Key Findings from the Climate Geoengineering Governance (CGG) Project

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Climate Geoengineering Governance (CCG)

Climate Geoengineering Governance (http://geoengineering-governance-research.org) is a research project which aims to provide a timely basis for the governance of geoengineering through robust research on the ethical, legal, social and political implications of a range of geoengineering approaches. It is funded by the Economic and Social Research Council (ESRC) and the Arts and Humanities Research Council (AHRC) - grant ES/J007730/1

CGG Working Papers

The CGG Working Paper series is designed to give a first public airing to a wide range of papers broadly related to the project's themes. Papers published in this series may be, but are not necessarily, early outputs from the project team; equally they may be from other authors, and reflect different perspectives and different issues from those directly pursued by the project itself. The aim is to promote vigorous and informed debate, in a spirit of pluralism.

What the working papers have in common is that they will all be at an early stage of development, prior to full publication. Comment and response, at any level of detail, is therefore doubly welcome. Please send all responses in the first instance to the authors themselves - each paper contains a correspondence address. We will be looking for opportunities to use the website or other project activities to give a wider airing to any dialogues and debates that develop around a paper or issue.

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Key Findings from the Climate Geoengineering Governance (CGG) Project

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1. The context for the project and its goals

1.1 The Royal Society report *Geoengineering the Climate* (Shepherd et al 2009) concluded that "the acceptability of geoengineering will be determined as much by social, legal and political issues as by scientific and technical factors" and recommended "the development of governance frameworks to guide both the research and development...and possible deployment.''

1.2 Climate geoengineering presents distinctive governance challenges because it:

- includes a wide range of possible technologies embodying highly heterogeneous technical practices;
- they are novel propositions whose full consequences are hard to assess
- even experimental work on many of them (but not all) is controversial and likely to involve activities and consequences that cross jurisdictions; and
- deployment of any of them would have to be considered and implemented in relation to further efforts in mitigation and adaptation, and in relation to problems (e.g. food shortages,

lack of disaster resilience, migration) in which anthropogenic climate change will be only one contributory cause.

1.3 CGG, funded by ESRC and AHRC between 2012-2014, was one of three projects funded by the UK research councils which ran more or less contemporaneously. The others were the SPICE (Stratospheric Particle Injection for Climate Engineering) project and the IAGP (Integrated Assessment of Geoengineering Proposals), both funded by EPSRC and NERC.

1.4 CGG's starting point was the need to understand and research the social relations and implications of different technologies, in addition to research on the nuts and bolts themselves, before policy makers and publics can decide whether any of these things are likely to make a helpful contribution to climate change management or to societal development more broadly.

1.5 The project had four principal goals:

- To identify the different ways in which geoengineering was framed, in interconnected technical, economic, legal, ethical and social terms;
- To explicate the problems of control, or the challenges of controlling the technologies right the way through from initial research in computer simulations, all the way through to possible deployment, thinking about such issues as lock-in and path dependency, and public acceptability;
- To explore governance and regulatory requirements - what kinds of regulatory frameworks might be considered, and why; and
- To stimulate dialogue between key stakeholders.

1.6 The basic work on conceptualisation and framing under theme 1 fed into the next theme of the project on how to characterise and confront the issues of safety, efficacy, affordability and public acceptability under various technological options for pursuing geoengineering. Effective technology governance in the current world has to recognise the interactions between local, national and multinational levels of governance, and the advent of rising powers.

1.7 The third theme of the project centred on policy choice. It integrated the findings in order to assist researchers, policymakers, the private sector and civil society organisations to define the conditions under which research into, and eventual deployment of, geoengineering measures might be conducted, taking proper consideration and the regulatory and other governance criteria and arrangements which will be required.

1.8 The goal of this research was to establish a base of information and approaches on which to build as the field of geoengineering develops over the long term. The work packages under each theme were supported by a common set of workshops designed to help integrate the insights from the work package elements, and generate increased engagement with policymakers, practitioners and representatives of civil society. This approach drew on an engagement process, starting early in 2011, organised by the Oxford Geoengineering Programme and consisted of four strands of activity: workshops with participants drawn from government departments and agencies, with the private sector, with civil society organisations and with salient international researchers and policymakers.

2. How geoengineering is framed

2.1 The dynamics of emerging technologies can be seen as processes by which a specific set of socio-technical arrangements to pursue a goal are selected and stabilised (Healey 2014 – CGGWP15).

Typically such a stabilisation allows diverse interests and heterogeneous technical practices to come together in one sociotechnical image of the future – or imaginary (Jasanoff & Kim 2009) - that can claim novelty and innovative power and attract political and financial resources. For example, nanotechnology, as a distinctive, discrete framework for understanding technological choices, was stabilised out of molecular engineering, electronic miniaturisation and microbiology, partly through the intellectual entrepreneurship of Mihael Roco at the US National Science Foundation (see Roco & Bainbridge 2003).

2.2 The term "geoengineering" is itself very controversial. Under this umbrella term we find a heterogeneous collection of technical practices that have little in common with each other. The science and engineering of sulphate aerosols has almost nothing in common with that of carbon dioxide removal from ambient air.

2.3 Definitional politics are constantly at work specifying and re-specifying what, at any given moment, might be included under the geoengineering banner. What is on the list will vary over time as a result of the view that proponents of different approaches take of the financial and other resources that defining their research areas as geoengineering may bring. This is balanced against an assessment of what additional regulations their field may face. For example, advocates of large-scale afforestation tend to resist forestry being included in geoengineering out of concern that this will place them under additional regulatory burdens. On the other hand, advocates of biochar have lobbied to be included because they view geoengineering as a potential opportunity to develop their favoured technology. In thinking about the governance implications of geoengineering it is important to specify the particular technological practice under consideration. The recent publication of two linked reports by the US NRC (2015) reflect this continuing definitional politics, seeking to recast geoengineering as "climate intervention" and redefining solar radiation management as "albedo modification".

2.4 What these practices do share for the most part is their immaturity. The field of geoengineering consists of very early stage technical concepts. While there is much conjecture and speculation about how these might be developed into fully fledged sociotechnical systems, our understanding of what these technologies might be, how they might work in practice at scale remains sketchy and contested (US NRC 2015). Climate models have been used to simulate the effects of sulphate aerosols (see, for example, the GeoMIP project), but the reliability of such simulations are contested (e.g. Hulme 2014a). There are bits of equipment that already exist and could be adapted for incorporation into geoengineering technologies, spray nozzles and aeroplanes, for example. But we have nothing close to a sociotechnical system capable of delivering the kinds of outcomes that geoengineering promises to deliver at some point in the future.

2.5 Typically in debates on emerging new technologies, discussions about the science are more evident than explicit discussion of the social values that may lie behind them. Controversy about GM crops and nanomaterials, for example, only arose after the technologies had been developed and already achieved a significant level of adoption (at least in some parts of the world). In these cases, there was already a significant body of scientific knowledge that provided a surrogate arena for contesting values. Because geoengineering science is currently underdeveloped, the values in geoengineering debates are unusually explicit at this stage. The value differences are clear, and there are no strong science claims to hide behind in articulating those values (Sarewitz 2004). Quite the contrary, everyone seems to acknowledge that we currently know very little. Once research gets under way (if it does), then the debates will likely change, and explicitly begin to focus on what's being learned by the research, and what it tells us. And once that happens, debates over the science will displace the debate over the values (Rayner 2014 – CGGWP10).

2.6 The influence of divergent values underlies the results of a CGG analysis of expert framings of geoengineering, (Cairns 2013a – CGGWP2), which shows that experts were highly polarised about different constructions that they had of the pros and cons of geoengineering. Four distinctive framings emerged from this analysis, labelled: 'At the very least we need more research'; 'We are the planetary maintenance engineers'; 'Geoengineering is a political project'; and 'Let's focus on Carbon.' Results indicate a strong polarity around these divergently construed pros and cons of geoengineering as a whole – underscoring the political salience of this term. But the analysis also suggests a more nuanced picture than straightforward pro/anti positioning.

2.7 The ambiguity of the term *geoengineering* offers interpretive flexibility for articulating diverse interests within and across contending framings. It is questionable whether increasing precision in terminology will necessarily facilitate greater clarity in governance discussions or public engagement. The merits of any given form of precision will depend on particular framings. Much ambiguity in this area may thus be irreducible. Hence the challenge lies rather in understanding the wider implications of the range of political positions that the study reveals.

2.8 Another CGG framing study (Markusson 2013 – CGGWP3, Markusson et al 2013 – CGGWP5) looked at the way in which

Wikipedia links represent geoengineering. With the exception of land-based carbon-dioxide removal that clusters with mitigation and adaptation, the analysis showed a clear disconnection between the discourses of geo-engineering on Wikipedia and the discourse about mainstream climate change. A possible explanation for this is that the technologies in the land-based sequestration group have already been relatively well established as climate mitigation and adaptation technologies: whereas the core group represents technologies with a less secure role in policy and with less well developed support bases and funding streams. However the disconnect between geoengineering and mainstream climate discourse on Wikipedia seems to reflect a similar disconnect in the non-virtual world. This seems problematic for geoengineering governance. It would be helpful if future research and policy debate were to consider geoengineering options in the context of other approaches to managing climate change: mitigation and adaptation.

2.8 Another study using a multi-criteria Deliberative Mapping methodology appraised geoengineering options in the context of mitigation options and adaptation for the first time (Bellamy *et al.*, 2013). In 'opening up' to these alternatives and to diverse framings from international experts, stakeholders and members of the UK public, geoengineering proposals were seen to perform relatively poorly compared to mitigation options and adaptation. The study concluded with a number of propositions for governing responses to climate change at large, including the need to gain reflexive foresight of the imagined futures in which geoengineering might reside, and the importance of identifying 'robust' options perform relatively well against broad framings, rather than seemingly 'optimal' ones that emerge from more narrowly framed processes (Bellamy, 2014 - CGGWP 11).

2.9 CGG also explored two particularly problematic framings. One is the climate emergency framing (Heyward & Rayner 2013a – CGGWP6) which has previously been deployed in attempts to intensify efforts aimed at conventional greenhouse gas mitigation, but has proven controversial since being appropriated by geoengineering advocates. This framing was quite prominent in the Royal Society report (Shepherd et al 2009) and was popularly talked about around 2009-2010. CGG authors suggest that that while the idea of climatic emergency played a vital role in softening the initial taboo on even discussing geoengineering, it is become less prominent as the idea of geoengineering becomes more accepted. Subsequent to the Royal Society report the climatic emergency framing has been heavily critiqued, particularly by social scientists who have pointed out that emergencies don't just occur: they are declared. They are political constructions and the idea of a climatic emergency has real problems in terms of the potential for the imposition of undemocratic forms of technocratic management of climate and the environment (Hulme 2014b). It is also impractical (Lenton 2014). When would we know when we were on the verge of climate emergency? How soon before a climate emergency would we have to know to be able to implement any of these technologies to counter it?

2.10 A second framing - the Plan B framing - is also problematic. The Royal Society report itself doesn't mention Plan B, that expression is only used in the president's preface to the report. But it was nevertheless a framing that was used prominently in the period from 2010 onwards. This has caused confusion because people have different ideas about what is implied by this. Is Plan B a supplement to Plan A to do a little bit more? Or is Plan B the last resort when Plan A has demonstrably failed? More recently, partly reflecting this ambiguity, the Plan B vocabulary has been dropping out of use.

3. The costs and economics of geoengineering options

3.1 CGG analyses of costs (MacKerron 2014 – CGGWP13) actually deepen the Royal Society's (2009) conclusion that all of the cost estimates of geoengineering are entirely overdetermined by their input assumptions. A proponent can make geoengineering technology look cheap, or at least affordable, by selecting the appropriate assumptions. Opponents who want to make it look expensive will also select the assumptions that lead to their desired result. CGG analysis of cost estimates confirm that this remains the case more than five years after the Royal Society report.

3.2 Furthermore the cost estimates that have been prepared ignore the social and environmental externalities, they only actually look at the project costs (e.g. Roco & Bainbridge Barrett, 2008; Bickel and Lane, 2009, Weitzman, 2011). Should sulphate aerosol injection prove detrimental to the Indian Monsoon or to agriculture in sub-Saharan Africa, those costs are not included. Something that looks to be relatively cheap in terms of the project costs compared to conventional mitigation has the potential to be very expensive were potential environmental externalities to be included in the calculation. The major projects literature (e.g., Flyvbjerg et al 2003) tells us that almost every major infrastructure project that has been developed turned out to be more expensive than it was originally estimated due to conscious or unconscious selection of assumptions by project advocates.

4. Ethical issues and geoengineering

4.1 CGG explored geoengineering in the larger framework of climate ethics. Perhaps the most surprising finding is that in fact, contrary to what is often claimed (e.g., Fleming 2007, Preston 2012, Hamilton

2013) geoengineering does not pose new and distinct ethical problems. For example, uncertainty about geoengineering has sometimes been used to characterise its uniqueness, but uncertainty is also a feature of 'standard' anthropogenic climate change or of other new technologies, such as nanotechnology (RCEP 2008). Rather than introducing new ethical issues geoengineering highlights aspects of problems that are often underdeveloped in the discussion of climate change to date and even of climate ethics. (Wong et al. 2014 - CGGWP8, Wong 2014 - CGGWP17).

4.2 This applies to issues related to institutional trust and liabilities. These loom larger in geoengineering discourses than in discussions of conventional mitigation and even adaptation. This seems to be because there is a clearer cause-and-effect relationship with a deliberate intervention in the climate, such as geoengineering, than with the accidental disruption of the climate caused by the historic emissions of fossil fuels (although not a relationship so clear that problems of attribution are escaped entirely). Geoengineering also leads us to focus on issues of democracy and consent. Who would have to consent and how in order for any agent to engage in either research or the implementation of these technologies at different geographical scales? (Macnaghten & Szerszynski 2013, Heyward & Rayner 2013b – CGGWP7)

4.3 Geoengineering forces us to focus on another ethical theme that is underdeveloped in the mainstream climate change literature: that is the issue of humanity's relation to nature. Geoengineering raises the question of whether there are ethical concerns not only about the distribution of benefits and damages from deliberate intervention In global earth systems, but whether it is permissible even in principle ton deliberately intervene in, or as some would have it, "playing God with the climate" (Fleming 2007, Hamilton 2013).

4.4 All of these ethical issues are almost entirely discussed within the perspectives of western philosophical traditions. There has been, for example, no previous attempt to take account of Confucian ethics and the different understandings of such key moral concepts as autonomy, equality, and human nature that a Confucian approach embodies (Wong 2013 – CGGWP4). Clearly in dealing with a global problem of this sort and reaching for transnational governance arrangements there is a pressing need to diversify the range of ethical discussions.

5. Global security implications

5.1 CGG explored the global security implications of geoengineering proposals that have given rise to concerns (Cairns 2014 – CGGWP16). Some commentators have been concerned that geoengineering technologies might be weaponised for example. CGG's assessment is that this is highly unlikely; there are much easier, cheaper and better targeted ways of killing people and causing terror than by trying to weaponise climate geoengineering technologies (Robock 2008, Fleming 2010).

5.2 The principal military applications for weather and climate control appear to be terrain denial and demoralisation of civilian populations, but there are more controllable options already available for these functions. Furthermore, any state’s use of geoengineering in a fashion that deliberately or accidently injures another state would be a violation of existing customary international law. Any explicitly military application would violate an existing (if hitherto inactive) treaty: the United Nations Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD) already prohibits environmental warfare.

5.3 But that does not mean to say that these technologies are without any security implications at all. The indirect threat of cross border impacts is a very real one. Had India conducted some sulphate aerosol injection experiments immediately before the 2010 floods in Pakistan, it is hard to imagine that members of the Pakistani public, and certainly Pakistani politicians would not have held India responsible for the damage that had been caused by the floods. The problem of perceived cross-border impacts would inevitably arise from geoengineering experiments when attribution for climatic events is unclear.

5.4 It is also the case that the implementation of technologies like sulphate aerosol injection would be carried out by or in conjunction with military contractors. In Europe companies like BAE Systems, EADS or Finmeccanica have particular skills and capacities that would make them likely equipment suppliers. The likes of General Dynamics, Lockheed Martin, or Halliburton would be likely suppliers or even contractors implementing any US-based programme. In China, implementation would undoubtedly fall to the People's Liberation Army, which currently conducts the vast array of weather modification activities in that country. In the US the national security linkage would likely occur not only because the military would have the relevant technical capacities, but because the risks of a rapid temperature spike caused by a sudden cessation of SAI would mean that such a project would be likely to be considered part of the country's critical infrastructure from the very start, and thus subject to the closest national control.

5.5 A third possibility is counter-geoengineering. There are some countries that perceive themselves as benefiting from increased global temperatures. It is quite plausible that if one group of countries were to try to geoengineer to stabilise temperatures at lower levels, then those countries that see themselves as benefiting from climate change might increase their emission of greenhouse gases in response so as to continue to obtain what they see as benefits (Nightingale & Cairns 2014 – CGGWP18).

6. National and international law and governance

6.1 In line with the promptings of the Royal Society Report, CGG analysis of international law and governance looked what provisions are already in place at national or supranational level with the potential to respond to existing imaginaries of geoengineering and what new provisions might be necessary (Armeni & Redgwell 2015a - CGGWP21). The study focused on technologies that were encapsulated from the environment, such as carbon capture from the atmosphere, which in principle can be regulated under the law of the nation where they are sited; as well as unencapsulated technologies such as ocean iron fertilisation and solar radiation management technologies. CGG looked at these in relation to three exemplary jurisdictions selected because they had undertaken research and experienced some debate: the US, Germany and the UK (Armeni & Redgwell 2015c & d - CCGWP23 & CCGWP24). How far can existing legal provisions take us? Where are the regulatory gaps, and what new provisions might be necessary?

6.2 There is little academic and policy debate on the availability and adaptability of national laws and regulation. There is potential for some adaptation of existing rules and regulations, while acknowledging national particularities. For example, freedom of scientific research is protected under German Basic Law. Because of the heterogeneity and scope of geoengineering proposals, no single regulatory body or government department is likely to have a full mandate to regulate research or implementation even within a country's national boundaries: collaboration would be necessary.

6.3 International regulatory machinery could take three (not mutually exclusive) forms: adapting existing provisions; bespoke coverage of gaps in those provisions; and developing general principles of governance. In developing any regulatory framework, it is necessary to be aware of regulatory intention: is the law seeking to keep options open, or to limit potential risks?

6.4 CGG developed a set of criteria to assess *the applicability/adaptability of existing legal instruments to geoengineering* (Armeni & Redgwell 2015b - CGGWP22). There is no directly applicable existing international treaty broadly applicable to geoengineering except for the 1977 ENMOD treaty, which prohibits the hostile use of weather modification. This however assumes the intention to cause harm. General legal principles applying to the conduct of states would require in any case that they exercise due diligence to ensure that nothing they did would cause significant harm across boundaries with other States, or the high seas or air space above. Otherwise no single instrument ticks all boxes as a one-stop shop for the international governance of geoengineering. The Convention on Biological Diversity (CBD) comes closest, but lacks robust enforcement mechanisms, and, given its biodiversity focus, is not an instrument of general application. At the level of specific technologies the London Convention/London Protocol (LC/LP) has shown itself to be a flexible instrument for dealing with ocean iron fertilisation, starting with non-binding guidelines and then progressing to binding arrangements. It could provide a useful template in designing regulation of other specific technologies.

6.5 The atmosphere - the domain where solar radiation management (SRM) technologies would be deployed - constitutes a clear case of a gap requiring new regulatory machinery. While it is generally acknowledged that state control extends to the air space above national territory, there is no direct national control of air space in areas beyond national jurisdiction, nor any single instrument that regulates the introduction of substances, e.g. sulphate aerosols, into the stratosphere.

6.6 Voluntary guidelines, working in conjunction with existing instruments in an effective 'smart instrument mix', would fit in well with a moratorium on deployment.

6.7 In summary, there is no one existing authority with the scope and competence to cover the whole range of international governance requirements for geoengineering. In particular areas of technology there is some scope for adaption of existing regulatory machinery as we have seen with LC/LP, but the regulation of what is done within the atmosphere constitutes a real gap requiring new provisions. This might be considered a priority given the attention currently being given to SRM technologies. Voluntary bottom-up arrangements have a contribution to make, but require a minimum of an oversight organisation to keep track of what each country was doing on regulation and attribution, and to guard against regulatory fragmentation. Finally any machinery requires flexibility to be able to cope with changes in the technologies themselves or with the capacities to monitor and attribute their impacts.

6.8 Some commentators, (e.g., Hulme 2013b, Macnaghten & Szerszynski 2013, Cairns 2014 – CCGWP16) have suggested that certain forms of geoengineering, specifically SAI, are constitutionally incompatible with democracy. Others, (e.g., Heyward & Rayner 2013 – CGWP7) argue that the eventual shape of the technology is sufficiently underdetermined at this stage as to render such judgments, at best, premature. If further research on the technologies is required, the key question becomes how to ensure that such research is conducted responsibly and can be halted in the event that society decides that it is moving in an unacceptable direction.

7. Regulating geoengineering research

7.1 The first problem facing any effort to regulate geoengineering research is distinguishing geoengineering research from basic science. A geoengineering experiment may be functionally indistinguishable from a basic science experiment to explore how droplets form around particles in the stratosphere or to explore marine cloud formation. Does intention matter? Should researchers only be subject to regulation if they come out and say, "I'm doing this for geo-engineering," but not if they say they are doing basic science?

7.2 A similar problem arises from the view that solar radiation management, and particularly sulphate aerosol injection, could only be fully tested at large scale. Where is the cut-off point, if any, between the idea of research and implementation? These are highly contested areas. They have not been resolved. They continue to be subject to contestation.

7.3 The notion of the 'slippery slope' has particularly concerned those who advocate a research moratorium or a ban and who worry that once we take the first step in developing these technologies then implementation becomes inevitable. Counter to such concerns, billions of dollars were invested into developing fast breeder reactors around the world and no such reactors exist today. So the notion that a slippery slope is inevitable does not appear to be verified. Similar to the concern about the slippery slope are notions of path dependence and lock-in. The slippery slope can be seen as a form of 'intellectual lock-in' to a particular course of action.

Although all programmes of innovation need a degree of sociotechnical commitment, and therefore lock-in, to succeed, society needs to avoid lock-in to inappropriate or unacceptable technology and to inappropriate governance architecture (Markussen & Wong 2015 – CGGWP20).

7.4 There are two broad levels of analysis of lock-in: a focus on particular technologies or classes of technology and the potential mechanisms and consequences of lock-in that might result from their development and deployment; and a focus on the broader context of existing fossil fuel dependence or so-called ‘carbon lock-in’, and the ways in which particular technologies might disrupt or reinforce this. CGG examined 'social lock-in', in which many of the proposed technologies (e.g. direct air capture), would be dependent on the existence of a highly capital-intensive physical infrastructure, with large sunk costs creating vested interests in keeping facilities operational and 'cognitive lock-in' in which instrumental framing effects the outcomes of technology assessments (Cairns, 2013b). These impacts may be:

- on the outcomes of the choice of contextual problem frame within which appraisal of geoengineering takes place (e.g. the idea of climate emergency or the failure of mitigation);
- on the choice of appraisal methods applied (e.g. the use of expert-analytic methods such as computer modelling, economic assessment and expert opinions);
- and on the selection of particular options appraised (e.g. the choice to focus on a limited number of geoengineering options, or to compare geoengineering options in contextual isolation rather than with the wider portfolio of responses to climate change).

Quite often a combination of these forms of lock-in will be in play, and may reinforce each other. Locking-in to particular technologies can also be seen as a locking-out others. This might limit the paths of response to a climate emergency, or make investment in renewables less likely.

7.5 On governance architecture, there has been and continues to be an persistent tension between advocates of top-down anticipatory structures, those who feel that there ought to be some kind of global treaty in place, even before research is conducted (Bodle et al 2014), and those who favour a bottom-up emergent approach to geoengineering governance (Long, Loy & Low 2015). There has been in some quarters, some support for the idea of the Convention on Biodiversity (CBD) being that overall top-down body but others have questioned whether that's actually a suitable role for the CBD and whether it has the potential to undertake that.

7.6 There is also a range of dilemmas for the control of research: who should govern and regulate it? As well as the idea that there ought to be some kind of overarching international regulatory framework, different proposals have been made ranging from self-governance by scientists, through national government regulation, through to the idea that research councils and funding bodies should regulate it, since they have the prime responsibility to decide the allocation of research resources and also often have the best information about what is proposed.

7.7 But there is the question how much of a comprehensive governance architecture is required even before embarking on research? Should there even be research (Rayner 2014 – CGGWP10)? On this issue Mike Hulme (2014b) has argued recently that we simply cannot know enough about how solar radiation management would behave to justify doing it; seeing the models that we use being mere "calculative cartoons" relative to the reality that we would have to deal with. And in any case he says it is morally reprehensible, so our ignorance will save us from folly. By way of contrast, David Keith (2013), a US engineer, has set out a programme by which he believes that ignorance can be reduced by carefully constructed, carefully staged, escalating research, and argues, contrary to Mike Hume, that it would be folly to remain ignorant of our ignorance. Is it possible to improve our knowledge of the potential performance of SRM in an environmentally and socially responsible manner?

7.8 Members of the CGG team developed the Oxford Principles in 2010, initially for the House of Commons Science and Technology Committee, to act as initial guidelines in dealing with these questions of research governance (Rayner et al 2013 - CGGWP1). They are that:

1. Geo-engineering should be regulated as a public good and in the public interest:
2. There should be participation in decision-making at the appropriate level, depending on where you're going from computer-based research to outdoor research in a locality, or to things on a national or international scale;
3. There should be full disclosure of geo-engineering research results and open publication of all results (this is something which we thought was important in the light of experience in the pharmaceutical industry which has tended not to publish unfavourable clinical trial results);
4. There should be independent assessments of the research and particularly of impacts;
5. The governance arrangements needed to be clear prior to deployment.

CGG developed these principles further in the course of the project (Rayner et al 2013).

7.9 These general principles could be applied to almost any potentially controversial area of technology innovation, but need to be made specific in the instance of geoengineering. And so our approach to research governance is to combine the idea of technology-specific protocols with the idea of the stage-gate that emerged in the SPICE Project - the idea that before each pre-specified stage of research is commenced there would have to be an assessment that shows how the Oxford Principles were being addressed. Once each stage of research is completed, before continuing to a further stage, researchers and funding bodies would assess how those principles had been implemented in the previous stage and then specify how they would be addressed in the next stage. In our view such a process allows a process of pursuit of better knowledge and understanding to be pursued while offering some reasonable assurance that society retains the right to close down research and the capacity to make judgements to close down research should it deem it appropriate to do so.

7.10 Some researchers are currently proposing to conduct solar radiation management (SRM) experiments in the ambient environment. While these would be on a scale that would appear to present no immediate physical danger, this is arguably the most controversial of geoengineering proposals. Since there is as yet no accepted boundary between SRM research and implementation, it is important that early experiments also establish a clear pattern of environmental and social responsibility from the beginning.

7.11 CGG therefore recommend that governments, research funding organizations and scientific and professional bodies require the establishment of an open and transparent review process that ensures that any such experiments have the necessary social licence to operate.

7.12 At a minimum such a review process should involve prior open publication of research plans in order to assure the integrity of the process, with independent evaluation of all existing evidence, plans and results, and should actively seek public participation. We consider that such a process will promote the scientific integrity and public legitimacy of any such experimental work.

8. Stimulating and understanding wider dialogue

8.1 At CGG's initiative, and with major organisational input from IAGP, two joint activities were held to bring together all three parallel RCUK funded geoengineering projects - CGG, IAGP and SPICE. The first was a two-day workshop in October 2014 designed to give the researchers of the three projects an opportunity to learn about each other's work at some depth, and to examine broader lessons for future research. At the second event, organised at the Royal Society, the results of all three projects were presented in summary and discussed an audience of policymakers, research funders, scientists, and members of civil society organisations in the UK, plus some distinguished foreign guests. The Royal Society proceedings are available online [CGG/IAGP/SPICE 2014].

8.2 CGG had an objective of extending dialogue beyond the UK research community. To this end, we held a range of workshops with stakeholders in the UK, India, China and, shortly before the project started, Singapore. The project has given lectures and presentations around the world. It has had extensive engagement with international press and media. The Oxford principles have been widely cited, mostly, but not always approvingly, but they clearly have had an impact on the discourse. More generally the UK is recognised as a leading serious thinker on geoengineering, which reflects also the work done in SPICE and IAGP and other UK contributions to the research literature, as well as the engagement with geoengineering of both the UK Government and Parliament.

8.3 Towards the end of the project, CGG convened a one-day scenarios workshop with key national and international experts and stakeholders. The purpose of the workshop was to stimulate more thinking about the temporality or process dimensions of geoengineering governance, as distinct to prevailing thoughts about outcomes. In particular it sought to explore how far geoengineering proposals may develop and under what institutional arrangements. Participants were presented with four policy-relevant geoengineering proposals: stratospheric aerosol injection (SAI); cloud albedo enhancement (CAE); bio-energy with carbon capture and storage (BECCS); and air capture and storage (DACS). Allocated into four heterogeneous groups of between 6–10 participants, the groups were asked to consider two of these proposals (one solar geoengineering proposal and one carbon geoengineering proposal), either: SAI & BECCS, SAI & DACS, CAE & BECCS or CAE & DACS. Three broad governance styles ran through the discussion: 'top-down' relatively centralised global governance, market mechanisms which in this case were driven by the setting of a world price for carbon, and a more decentralised, gradualist 'principles and protocols' approach.

8.4 One group expanded upon the 'principles and protocols' approach, questioning why it is often assumed that political and popular acceptability for BECCS would be hard to achieve? This may be true in Europe, but not everywhere. Take China, for example. If the switch from coal to shale gas is not feasible for China, a country with huge amounts of land, does BECCS become more attractive to them as a substitute for shale gas and as the means to keep coal plants running longer (BECCS as a sort of greenwash for coal)? This possible scenario might provide incentives for research on

BECCS in China. Further, if it comes to deployment, the political system might be more amenable to BECCS in China than in Europe or India, which have to square such developments with democratic traditions, and where local considerations of climate and energy policy are more directly related to different types of public response. There may be a value to the Chinese in greening its Western Provinces not just in term of energy production and climate change, but in helping to further integrate them geopolitically. Similar incentives apply to other coal-intensive energy systems, especially where there are large tracts of under-utilised land, such as in Russia or Kazakhstan. This led to the idea of variable geometry, of seeing the management of climate change in terms of local portfolios of actions whose make-up would be prompted by local values and interests. National geopolitical considerations mean that not all inflection points in the assessment of a single technology will be the same, and there will be different inflection points on policy too (Bellamy & Healey 2015).

8.5 Besides the UK, the two countries which are leading thinking on geoengineering are the US and Germany, both also on the basis of a combination of research activity and policy engagement. It is noticeable that despite the activity of some NGOs, and a strand of popular discourse which believes that condensation trails from aircraft indicate that geoengineering is already underway, (Cairns 2014 – CGGWP9), most of what we understand of wider public attitudes to geoengineering originates from experimental research rather than wider public or media discourse. We have assessed this history of experimental public engagement, and added to it through a CGG workshop in Norfolk which examined how different broad preferences for how society is organised affects the choice of approaches to geoengineering regulation.

8.6 CGG has reviewed the experience of public dialogue on geoengineering gathered in the UK since the publication of the Royal Society report (Bellamy & Lezaun, 2015 - CGGWP 19). The UK has pioneered a series of deliberative formats to address public concerns and expectations about climate engineering options. This experience of public initially focused on assessing the cost-benefit parameters of discrete geoengineering options, but has shifted in recent years to considerations of climate engineering and its desirability that encompass (rather than exclude) alternative strategies, particularly mitigation.

8.7 CGG conducted its own stream of public dialogues on geoengineering, in a series of focus groups conducted in Norwich in September 2014 (Bellamy, Palmer & Lezaun, 2015). We identified a series of themes structuring public perceptions of geoengineering techniques, as well as some key notions shaping public perceptions of governance alternatives. The themes structuring public views on the technology include:

- the need for geoengineering and mitigation to be complementary;
- the salience of issues surrounding economic feasibility and harmful side effects;
- concerns about 'messing with nature'; and
- the undertaking of geoengineering as a dangerous step into the 'unknown'.
- Discussions of research governance options often centred on the scale of the proposed experiments, focussing on:
- scepticism over the possibility of reaching binding international agreements;
- the need for transparency and accountability;
- guarding against a 'slippery slope' to premature deployment, yet concurrently defending scientific autonomy; and

- an implicit distinction between political and scientific aspects of geoengineering governance.

8.8 As promised in the research proposal for CGG, the project has also partnered with the Oxford Geoengineering Programme, funded by the Oxford Martin School, to run a series of events engaging scientists and policy makers. These included:

- The Oxford Summer School on Geoengineering Research in August 2012 as part of a series of such events in partnership with Heidelberg and Harvard. This brought together sixty early-career researchers from across the globe to learn about the technical and social issues associated with geoengineering
- The Oxford Conference on Negative Emissions Technologies in September 2013, which brought together 100 participants from academic, policymaker, civil society, industry and media circles to explore the issues associated with CDR. Sir Mark Walport, the Government's Chief Scientific Advisor, gave the keynote speech
- Two sessions at the 2012 "Planet Under Pressure" conference – one on geoengineering governance and the other on the engineering constraints of geoengineering – and one entitled: "Climate Justice 2.0?"
- Co-sponsorship of a meeting in Ottawa in 2012 to develop "Geoengineering Our Climate?" a book on the ethics, politics and governance of geoengineering
- Partnering with the Environmental Sustainability Knowledge Transfer Network, to establish the Negative Emission Technology Interest Group, and conducting a launch meeting at the Royal Academy of Engineering in March 2013
- Briefing the Directors of Counter-Proliferation of the G8+1 countries at a meeting in London to discuss novel proliferation threats

- Briefing officials of the Foreign Office on international regulatory issues as they relate to geoengineering
- Organising a meeting with the UK Carbon Capture and Storage Research Centre on Unconventional Carbon Storage in June 2014
- Briefing the World Economic Forum's Summer Meeting in Tianjin, China on geoengineering techniques and their societal implications
- Co-convening with the Children's Investment Fund Foundation a Roundtable Meeting on Greenhouse Gas Removal in December 2014 – a meeting of leading academics, NGO representatives and policymakers with five large philanthropic foundations which are interested in funding work in this area.

8.9 CGG researchers also participated in interviews on BBC Radio about geoengineering on both *The World Tonight* and on *Material World*, and have been quoted extensively in the print media coverage of geoengineering in the UK and internationally.

9. Some broader conclusions.

9.1 Finally there are two sets of questions that CGG would ask going forward. The first question is what can geoengineering do for the climate? This is the obvious question from the policy point of view. We argue that it needs to be firmly relocated in the context of mitigation and adaptation discourses. We are concerned as to whether the CDR technologies that are assumed in RPC 2.6 could in fact be scaled up to the level necessary to have the impact that they are assumed to have on temperatures by mid-century and the end of this century. And that while solar radiation management promises high leverage and fast acting impacts it would be very difficult to govern.

9.2 So the outcome of this suggests that in fact if decision makers seek to save lives and property this century not only do they have to address mitigation, which will have a long-term benefit, but it would be prudent to put increased emphasis on adaptation.

9. 3 But as social scientists, we also want to ask what can geoengineering, particularly geoengineering discourses, do for society? At the moment, unlike the development of cases like the nanotechnology and GM disputes, the discussion of values is right up front. We are having the discussion about values before the technology is developed. This is something that social scientists and others advocating responsible innovation have argued in favour of for a long time. At this stage there is little science to hide those values behind. So geoengineering provides opportunities to explore things like the way we think about nature, what we think is the good society, what's the role of technology in our lives? What are the implications for social justice of technological interventions, and so forth? And what can geoengineering teach us about the governance of other emerging global technologies?

References

Armeni, C., & C. Redgwell, (2015a) *International legal and regulatory issues of climate geoengineering governance: rethinking the approach*. CGG Working Paper 21. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper21armeniredgwelltheinternationalcontext-2.pdf

Armeni, C., & C. Redgwell, (2015b) *Assessment of International Treaties Applicable, or At least Adaptable, to Geoengineering-Related Activities Through Indicators*. Annex to CGG Working Paper 21, published separately as CGG Working Paper 22. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper22armeniredgwellannextowp21assessmentofnternationaltreatiesapplicableoratleastadapatabletogeoengineering-relatedactivitiesthroughndicators.pdf

Armeni, C., & C. Redgwell (2015c) *Geoengineering Under National Law: A Case Study of the United Kingdom.* CGG Working Paper 23. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper23armeniredgwelltheuk.pdf

Armeni, C., & C. Redgwell (2015d) *Geoengineering Under National Law: A Case Study of Germany.* CGG Working Paper 24. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper24armeniredgwellgermany.pdf

Barrett, S. (2008) The Incredible Economics of Geoengineering. *Environmental and Resource Economics* 39, 45-54.

Bellamy, R. (2014) *Beyond Climate Control: 'Opening up' Propositions for geoengineering Governance.* CGG Working Paper 11. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper11bellamybeyondclimatecontrol.pdf

Bellamy, R., J. Chilvers, N. Vaughan, & T. Lenton, (2013): 'Opening up' geoengineering appraisal: Multi-Criteria Mapping of options for tackling climate change. *Global Environmental Change*, **23**, 926 – 937.

Bellamy, R., & P. Healey (2015) *A Report on the CGG Project Scenarios Workshop*. Available at: http://geoengineering-governance-research.org/perch/resources/areportontheclimategeoengineeringscenariosworkshoprbphfinal.pdf

Bellamy, R. & J. Lezaun (2015) *A Review of Deliberative Public Engagements with Climate Geoengineering.* CGG Working Paper 19. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper19bellamylezauna-reviewofdeliberativepublicengagementswithclimategeoengineering.pdf

Bellamy, R., J. Palmer & J. Lezaun (2015) *Public Engagement in the Climate Geoengineering Governance Project.* Available at: http://geoengineering-governance-research.org/perch/resources/a-report-on-cgg-public-engagement.pdf

Bickel, E. & L. Lane, (2009) *An analysis of climate engineering as a response to climate change.* Copenhagen Consensus Center, Copenhagen Business School

Bodle. R, S., Oberthür, L.Donat, G. Homann, S.Sina, E. Tedsen (2014) *Options and Proposals for the International Governance of Geoengineering.* Dessau*:* German Environment Agency. Available at: http://www.umweltbundesamt.de/publikationen/options-proposals-for-the-international-governance

Cairns, R. (2013a) *Examining framings of geoengineering using Q methodology*. CGG Working Paper 2. Available at:

http://geoengineering-governance-research.org/perch/resources/workingpaper2cairnsframings-ofge-usingqmethodology.pdf

Cairns, R (2013b) *Geoengineering: Issues of Path-dependence and Socio-technical Lock-in*. Originally prepared as a background paper for the CGG Workshop on this theme. Available at:
http://geoengineering-governance-research.org/perch/resources/background-briefing.pdf
Other papers from the CGG Lock-in Workshop are available at:
http://geoengineering-governance-research.org/lockinworkshoppresentations.php

Cairns, R (2014) *Climates of suspicion: 'chemtrail' conspiracy narratives and the international politics of geoengineering*. CGG Working Paper 9. Available at:
http://geoengineering-governance-research.org/perch/resources/workingpaper9cairnsclimatesofsuspicion-1.pdf

CGG/IAGP/SPICE 2014 *Joint Conference Geoengineering Research: Where Next?* Proceedings available at:
http://geoengineering-governance-research.org/news-detail.php?s=2015-01-23-geoengineering-research-where-next-presentations-now-available-on-youtube

Fleming, J.R. (2007). The Climate Engineers: Playing god to save the planet. *Wilson Quarterly* 31.2: pp. 46-60

Fleming, J.R. (2010) *Fixing the Sky: The Checkered History of Weather and Climate Control*. New York: Columbia University Press.

Flyvbyerg, B. , N. Bruzelius, W. Rotherngatter, (2003) *Megaprojects and risk: anatomy of ambition,* Cambridge University Press.

GeoMIP Project - The Geoengineering Model Intercomparison Project. Available at:
http://climate.envsci.rutgers.edu/GeoMIP/

Hamilton, C. (2013). *Earthmasters: Playing God with the climate*. Allen & Unwin, London

Healey, P. (2014) *The Stabilisation of Geoengineering: Stabilising the Inherently Unstable?* CGG Working Paper 15. Available at:
http://geoengineering-governance-research.org/perch/resources/workingpaper15healeythestabilisationofgeoengineering.pdf

Heyward, C & S. Rayner (2013a) *Apocalypse Nicked*. CGG Working Paper 6. Available at:
http://geoengineering-governance-research.org/perch/resources/workingpaper6heywardraynerapocalypsenicked.pdf

Heyward, C & S. Rayner (2013b) *A Curious Asymmetry: Social Science Expertise and Geoengineering.* CGG Working Paper 7. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper7heywardrayneracuriousasymmetry.pdf

Heyward, C., & S. Rayner, (in press) Uneasy Expertise: Geoengineering, Social Science, and Democracy in the Anthropocene. In M. Heazle & J. Kane (eds) *Policy Legitimacy, Science and Political Authority: Knowledge and Action in Liberal Democracies.* Routledge Earthscan, Abingdon

Heyward, C., & S. Rayner, (2015) Apocalypse Nicked: Stolen Rhetoric in Early Geoengineering Advocacy. In S. Crate & M. Nuttall (eds) *Anthropology and Climate Change, 2nd Edition,* West Coast Press, Walnut Creek CA

Heyward, C., S. Rayner, J.Savulescu (in press) Early Geoengineering Governance: The Oxford Principles. In D. Kaplan & J.B. Callicott (eds) *Technology and the Environment*, MIT Press, Cambridge MA

Hulme, M (2014a) "Attributing weather extremes to 'climate change', a review". *Progress in Physical Geography*, 38, 4, 499-511

Hulme, M (2014b) *Can Science Fix Climate Change? A Case Against Climate Engineering*. Cambridge: Polity Press

Jasanoff, Sheila & Kim, Sang-Hyun (2009) Containing the Atom: Sociotechnical Imaginaries and Nuclear Power in the United States and South Korea, *Minerva*, 47, 119-146 (DOI 10.1007/s11024-009-9124-4)

Keith, D (2013) A Case for Climate Engineering. Boston: MIT Press/A Boston Review Book

Lenton, T.M. (2014) *Can Emergency Climate Engineering Really Avoid Climate Tipping Points?* Paper delivered at Climate Geoengineering Conference 2014, Berlin

Long, Jane C.S., Frank Loy & M. Granger Morgan (2015) Policy: Start research on climate engineering. *Nature* 518**,** 29–31 (05 February 2015) doi:10.1038/518029a

MacKerron, G (2014) *Costs and Economics of Geoengineering*. CGG Working Paper 13. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper13mackerroncostsandeconomicsofgeoengineering.pdf

Macnaghten, P., & B. Szerszynski (2013) Living the Global Social Experiment: An analysis of public discourse on solar radiation management and its implications for governance. *Global Environmental Change*, published online by Elsevier 21 January 2013. http://dx.doi.org/10.1016/j.gloenvcha.2012.12.008

Markusson, N.(2013) *Tensions in framings of geoengineering: Constitutive diversity and ambivalence*. CGG Working Paper 3. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper3-markussontensions-inframingsofgeoengineering-1.pdf

Markusson, N., A. Kaltenbrunner, D. Laniado, T.Venturini, (2013) *Bounding Boundaries: The Construction of Geoengineering on Wikipedia*. CGG Working Paper 5. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper5markusson-et-algeinccwikipediadataset.pdf

Markusson, N., & P-H Wong (2015) *Geoengineering Governance, the Linear Model of Innovation, and the Accompanying Geoengineering Approach.* CGG Working Paper 20. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper-20markussonwonggeoengineeringgovernanceandthelinearmodel.pdf

Nightingale, P. & R. Cairns (2014, revised 2015) *The Security Implications of Geoengineering: Blame, Imposed Agreement and the Security of Critical Infrastructure*. CGG Working Paper 18. Available at: http://geoengineering-governance-research.org/perch/resources/cgg-working-paper-18revisefeb15.pdf

Preston, C.J. (2012) "Introduction: The Extraordinary Ethics of Solar Radiation Management" In C.J. Preston (ed) *Engineering the Climate: The Ethics of Solar Radiation Management.* Lexington Books, Lanham MD

Rayner, S. (2014) *To Know or Not to Know? A Note on Ignorance as a Rhetorical Resource in Geoengineering Debates.* CGG Working Paper 10. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper10raynertoknowornottoknow-1.pdf

Rayner, S. (2013), C. Heyward, T.Kruger, N.Pidgeon, C.Redgwell, J.Savulescu. *The Oxford Principles*. CGG Working Paper 1. Available at: http://geoengineering-governance-research.org/perch/resources/workingpaper1rayneretaltheoxfordprinciples.pdf

Rayner, S. (2015) To Know or Not to Know? A Note on Ignorance as a Rhetorical Resource in Geoengineering Debates. In L. McGoey & M. Gross (eds) *International Handbook of Ignorance Studies*, Routledge, London

Rayner, S. & C. Heyward 2013 The Inevitability of Nature as a Rhetorical Resource. In K. Hastrup (ed) *Nature/Society: Anthropology on the Edge*. Routledge, Abingdon

Royal Commission on Environmental Pollution (2008) *Novel Materials in the Environment: The Case of Nanotechnology*. The Stationery Office. London

Robock, A (2008) "20 Reasons why Geoengineering may be a Bad Idea". *Bulletin of the Atomic Scientists*, 64, 2, 14-18.

Roco, M. C., & W.S. Bainbridge (2003). *Converging technologies for improving human performance: Nanotechnology, biotechnology, information technology and cognitive science*. Kluwer Academic Publishers.

Sarewitz, D. (2004). How Science Makes Environmental Controversies Worse. *Environmental Science and Policy*, 7:385–403.

Shepherd et al. (2009) *Geoengineering the Climate: science, Governance and Uncertainty.* London: Royal Society - Policy document 10/09. Available at: https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2009/8693.pdf

US NRC (2015). US National Research Council reports on *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration* and on *Climate Intervention: Reflecting Sunlight to Cool Earth.* Available at: http://nas-sites.org/americasclimatechoices/public-release-event-climate-intervention-reports/

Weitzman, M. (2011) "Fat Tailed Uncertainty in the Economics of Catastrophic Climate Change." *Oxford Review of Economic Policy* 5, 275.

Wong, P-H. (2013) *The Public and Geoengineering Decision-Making: A View from Confucian Political Philosophy.* CGG Working Paper 4. Available at: http://geoengineering-governance-research.org/perch/resources/working-paper4wongthepublicandgedecision-making-.pdf