Public Engagement in the Climate Geoengineering Governance project[1]

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Introduction: Climate Engineering and Public Engagement

Insufficient efforts to mitigate global warming have given rise to an alternative set of proposals involving large–scale technological interventions in the Earth's climate system. Broadly, these climate engineering (or geoengineering) options comprise carbon climate engineering, which focuses on removing carbon dioxide from the atmosphere, and solar climate engineering, which consists of proposals to reflect sunlight away from the Earth (Royal Society, 2009). In order to test the technical viability of these ideas, scientists and engineers have begun to carry out climate engineering experiments, many involving familiar technologies (e.g. the production of pyrolyzed biomass and its application to soils, also known as 'biochar') and/or non–invasive scales of research (e.g. computational modelling). Yet, other experiments have been both unfamiliar and invasive, quickly attracting public concern and controversy.

One prominent example is the Stratospheric Particle Injection for Climate Engineering project (SPICE), a testbed for the solar climate engineering proposal known as stratospheric aerosol injection. The experiment consisted in the injection of water into the troposphere via a pipe and tethered balloon. It was launched in 2010 and cancelled in 2012 amidst concerns about conflicts of interest in technology patenting and a lack of proper governance mechanisms (Cressey, 2012). Other recent controversial experiments in climate engineering have involved the addition iron sulphate to the ocean's surface in order to stimulate the growth of phytoplankton (Strong *et al.*, 2009). When one hundred tonnes of iron sulphate were released into the North Pacific Ocean near Canada's Haida Gwaii archipelago, for instance, local islanders complained about having been misled as to the purpose of the

[1] This is an initial report of the deliberative workshops conducted under the remit of the CGG project.

release, and raised questions about adverse ecosystem impacts (Lukacs, 2012; Tollefson, 2012).

These controversies reflect public concerns that have been recorded in other emerging domains of science and technology governance, namely proponents' *purposes* and motivations, *trust* in those undertaking the research, public *inclusion* in decision making, the *speed* and *direction* of innovation, and *ethical* judgements of social benefit (Macnaghten & Chilvers, 2014). These concerns join a multitude of imperatives for public participation in such issues, including normative, substantive and instrumental rationales (Fiorino, 1990), responses to highly complex and uncertain 'post–normal' science (Funtowicz & Ravetz, 1993), indeterminacy and contingent social commitments (Wynne, 1992), and incertitude and ambiguity (Stirling *et al.*, 2007). Taken together, such concerns and imperatives intensify the need for public debate and demonstrate the need for new, 'responsible' forms of science governance that are *anticipatory* of impacts, *reflexive* of assumptions, *inclusive* of framings and *responsive* to changing societal values and conditions (Owen *et al.*, 2013).

Whilst not always espousing the sorts of open and broad deliberation demanded by ambitions for responsible research and innovation, early public engagements with climate engineering have begun to reveal public views on this field of technoscientific practice. Whilst awareness of climate engineering has been shown to be low amongst publics, high levels of public support for the technology have nonetheless been elicited (NERC, 2010; Spence *et al.*, 2010; GAO, 2011; Pidgeon *et al.*, 2012, 2014). Beneath these headline findings, however, important differences exist – attitudes towards carbon climate engineering proposals, for instance, appear consistently more favourable than those towards their solar counterparts (NERC, 2010; Spence *et al.*, 2010; GAO, 2011; Bostrom *et al.*, 2012; Bellamy *et al.*, 2014; Wright *et al.*, 2014). Whilst attitudes towards enhanced weathering and ocean iron fertilisation have been shown to be very negative (NERC, 2010; Royal Society, 2009), large-scale afforestation, biochar, and indeed air capture and storage have all been viewed reasonably favourably, with many studies suggesting that such appeal is linked in part to these technologies' perceived compatibility with conventional climate change mitigation (NERC, 2010; GAO, 2011; Bellamy *et al.*, 2014).[2]

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[2] Indeed, it would seem that fears over a moral hazard may be misplaced, with even solar climate engineering proposals being seen as likely to galvanise rather than harm mitigation efforts (Royal Society, 2009; NERC, 2010; Kahan *et al.*, 2012; cf. Corner & Pidgeon, 2014).

In the realm of solar climate engineering proposals, stratospheric aerosol injection has received the most attention overall, largely due to its rising hegemony in climate engineering discourses (Bellamy *et al.*, 2012). Despite its favourable performance in technical assessments (Keith & Dowlatabadi, 2002; Keith, 2000; Levi, 2008; Bickel & Lane, 2009; Izrael *et al.*, 2009; Lenton & Vaughan, 2009; Royal Society, 2009; Fox & Chapman, 2011), public attitudes towards this proposal have been mostly negative (Royal Society, 2009; NERC, 2010; Parkhill & Pidgeon, 2011; Bostrom *et al.*, 2012; Macnaghten & Szerszynski, 2013; Pidgeon *et al.*, 2013; Bellamy *et al.*, 2014; Merk *et al.*, 2014; Wright *et al.*, 2014; cf. Mercer *et al.*, 2011). Otherwise, cloud albedo enhancement has received the most favourable reception of any of the solar climate engineering proposals (NERC, 2010), or is at least likely to receive the most muted reception in future due to its indistinctive concept image (Wright *et al.*, 2014).

Despite concerns however, publics have shown receptivity towards research under certain conditions (Parkhill & Pidgeon, 2011; Macnaghten & Szerszynski, 2013; Pidgeon *et al.*, 2013; Merk *et al.*, 2014), echoing the conditionality of attitudes towards nuclear energy (Bickerstaff *et al.*, 2008). Public engagement for the SPICE project testbed for instance suggested that the development of international governance and regulatory structures begin immediately, that Research Council strategies for funding research be made transparent, and that broad communication of results be made essential (Parkhill & Pidgeon, 2011; Pidgeon *et al.*, 2013). Public engagement with stratospheric aerosol injection more generally has stressed a requirement for confidence on five fronts: in climate science as a reliable guide to policy; in the ability of research to predict side effects (see also Merk *et al.*, 2014); in the ability of research to demonstrate efficacy; in effective governance; and in the capacity of democracy to accommodate the proposed technology (Macnaghten & Szerszynski, 2013). The likelihood of all five of these conditions being met, however, is seen by some as highly improbable (Szerszynski *et al.*, 2013).

Collectively, such conditions amount to calls for the general governance of stratospheric aerosol injection. Those few public engagements that have engaged with the governance requirements of climate engineering more broadly include the *Experiment Earth* public dialogue, which identified as particularly crucial questions about how climate engineering should be done and how it could be regulated fairly, as well as about different proposals' controllability, reversibility, and costs and benefits (NERC, 2010). More recently, an integrated expert–public Deliberative Mapping process has elicited more than 80 criteria (encompassing efficacy, environment, feasibility, economics, safety, politics, society, ethics and co–benefits) with which to appraise and govern different climate engineering proposals in context with alternative options for tackling climate change (Bellamy *et al.*, 2013; Bellamy *et al.*, 2014).

Public engagement efforts have thus begun to explore the perceptions of climate engineering proposals that will help determine their acceptability. The concerns raised ultimately point to the need for climate engineering to be governed *responsibly*. Yet very few engagements have considered climate engineering governance, and none at all have considered what such governance could or should look like in its architecture. In this article we therefore seek to address this gap by presenting the findings of the first engagement exercise to explicitly examine public views on climate engineering governance. We begin by outlining our own novel public engagement methodology, before then presenting the findings of our engagement exercise in two parts: (1) public perceptions of climate engineering; and (2) public preferences for climate engineering governance. The article finally concludes by discussing our findings in the light of other research and by making recommendations for future research and policy.

CGG Public Engagement Workshop: Methods

In September 2014 a one–day deliberative workshop was conducted in Norwich (UK). In order to recruit participants, a 'topic blind' online survey on 'global environmental issues' was administered via Norfolk's 'Your Voice' membership scheme. Twenty–one diverse participants were recruited into three discussion groups, and each participant received an honorarium for their full participation in the workshop. The workshop itself was facilitated by the authors and was composed of several phases. First of all, participants were given sequential presentations in plenary on: (1) the causes and risks of anthropogenic climate change; (2) options for tackling climate change at the level of mitigation, adaptation and geoengineering; and (3) four specific climate engineering proposals selected for their policy relevance and representation of the methodological diversity that exists amongst the disparate ideas:

- *Air capture and storage* involves researching technology to capture carbon dioxide from the atmosphere and storing it underground.

- *Ocean iron fertilisation* involves researching the addition of iron nutrient into the ocean to encourage algal growth, to absorb more carbon dioxide and store it in the ocean.
- *Marine cloud brightening* involves researching technology to make clouds brighter to reflect some sunlight back into space.
- *Stratospheric aerosol injection* involves researching launching sulphate particles into the atmosphere to reflect some sunlight back into space.

Participants were then organised into their predetermined groups and invited to explore, over the course of ninety minutes, their initial perceptions of the climate engineering proposals under consideration. Following exploration of these initial perceptions, participants reconvened in plenary to be given one further presentation on four idealised governance models for climate engineering research and development, selected for their prominence in climate engineering discourses (Bellamy, 2014b). These idealised governance models were:

- *Self–regulation* of research should be permitted within existing governance regimes.
- An *independent body* should be established to review and approve research plans.
- An *international agreement* should be made to regulate research.
- An *international moratorium* should be enacted to ban research.

Participants were then reconvened into their predetermined groups for a further ninety minutes, and tasked with reaching a decision on how to govern research into the four climate engineering proposals. Participants were encouraged to think about their decision by way of adopting one of the idealised governance models, adopting several in combination, or developing something completely different. In particular, facilitators explored why and how such models might work in practice for different levels of experimentation: computer simulations, laboratory experiments, small–, medium– and large–scale outdoor experiments, as well as inadvertent experiments in Earth system science that may have implications for climate engineering. At the end of the workshop, each group presented their findings to the other groups as part of a discussion in plenary.

Analysis 1: Public Perceptions of Geoengineering

Each of the three discussion groups drew upon various **analogies** to contextualise their understandings of, and reactions to, the four climate geoengineering proposals under consideration. This was most prevalent for air capture and storage, where aspects of the technology proposal were compared with the long-standing controversies surrounding the aesthetics of onshore wind energy, the risks of radioactive waste disposal, and – more recently - the risks of hydraulic fracturing, or 'fracking'. Ocean iron fertilisation was compared with land-based agricultural fertiliser, whilst stratospheric aerosol injection was compared with natural volcanic eruptions. Local context played an important role in the formulation of these perceptions too, with the controversies surrounding a nearby waste incinerator project used to question whether there might be safer alternatives to climate geoengineering proposals.

> 'It's going to be the NIMBY [not in my back yard] scenario because if you can't see it there's not going to be any complaints… But… you put anything up, like a windmill, there's going to be somebody complaining about it' (Participant 5, Group 1, referring to air capture and storage)

> 'You can look at what fertiliser's done to the ground can't you, in a lot of places, the consequences of that' (Participant 3, Group 3, referring to ocean iron fertilisation)

> 'That was the thing about the incinerator really… There was much better technology, so irrespective of the argument about [where it should go], there was much better technology and we didn't need the incinerator at all' (Participant 2, Group 3)

The perceived **costs and risks** posed by the different geoengineering proposals formed a major technical focus in each of the discussion groups. The economic viability of the proposals was particularly prominent in this respect, with air capture and storage and marine cloud brightening viewed as relatively expensive, and ocean iron fertilisation and stratospheric aerosol injection seen as relatively cheap. Possible risks and harmful side effects were also identified though, with numerous threats to the marine environment identified with respect to ocean iron fertilisation, and various disruptions to meteorological patterns with respect to marine cloud brightening and stratospheric aerosol injection. The generation of waste products by geoengineering was a concern raised with particular reference to the long-term 'storage' component of air capture and storage. Finding secondary uses for such waste products was seen as an important goal for both Groups 1 and 2.

> ‘There’s been at least one case where an entrepreneur decided that something had to be done about climate change, so ocean fertilisation was the easiest option to take this line on because it’s cheap and the materials are not very expensive’ (Participant 1, Group 3)

> ‘It seems like that would disturb the weather systems and create the problems that global warming is causing anyway, like floods’ (Participant 1, Group 1, referring to marine cloud brightening)

> ‘There’s no end product that can be practically used. Most things are based on something where the end product that can be used or sold or for some other reason, and to my mind this isn’t’ (Participant 5, Group 2, referring to air capture and storage)

Issues of scale were prevalent in discussions surrounding *all* of the geoengineering proposals. Proposals that could operate locally (namely air capture and storage), for example, were seen as less problematic than those with transboundary impacts. The need for global level effectiveness was important to Group 2, but this raised questions about whether the challenging requirements for scaling geoengineering activities could be met. Their practicality was thus disputed, most clearly in relation to the delivery of sulphate particles to the atmosphere in the case of stratospheric aerosol injection. Without geoengineering research activity of a meaningful scale then, further questions were also raised about the ability to measure the proposals’ effectiveness. Moreover, even if a meaningful scale *could* be attained, research would then become synonymous with deployment itself. Given the risks of deployment, for Group 1 the concept of a ‘cloned Earth’ gained appeal for remotely and safely conducting full-scale geoengineering research.

> ‘Of these four options [air capture and storage] is the one which is most likely to be realised within our lifetimes because the others involve, say global impacts, they’re not local’ (Participant 2, Group 3)

> ‘A bit of a finger in the air really, because how are you going to measure? We’d never be able to measure the effectiveness of this. Only if you did it on an industrial scale’ (Participant 5, Group 2)

> ‘We [could] try everything out on a cloned earth and, selfishly, it doesn’t impact on us’ (Participant 2, Group 1)

An overarching theme running throughout the dialogues was that by embarking on geoengineering projects, humanity would be taking a great leap **‘into the unknown’**. Uncertainties about the efficacies or risks, or even outright ignorance, of how geoengineering proposals might play out in reality dominated this theme. Indeed, for Group 1, all of the proposals were considered to be 'science fiction' in one form or another. The idea that geoengineering proposals would amount to humans 'messing with nature' was an important focus, and one that has also been prevalent in other early public engagements with geoengineering. For Groups 1 and 2, the controllability and reversibility of geoengineering was a key concern. The two carbon geoengineering proposals were viewed relatively positively in these regards, whilst the two solar geoengineering proposals were seen as much less controllable and posing irreversible risks. The leap into the unknown would also be a threat to transparency through conspiracy according to Group 1, who argued that 'We wouldn't know' (Participant 2) or even, 'How do we know it's not happening now?' (Participant 6).

> 'Well short term or long term, if you do it on a big scale you could argue that actually the fish population ultimately would adapt, you could argue, but that might take an extraordinarily long time. But you just don't know. It would be a huge global risk; it would be a venture into the unknown' (Participant 2, Group 1, referring to ocean iron fertilisation)

> 'Just by looking at the four pictures, three seem feasible and that one doesn't, because that's so futuristic and it's more like *Star Wars*' (Participant 6, Group 1, referring to marine cloud brightening)

> 'At least with [air capture and storage and ocean iron fertilisation] you've got some degree of control, but the other two [marine cloud brightening and stratospheric aerosol injection, I'm afraid we haven't got any control and it's a finger in the air kind of technology, and that's no good at all' (Participant 5, Group 2)

Finally, geoengineering's **relationship to mitigation** was also an important area of dialogue amongst all three groups. All proposals were seen as 'end-of-pipe solutions', bypassing the principal causes of the problem of climate change, namely the combustion of fossil fuels. For Group 1, this meant that mitigation efforts should come first, before any attempts at geoengineering. For Group 3, however, it meant that geoengineering proposals should be pursued in tandem with mitigation activities. Here, the scale and proximity of climate change and its risks meant that geoengineering could not afford to be ignored.

> ‘It’s got to be [greenhouse gas emissions] reduction first and it’s got to be education before that, because it’s not just us in the western world, as I’ve said before, it’s the eastern world. But education costs money and so does reducing’ (Participant 5, Group 1)

> ‘We need to do both, we need to be able to clear the air and stop it from happening in the first place’ (Participant 5, Group 3)

> ‘We’ve hit the point of no return with carbon emissions and even to stand still, even if there were no more power stations or anything and we just ran the ones that we’ve got we’re still churning it out into the atmosphere. We’ve raised the carbon dioxide in the atmosphere so that it’s having an effect so we need to be doing something to start reversing it but we also need to mitigate at the same time, we need to hit it from all angles’ (Participant 7, Group 3)

Analysis 2: Public Preferences for Geoengineering Governance

In much the same way as they had done in discussions about initial perceptions of climate geoengineering, participants articulating preferences for geoengineering governance in all three groups again drew upon various **analogies** to help contextualise their inclinations. These were most often oriented around biological science analogues (including research into human and animal genetic manipulation and pharmaceutical drug development), but in some instances also touched on nuclear energy and nuclear weapons. Issues around radioactive waste disposal, for instance, were seen as particularly instructive in relation to research on air capture and storage, as was the more contemporary challenge of governing hydraulic fracturing. By contrast, the other three, more trans-boundary geoengineering proposals were often discussed within the contextual framework provided by existing international agreements governing atomic weapons testing:

> ‘Think about pharmaceutical drug research, things that people would be swallowing to live or die; that’s pretty much self-regulation, and the independent review of there would be NICE, National Institute for Clinical Excellence. So, that is your independent oversight. But they’re not checking the research; the research is happening in the pharmaceutical labs and within the laws of the land’ (Participant 4, Group 1)

> ‘One possible comparison would be international agreements governing testing of nuclear weapons, which is a form of research right, you want to know whether a nuclear weapon works... There is a fairly dense international regime governing that. Well,

governing in the sense that countries agree not to test nuclear weapons and then if a country's found testing a nuclear device then there's sanctions. Now that of course is based on the fact that you can know when someone has tested a nuclear device... and you know which country has done it... It's one thing to have an international treaty and it's a different thing to then police it or be in a position to punish those who break the rules' (Participant 1, Group 3)

'It would have to be nationally regulated. I guess if the UK wanted to do air capture there'd have to be a national policy on it a bit like the fracking' (Participant 7, Group 3)

Unlike in the earlier discussions exploring initial perceptions of geoengineering where participants considered (meaningful) research to be tantamount to deployment, in the discussions on governance preferences participants clearly sought to **differentiate scales of activity**. An ostensibly clear boundary was often drawn at the point where research 'leaves the laboratory' and 'enters the outside world', but participants disagreed within and between groups about the possible roles for self-regulation, independent review panels, international agreements or moratoria in recognising the novelties of those scales. Intriguingly, there was minimal distinction between the geoengineering proposals themselves when it came to identifying governance possibilities. Instead, a hegemonic position tended to emerge within each group. For instance, in Group 1 this meant the establishment of a general code of conduct, not even just for geoengineering research, but for all scientific research, that would see independent review panels prior to outdoor experiments, and international agreements thereafter.

'In terms of these technologies on small scale research, the planet is huge...You've got a machine sucking out a few kilograms of CO_2 out of the atmosphere, it's not going to keep me awake at night really' (Participant 4, Group 1)

'I think there are two tiers here actually. I think research is one thing. If you take pure research I don't believe in too much regulation on research; I think it inhibits what you're doing. But I think when it comes to application there should be some kind of control over that as it will affect us all. But I think as far as research goes I'm a great believer in letting research look after itself, as long as it doesn't apply to the actual finished article without regulation' (Participant 8, Group 2)

'I don't think you can pick and choose. If you're going to do research then everybody needs to be quite clear that this is the process: you've got an idea for research; that it goes to an independent review; it gets to the point at which probably you want to do

> outdoor stuff because it's not contained then; and then it goes to international. That would be my answer for all four of them to be honest' (Participant 2, Group 1)

The need for **transparency and trust** in geoengineering research was a recurring theme across the three groups. Full disclosure of the results of research was seen as vital, with participants drawing parallels with the early trialling of the antipsychotic drug, clozapine. In that case, several deaths had arisen from the non-disclosure of 'bad' results. The governance of whaling practices was also drawn upon as an example of how research itself might be framed to hide other activities, a point arguably of particular relevance to 'inadvertent' experiments in marine cloud brightening. Independent oversight and scrutiny of research was thus deemed to be essential across the three groups. For Group 1, this meant broader government, civil society and public oversight, whilst for Group 3, this was seen to be the domain of experts alone.

> 'The problem with this drug clozapine was that they hid some of the effects of it and got it out on the market because it was such a great drug. So, on the one hand you can go, well okay it was only a very small number of people who died; thousands took it, did really well; eight people died, that's terrible but it was only eight. Well, for the eight families that was horrendous' (Participant 2, Group 1)

> 'So is whaling better for having an agreement or not having an agreement?' (Participant 2, Group 3)... 'Well there's a get out clause: research' (Participant 4, Group 3)

> 'The best people to judge the efficacy of research and the value and purpose and impact of that research are people who know about things like that. So people who know about human genetics, animal genetics, who know about other aspects that are relevant and people with ethical involvement in such things. So I place a lot of faith in collective human judgement' (Participant 2, Group 3)

International cooperation was typically deemed by participants to be an idealistic, but not realistic, plan for governing geoengineering research. The proposals under discussion were at best deemed to require some form of international collaboration in order to make a real, substantial difference to tackling climate change (air capture and storage), and at worst seen as harbingers of international risks and harmful side effects (ocean iron fertilisation, marine cloud brightening and stratospheric aerosol injection). Consequently, the purported infeasibility of international cooperation was seen as a major obstacle to governance:

> ‘I think if it’s going to be outdoor it definitely needs to have international agreement because you couldn’t just go out into the ocean and do something or put something in the clouds without [that]... ’ (Participant 3, Group 3)

> ‘No ships in the middle of the ocean or hosepipes to the stratosphere or iron to the ocean or air capture; none of it is going to work without international and national involvement... Inevitably once you get to medium scale and large scale plans you’re going to need governmental involvement and controls. And I think we all want those controls put in place before people start chucking stuff into the sea or up into the atmosphere’ (Participant 6, Group 2)

> ‘When we say international agreement do we just mean sort of every country or...? Because you could be waiting a long while to get that international agreement couldn’t you, meanwhile we carry on destroying... ’ (Participant 6, Group 3)

Finally, perhaps the greatest area of contestation in discussions about the governance of geoengineering research arose in relation to the unavoidable task of **balancing autonomy with responsibility**. Imposing unnecessary or overly stringent regulations and restrictions on research was widely viewed as likely to stifle scientific creativity, and moreover as a potential incentive for ‘maverick’ scientists and entrepreneurs to proceed with their research irresponsibly, in the absence of defined norms and standards. Conversely, failing to impose sufficiently stringent regulation, or indeed failing to regulate at all, was seen as a risk in the sense that it could tacitly legitimise unconstrained action, or indeed initiate a slide down a so-called ‘slippery slope’ from research to deployment. In this last respect a particular concern was that scientists could be left unaccountable for any harmful actions:

> ‘If you’re getting potentially... somebody that’s operating outside being a bit more creative or a bit more... If you over-regulate something do you squash ideas or repress them? I’m not saying that things should be unregulated but I’m just wondering like Bill Gates with his thing, he saw some scientist that he thought had potential’ (Participant 5, Group 3)

> ‘Looking back on history we’ve allowed lots of people to self-regulate. And almost invariably that goes wrong at some point. It’s how we’ve ended up with the Police Complaints Commission, the Press Review... it doesn’t matter what it is. Because unfortunately human beings are involved and there’s always that variable. And I can’t see anything wrong with independent review. If it’s done correctly it can be a critical appraisal; it can be really helpful’ (Participant 2, Group 1)

'If you're going to say these things shouldn't be worked on without international agreement then... scientists are pretty independent people and they would not want to work in such an environment, they would just say that I'm not going to do this research because they want to do what interests them, they don't want to be doing what they're told to do by some international regulatory environment' (Participant 2, Group 3)

Conclusions

When placed in the context of wider efforts to explore public perceptions of climate engineering, the findings of this one-day workshop offer both valuable confirmatory evidence of previously identified trends, and a range of novel insights. As far as the perceptions of geoengineering technologies is concerned, the findings reinforce previous work by demonstrating a greater level of public concern and apprehension around ocean iron fertilisation, stratospheric aerosol injection and cloud brightening than around air capture and storage options. Moreover, and again in line with the findings of previous work, all three discussion groups at this workshop quickly established a broad distinction between carbon climate geoengineering and solar climate geoengineering, in which the former was seen more favourably because of their perceived closer affiliation with conventional climate change mitigation efforts (NERC, 2010; GAO, 2011; Bellamy *et al.*, 2014). Intriguingly however, theoretical arguments about the potential for a so-called 'moral hazard' to manifest, whereby conventional climate mitigation efforts would lose impetus as a direct result of directing scientific and political attention towards geoengineering, appear on the basis of this work to be ill founded. Instead, the intrinsic severity of the threats posed by climate change was deemed by almost all participants to automatically override any potential for 'trade-offs' to occur between different scientific and political approaches to solving the problem. Whether these viewpoints align with previous work in which some solar climate geoengineering solutions could even be viewed as having the potential to *galvanise* conventional climate mitigation efforts – as opposed to simply failing to diminish those efforts' urgency - is less clear, however (Royal Society, 2009; NERC, 2010; Kahan *et al.*, 2012; cf. Corner & Pidgeon, 2014).

Whilst the workshop also reiterates the importance – again identified in previous public engagement exercises around geoengineering – of being able to evaluate the costs and benefits of different technological proposals as clearly as possible (NERC, 2010), it also demonstrates that publics recognise a diverse range of indeterminacies and uncertainties as inevitably complicating efforts at straightforward cost-benefit analysis. In this sense benefits, costs and risks – whilst important considerations - form only one part of a broader constellation of political, social and ethical considerations that publics seek to appraise *in toto*. In seeking to think through some of these complex indeterminacies and uncertainties, a critical cognitive resource deployed by participants at this workshop was found in familiar analogies drawn to less abstract examples of technological controversy. The conundrums of nuclear waste disposal and the politics of local planning and siting disputes (most notably in relation to a waste incinerator), for instance, appeared especially useful "thinking devices" for assessing the intrinsic feasibility and desirability of each geoengineering proposal on its own terms.

Analogies were also deployed as cognitive devices in participants' attempts to think through questions of how geoengineering should be governed. Here, indeed, the workshop offers novel insights in providing evidence of public *doubts* about the feasibility (or even desirability) of international agreements or treaties – and not only because establishing this type of governance framework would represent a major political and logistical challenge. In drawing comparisons and contrasts with existing international agreements in the realms of nuclear weapons testing and whaling, participants identified potential issues with a putative international geoengineering research treaty relating both to *attribution* (how would authorities identify those responsible for an illegal geoengineering experiment?) and to the identification of *stealth research* (how would authorities distinguish between interventions in the earth's atmosphere-ocean-biosphere system designed explicitly to engineer the climate, and those intended to achieve alternative objectives?) These findings raise interesting questions in light of previous work, such as the deliberative public engagement exercises conducted around the SPICE project testbed, which has suggested that the development of *international* governance and regulatory structures around geoengineering should begin immediately (Parkhill & Pidgeon, 2011; Pidgeon *et al.*, 2013).

In light of scepticism about an international geoengineering research agreement or treaty, discussions at this workshop centred more substantially on questions of how to draw the line between scientific autonomy and scientific responsibility. Once again, analogies played a critical role as thinking devices, with references to an historical lack of transparency in pharmaceutical drugs testing used, for instance, used to build a case for independent review panels as the 'default option' if outdoor geoengineering experiments were under consideration. In light of previous public engagement work, these findings arguably have significant implications on three fronts. To begin with, they of course add further weight to evidence provided by previous engagement work around geoengineering, which clearly indicates that publics regard scientific transparency and openness as a *sine qua non* of scientific legitimacy itself. Secondly however, and more intriguingly, they also appear to suggest that public attitudes of governance may hinge more critically on distinctions of research 'scale' and 'invasiveness' than they do on the specific characteristics of geoengineering technologies themselves. More specifically here, public assumptions about the intrinsic 'unknowability' of scientific research outcomes (whether positive or negative) appear to fuel a stubborn reluctance to draw any form of *a priori* distinction between the governance mechanisms that should be applied to research into different geoengineering technologies, or indeed, even to research carried out in the broad categories of carbon and solar climate geoengineering respectively.

Finally, and linked to the previous point, the findings also suggest that public assumptions about the nature of science itself are in some ways incommensurate with more nuanced attitudes to the nature of 'independence', at least as revealed by discussions of how independent review panels would work in practice. Specifically, whilst many participants recognised that it was not straightforward to define 'independence' in the realm of geoengineering research, or indeed to identify the circumstances under which independent review of research proposals would be required, almost all nonetheless clung on to a view of 'pure' scientific research as an unmitigated public good whose scope should not be curtailed or dictated independently unless negative outcomes were *certain*. In this last sense therefore, the workshop suggests that public attempts to delineate an appropriate 'balance', or 'trade-off', between scientific autonomy and scientific responsibility may well be constrained by discursive constructions of binary relationships, both at the 'interface' between the laboratory and the outside world, and at the interface between 'experts' and non-experts.