See S Adelman, 'Epistemologies of Mastery' in A Grear and L J Kotzé, *Research Handbook on Human Rights and the Environment* (Edward Elgar, Cheltenham 2015).
[73] Hulme n 69 54.
[74] Cotton n 41, at p. 19.

corollary of such a right.'[75] SRM threatens such a right unless it can be demonstrated beyond reasonable doubt that its advantages outweigh its risks. Principle 1 of the 1972 Stockholm Declaration of the United Nations Conference on the Human Environment declares 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 [… bear] a solemn responsibility to protect and improve the environment for present and future generations.'[76]

The only instrument that unambiguously regulates intentional attempts to control the climate is the Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD).[77] Article 1 prohibits the use of environmental modification techniques for military or other hostile purposes but ENMOD does not prohibit research. Article 3.1 states the Convention 'shall not hinder the use of environmental modification techniques for peaceful purposes.'

Establishing a regime to regulate geoengineering will succeed only if its membership and decision-making processes are accepted as politically legitimate, and this in turn depends upon acceptable levels of transparency and ethical accountability.[78] The importance of public participation in matters of environmental risk is recognised in international law and some writers argue that consent is amongst the most important ethical issues in climate engineering.[79] It is widely accepted that states must incorporate procedural safeguards when making decisions that may cause environmental harms which undermine the enjoyment of human rights, including environmental impact assessments, securing the full and informed participation of those affected, and effective remedies for non-compliance. Gardiner contends that although geoengineering that has the consent of the most vulnerable is morally better than deployment without consultation, such consent is likely to be severely restricted and

[75] S Vanderheiden, *Atmospheric Justice: A Political Theory of Climate Change* (Oxford: Oxford University Press, 2008) 241-42.
[76] Available at <http://www.unep.org/Documents.multilingual/Default.asp?DocumentID=97&ArticleID=1503> accessed 17 September 2014.
[77] Reynolds n 4 441-43. He is a strong advocate of geoengineering despite the risks and argues at p. 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.' See also Daniel Bodansky, 'The Who, What, and Wherefore of Geoengineering Governance' (2013) *Climatic Change* 121(3) 539.
[78] S M Gardiner, 'Some Early Ethics of Geoengineering the Climate: A Commentary on the Values of the Royal Society Report' (2011) *Environmental Values* 20(2) 163.
[79] Corner and Pidgeon n 57. Christopher Preston, 'The Extraordinary Ethics of Solar Radiation Management' in C Preston (ed), *The Ethics of Solar Radiation Management* (Lexington Books, Lanham, MD 2012).

given under duress: the consent of the desperate cannot justify geoengineering if it violated their rights or the rights of others, including the right 'not to be subject to domination by another power.' Obtaining assent in this manner would constitute an act of profound subjugation.[80]

> 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.[81]

Syzerszinski et al. believe that SRM poses immense challenges to liberal democracies because 'the unequal distribution of and uncertainties about SRM impacts will cause conflicts within existing institutions; that SRM will act at the planetary level and necessitate autocratic governance; that the motivations for SRM will always be plural and unstable; and that SRM will become conditioned by economic forces.'[82] It will be difficult to construct processes to secure consent for climate engineering that do not replicate or deepen the democracy and legitimacy deficits that characterise so much decision making on climate and environmental issues, including the UN Framework Convention on Climate Change (UNFCCC).[83]

The 1998 Aarhus Convention was the first multilateral environmental agreement to outline the obligations of states towards their citizens. It encourages participatory decision making and promotes the rule of law by enabling citizens to enforce their rights. The Convention states that 'every person has the right to live in an environment adequate to his or her health and well-being.'[84] It contains provisions for notifying the public and facilitating effective participation in decisions affecting the environment, but does not stipulate who must be

[80] Gardiner (2013) n 54 31. A further difficulty is that future generations cannot be consulted about their views about survival on a devastated planet.
[81] Ibid. 29.
[82] B Szerszynski et al., 'Why solar radiation management geoengineering and democracy won't mix' (2013) *Environment and Planning A* 45 2809.
[83] See P-H Wong, 'Consenting to Geoengineering' (2015) *Philosophy & Technology* DOI 10.1007/s13347-015-0203-1 1 and D R Morrow, R E Kopp and M Oppenheimer, 'Toward Ethical Norms and Institutions for Climate Engineering Research' (2009) *Environmental Research Letters* 4(4).
[84] *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 regional instrument but is open to ratification by other states willing to bring their legislation into conformity with it.

consulted or the form that consultation should take. In addition, it does not require mandatory environmental impact assessments for every research project that carries an environmental risk and exempts research, development and testing ‘unless they would be likely to cause a significant adverse effect on environment or health’-a provision that appears to cover large-scale geoengineering projects.[85]

5.1 International Legal Principles

Scott argues that the core principles of international environmental law applicable to geoengineering are prevention of harm; prevention of pollution; protection of vulnerable ecosystems and species; the precautionary principle; cooperation, information exchange, and environmental impact assessments; due regard for other states and users; state responsibility for environmental harm; and, possibly, sustainable development.[86]

She concludes that the no-harm principle is an *erga omnes* norm that can be invoked by any state likely to be harmed by geoengineering-although it is unclear at what threshold the principle would become operational-and points out that the applicability of the principle may be tenuous because the aim of geoengineering is to mitigate the harms caused by anthropogenic global warming.[87] Proving causation is likely to be difficult because claimant states will have to demonstrate that the harms caused result primarily geoengineering rather than the pre-existing impacts of climate change.

In Scott’s view, ‘as a principle of customary international law, the precautionary approach requires the risk of serious harm to the environment and the degree of scientific uncertainty to be explicitly considered by decision makers charged with authorizing any geoengineering-related activity.’[88] The principle, which is designed to prevent adverse environmental impacts, appears in numerous multilateral environmental agreements as well as regional and domestic legislation. Principle 15 in the 1992 Rio Declaration on Environment and Development states: ‘In order to protect the environment, the precautionary approach shall be

[85] Article 21.
[86] K N Scott, ‘International Law in the Anthropocene: Responding to the Geoengineering Challenge’, (2013) *Michigan Journal of International Law* 34(2), 309, 357.
[87] Ibid. 333-335.
[88] Ibid. 343. See also P W Birnie, A E Boyle and C Redgwell. *International Law and the Environment* (OUP, 2009) 162-63.

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.'[89] This raises the question whether SRM, and SSI in particular, should be viewed as ecological threats or potentially cost-effective means of decreasing damage wrought by climate change. Differing interpretations of the principle mean that it's efficacy as a norm of customary international law is contested. The principle was confirmed as customary international law by the International Court of Justice in the *Pulp Mills* decision, but its content of the principle is ambiguous and contested and the extent to which it is applicable to geoengineering is debatable.[90] The strong version of the principle places the onus of proving beyond a reasonable doubt that a technology is safe on the party wishing to utilise it and makes prohibition the default position when the science is uncertain and risks of environmental harms are strong. The weak version in Article 3(3) of the UNFCCC permits the degree of risk involved and the costs of making it safe to be taken into consideration, and permits deployment even though full scientific certainty cannot be established so long steps are taken to avoid serious irreversible damage. Bodle argues that its status in the UNFCCC is ambiguous at best.[91]

The strong version prohibits SRM so long as risks of extensive and irreversible environmental harms exist, which will always be the case because these technologies cannot be tested on a wide scale without running such risks. In contrast, the weak version of the principle may allow SRM as a lesser evil than climate change despite lack of scientific certainty about its risks and the irreversible harms that may ensue. The strong version has been criticised as vague about its how it should be enforced;[92] the weak version is less a guiding principle than a form of risk assessment.

Farber argues that the precautionary principle is controversial because of the absence of consensus about its meaning and application. Some regard it as a basis for halting activities

[89] Available at <http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=78&ArticleID=1163> accessed 17 September 2014. See also Article 3.3 of the UNFCCC.
[90] *Case Concerning Pulp Mills on the River Uruguay* (Argentina v Uruguay) 2010 ICJ Rep 14 (20 April 2010).
[91] R Bodle, 'Geoengineering and International Law: The Search for Common Legal Ground' (2010) *Tulsa Law Review* 46(2) 305, 311. On the status of the principle, see John Virgoe, 'International Governance of a Possible Geoengineering Intervention to Combat Climate Change' *(2009) Climatic Change* 95(1-2) 103, 111.
[92] C Sunstein 'Beyond the Precautionary Principle' (2003) 151 *University of Pennsylvania Law Review* 1003, 1005.

when a certain level of risk becomes apparent, irrespective of cost, while for others it 'merely creates a presumption against activities potentially harmful to the environment, placing the burden of proof on the advocates of those activities.'[93] Neither formulation is precise and principle has been described as nothing more than advice to be careful. Farber discusses the argument that the principle should be developed on a case-by-case basis and efforts made to refine it in relation to situations in which there is uncertainty in addition to risk-such as a future climatic tipping point, where a failure to regulate may result in irreversible catastrophic harm.[94] Climate engineering that altered the pattern of the South Asian monsoon would clearly satisfy these conditions unless those seeking to deploy a technique such as SRM were able to demonstrate its reversibility beyond reasonable doubt.

Both weak and strong versions of the principle seem clearly applicable to geoengineering but proponents might argue that lack of full scientific certainty whether SSI will cause serious or irreversible damage should not be used as a reason for postponing its potential efficacy as a means of preventing further environmental degradation. As Bodansky observes, 'in the case of geoengineering, 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.'[95] Ethics and politics arguably carry greater weight when the science is unclear and the law uncertain; the Royal Society report argued that 'the acceptability of geoengineering will be determined as much by social, legal and political factors, as by scientific and technical factors.'[96]

State practice makes it unclear whether precaution is more an attitude than an effective principle.[97] The UK House of Commons Science and Technology Committee considered the five Oxford Principles in its deliberations: geoengineering should be regulated as a public good;[98] public participation in decision making; full disclosure of geoengineering research and open publication of results; and independent assessment of possible impacts; and

93 D A Farber, 'Coping with Uncertainty: Cost-Benefit Analysis, the Precautionary Principle, and Climate Change', (2015) *Washington Law Review* 90(4) 1659-1725 at 1674.
94 Ibid, p 1675.
95 Bodansky n 77 542.
96 Royal Society, n 1 50.
97 House of Commons, *Science and Technology Committee: The Regulation of Geoengineering, Fifth report of session 2009-10* (The Stationery Office, London 2010).
98 House of Commons n 24. Gardiner resists the idea that geoengineering should be regarded as a public good in S Gardiner 'Why geoengineering is not a "global public good", and why it is ethically misleading to frame it as one' (2013) *Climatic Change* 121(3) 513.

governance structures to be in place prior to deployment.[99] It called for a set of principles to guide international regimes on geoengineering techniques and for 'the groundwork for regulatory arrangements to begin.[100] Stilgoe argues that collective experimentation is an appropriate mode of governance of geoengineering.[101] It is impossible to prevent geoengineering research from taking place and unlikely that experimentation will escape surveillance. A comprehensive regulatory framework that promotes transparency and accountability would do much to secure consent and legitimacy but the diversity of geoengineering techniques militates against regulation and makes it difficult to justify a blanket prohibition on research.[102] Such a framework might limit inadvertent transgressions, but intrinsic scientific uncertainties and the possibility that some technologies cannot be reversed makes it impossible for regulation to guarantee that human rights will not be violated. Relying on mitigation may be more difficult and less glamorous but much wiser than Plan B.

6. Conclusion

The failure of mitigation has encouraged advocates of geoengineering and those perhaps more concerned with patents and profits than ethics. Whether the Paris Agreement, whose enforcement mechanism appears to be naming and shaming, succeeds remains to be seen. Hulme describes climate change as a wicked problem that science cannot and should not try to fix.[103] In his view, since science offers limited solutions the only way forward is to deal with the social, political, economic and ethical issues that have contributed to climate change. In Harvey's words, 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] We need to fix our attitudes rather than attempting to fix the planet. Shue

[99] S Rayner et al., 'The Oxford Principles' (2013) *Climatic Change* 121(3) 499. In 2009, the principles were endorsed by the House of Commons Select Committee, which recommended that they be developed further.
[100] House of Commons n 98 3.
[101] Stilgoe n 61.
[102] D Humphreys, 'Smoke and Mirrors: Some Reflections on the Science and Politics of Geoengineering' (2011) *Journal of Environment & Development* 20(2) 99, 106.
[103] Hulme (n 69 119) 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> accessed 12 September 2014.
[104] Harvey n 64 14.

argues that delaying the transition to renewable technologies is unethical 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.[105]

Proponents of geoengineering have yet to provide a coherent response to Gardiner's question: 'if the problem is social and political, why isn't the solution social and political as well?'[106]

Klein accurately argues that geoengineering is 'the ultimate expression of a desire to avoid doing the hard work of reducing emissions'[107] and even a strong proponent like Keith accepts that it is '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] 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]

Anthropogenic climate change began with the extraction of coal through the use of technologies once regarded as benign ultimately had vast unforeseen, cataclysmic consequences. Currently, the mainstream view is that SRM technologies are too risky to deploy because they 'carry risks that are poorly identified in their nature and unquantified.' There is thus 'significant potential for unanticipated, unmanageable, and regrettable consequences in multiple human dimensions from albedo modification at climate altering

105 Shue n 10 215.
106 Gardiner n 78 173. Gardiner n 44 correctly argues that political inertia will increase support for geoengineering.
107 Interview with Naomi Klein, 'Green groups may be more damaging than climate change deniers': http://simongros.com/text/articles/naomi-klein-green-groups-may-damaging-climate-change-deniers/ (acc-essed 12 September 2014).
108 Keith n 31 277.
109 Hulme n 69 118.

scales, including political, social, legal, economic, and ethical dimensions.'[110] We should heed the warning from the National Academy of Sciences that:

> The uncertainties in modelling of both climate change and the consequences of albedo modification make it impossible today to provide reliable, quantitative statements about relative risks, consequences, and benefits of albedo modification to the Earth system as a whole, let alone benefits and risks to specific regions of the planet.[111]

The Royal Society report acknowledged that none of the methods it evaluated 'offer an immediate solution to the problem of climate change and it is unclear which, if any, may ever pass tests required for potential deployment'-and little has changed since 2009.[112] Renewable energy-technologies of humility-offers safe and cheap technologies that enable us to meet our ethical obligations, protect the human rights of current and future generations and resist the siren calls of those promoting unproven geoengineering methods, too often with profit in mind. The problem is less the absence of technological solutions than a suspension of morality and a failure of political will. The Paris Agreement contains lofty ambitions couched in vague terminology that do not bode well for the imperative to reduce GHG emissions; we may be running out of time, but mitigation is both prudent and ethically preferable at this juncture. As Caney argues, human rights are moral thresholds that should not be traded off against other putative advantages.[113] They are not substitutable for other goods or values, and cannot easily be remedied when they are violated. Ethics requires preventing harm, prudence dictates precaution, and wisdom suggests that the safest technological solutions are best.

[110] National Academy of Sciences n 27 7. The report does however recommend that an albedo research modification programme should be developed.
[111] Ibid. 147.
[112] Royal Society, n 1 61.
[113] Caney n 46.