Living the Global Social Experiment:

An analysis of public discourse on solar radiation management and its implications for governance

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1. Introduction

1.1 The emergence of geoengineering as a policy option

There has been a recent and rapid growth of interest within the scientific and policy community in exploring a range of techniques, collectively termed 'geoengineering'(or alternatively 'climate engineering'), for deliberatively intervening in the climate to counteract global warming (American Meteorological Society, 2009; Bipartisan Policy Centre Task Force, 2011; Royal Society, 2009; United States Government Accountability Office, 2011). Within the space of a few years, and with the endorsement of learned societies and governance institutions, geoengineering has been transformed from a topic discussed largely in science fiction and esoteric scientific papers into mainstream scientific and policy debate. One class of method of geoengineering, termed solar radiation management, has received particular attention. Solar radiation management techniques are intended to reflect some of the inbound sunlight back into space with the effect of reducing global warming. This contrasts with carbon dioxide removal techniques, which attempt to address the root cause of climate change by removing greenhouse gases from the atmosphere, and are seen by many as safer, but slower and more expensive. For the purposes of this paper we will focus on solar radiation management.

There are a number of ways of explaining the rise of solar radiation management as an emergent policy discourse. First, the slow progress of international climate negotiations has led to concerns that current mitigation policies may not produce the necessary reductions in emissions that are necessary to avoid dangerous climate change. Second, proponents of the technology argue that solar radiation management could not only reduce global temperatures relatively quickly, perhaps within a few months of deployment, but also relatively cheaply, relative to the cost of implementing greenhouse gas emissions reductions (Boyd, 2008; Caldeira and Keith, 2010; SRMGI, 2011). Geoengineering is thus becoming seen as a third policy route for responding to climate change, alongside mitigation and adaptation (Nurse, 2011).

1.2 The debate about geoengineering governance

The policy debate on geoengineering governance and regulation is in its infancy. There currently exist no international treaties that cover all geoengineering techniques, although it is widely assumed that most techniques could be covered by an extension of existing treaties (Royal Society, 2009; SRMGI, 2011). Nevertheless, there have been some early statements by policy bodies. In 2010, for example, the 193 member United Nations Convention on Biodiversity declared that there should be no field tests of geoengineering projects that might affect biodiversity (Convention on Biological Diversity, 2010), while in October 2011 the European Parliament expressed 'its opposition to proposals for large scale geo-engineering' (Marshall, 2011). Such statements are not legally binding; but they nevertheless reflect early political unease with the prospect of geoengineering taking place without adequate regulatory arrangements (see also Virgoe, 2009; Lempert and Prosnitz, 2011; Olson, 2011; SRMGI, 2011).

A number of initiatives have occurred in recent years, aimed at articulating the goals and possible form of geoengineering research governance. These include: (1) the establishment of the 'Oxford Principles' for the responsible conduct of geoengineering research, submitted and adopted by the UK House of Commons Science and Technology Committee and subsequently approved by the Scientific Organising Committee at the Asilomar International Conference on Climate Intervention Technologies (Rayner et al., 2010; Asilomar Scientific Organizing Committee, 2010); (2) the development of a framework for responsible innovation aimed at guiding assessment on whether the UK Stratospheric Particle Injection for Climate Engineering (SPICE) research project's proposed test-bed – the United Kingdom's first field trial of solar radiation management technology – should be permitted (Macnaghten and Owen, 2011); and (3) the Solar Radiation Management Governance Initiative (SRMGI) – an international, NGO-driven initiative aimed at examining in depth the governance issues raised by research into solar radiation management methods (SRMGI, 2011).

There is still considerable diversity of opinion about exactly what form geoengineering governance should take. However, there seems to be an emerging consensus that it should involve a combination of soft law and hard law, be guided by principles such as 'the public interest' and transparency, and involve 'upstream' engagement with wider stakeholders and the public (Corner et al., 2012; Rayner et al., 2010; SRMGI, 2011). It is also argued that governance during the research stage might be relatively 'soft' to permit or even encourage 'safe', laboratory or small-scale research (with proposed governance mechanisms ranging through laissez-faire permissiveness, self-regulation, independent national policies, to an informal consortium of countries); however, most argue that governance would have to become 'harder' before any large-scale field research or deployment, probably through a multilateral, international body such as the United Nations (Virgoe, 2009; SRMGI, 2011).

However, despite the growing sophistication of the debate around solar radiation management governance, a number of assumptions persist in the policy literature that require further scrutiny. Firstly, it is assumed that debates around solar radiation management are debates about a unified, stable, technological object, about which different people might make different knowledge claims, or to which they might attach different values, rather than a more complex conversation in which the very nature of geoengineering is put into question. Secondly, it is assumed that it is in principle possible to make a clear distinction between research into, and deployment of, solar radiation management. This assumption manifests in the beliefs that meaningful research into the feasibility of these techniques can be carried out before deployment, and that this research will help ensure that any future deployment would be less likely to involve major surprises.

Thirdly, it is assumed that the development of solar radiation management is similar enough to earlier episodes of technoscientific innovation that future governance processes will be able to follow existing and emerging frameworks of technology assessment, such as those of responsible innovation, 'upstream' public engagement and real-time technology assessment (Barben et al., 2009; Corner et al., 2011; Corner et al., 2012; Macnaghten and Owen, 2011). Fourthly, it is assumed that new institutional arrangements for the proper regulation of geoengineering can in principle be built on existing international instruments used to regulate transboundary issues, and more generally can be accommodated within the structures of democratic national and international governance (see discussion in Virgoe, 2009). Fifthly, it is assumed that survey, qualitative and public engagement research can help clarify public attitudes to solar radiation management (see Ipsos-MORI, 2010; Leiserowitz et al., 2010; Mercer et al., 2011; Parkhill and Pidgeon, 2011; Pidgeon et al., 2012; Poumadere et al., 2011; Spence et al., 2010), and that the main role of such research should be to incorporate value-based considerations about geoengineering into decision-making (see Corner et al., 2012 for a review). Notwithstanding the importance of such research, what has been insufficiently explored is how public engagement methods can be used to explore *the kinds of world* that solar radiation management techniques might bring into being, and thereby to critically explore the assumptions that underpin governance debates around this technology.

1.3 Solar Radiation Management geoengineering, the social sciences and the public

In this section we argue that, as solar radiation management is becoming more clearly formed as a policy option, it is taking on a particular 'social constitution' – a distinctive set of implications about the sort of world that its deployment would likely bring into being (Grove-White et al., 2000; see also Kearnes et al., 2006, p. 301). This social constitution renders problematic the assumptions listed above, and thereby will make solar radiation management particularly difficult to accommodate within conventional understandings of governance. Building on existing public engagement research on geoengineering we go on to articulate a more critical role that the social sciences should be playing in public engagement with solar radiation management.

First, unlike many technoscientific issues, the distinctiveness of solar radiation management does not lie in the use of novel technologies with new properties: the actual interventions themselves typically involve mundane technologies such as mirrors, iron dust, sulphate particles or crumbled rock, albeit deployed at a very large scale. Its novelty rather lies in the intention to use these technologies to establish a radically new relationship between society and nature, through a project of bringing planetary systems under human control and the 'making' of new climates (Galarraga and Szerszynski, 2012; see also Corner et al., 2012; Hulme 2012; Ipsos-MORI, 2010).

Second, even though existing research has highlighted public concerns over the unintended consequences of solar radiation management (Corner and Pidgeon 2010; Pidgeon et al., 2012), we go further to suggest that solar radiation management has a distinctive and constitutive relationship with uncertainty. With most technologies, it is the side-effects that are likely to be hard to predict and difficult to attribute, because of the way that they often depend on stochastic processes. It is this feature of many contemporary technologies which led Ulrich Beck to suggest that we now live in a 'risk society' (1992), one pervaded by unwanted and probabilistic side-effects of modernisation. But with solar radiation management techniques, because even the intended effects are probabilistic – since their goal is to affect statistical constructs such as 'global average temperature' through intervening into an earth system which is highly chaotic and in a constant process of formation – uncertainty becomes even more unavoidable.

Third, the way that solar radiation management is constituted as a global technology of planetary management further alters the more usual spatial relationship between the 'effects' and 'side-effects' of a technology. It is more usual for technologies to be designed to bring about a local effect, but later to be found to have very different distant and often long-term side-effects, which then have to be managed and minimised through international treaties and protocols (EEA, 2002). With solar radiation management, however, this relationship is more or less reversed: it is the intended effects (for example, a reduction in average global temperature) that are global, that may only occur over long timescales, and that will depend on tightly coordinated action. The binding together of the fate of different nations will thus follow a very different logic to that of earlier issues such as acid rain and ozone depletion, and will be more complete: in the case of geoengineering, international agreement will not just be necessary to control any transboundary side-effects of any specific interventions; it will be involved in constituting the very technology from the outset.

Fourth, governing solar radiation management will involve engaging to an unusual degree with the issue of intent (Corner and Pidgeon, 2010; Stilgoe, 2011). Intention is particularly integral to the very definition of geoengineering, as a research and engineering project with a particular purpose – to offset anthropogenic climate change. Thus, whether or not a specific action such as releasing particles into the upper atmosphere counts as solar radiation management, as research, or as mere pollution cannot be determined by an objective test: the governance of geoengineering logically requires the scrutiny and regulation of the aims and intentions, both explicit and implicit, not just of real-world deployment but also of purported research activity. The interpretive flexibility of intent in solar radiation management research means that it would be likely to create even greater governance challenges than the issue of nuclear proliferation. Furthermore, if the objectives towards which the technology is employed were to alter, then its very nature would have thereby changed – rendering problematic claims of legality or prior democratic consent.

Solar radiation management is perhaps not unique in possessing any one of these characteristics. But cumulatively they suggest that debate around these techniques should proceed in a way that recognises that it is by no means a straightforward object of governance. Table 1 summarises the five assumptions that underpin current policy debates on geoengineering governance outlined in Section 1.2 and how each of them may be reconfigured through critical social science inquiry.

Table 1. Current debates on solar radiation management governance and their critique

Mediating factor	**Assumptions within debates on solar radiation management governance**	**A critical approach to solar radiation management governance**
Status of geoengineering	Solar radiation management is a unified, stable technological object with clear intent that can be judged against other policy options for dealing with climate change	Solar radiation management is a political project with unstable intent whose novelty lies in using mundane technologies to bring planetary systems under human control
Approach to research	The function of research is that of ironing out uncertainties and understanding side-effects prior to deployment	The effects of solar radiation management will inevitably be at best probabilistic meaning that deployment will have the unavoidable character of research
Approach to governance	Governance processes can be developed out of previous cases on scientific governance	Solar radiation management may create novel socio-political effects because of its distinctive spatio-temporal logic
Approach to politics	Solar radiation management governance can be accommodated within existing forms of democratic governance	Solar radiation management governance may raise significant challenges for democratic governance
Approach to public engagement	The role of public engagement is to incorporate public views and values into governance arrangements	The role of public engagement is to help understand the sort of world(s) that solar radiation management deployment might bring into being

One implication of this suggested critical reconfiguration for the conduct of social science research is the need to be particularly attentive to the process of issue and identity formation in public engagement exercises (on this issue see Chilvers, 2010; Irwin, 2006; Lezaun and Soneryd, 2007; Stirling, 2008; Wynne, 2006). It is important that public engagement exercises do not pre-define the issue in line with existing framings or obscure their role as sites at which both issues and publics are simultaneously shaped and articulated (Felt and Fochler, 2010; see also Jasanoff, 2004; Felt and Wynne, 2007; Marres, 2007). This presents a considerable set of challenges and responsibilities for the social sciences in respect to the public: *methodologically*, to be able to develop robust methods able to elicit public responses in ways that do not simply reproduce dominant framings; *conceptually*, to be able to understand public responses and the factors that shape them; *politically*, to be able to interpret public responses and their implications for geoengineering governance. The ability to explore future worlds is perhaps the greatest challenge for deliberation on solar radiation management (on this issue, see Callon et al., 2009). In order to further develop public engagement research in this area (for a review of the state of the art, see Corner et al., 2012), it will be necessary to develop techniques and skills to imagine the composition of a geoengineered future that might be brought into being through solar radiation management– its phenomenology, its political economy, its lifeworld. This requires participants being facilitated to deliberate on the dominant imaginaries of key actors – scientists, policy-makers, civil society actors – and to imagine how the future will unfold with respect to those imaginaries under real-world conditions (see Macnaghten, 2010, for an elaboration of this argument with respect to nanotechnology).

2. Methods

Taking the above arguments into account a deliberative focus group methodology was developed to meet the following criteria: (1) in the absence of a public debate, to design stimulus materials to offer participants a range of rhetorical resources without closing down or narrowing the issue in the first place (Felt et al., 2012; Stirling, 2008; Sciencewise-ERC, 2010); (2) to ensure the discussion was not framed by experts, through the decision not to include a technical geoengineering expert in the discussions (as previous research has indicated that the presence of experts can induce deference to prior framings amongst lay participants; see Wynne, 2006); (3) to moderate the discussions to ensure a diversity of voice, independent of background or experience, in line with agreed norms of focus group moderation (Barbour, 2008; Barbour and Kitzinger, 1999); (4) to require participants not necessarily to arrive at a common output or consensus, but nevertheless to articulate shared issue definitions, when present (Callon et al., 2009); (5) to model research on recent deliberative research and guidance on 'upstream' public engagement (Davies et al., 2009; Pidgeon et al., 2012; Wilsdon and Willis, 2004); and (6) to employ techniques that will support participants in the process of imagining the kinds of world that solar radiation management might bring into being, in order to test the plausibility of the assumptions underpinning governance debates.

The focus groups were moderated by the authors, both experienced focus group practitioners. Seven focus groups were carried out in three UK cities (Durham, Newcastle and London) in December 2011, each with eight participants and lasting three hours. The sampling specification was theoretically derived: designed to cover a diverse variety of backgrounds and demographics (age, gender, socio-economic class) but with topic-specific variants. Three of the groups were selected due to their having a practical interest in the climate: a group of keen gardeners (focus group 7, all women, aged 40–60, socio-economic class B/C1/C2), a group of outdoor manual workers (focus group 6, all men, aged 25–35, socio-economic class C2/D) and a group of outdoor enthusiasts (focus group 1, both men and women, aged 30–50, socio-economic class B/C1). The four other groups were chosen to have a particular lifeworld orientation that might shape their general attitude to geoengineering in different ways: a group of engineers and managers (focus group 5, all men, aged 30–50, socio-economic class B/C1), a group of mothers of young children involved with their local community (focus group 2, all women, aged 25–40, socio-economic class B/C1), a group of professional men working in the public sector and with an interest in current affairs (focus group 3, all men, aged 40-60, socio-economic class A/B) and a group of individuals signed up to participate in a citizens' panel on living with environmental change (focus group 4, both men and women, socio-economic class B/ C1/ C2/ D). The rationale for the selection criteria was to explore whether shared lifeworld experiences would structure responses to geoengineering: for example, would the engineers be more favourably disposed to a 'technical fix' for climate change; would the public sector professionals engage collectively with the politics; would the mothers be sensitised to the kind of future that solar radiation management would bring into being. The decision to bring participants together on the basis of shared experience was to foster a favourable setting for the collective discussion of an unfamiliar topic (see Macnaghten and Myers, 2004; Morgan, 1988). Recruitment was topic-blind: participants were recruited to take part in a discussion on 'global issues', and geoengineering was only introduced 70 minutes into the discussion. Participants were recruited by professional recruiters.

The materials were developed by the authors and externally reviewed by three colleagues, all experts in public deliberation and technological governance. The materials were presented on large A1 boards, consisted of pictures and text (all attributed) and presented to the group to stimulate conversation. The focus groups began with an open-ended discussion on experience of the weather and the climate, designed to provide a context for future deliberations on geoengineering as a climate change modification technology. This was followed by a discussion on climate change and policy responses. A concept board was used with material from International Panel on Climate Change reports and using direct quotes from newspapers and non-governmental organisation campaigns to highlight current debates on targets and the slow progress of climate negotiations. The purpose of this section of conversation was to provide a framing that was relatively open to geoengineering as a policy option; one that is reflective of the current dominant policy discourse (see Bipartisan Policy Centre Task Force, 2011; Royal Society, 2009). Subsequently, the concept of geoengineering was introduced: both as a set of techniques, with specific reference to Solar Radiation Management and Carbon Dioxide Reduction methods, and as a policy response to anthropogenic climate change. Again, the intent was to use the framing from within the establishment science-policy community. After an exploration of views on geoengineering in general and solar radiation management in particular, we then introduced how environmental and civil society actors were thinking about solar radiation management, designed to explore public views and perspectives on civil society and oppositional perspectives. This was followed by an engagement with a different kind of frame, setting out the geopolitical history of weather and climate modification (see Fleming, 2010). This was designed to explore the salience of alternative frames surrounding the possible use of solar radiation management techniques for other social, political and military purposes. Finally, we discussed the implications of solar radiation management for society and politics: what kind of people we would become, what kind of politics would be required, and what messages the participants had for science, politics and policy-makers.

3. Findings: An Analysis of Public Discourse

3.1 Conditional acceptance

Perhaps not surprisingly, the public responses to solar radiation management that we elicited were complex, multi-faceted, difficult to interpret and rich in content. However, notwithstanding the complexity of the topic, across all the groups, participants were able to learn about the issues, to consider and reflect on them, to become engaged, hear different perspectives, change their minds, develop their points of view and co-evolve a set of consistent scenarios of life in a geoengineered world. Despite notable differences between the focus groups, what emerged most clearly was the similar themes that emerged across the focus groups and the pathways through which these developed as the discussions progressed. It is the analysis of these common themes that we focus on in this paper.

The early stages of deliberation was characterised by a complexity of positions. For some, solar radiation management should be opposed completely; for others, it was an option to be explored. Below is an extract from one of the engineers expressing his initial support for solar radiation management:

> Michael: I think the main principle is "let's do something". We're all doing some elements of recycling. Companies aren't particularly signing up to any hard and fast issues of penalties to punish or anything like that. If this could buy 20-25 years or whatever, when we stem the growth in terms of temperature increase. So why wouldn't you that? Let's do something.
> (Focus Group 5: Engineers)

Michael is here extolling the principle of doing something rather than simply waiting for nature to take its course. This was a discourse that was popular with the engineers and technicians who made up Focus Group 5, and who appeared to be more accepting, philosophically, of the idea of using technology to deliberatively intervene in the Earth's climate system. The idea of solar radiation management 'buying time' is a discourse common amongst geoengineering researchers in arguments promoting the need for research (see Caldeira and Keith, 2010; Keith et al., 2010).

Michael could be described as a 'supporter' of solar radiation management using a typology used by Mercer et al. (2011) in segmenting attitudinal groups. However, this would be to misunderstand his response. Rather, he is deploying the discourse of 'conditional acceptance' (see also Bickerstaff et al., 2008). Michael is not advocating acceptance of solar radiation management in a straightforward sense, but only reluctantly, and only if certain conditions are met: in this case, to buy time. Later in the discussion, when participants were exposed to other framings of the technology, Michael (and others who had adopted similar early support for the technology) had developed a clearer and more developed articulation of the conditions attached.

A more comprehensive thematic analysis of the focus group transcripts allowed us to identify five conditions as particularly salient in the discussions. While these are neither exhaustive nor exclusive, they were clearly critical in modulating the respondents' views on the acceptability of solar radiation management. These were:

1. Confidence in climate science as a reliable guide to policy and action (Condition of scientific robustness);
2. Confidence in the ability of research to anticipate the side-effects of solar radiation management (Condition of research foreseeability);
3. Confidence in the ability of research to demonstrate the efficacy of solar radiation management (Condition of research efficacy);
4. Confidence in the political organisation and effective governance of solar radiation management (Condition of effective governance);
5. Confidence in the capacity of existing political systems to accommodate solar radiation management (Condition of democracy).

3.2 Conditions under scrutiny

The approach that we adopted builds on a model developed by Cynthia Selin (2011) in which she subjects future visions of a technology – in her case nanotechnology – to public scrutiny using the criterion of plausibility. This technique is used as a means of deliberating the social implications of an emergent technology where outcomes are as yet unknown. Only if such visions are seen as plausible by wider actors will they contribute to reasonable public policy. This technique is presented as having the potential to build reflexivity into policy deliberation and enable anticipatory governance and responsible innovation (see also Barben et al., 2008; Owen et al., 2012). In our research we subjected the above conditions – which were embedded in scientific and policy debates on solar radiation management as outlined in Section 1.2 and Section 1.3 – to public scrutiny and deliberation. We examine how realistic, tenable, feasible, likely, probable, believable the conditions were perceived to be under real world contingencies.

3.2.1 Condition 1: Confidence in climate science as a reliable guide to policy

Arguably, the foundational condition required for any form of solar radiation management proposal is that people have confidence in the science of climate change as a reliable basis for policy (Condition 1). Only if people believe in the ability and authority of climate science to predict with confidence, and progressively greater certainty, the reality and consequences of climate change, can policies aimed at climate remediation gain traction (Sarewitz, 2010). Amongst our participants this level of confidence was rarely held. Even though the clear majority of participants shared the view that polluting activities were impacting on the climate, there was much less confidence in official accounts of expert scientific opinion as providing authoritative evidence of precise linkages between greenhouse gas emissions and degrees of warming of the climate system. In the extract below, Andrew is expressing the idea that nature may operate according to processes and cycles that are barely comprehended by contemporary science:

Andrew: I think it's not an exact science, you can't say… the last three years the temperature's gone up one degree, but I think in context it's only a small blip of the total world cycle, and I think personally a lot of it is the hype in the media and people are being misled into saying it's global warming, and all the rest of it. And me being naturally cynical, I think it's part of the way that the government are getting more money out of you in green taxes from the public, getting them to pay more. And I think it's a big con personally, because I don't think anybody can say for certain even if it is getting warmer [if] it's down to carbon emissions. I think it's life's natural cycle..
(Focus Group 1: Outdoor Enthusiasts)

In this extract Andrew is articulating the view that the science of climate change may be less certain than is commonly accredited, and that climate policy, in addition, may be tainted by the impure motives of the media and/or governments. Variants on this discourse were commonplace across the focus groups, and were the source of considerable debate and discussion. This kind of response complements survey findings that suggest that, despite low absolute levels of public scepticism about the concept of anthropogenic climate change in the UK (Poortinga et al., 2011), public scepticism about climate *science* is growing in the UK as well as the USA (BBC, 2010; Leiserowitz et al., 2010; Pew Research Centre, 2009; Pidgeon and Fischhoff, 2011). Interestingly, these extracts of conversation took place prior to discussion of geoengineering but prefigured doubts later expressed over the efficacy of solar radiation management proposals. People felt that, if climate scientists and policymakers are over-estimating their understanding of the complex and apparently chaotic earth–ocean–atmosphere system, solar radiation management proposals may unwittingly introduce perturbations into that system in unpredictable and potentially dangerous ways.

3.2.2 Condition 2: Confidence in the ability of research to predict side-effects

Earlier, we argued that policy discussions tends to assume that the uncertainties associated with geoengineering deployment can in principle be minimized and managed in advance by research. Such a belief is necessary if solar radiation management is to be seen as having the potential to 'restore' or 'remediate' the climate, a discursive frame commonly adopted by scientific and science policy communities (see, for example, Bipartisan Policy Centre Task Force, 2011). The second condition concerns the plausibility of this claim: whether research is perceived to have the ability to predict (and manage) the side-effects of solar radiation management in advance of full deployment, and thus restore the climate to a previous state. Without accurate foresight – and control measures – solar radiation management could bring in its wake nasty surprises.

For most participants, there was little belief in the capacity of science to identify possible side-effects in advance. For most, solar radiation management was seen as 'messing with nature' and, as a consequence, as inevitably creating unpredictable and potentially dangerous shocks and surprises, especially if current understandings and predictions of climate changes proved to be ill-founded. Nearly all participants agreed that such techniques would unwittingly produce side-effects not anticipated in advance by science. This *'unforeseen effects'* discourse was commonplace in all discussions. For some, these unforeseen effects were seen as likely to arise as a consequence of nature 'fighting back'. The model of nature was one of an active agent – for some a wild beast (see also Pearce, 2007) – who would not placidly accept such intrusive interventions in an accommodating manner. The idea of solar radiation management 'restoring' or 'remediating' the climate was by and large rejected. Across the groups we found recurrent themes: that it is impossible to predict how solar radiation management will impact on the Earth's climate system; that unforeseen and dangerous effects are not simply possible but probable given the scale of the proposed interventions; that such effects will take decades or longer to materialise; and that solar radiation management is likely to be more dangerous than what it is trying to prevent. Given the uncertainties involved, and the probable and potentially dangerous side-effects associated, the inevitable consequence is that we will be 'living the experiment'. We will, in effect, be 'guinea pigs'. Since science will not have the capacity to provide answers in advance, this pervasive experimentality will be part of the new human condition:

Kaitlyn: The thing that scares me is that the experiment will be done in our [life times]...
Natalie: It's such a huge thing, though, isn't it?

Kaitlyn: Yeah. The experiment will be while we're here... and ... for our children. What if the experiment goes wrong? Then what happens?
Lillian: Do you think it could destroy the Earth?
Kaitlyn: Yeah, it could go the other way. How can you test...? Can it be tested in a laboratory? But then it's got to go out there.
Mod: Yeah, sure. So that's the big question for you. We'll be living the experiment, in a sense. Is that what you're saying?
Kaitlyn: Yeah.
Natalie: We're the lab rats.
(Focus Group 2: Mothers)

3.2.3 Condition 3: Confidence in the ability of research to demonstrate efficacy

A further assumption embedded in policy discourse is that research is able to demonstrate the efficacy of solar radiation management proposals. Only if research is able to demonstrate in plausible ways that solar radiation management is likely to be effective in practical and operational terms will moves to deployment be seen as credible. In the group discussions there was widespread discussion on the technicalities of proposed solutions. Considerable time was devoted to exploring questions surrounding one particular geoengineering research project – the Stratospheric Particle Injection for Climate Engineering (SPICE) project – and its proposal to test the design of a stratospheric aerosol delivery system using a tethered balloon and pipe in what would have been the UK's first field trial of solar radiation management technology (Macnaghten and Owen, 2011). Particularly amongst the more technically minded participants (Groups 1, 4 & 5), considerable doubt was raised as to whether such a scheme would be technically feasible, and whether the proposed 1:20 scale test-bed spraying water would provide useful and relevant information for full deployment scenarios (see Parkhill and Pidgeon, 2011 for a more extensive analysis of a public deliberation exercise on the SPICE project). The extract below illustrates how the engineers responded to the SPICE project:

Michael: The point that I think you guys made is that, you know, one kilometre versus 20 kilometres. Is that really gonna - is it a true representative of the view of the technology. You know, is it literally gonna be - is it pointless following it because the leap between 1k and 20k is so huge.
Daniel: It's massive.
Adrian: It's phenomenal, isn't it.
Michael: It requires completely new different type of technology, greater pumping facilities, etcetera. So actually you're not really trialling anything by that …
(Focus Group 5: Engineers)

There was similar scepticism about the possibility of ascertaining how much, of what, needs to be injected into the atmosphere to effectively and safely manage the climate system. For our participants, it was implausible to imagine that the effects of particulate injection could be known except in the context of full deployment, at a planetary level and across considerable timescales. The scale of planetary intervention is the subject of the extract below:

Robert: You can't experiment with this. Like a lot of projects I work on you do tests and modelling and mock-ups but you can't test this. Test it on the planet?
(Focus Group 3: Public Sector Professionals)

This deliberation led some participants to question their support for solar radiation management research at all. While there was initial acceptance of the need for research in principle, following deliberation there was more general reticence for a number of reasons: that research would be predominantly based on models, that proposed field trial experiments looked technically unfeasible and unlikely to produce any knowledge of substance, that researchers would be pressurised to tell only positive results, and that the planetary scale at which deployment was imagined was such that research only makes sense at that level.

3.2.4 Condition 4: Confidence in the effective governance of solar radiation management

In Section 1.3 we argued that the governance challenges raised by geoengineering will involve engaging with the issue of 'intent', given that the technology is defined by its intention of counteracting climate change by technological intervention. To have confidence in the effective governance of solar radiation management proposals (Condition 4) will require endorsement on two levels: acceptance of the concept of solar radiation management as a set of techniques and policy options that complement those of mitigation and adaptation (the 'Plan B' argument); and confidence that these techniques will be used primarily and exclusively by governments and other actors for the said purposes of counteracting anthropogenic climate change. To what extent was the effective governance condition seen as plausible?

By and large solar radiation management philosophically was regarded as treating the symptoms rather than the underlying causes of global warming. Participants were told that it was presented by policymakers as a way of 'buying time' for climate mitigation policies to take effect; but it was nevertheless seen by most as a 'techno-fix' for a problem that was political, commercial and perhaps even moral in origin. Even though solar radiation management may be presented in good faith as 'Plan B' ('Plan A' being continued effort at climate mitigation), there was a shared concern across the groups that its very availability as an technological option would weaken the commitment to climate mitigation – the well-known 'moral hazard' argument, that today's 'Plan B' would become tomorrow's 'Plan A'.

However, just as the pursuit of solar radiation management techniques could reduce the political impetus for international climate negotiations and emissions policy, so too might geopolitical considerations impact on how and where the technology gets pursued and for what ends. In the focus group discussions we raised explicitly the question of whether the good intentions of solar radiation management could be assured, thus scrutinising further the plausibility of Condition 4. By and large the answer was 'no'. Not only would the technology become politicised, according to our participants, but it would do so for national and regional advantage, in ways that may be radically at odds with its intended purpose of counteracting anthropogenic climate change. Interestingly, these discussions took place after the presentation of a concept board, setting out the history of earlier attempts at weather and climate modification, including for military and geopolitical purposes, and after an exercise in which people imagined how life would be changed by solar radiation management. Below is one typical contribution:

Andrew: What's to do stop this being proven technology and the Chinese say "Well okay, we need to do something to help China"? They introduce something like that which then makes it ten degrees colder in the north-east of England. Do you really think the Chinese are going to be bothered about us in Newcastle? And that's my fear: that greed and all the corporate type of greed that goes on could affect people in the world.
(Focus Group 1: Outdoor Enthusiasts)

3.2.5 Condition 5: Confidence in the capacity of democracy to accommodate solar radiation management

The fifth and final condition concerns public confidence in the capacity of existing political systems to accommodate solar radiation management. To what extent was this condition seen as plausible? Difficulties associated with this condition related to a number of characteristics of solar radiation management that we outlined in section 1.3: its distinctively global character, its inherent uncertainty, and its 'social constitution' as a political project of planetary control. The concern expressed by participants across a number of groups was that planetary governance would be intensely difficult to achieve within current political arrangements. Current omens were poor: given the lack of progress to achieve global consensus on to the mitigation of climate change, what chance would there be to achieve a consensual politics and set of agreements on solar radiation management proposals?

Robert: Well … if we can't agree on a global level for emissions or other targets how can we possibly agree on a global level to invest in these types of projects? … To get a global agreement on these types of projects and investment levels, as you were saying … good luck to them.

Nicholas: Well I don't see, one, how you get America involved when it doesn't admit there's climate change anyway. So you've got that problem. The ones that do admit can't do anything about it because their economies are growing, they can't afford it. That's the three biggest economies in the world and to put it politely you're stuffed.

Martin: … We can't even agree what's going on in Brussels, they can't agree with us. Then we're suddenly talking about geoengineering and creating false atmospheres to change the climate. (Focus Group 3: Public Sector Professionals)

This extract is from the Public Sector Professionals group. All recruited on account of their interest in politics and current affairs, this group relished the opportunity to explore just how complex – and unrealistic – it would be to achieve the kinds of global agreements that would be required for nations to sign up to solar radiation management deployment. Interestingly, when asked what kind of citizens we would need to become to accommodate solar radiation management the response from a member of this group was "gullible" ones. The theme of the technology being unable to be accommodated within a democratic politics was shared by other groups, including the Citizens Panel (focus group 4) who offered the view that solar radiation management could only work in conditions of a 'benign dictatorship'. Other groups suggested that the dictatorship would be less benign, not least because solar radiation management would necessarily be carried out on a planetary basis with no accommodation for dissent or 'opt out'. Thus, in the outdoor workers' group (focus group 6), participants argued that the technology would inevitably lead to conflict, arguing in colourful language that "You've just got to pray that some nutter don't get in charge of it". The difficulty was seen as further compounded given that the effects of solar radiation management deployment would only be known after a significant time period and then would be subject to contestation.

4. Discussion and Conclusions

4.1 Contributions to existing literatures

This study generated many findings which were broadly consistent with the existing literature on public attitudes to solar radiation management. These included: general concern about the uncertainties involved, concern about unintended effects and about the 'unnaturalness' of solar radiation management techniques, concern that the technology constituted a short-term fix rather than a genuine solution to climate change, and at best reluctant or conditional acceptance of the technology (Corner et al., 2012; Ipsos-MORI, 2010; Mercer at al., 2011; Parkhill and Pidgeon, 2011; Pidgeon et al., 2012). However, in some important ways, our findings extend existing analyses.

Firstly, unlike Mercer et al. (2011) we did not find clearly opposing ranks of supporters and detractors. Although some respondents from some of the groups would have identified themselves as conditional supporters at the start of the discussions – predominantly some from Group 1 (outdoor enthusiasts), Group 4 (Citizens' Panel) and Group 5 (engineers) – as the groups went on to collectively deliberate about whether the conditions under which they would find solar radiation management acceptable could be realised in practice, these respondents by and large came to adopt far more sceptical and circumspect positions. Our analysis identified five different conditions which modulated discussion – some linked, others quite distinct – which provided a backdrop to questions of public acceptability. Deliberation on the plausibility of these conditions provided the participants with repertoires that they mobilised and deployed as resources for deliberation. As they did so, even participants who had started from a position of conditional acceptance came to see the conditions for successful, acceptable deployment as unfeasible and implausible, and thus became more sceptical.

Of course, the relationship between conditionality and acceptance is, at least in part, contingent on unfolding events. Real-world developments, such as growing climate sensitivity, new evidence of climate-related damage or the further break-down of climate negotiations, may plausibly create dynamics in which people soften their opposition to solar radiation management. However, alternatively, as the potential political and social implications become clearer and better articulated, opposition may harden. Either way, what this analysis suggests is for the need for policy-makers to take into account the conditions attached to publicly-acceptable solar radiation management, as an integral element of decision-making processes.

Secondly, even though the conditionality of public acceptability of solar radiation management has been noted by Corner et al. (2012), our analysis constitutes the first attempt to systematically set out what these conditions are and the implausibility of them being realised under real-world circumstances. This analysis thus helps explain one survey finding: that the more people know about the technology, the more sceptical they appear to become (Corner et al., 2012; Spence et al., 2010). Thirdly, our analysis extends understanding of the conditions themselves. Thus, whereas existing analyses have highlighted the issue of unintended consequences and side-effects (Betz, 2012; Corner and Pidgeon, 2010; Pidgeon et al., 2012; Vaughan and Lenton, 2011), our research has extended this analysis to highlight how solar radiation management has the potential to propagate a new condition of global experimentality. Whereas existing analyses have highlighted the problem of achieving consent in governance arrangements (Corner and Pidgeon, 2010; Svoboda et al., 2011), our research has questioned whether solar radiation management can be accommodated within democratic institutions given its centralising and autocratic 'social constitution' (see also Grove-White et al., 2000). Whereas existing analyses have found 'cautious and qualified support for well-regulated and limited research' into solar radiation management (Corner et al., 2012, 458; see also Parkhill and Pidgeon, 2011), our research has found evidence of scepticism even of limited research, given that the effects were perceived by some to be knowable only in the context of full deployment.

Overall, the participants in this study seemed to arrive at more consistently sceptical positions about the prospect of geoengineering than have been reported in earlier research.

We can only speculate why this may be the case. In contrast to survey methods, the deliberative method gave participants a collective opportunity to explore the issue, to think through its implications more fully, and to arrive at what are arguably more considered positions. The contrast with the findings of other deliberative research is perhaps more interesting. The authors were careful to introduce the topic of geoengineering within the conventional frame of the perceived need to buy more time for greenhouse gas mitigation policies to become effective, in line with other deliberative exercises (see Ipsos-MORI, 2010; Parkhill and Pidgeon, 2011). But other possible framings of geoengineering were also introduced later on, facilitating a discussion on the difficulty of policing 'intent'. The specific combination of deliberative methods used also included a phenomenological focus on getting the participants to imagine what it would be like to live in a world shaped by solar radiation management – technically, politically, socially and personally. This combination of factors, we feel, created the conditions for a richer representation of the kind of public dynamics likely to unfold when a wider discussion of geoengineering ensues. Whether our framing strategy is more substantive and possibly more realistic is a matter of debate: some may argue that it may have unduly shaped subsequent public responses. Our response is that these additional frames were necessary to help 'open up' policy deliberation given their potential to reconfigure governance debates as geoengineering evolves as an issue (on the importance of framing in public engagement activities, see Jasanoff, 2004; Stirling 2008).

4.2 Implications for policy and politics

To conclude, we offer three provocative thoughts for policy deliberation and on the need for explicit discussion on whether solar radiation management can be accommodated within democratic governance. The Oxford Principles on geoengineering research state that 'geoengineering must be regulated as a public good' and that there should be 'public participation in geoengineering decision-making' (Rayner et al., 2010). In our research we question whether such goals are attainable. Democracy, in its various forms, depends on the articulation, negotiation and accommodation of plural views and interests. It relies on an evolving and partially flexible relationship between citizens and governance institutions. solar radiation management by contrast exists as a planetary technology. While plausibly able to accommodate diverse views into the formulation of its use, once deployed, there remains little opportunity for opt-out or for the accommodation of diverse perspectives. By its social constitution it appears inimical to the accommodation of difference. Following deployment it could only be controlled centrally and on a planetary scale. For these reasons, one important role of bringing publics into the democratic governance of solar radiation management may be, ironically, as a method of articulating the anti-democratic constitution of the technology and its incompatibility with liberal democracy.

Secondly, the effects of solar radiation management can only be known with certainty through deployment and across substantial timescales (of at least decades). Anticipating the efficacy and side-effects of the technology depend on modelling and simulations. The stakes involved – including legal, political and human dangers associated with the technology not running to plan – means that in effect we will be living the global social experiment. Deciding how to enter into this experiment, and on whose terms, raises questions for global governance of a novel kind. This also implies responsibilities for science of a character that is perhaps unprecedented.

Thirdly, there remains the problem of governing solar radiation management and of ensuring that the technology is deployed for good purposes – for example, to combat global warming rather than for national or regional advantage. Our participants regarded this prospect as highly implausible. Whether their judgement turns out to be justified, only time will tell, though it is quite possible that our participants are being more realistic than policy actors. What is does suggest however, is the potential for the technology to generate new forms of conflict and to reconfigure geopolitics. Anticipating the pathways and scenarios that this may take is a further challenge for solar radiation management governance.

How to bring into democracy these issues – the potential for solar radiation management to negate democracy; the challenges of bringing publics and democratic processes into the decision of initiating a global social experiment; and the anticipation of dynamics of geopolitical conflict that may ensue – remains key questions that will have to be addressed in advance of any discussions of solar radiation management deployment. Therein lies a set of formidable challenges for the social sciences.

References

American Meteorological Society, 2009. Geoengineering the Climate System: A Policy Statement of the American Meteorological Society. Washington DC. Also at http://www.ametsoc.org/policy/2009geoengineeringclimate_amsstatement.html (accessed 20 June 2012).

Asilomar Scientific Organizing Committee, 2010. The Asilomar Conference Recommendations on Principles for Research into Climate Engineering Techniques. Washington DC, Climate Institute. Also at http://climate.org/PDF/AsilomarConferenceReport.pdf (accessed 20 June 2012).

Barben, D., Fisher, E., Selin, C., Guston, D. 2008. Anticipatory governance of nanotechnology: foresight, engagement, and integration. In: Hackett, E., Amsterdamska, O., Lynch, M., Wajcman, J. (Eds.), The Handbook of Science and Technology Studies, Third Edition. MIT Press, Cambridge, MA, pp. 979–1000.

Barbour, R. 2008. Doing Focus Groups. Sage, London.

Barbour, R., Kitzinger, J. (Eds.), 1999. Developing Focus Group Research: Politics, Theory and Practice. Sage, London.

BBC , 2010. British Broadcasting Corporation Climate Change Poll – February 2010. Available from: http://news.bbc.co.uk/nol/shared/bsp/hi/pdfs/05_02_10climatechange.pdf (accessed 20 June 2012).

Beck, U. 1992. The Risk Society: towards a new modernity. Sage, London.

Betz, G. 2012. The case for climate engineering research: an analysis of the “arm the future” argument. Climatic Change 111: 473–485.

Bickerstaff , K., Lorenzoni, I., Pidgeon, N., Poortinga, W., Simmons, P. 2008. Re-framing nuclear power in the UK energy debate: nuclear power, climate change mitigation and radioactive waste. Public Understanding of Science 17, 145–169.

Bipartisan Policy Centre Task Force on Climate Remediation Research, 2011. Geoengineering: A National Strategic Plan for Research on the Potential Effectiveness, Feasibility, and Consequences of Climate Remediation Technologies. Washington DC. Available at http://www.bipartisanpolicy.org/library/report/task-force-climate-remediation-research (accessed 20 June 2012).

Boyd, P. 2008. Ranking geo-engineering schemes. Nature Geoscience 1, 722–723.

Caldeira, K., Keith, D. 2010. The need for climate engineering research. Issues in Science and Technology Fall, 57–62.

Callon, M., Lascoumes, P., Barthe, Y. 2009. Acting in an Uncertain World: An Essay on Technical Democracy. MIT Press, Cambridge, MA.

Chilvers, J. 2010. Sustainable Participation? Mapping Out and Reflecting on the Field of Public Dialogue on Science and Technology. Sciencewise Expert Resource Centre, Harwell, England.

Convention on Biological Diversity, 2010. Climate-related Geoengineering and Biodiversity: Technical and Regulatory Matters on Geoengineering in relation to the CBD. Available at http://www.cbd.int/climate/geoengineering/ (accessed 01 December 2012).

Corner, A., Pidgeon, N. 2010. Geoengineering the climate: the social and ethical implications. Environment 52, 24-37.

Corner, A., Parkhill, K., Pidgeon, N. 2011. 'Experiment Earth?' reflections on a public dialogue on geoengineering. Understanding Risk Working Paper 11-02, Cardiff, School of Psychology, Cardiff University.

Corner, A., Pidgeon, N., Parkhill, K. 2012 Perceptions of geoengineering: public attitudes, stakeholder perspectives, and the challenge of "upstream" engagement, WIREs Climate Change 3, 451–466.

Davies, S., Macnaghten, P. and Kearnes, M. (Eds.), 2009. Reconfiguring Responsibility: Deepening Debate on Nanotechnology. Durham, Durham University.

EEA, 2002. Late Lessons from Early Warnings: The Precautionary Principle 1896-2000. Environmental issue report no. 22. European Environment Agency, Copenhagen. Available at http://www.eea.europa.eu/publications/environmental_issue_report_2001_22 (accessed 20 June 2012).

Felt, U., Fochler, M. 2010. Machineries for making publics: inscribing and de-scribing publics in public engagement. Minerva 48, 219–238.

Felt, U., Schumann, S., Schwarz, C., Strassnig, M. 2012. Technology of Imagination. A Card-based Public Engagement Method for Debating Emerging Technologies. Published by the Department of Social Studies of Science, University of Vienna, May 2012. Available at http://sciencestudies.univie.ac.at/publications (Accessed 15 November 2012)

Felt, U., Wynne, B. et al. 2007. Taking European Knowledge Seriously. Report of the Expert Group on Science and Governance to the Science, Economy and Society Directorate. Directorate-General for Research, European Commission, Brussels. Available at http://ec.europa.eu/research/science-society/document_library/pdf_06/european-knowledge-society_en.pdf (accessed 20 June 2012).

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

Galarraga, M., Szerszynski, B. 2012. Making climates: solar radiation management and the ethics of fabrication. In: Preston, C. (Ed.), Engineering the Climate: The Ethics of Solar Radiation Management. Lexington, Massachusetts, pp. 211–225.

Grove-White, R., Macnaghten, P., Wynne, B. 2000. Wising Up: the public and new technologies. Centre for the Study of Environmental Change, Lancaster University, Lancaster. Available at http://www.csec.lancs.ac.uk/docs/wising_upmacnaghten.pdf (accessed 20 June 2012).

Hulme, M. 2012. Climate change: climate engineering through stratospheric aerosol injection. Progress in Physical Geography 36 (5), 694-705.

Ipsos-MORI, 2010. Experiment Earth: Report on a Public Dialogue on Geoengineering. Natural Environment Research Council, Swindon. Available at www.nerc.ac.uk/about/consult/geoengineering-dialogue-final-report.pdf (accessed 20 June 2012).

Irwin, A. 2006. The politics of talk: Coming to terms with the "new" scientific governance. Social Studies of Science 36, 299–320.

Jasanoff, S. (Ed), 2004. States of Knowledge: The Co-production of Science and Social Order. Routledge, London.

Kearnes, M., Grove-White, R., Macnaghten, P., Wilsdon, J., Wynne, B. 2006. From Bio to Nano: learning the lessons, interrogating the comparison. Science as Culture 15, 291–307.

Keith, D., Parsons, E., Morgan, M. 2010. Research on global sun block needed now. Nature 463, 426-427.

Leiserowitz, A., Maibach, E., Roser-Renouf, C., Smith, N. 2010. Climate Change in the American Mind: Americans' Global Warming Beliefs and Attitudes in June 2010. Yale University and George Mason University, New Haven, CT. Yale Project on Climate Change Communication, 2010. 33. Available at http://www.climatechangecommunication.org/images/files/ClimateBeliefsJune2010.pdf (accessed 20 June 2012).

Lempert, R., Prosnitz, D. 2011. Governing Geoengineering Research: A Political and Technical Vulnerability Analysis of Potential Near-term Options. (TR 846) RAND Corporation [Online]. Available at http://www.rand.org/pubs/technical_reports/TR846.html (accessed 20 June 2012).

Lezaun, J., Soneryd, L. 2007. Consulting citizens: technologies of elicitation and the mobility of publics. Public Understanding of Science 16, 279–297.

Macnaghten, P. 2010. Researching technoscientific concerns in the making: narrative structures, public responses and emerging nanotechnologies. Environment and Planning A 41, 23–37.

Macnaghten, P., Myers, G. 2004. Focus groups: the moderator's view and the analyst's view. In: Gobo, G., Gubrium, J., Seale, C., Silverman, D. (Eds.), Qualitative Research Practice. Sage, London, pp. 65–79.

Macnaghten, P., Owen, R. 2011. Good governance for geoengineering. Nature 479, 293.

Marshall, M. 2011. Political backlash to geo-engineering begins. The New Scientist 03 October 2011. Available at http://www.newscientist.com/article/dn20996-political-backlash-to-geoengineering-begins.html (accessed 20 June 2012).

Morgan, D. 1988. Focus Groups as Qualitative Research. Sage, Thousand Oaks, CA.

Marres, N. 2007. The issues deserve more credit: pragmatist contributions to the study of public involvement in controversy. Social Studies of Science 37, 759–780.

Mercer, A., Keith, D. Sharp, J. 2011. Public understanding of Solar Radiation Management. Environmental Research Letters 6, 044006 (9 pages).

Nurse, P. 2011. I hope we never need geoengineering, but we must research it. The Guardian 08 September. Available at http://www.guardian.co.uk/environment/2011/sep/08/geoengineering-research-royal-society (accessed 20 June 2012).

Olson, R. 2011. Geoengineering for Decision-makers. Science and Technology Innovation Program, Woodrow Wilson International Center for Scholars, Washington DC.

Owen, R., Macnaghten, P., Stilgoe, J. 2012 in press. Dimensions of responsible innovation. In: Owen, O., Bessant, J., Heitz, M (Eds.), Responsible Innovation. Wiley, Oxford.

Parkhill, K., Pidgeon, N. 2011. Public engagement on geoengineering research: preliminary report on the SPICE deliberative workshops. Technical Report, Understanding Risk Group Working Paper, 11-01. Cardiff University School of Psychology, Cardiff. Available at http://psych.cf.ac.uk/understandingrisk/docs/spice.pdf (accessed 20 June 2012).

Pearce, F. 2007. With Speed and Violence: Why Scientists Fear Tipping Points on Climate Change. Bloomsbury, London.

Pew Research Centre for the People and the Press, 2009. Fewer Americans See Solid Evidence of Global Warming. Available at http://www.people-press.org/2009/10/22/fewer-americans-see-solid-evidence-of-global-warming/ (accessed 20 June 2012).

Pidgeon, N., Corner, A., Parkhill, K., Spence, A., Butler, C., Poortinga, W. 2012. Exploring early public responses to geoengineering. Philosophical Transactions of The Royal Society 370, 4176–96.

Pidgeon, N., Fischhoff, B. 2011. The role of social and decision sciences in communicating uncertain climate risks. Nature Climate Change 1, 35–41.

Poortinga, W., Spence, A., Whitmarsh, L., Capstick, S., Pidgeon, N. 2011. Uncertain climate: an investigation of public scepticism about anthropogenic climate change. Global Environmental Change 21, 1015–1024.

Poumadere, M., Bertoldo, R., Samadi, J. 2011. Public perceptions and governance of controversial technologies to tackle climate change: nuclear, power, carbon capture and storage, wind and geoengineering. WIREs Climate Change 2, 712–727.

Rayner, S., Redgwell, C., Sauvulescu, J., Pidgeon, N., Kruger, T. 2010. Draft Principles for the Conduct of Geoengineering Research (the 'Oxford Principles'). Reproduced in House of Commons Science and Technology Committee, The Regulation of Geoengineering, Fifth Report of session 2009-2010, HC221, 29-30. Available at http://www.publications.parliament.uk/pa/cm200910/cmselect/cmsctech/221/221.pdf (accessed 20 June 2012).

Royal Society, 2009. Geoengineering the Climate: Science, Governance and Uncertainty. The Royal Society, London. Available at http://royalsociety.org/policy/publications/2009/geoengineering-climate/ (accessed 20 June 2012).

Sarewitz, D. (2010) Curing climate backlash, *Nature*, 464, 28.

Sciencewise–ERC, 2010. The Government's Approach to Public Dialogue on Science and Technology. Available at http://www.sciencewise-erc.org.uk/cms/assets/Uploads/Project-files/Sciencewise-ERC-Guiding-Principles.pdf. (accessed 20 June 2012).

Selin, C. 2011. Negotiating plausibility: intervening in the future of nanotechnology. Science and Engineering Ethics 17 (4), 723–737.

Spence, A., Venables, D., Pidgeon, N., Poortinga, W., Demski, C. 2010. Public perceptions of climate change and energy futures in Britain: summary findings of a survey conducted in January-March 2010. Technical Report, Understanding Risk Working Paper 10-01. Cardiff University School of Psychology, Cardiff. Available at http://psych.cf.ac.uk/understandingrisk/docs/final_report.pdf (accessed 20 June 2012).

SRMGI, 2011. Solar Radiation Management: The Governance of Research. The Royal Society/ EDF/ TWAS, London. Available at http://www.srmgi.org/files/2012/01/DES2391_SRMGI-report_web_11112.pdf (accessed 20 June 2012).

Stilgoe, J. 2011. A question of intent. Nature Climate Change 1, 325–326.

Stirling, A. 2008. "Opening up" and "closing down"—power, participation, and pluralism in the social appraisal of technology. Science, Technology & Human Values 33, 262–294.

Svoboda, T., Keller, K., Goes, M., Tuana, N. 2011. Sulfate aerosol engineering: the question of justice. Public Affairs Quarterly 25 (3), 175-180.

United States Government Accountability Office Technical Report, 2011. Climate Engineering: Technical Status, Future Directions, and Potential Responses. GAO-11-71. Washington DC. Available at http://www.gao.gov/assets/330/322208.pdf (accessed 20 June 2012).

Vaughan, N., Lenton, T. 2011. A review of climate geoengineering proposals. Climatic Change 109 (3–4), 791–825.

Virgoe, J. 2009. International governance of a possible geoengineering intervention to combat climate change. Climatic Change 95 (1), 103-119.

Wilsdon, J., Willis, R. 2004. See-through Science: Why Public Engagement Needs to Move Upstream. Demos, London. Available at http://www.demos.co.uk/publications/paddlingupstream (accessed 20 June 2012).

Wynne, B. 2006. Public engagement as a means of restoring public trust in science – hitting the notes, but missing the music? Community Genetics 9, 211–220.