Understanding Risk Research Group, Cardiff University.

Public Engagement on Geoengineering Research: Preliminary Report on the SPICE Deliberative Workshops

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Contents

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1.0 Preface

In 2010 two research councils – the Engineering and Physical Sciences Research Council [EPSRC] and the Natural Environment Research Council [NERC] – published a joint call for research into geoengineering which is the deliberate and large-scale intervention in the Earth's climatic system. Their aim was "to fund research which will allow informed and intelligent assessments about the development of Geoengineering technologies" (EPSRC, 2010). A sandpit[1] event was held in spring 2010 resulting in two geoengineering projects being funded: First, of which the authors of this report are formally a part of, Integrated Assessment of Geoengineering Proposals (IAGP) and second, a separate autonomous project, Stratospheric Particle Injection for Climate Engineering (SPICE).

Headed by Professor Piers Forster (University of Leeds) IAGP consists of a consortium of partners from other UK scientific institutions including Lancaster University, University of East Anglia, Cambridge University, Cardiff University and the Hadley Centre. IAGP has three core objectives:

1) To evaluate the effectiveness and side effects of a broad range of geoengineering proposals
2) To evaluate the controllability of global climate using these proposals
3) To elicit and include stakeholder and public values into the evaluation

It is important to note that IAGP will only use computer modelling (climate and engineering) when evaluating the effectiveness of geoegineering proposals and their implications and will not use any real world testing; this is largely a desk-based and laboratory-based study. A key part of IAGP from its very inceptions was the undertaking of public dialogue on geoengineering in the form of upstream public deliberative workshops. This has two aims: in the first instance IAGP wish to explore public perceptions of geonengineering proposals and their dangers; secondly, during the latter part of the project the public will contribute to the criteria and metrics formed to evaluate geogengineering proposals.

The second project, SPICE led by Dr Mathew Watson (Bristol University), involves a consortium of researchers based at partner scientific institutions including Cambridge University, Oxford University and the Hadley Centre. SPICE seeks to investigate the potential means, efficacy, impacts and modes of delivery of a particular form of solar radiation management - stratospheric particles. The basic hypothesis is that stratospheric particles can be injected via a 20km pipe held up by a balloon. In the main, as with IAGP, the majority of the work SPICE will undertake is laboratory-based and computer modelling (including engineering and climatic). However, there is one work package where the researchers wish to scale-down the 20km pipe and balloon to a 1km test-bed which aims to explore the engineering challenges of using this mechanism and the accuracy/efficacy of using computer models to predict the pipe and balloon movement. This test would not involve any real world testing of the cooling properties of stratospheric particles and would likely only consist of pumping fresh water, with the majority of the test-bed time and resources being used to test the engineering aspects of the pipe, in particular balloon/pipe deployment and recall.

As part of EPSRC's commitment to responsible innovation and on the recommendation of peer reviewers, funding for the 1km test-bed was held back, as part of a stagegate process, until the principal investigator could collate materials and evidence which could be evaluated by a panel who would then make a recommendation to

[1] A sandpit is an intensive, interactive prolonged workshop (in this case lasting 5 days) where a diverse group of participants from a range of disciplines and backgrounds get together in order to construct innovative research proposals. These proposals go through a full concentrated peer review process, with funding decisions made at the end of the event.

EPSRC/NERC with regards to releasing the funds and allowing the 1km test-bed to go ahead or not. This panel had a wide range of skills and was chaired by one member from the EPSRC's Societal Issues Panel. As part of the evidence to be evaluated, IAGP were asked by EPSRC to complete public deliberative work specifically focused on the SPICE project (after due consideration was given to societal responses to climate change and geoengineering more broadly – see section 3.0 Methodology). Accordingly, IAGP researchers with expertise in public deliberative engagement, led by Professor Nick Pidgeon and Dr Karen Parkhill designed, carried out and are subsequently analysing this "extra" work package, the preliminary results of which this report is set to outline.

Other than the IAGP carrying out this deliberative work at EPSRC's request, as reported here, the IAGP and SPICE projects are entirely independent of one another.

2.0 Aims & Objectives of the SPICE public deliberative workshops

The SPICE public deliberative workshops aimed to explore perceptions of generic geoengineering proposals, stratospheric aerosols and in particular the SPICE 1km test-bed (hereafter 'test-bed') through completing the following four objectives[2]:

1. To give an overview of the likely varied and nuanced perspectives of the members of the general public and report to the EPSRC Societal Issues Panel (SIP).
2. To provide one piece of evidence that SIP might deem useful when completing their stagegate evaluation.
3. To explore, without guarding against future public or media contestation regarding either the development of geoengineering techniques (individual and holistically) or specific investment into research of the SPICE techniques, possible public concerns, questions, and conditions regarding SPICE and geoengineering more generically which may ignite said controversies[3].
4. To map the range of perspectives and framings each participant themselves brings to bear on geoengineering in general, and as part of this to the stratospheric aerosols and the SPICE Assembly development in particular, when this is introduced to them in a structured way.

3.0 Methodology

3.1 Design

3.1.1 Sampling

Three deliberative workshops were completed in three cities (Cardiff, Norwich and Nottingham) each with 8-12 participants (total n=32). Gender, age, socio-economic status, educational level, ethnicity and location, were contributors to our theoretically informed sampling strategy. The sampling frame was designed to capture a diverse range of viewpoints. Main workshops were preceded by two pilots held in Cardiff. Crucially recruitment was 'topic blind', with geoengineering not mentioned during the recruitment process; instead participants were recruited to take part in discussions related to 'societal responses to climate change'. Participants were recruited through a professional recruitment agency.

3.1.2 Format

The workshops were reconvened over 1.5 days with participants completing a "homework" task in between the two sessions. The reconvened element reflected both practical (i.e. activities/discussions needed to extend beyond one day) and deliberative considerations (participants were able to reflect upon and explore their viewpoints, and those of others, overnight). The workshops were designed guided by recent examples of good practice for 'upstream citizen engagement' (see for example, Pidgeon et al., 2008; Davies et al., 2009; Fynn et al., 2009) but with awareness also of recent methodological and conceptual discussions of the approach (Wynne, 2007; Felt and Fochler, 2010).

All workshops were facilitated by the Cardiff University Integrated Assessment of Geoengineering Proposals (IAGP) team (Parkhill & Pidgeon). Also in attendance on both days in all locations was Dr Naomi Vaughan also from the IAGP team and the UEA Tyndall Centre, to answer technical questions related to climate change and geoengineering. A representative from the SPICE project, Dr Kirsty Kuo was in attendance on the reconvened (Day 2) session only, at all locations, to answer participants' questions related to the test-bed, the SPICE project

[2] See section 3.1 for caveats to this report.

[3] However, it should be noted that such controversies are always driven by a combination of factors, including but not confined to public concerns. NGO activities and campaigns, particular media news cycles, events which push an issue onto the policy and media agenda (cf. the UEA-CRU climate e-mails saga) are much more likely to drive adverse comment.

and stratospheric aerosols more generally. The workshops combined a mixture of presentations from the facilitators and experts, whole group discussions, world café style small group discussions and individual written responses. Appendix 1 depicts the format and individual tasks in more detail.

All of the workshops were, with all participants consent, digitally audio and video recorded – including all of the small group sessions. Audio recordings were then transcribed by a professional transcription company. Once transcribed, every transcript was rigorously checked for errors either in attribution and/or misquoting against the video files by a member of our research team, to ensure the highest transcript quality possible. During this process, all transcripts were anonymised with original names of participants being replaced with pseudonyms.

3.1.3 Materials & Framings

Most materials used (including world café materials, presentations and discussion prompts) were externally reviewed by climate science/geoengineering expert Dr Naomi Vaughan, public dialogue expert Pippa Hyam (Director of Dialogue By Design), plus a number of IAGP Advisory Panel members (including Tim Krueger Oxford University, Duncan McLaren Friend of the Earth Scotland, Catherine Redgewell UCL, and Richard Owen Exeter University).

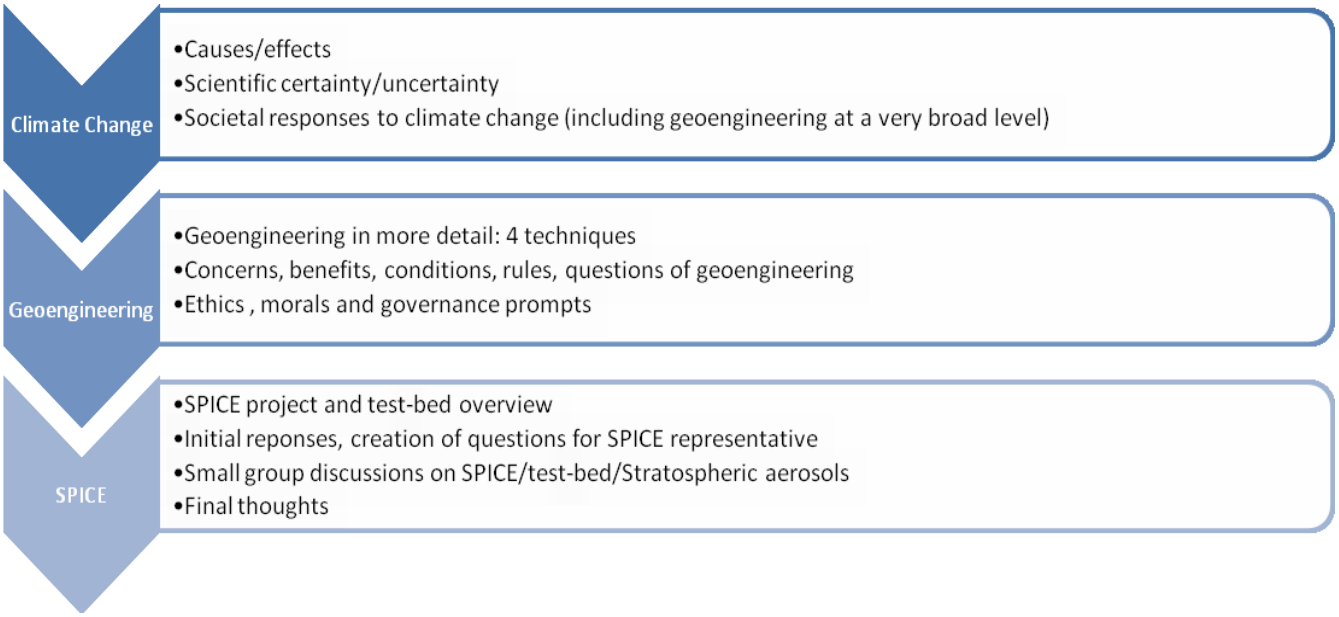
To ensure information was accessible as possible to all (and following reflections made during the piloting) technical terms were wherever possible avoided or combined with more lay discourses. For example, mitigation became 'reduction' (reducing carbon emissions/our carbon footprint), geoengineering was used alongside 'techniques for climate control', solar radiation management techniques were referred to as 'Reflective Approaches' (hereafter 'RA') and Carbon Dioxide Removal was adapted to 'Carbon Removal' (hereafter 'CR').

Before discussing the SPICE project (which did not occur until day 2), and specifically the test-bed, participants were navigated through several stages which funnelled down from climate change to specific geoengineering approaches (see diagram below). Geoengineering was situated as one of three possible societal responses to climate change. Whilst climate change was emphasised as requiring urgent action, geoengineering as an 'emergency' response or 'emergency stop button' framings were **NOT** used. Other framings avoided throughout the workshops (as a result of our analysis of issues arising with the IPSOS/NERC 'Experiment Earth' methodology) were 'naturalness' or 'mimicking natural processes', and 'carbon removal as dealing with the cause of climate change'. If such responses/issues emerged spontaneously from the participants, as they at times did, these were explored and reflected upon, but the researchers themselves avoided introducing them in the first instance. Estimates of costs of different approaches were also not presented: we stressed throughout that, due to the uncertainties surrounding costs and unintended impacts, nobody could currently answer this question properly and with any confidence.

The key framing we used was that geoengineering may be one possible response to climate change (with the latter also presented as a risk issue, rather than a debate about whether global warming was 'real' or not). Although we have yet to complete a full analysis, it is our contention that (dis)belief in climate change does not necessarily dictate levels of engagement with or nuanced stances on geoengineering. Instead, there may be other more critical dimensions underpinning perceptions which will be born out through the analysis.

A second important framing involved exploring concerns and conditions. Whilst potential benefits of geoengineering were indeed explored and oftentimes expressed (e.g. aiding slowing down or reversing climate change, being at the forefront of cutting edge science/research, leading by example), discussion tended to gravitate more towards controversy, concerns, disadvantages, risks and uncertainties etc.

As noted above, avoiding framings of naturalness and emergency response to climate change were an important methodological concern for us, particularly given the importance placed on the former as a finding from Experiment Earth (easy to say in hindsight, but for all its strengths, we suspect that the EE facilitators introduced this framing repeatedly and which may have amplified its occurrences). We found that even the hint of naturalness was a powerful discourse capable of legitimising or problematising the more radical aspects of geoengineering. Equally, emergency response framings would place participants in a disempowered position if they still dissent and wish to refrain from investigating geoengineering, and were again avoided.



To avoid participants becoming preoccupied with the specifics of geoengineering techniques, or completing an evaluation of the technology per se, particular approaches to geoengineering were left until participants had been given opportunity to discuss the broad notion of geoengineering and potential wider issues arising (governance, ethical questions, generic comparisons with mitigation and adaptation etc.). When specific techniques were introduced during a presentation, four were discussed (Appendix 2 depicts the slides used by Dr Naomi Vaughan). Biochar and air capture were used for CR, whilst stratospheric aerosols and cloud whitening were used for RA. These were selected to give a snapshot of the range of most plausible geoengineering approaches and were repeatedly described as being just that. Following advice from the IAGP Advisory Panel after the piloting, and to provide further context for the discussion of SPICE (given the framing shift from discussing generic to specific technology on day 2; cf Felt and Fochler, 2010), we gave an example of research currently taking place for each of the 4 techniques of geoengineering covered at the end of day one, whilst once again emphasising that we were only providing examples and not an exhaustive list. At this stage on day 1 (immediately before world café 2) , whilst the SPICE project was not mentioned by name, the underlying idea of using a 20km pipe and balloon was the research example used for stratospheric aerosols (see Appendix 2, slide 11). The Calgary work on air capture devices was, by contrast, the example used for direct CR, etc. Images were used carefully, with artists renderings clearly labelled as such. In day 2, when introducing the SPICE project and test-bed explicitly, we once again emphasised that this was one research project amongst several, and amongst many more geoengineering ideas being considered internationally. Attention was specifically drawn back to the previous day's overview of other research projects within other geoengineering techniques.

We should also emphasise that we recognise the importance of treading a fine line between providing enough information to facilitate deliberation without unduly influencing participants. In addition, we were very

sensitive to participants' own constructions which we explored exhaustively through the extensive use of such facilitator prompts as "what makes you say that?", "could you say a little of why you are interested in knowing that?". As such, our public(s) were active participants in the workshops and deliberative processes, capable of and encouraged to engage critically with all of the information and also to develop their own framings in an open and reflexive way.

4.0 Findings

4.1 Foreword

The workshops have generated an extensive dataset, particularly due to the number of parallel small group sessions held within each one. Accordingly, to meet the constraints of the SPICE stagegate deadline, we have had to restrict our analysis to those exercises completed by the public which pertain to the aims in section 1 which specifically relate to the SPICE project, the SPICE test-bed and (where this was salient) to the wider issue of stratospheric aerosols. A more comprehensive analysis which will examine in more detail perspectives on the test-bed in the context of geoengineering framings more generally, will be completed by the end of 2011.

The exercise from which the majority of this analysis (3.2.2 – 2.2.6) is formed was designed to, in the main, focus on public perceptions of the 1km test-bed. However, although it became clear that discourses of stratospheric aerosols and the test-bed can (and often do) inhabit different discursive spaces, with negative perceptions of stratospheric aerosols not necessarily inhibiting/curtailing support or acceptance of the test-bed, it is also clear that these are not wholly separate spaces, with linkages and slippage occurring for example where questions regarding the test-bed morphed into queries and concerns about full-scale deployment. Accordingly, although not the principal focus of this analysis, we have opted to include the questions, concerns and thoughts regarding full-scale deployment as they serve as a useful qualifier and context for the test-bed, revealing some of the conditions participants may place on longer-term future generic research into stratospheric aerosols.

It is also worth noting that the participants generated a wide variety of questions ranging from the more mundane practicalities of the test-bed (e.g. how big will the balloon be?) through to questioning the philosophical basis for even attempting such research. In our analysis we have included all of the different questions raised by participants in the figures below. Yet in our discussion of the data, we have opted to focus on probing the reasons for questions and nuances of concerns which one may typically not have expected, rather than those which focus on the more obvious or banal.

4.2 Analysis by themes

4.2.1 Perceptions of Stratospheric Aerosols Overview

This section will summarise public perceptions and discussions which took place around stratospheric aerosols and reflective approaches more broadly. This section is based on discussions held before the SPICE project and test-bed were fully introduced. Experiment Earth (2010) found that in general there was less public support for RA than CR, with participants finding it harder to understand the aims of RA and that such techniques are unable to deal with the "extra" carbon produced. Although we presented fewer technologies, our findings are not dissimilar from Experiment Earth. We concur that participants are more supportive of CR approaches over RA, with stratospheric aerosols in particular finding less traction. However, we differ slightly in that our participants were not perplexed over the aims of RA, rather they were frustrated, disappointed and concerned that all they would be able to do is provide a "stop gap" (Frank, Norwich):

> My first concern is that it is a short-term – you get a quick fix but it would have to be a very, very long term commitment. 'Cause once you start you have to maintain it.
> ...
> Because you're not actually changing the conditions that created it. All you're doing is controlling the temperature (Riley, Norwich).

For some the basis of malcontent with not only stratospheric aerosols or indeed geoengineering in general was the distinct possibility of being diverted away from more conventional forms of mitigation (viz the 'moral hazard'), and that we would be circumventing dealing with the actual problem i.e. our lifestyles:

> The only thing is when you put in the money it would take to set up those schemes to get that short-term gain, that could be money going into actually solving the problem, I think that's where the issue is. That's why it feels like it's cheating as I said (Laurel, Norwich).

> I said in that group in there, I said 'They're concentrating on too much stuff like this to try and get rid of it, rather than stop people using so much' (Rhobert, Cardiff).

> …I'm not trying to debate with anybody, but I feel as though if we know where we're going wrong then let's slow that down, that process down rather than doing all these other things that are wrong, because they've got to have consequences (Margie, Nottingham).

Perceived naturalness of a technique was a powerful stimulus for engendering support (Experiment Earth, 2010) with biochar in particular being perceived as such. By contrast stratospheric aerosols were deemed "Space, space, George Lucas made" (Frank, Norwich), unnatural and interfering with natural processes:

> …But in the circumstances of pumping something up into an area that we don't know anything about, it is extremely unnatural and I just think…On a personal level that kind of scares me to think what effect that could have overall (Victoria, Nottingham).

Perhaps more striking is that some techniques such as biochar were not just seen as more natural or more feasible, they were seen as (in comparison to stratospheric aerosols and RA in general) nurturing nature-society relations, or at the very least in keeping with them. In contrast, stratospheric aerosols were depicted by some as enhancing the disassociation of humankind from physical world interactions, through an increasingly technocentric society:

> Wilma: …So my point being…the more technology we get, I feel the further back we'll go…
> …
> Bert: The further away from touch and reality you are, I mean, I couldn't make a computer and no one in this room could ever make a computer.
> Facilitator: Yeah.
> Clarence: It has gone beyond a hammer and a screwdriver to fix things, and the fact is that's the world over. 'Cause we are totally dependent on technology. (Nottingham).

This disassociation also led to greater doubt over the efficacy of the method due to the perceived lack of precedent. Even when discussions relating to volcanic eruptions occurred, participants still seemed to judge the introduction of synthetic chemicals as being distinct from rather than an extension of the scientific logic. Greater uncertainties and global risks were also deemed likelier as a result, with participants questioning how it would be managed, controlled, reversed (if necessary) or indeed even if its (in) efficacy could be judged given the complicated interrelated systems involved. This also led to expressed concerns over how responsibility/culpability could be determined:

> …it's going to be over the whole of the planet so the risks are global (Barbara, Norwich).

> Putting something that's in the air, it's not like you can run around and pick it off the ground, it's so much harder to track or capture or to take back out, and that's the problem, once it's done, the horse has gone out the stable door (Laurel, Norwich).

Ethics and governance issues were seen as both more salient and problematic for stratospheric aerosols, with the ethical commentary of scholars (e.g. Corner and Pidgeon, 2010; also see Royal Society, 2009; Gardiner, 2011) resonating throughout their discourses. Most participants felt that it was an imperative to develop an international governance structure capable of seeking consensus for developing and deploying stratospheric aerosols, as well as determining codes of conduct for their ethical and responsible use. However, that such consensus could be found was also in doubt:

> It's a concern because when they've had these climate change seminars [e.g. Kyoto] and groups, nobody ever agrees and what guarantee would we have that everybody would actually agree over something like this? (Barbara, Norwich).

In addition, many participants could envision how RA and in particular stratospheric aerosols could cause conflict particularly if the negative impacts were geographically disparate from those territories deploying the technologies. Indeed, some participants observed that there would be governments perhaps willing to continue deploying the technology even if negative impacts were observed elsewhere. Concern over such behaviours further underlined the need for a governance structure, whilst at the same time emphasising the challenges of developing a coherent set of structures capable of ensuring equity.

Although just a brief overview of some of the discourses surrounding stratospheric aerosols, it is apparent that participants foresaw significant challenges and barriers to developing this technology. Whilst for many the scale of said challenges was enough to call into question the justification for even attempting to develop these methods further. However this was not the case for all participants. For some participants, there was inherent value and reassurance in scientists and researchers investigating all potential avenues. To such participants, this was not just about developing stratospheric aerosols (or reflective and geoengineering approaches more widely), it was also about ensuring there are spaces for innovation and ingenuity, which could in turn stimulate development in adjacent or parallel spheres to aid resolving the issue of climate change:

> Riley: …it takes quirky scientific brains occasionally to come up with some very ingenious solutions to problems that nobody else has ever thought about. And if you switched them off you're going to –
> William: Well that's very true, so the less money you give them the more chance they are of coming up with some, does that work harder.
> Riley: I'm not saying that, I'm just saying that there may be benefits to be gained from pursuing research alternatives to just reducing or just adaptation, or just splitting it that way. We have to continue to look at all the diverse methods that we might have.
> …
> Laurel: …The research is good 'cause it can be, you may find stuff in there that you can use for other aspects of future energy use and resources –
> William: So yes, stumble across something.
> Laurel: But I wouldn't say pouring a load of money in that that now…it's gonna tip the balance of things that need to be reduced. (Norwich).

Such participants were willing to support research into geoengineering, when it is carefully monitored and occurs in incremental stages, allowing reflexivity.

3.2.2 Methodology and Justification

How will the site be chosen?
Who would decide the site & criteria?
Why not do it in a more isolated place e.g. Antarctica more socially acceptable?
Would there be an independent overseer?
How can we trust who is doing it?
How will the test-bed be powered? Will it add CO2?
Will it cause pollution?
Where will the test-bed occur?
How much will the test-bed cost & who will pay?
How will you get the balloon up there?
How will the balloon stay up?
How will the balloon/pipe be controlled once it is up there?
How big is the balloon for the test-bed?
When will the test-bed occur?
Why fresh water and how much [why not the fluid which will be used to cool]?
How can you track the particles and what they do?
Have alternative ways of getting aerosols up there been investigated?
Where and how will it disperse?

Figure 1: Questions relating to methodology & justification[4]

Given our participants significant reservations regarding pursuing stratospheric aerosols, it is perhaps not surprising that they engaged critically with all aspects of the research process underpinning the test-bed. Importantly, questions were not only related to the more mundane/logistical inquires into how the test-bed would operate, participants were also deeply interested in why researchers, funders and so forth had all opted to pursue the lines of enquiry in the ways that they have. Indeed for some participants an apparent lack of justification threatened to de-value the worth of the test-bed.

Of key interest to many participants was how the test-bed site would be chosen. It was largely assumed that a site would be chosen which would be relatively isolated. Some recognised that proximity to the test-bed could potentially cause vociferous contestation. Indeed one participant went as far as suggesting an alternative location of Antarctica, believing that the extreme isolation would perhaps make the test-bed more socially acceptable. However, whilst distance from highly populated areas was clearly desirable to many, concern was not just related to any potential human impact; the environmental impact of hosting the test-bed was also a key concern, indicating that participants would be interested in not only risk assessment exercises (see below) but also environmental impact assessments, as well as how the site would be remediated post test-bed:

> Barbara: Everyone's going to say, "Not in my back yard" for a start.
> Riley: Yes, Indeed.
> Barbara: But I suppose the other thing is, are you going to use a place that's not widely populated and if you're going to do that is it an area of outstanding beauty? How are we going to decide who's going to make that final decision about where it can be sited? Because wherever it does somebody's going to kick off (Norwich).

[4] The questions used in the figures throughout this report have been paraphrased by a researcher **at the time** the public generated them. As such, the participants agreed the wording and these were the questions put to the SPICE representative during the Q&A feedback session.

Barbara's comments would also seem to be indicative of an interest not only in the criteria used, but also the weightings which will be applied to criteria. This was a theme in other workshops, with parallel concerns regarding the trustworthiness of the research team and an interest in how even the test-bed would be regulated and assessed:

> Facilitator: Cath, how would you feel if you found out it [test-bed] was going to be close to your home?
> Cath: I wouldn't like it 'cause I don't trust anybody [laughs] so I'd be concerned. They don't tell you the truth do they really so I'd be concerned if this went wrong or that went wrong what the effects would be for the youngsters really, the next generation. So I'd rather it was in the middle of nowhere, you'd feel safer anyway.
> Gwen: So going from what Cath's just said would there be like an independent like I dunno adjudicator or invigilator to oversee proceedings? (Cardiff)

The participants also called into question the feasibility of doing both the test-bed and full-scale deployment because of the energy it would use and the carbon footprint of the method:

> Wouldn't it be quite a powerful machine anyway to get the water up there in the first place; would it be using a lot of power to do this? (Margie, Nottingham)

This suggests that participants are not only concerned with the efficacy of the method, but also desire evidence that either the test-bed or deployment in their totality (i.e. through a full lifecycle including pre and post deployment) would contribute to excess carbon being produced. The use of resources to complete the test-bed was a common theme, with not only the carbon footprint and energy budget of interest, but also the amount of water being used. The interest in water was two-fold: first participants were clearly interested in what impact this extra "rainfall" may have wherever it dispersed to (see section 3.2.3 Safety and Impacts); second, in a similar manner to energy, participants were keen to know who would be responsible for paying for the local bill and that it would be at an equivalent rate to what they themselves pay to water companies.

Whilst many participants understood and perhaps saw value in completing an engineering test at this stage, other participants questioned why this was occurring before other more (to them) crucial questions had yet to be answered. Interestingly there were two distinct pathways with the first being related to whether the desired climatic effects or indeed the undesirable and perhaps unknown knock-on negative effects may be actualised:

> Bert: I think you could well be wasting a lot of money. I don't think that this will be cheap and you're looking at a delivery system, something that you don't know whether you're actually going to use it because you don't know the effects of the actual technique. I think you've got to see whether the technique works before you can deliver it or not.
> …
> Facilitator: So your preference would be before we do this test-bed, to do more of the laboratory and computer work to find out –
> Bert: No I think that you've got to start, if you've modelled it on computer, if you're going to start putting things into the stratosphere you've got to see whether that actually works before you spend a fortune on finding a way to pump stuff up there and find out that it has got such disastrous consequences you're not going to do it or it doesn't work .
> ...
> Bert: Don't do the delivery system until you know what you're delivering will actually work (Nottingham).

The second pathway was related to questioning why this was being pursued when there remain so many weighty concerns about stratospheric aerosols:

> I think because there is so many cons to it though [stratospheric aerosols] you'd look at that maybe before you did the actual mechanics of it (Victoria, Nottingham).

For the latter some participants were perplexed as to why this was being pursued given the many cons, perhaps indicating confusion over the drivers for this particular research project. Indeed some bemoaned that it was ironic it was being pursued given their utter dislike of the technique and relative support for the other geoengineering techniques we discussed (biochar, ambient air capture and cloud whitening). Reiterating that this was only one method of geoengineering (and indeed societal response to climate change) amongst many, one research project investigating this method and that other research projects into other methods are also occurring did makes this somewhat more palatable to some participants, except for those who had substantial, immovable concerns. This would suggest, that communicating how the SPICE project fits within the geoengineering research profile of the UK, not to downplay either the innovation or advanced nature of the SPICE test-bed, would be a useful exercise – a point we will return to in the following section. Cost underpinned some of the above, with participants such as Bert (see also above) calling into question whether this was a worthwhile investment, given to them, the illogic of the order of the research testing.

A final justification desired by participants was related to the need to pursue stratospheric aerosols over and above ways of dealing with having the extra carbon in the atmosphere, including both carbon removal geoengineering techniques and more conventional forms of mitigation:

> …why are we trialling this at all in that it's only a minor reduction in temperature over a very short time, and it's not actually addressing the nature of the problem that is the excessive production of CO2. And it's never going to address that. So I would like to know from the SPICE project what they perceive as being the global gain in a very short-term reduction in temperature, that we know is not going to be sustainable over huge periods of time (Riley, Norwich).

Responses which included explaining the important potential implications of a 2 degree or greater rise in temperature above pre-industrial levels did not necessarily resolve this conundrum and instead perhaps revealed an underlying frustration:

> So in essence it's delaying the inevitable (Riley, Norwich).

Whilst focused on the rationalities of the research team, such interest would also suggest that Research Councils may wish to make explicit their strategy for funding geoengineering research and how this sits in relation to wider research into responses to climate change.

4.2.3 Safety and Impacts

Would the spray cause impacts?
Would there be any health impacts?
Would there be any environmental impacts?
Will it cause more rain?
What if the pipe comes down?
What happens if it [pipe & balloon] falls down – is this possible?
What if it [balloon] blows away?
What about aeroplanes?
What effect will the full-scale have on other countries?
Could terrorist attack/use the test-bed?
Could terrorists use/attack full-scale?
What will the balloon be filled with and what are the risks?
Will there be a risk assessment?
Would the fluid interfere with satellites?
How will affect wavelengths of light?

Figure 2: Questions on safety & impact

A generic, yet unequivocal concern of all participants was that the test-bed should be safe. Questions centred on how safety would be ensured (e.g. completing a risk assessment), how danger would be avoided (e.g. concerns about aeroplanes) and potential implications for all concerned in the event that something goes wrong. When unpacking what/whom participants meant, this included safe for humans - those operating the test-bed, those living in close proximity and those who may be impacted – and the vulnerability of the wider environment/ecosystems to potential knock-on effects.

Whilst some of the concerns can be immediately addressed by explaining the safety regulations being followed (e.g. establishing a no fly zone around the pipe) the anxieties and vulnerabilities which underpin such concerns should not be dismissed. Take for example the following quote regarding the gas used in the balloon:

> Kristine: And what would the balloon be filled with? Would it be filled with nitrogen or –
> …
> Facilitator: Again when you're asking these questions, you've probably already said the answer but what would be the concern or the thought lying behind that question?
> …
> Frank: Hindenburg.
> Kristine: Hindenburg [laughter]
> …
> Frank: Yeah, it's a bomb in the air basically, a fireball waiting to happen (Norwich).

Similar to Frank and Kristine, there were those participants who cognitively linked the test-bed (and full scale deployment) to other previous disasters such as Chernobyl. Whilst clarifying the content of the balloon could allay some of the fears, a wider lesson can be drawn from such statements, including that when it comes to the test-bed, due to the unfamiliarity of the processes involved, public(s) will draw upon previous experiences, memories and incidents. Whilst one response might be to dismiss such comparisons due to incommensurability, we should pay attention to 'furtive anxieties' (Zonabend, 1993; Parkhill et al., 2011), vulnerabilities and cautions against scientific hubris, they may hold.

There were certain aspects of the test-bed which participants felt would be extremely critical to "make safe", and in particular the host site. Participants were sympathetic to the challenge this would present with multiple "threats" needing to be guarded against including rambunctious inquisitive mischief-making children who may see infiltrating the site a challenge:

> Morgan: It should be in a safe place shouldn't it? Like out of the way of – 'cause I know if it was anywhere around near where I live all the children round me they're all like a bunch of idiots to be honest with you and they would be out there messing with it … To tell you the truth they would try climbing it or something or pulling it back down…
> Meredith: It'd have to be like a compound.
> Morgan: Yeah. They'd need security guards there 24/7. (Cardiff)

Other security threats to the test-bed site, our participants were concerned with, were deemed far less benign and ranged from co-ordinated efforts in direct action or criminal behaviours to damage the equipment by environmental groups, through to actions aiming to manipulate the test-bed and full-scale deployment equipment to cause wider harm and threats to human health and the environment:

> I think it will be hassle for whoever's doing the project because…you're always going to get saboteurs (Alison, Nottingham)

> Well I hate to say health and safety, but my concern would be somebody being able to interfere with it and put something else in that could go up in the atmosphere that could have future effects on the country and other surrounding countries (Barbara, Norwich)

4.2.4 Knowledge limitations

To what extent can you upscale the findings from 1km to 20km?
How can we relate small scale to large?
How can the results from the test-bed be applicable to the longer pipe?
How can the data from the test-bed be used?
How will this address the wider risks of stratospheric aerosols?
How much can we learn about the cooling effects from this type of trial?
Can the other effects (e.g. wind, temperature and other effects) all be scaled up?
How will impacts be tested of the fill size project?
How will the negatives of the 20km pipe be dealt with?
Will the test-bed tell us what we need to know?
Are the other potential negative impacts/cons of using stratospheric aerosols also being investigated in the project?
How will fresh and salt water behave differently?
What would be, for Full-scale deployment, the impacts of temperature (e.g. frozen pipe?) and will the test-bed help?

You know the results from doing the test-bed, how will they take that, how will that be the same as if they do it on a full scale? (Margie, Nottingham).

Figure 3: Questions generated relating to knowledge

As can be seen from the questions, what knowledge the test-bed would be able to provide to assist with future research and ultimately full-scale deployment was of keen interest to the participants. Participants wished to understand the research process including how scientific knowledge is generated. Understanding the research process could be critical in avoiding contestation based in a lack of understanding the iterative, interpretive

'normally hidden day-to-day working of disputed science' – that which has plagued the climate change community particularly since the events of "climategate" (Collins, 2011: 2).

Many of the participants clearly understood and accepted that the test-bed is concerned with providing information regarding practical or engineering elements related to the mechanics of the pump, tethering and balloon rather than a test of the "climatic effects" (Orville, Norwich) of cooling. Whilst this lead to some being able to tolerate or even support such research or at the very least mitigate outright opposition, it did not preclude questions regarding the ability to upscale results related to "practicality and engineering" particularly given the differences between the conditions of the test-bed and full-scale deployment:

> Rowan: …this is at the bottom of my list of preferences but bearing in mind…because it's only basically a mechanical engineering test I don't have any real reservations about it other than whether it's relevant or not, whether you could actually scale it up from this but this is the kind of research that wouldn't bother me because we're not actually pumping up anything into the atmosphere on a sufficient scale to cause any lasting damage.
> […]
> Jane: Yeah but if it works they're gonna do it. (Nottingham)

> Orville: This test is about the balloon itself and how it practically works rather than about the climatic effects…but even on that level of practicality and engineering, if it's only going up one kilometre and on the full scale test does it have to go up about 15 kilometres is it?
> Facilitator: 20, I think.
> Orville: I mean how much does it really work out from that? (Norwich)

Such conditions included differences in what would be pumped, the heights involved, temperature (and what impact the below freezing temperatures at full scale may have the fluid being pumped up), fluid dispersal patterns, winds and wind speeds, being land-based or at sea. With the latter being a particular point of concern how could the computer models accurately predict the impact forces and movements of the balloon and tether in a more dynamic maritime situation. For some, until they became aware of the significant engineering challenges in pumping a fluid up a pipe connected to a balloon, there seemed to be an air of frustration that the test-bed would be so far removed from the 'end point' conditions of full-scale deployment (also see section 3.2.2 'Methodology').

Of key concern to some, was not only clarifying what the test-bed would be able to provide more information about, but also delineating the limits to the knowledge; the perceived substantial potential affects and impacts of full-scale deployment:

> You know they've said this is gonna be like three and a half years and initially it's just testing the mechanics so after the three and a half years are they actually gonna test what the consequences would be or is that something that if this mechanics do work then the only way to test the consequences is to do it at the full scale if they were to properly go ahead? (Victoria, Nottingham).

> I don't mind the research and everything, that's all perfectly fine, it's just the point where you start having to do larger trials to get an idea of how it's really going to work, to get any kind of idea of how this is really going to work you're going to do such a large scale trial you're practically doing it already and that's the bit that gets me. You're already doing it whether you've had like authority to or not, and whether you really know what the effects are going to be (Laurel, Norwich).

As both Victoria and Laurel intimate, a barrier to public acceptance of stratospheric aerosols is that even with rigorous and systematic multi-staged research, there is the perception and reality that we may never know all of the potential impacts until we try full deployment, and even then, in the event that something goes wrong, how do we trace causality? For such participants, the test-bed does little to alleviate or appease the resulting anxiety.

4.2.5 Governance and Communication

What international links are there?
Will other countries mind any outfall?
What will be done with the information from the test-bed?
What will be done with the results?
How will the results be shared with other countries?
Do we know what research is happening elsewhere?
How is the test-bed being publicised?
How will they inform people?
What will you tell the local people about it?
How will local government, councils etc be involved?
Who's accountable if things do go wrong?
Will scientists from other countries be involved with the full-scale project?
Who would be in control of the full-scale project?

Figure 4: Questions related to governance & communication

As with previous research (Experiment Earth, 2010), participants throughout all of the workshops were clearly interested in how stratospheric aerosols at full scale deployment would be governed, policed and regulated. It was seen imperative that there should be some sort of an international governance structure for all RA's, whereas CR approaches were seen as less mandatory and urgent. Through discussions about the SPICE research and test-bed, it became clear that for some participants such governance structures should be, whilst not necessarily already in place, already being worked on. For some this was to ensure that global support for what was seen as being eventually a global initiative was in evidence – otherwise pursuing even research into it was perceived as fruitless:

> Bert: …you want to know whether it's worth doing all this because it might turn out that what you've done it for isn't going to work or is not acceptable to the world as a community.
> Clarence: I still say you won't know that until the final test. (Nottingham)

For others governance, even through simply ensuring good communication structures are in place, would help to mediate anxiety, fear and concern. In part this would help to ensure even the research at this early stage being seen as legitimate, rather than fringe science, or scientists and the UK "going rogue" or acting impetuously/willfully:

> If it comes across as very informative and there's a big research governing body that's managing this…then most people, their concerns will be alleviated… (Fiona, Norwich).

Communicating - being transparent and open - about research such as SPICE within the international and national arena was not just seen as necessary, but obligatory. A variety of actors were held responsible for ensuring such communication takes place, including politicians and the researchers themselves. Simply relying on traditional means of communicating science (e.g. international conferences and science journals) was not

seen as satisfactory. For some, failure to ensure it would leave the UK vulnerable to unspecified forms of "retaliation":

> Margie: You can't just take the world in just this country's hands can we 'cause if we - it would cause a war wouldn't it if we affected another country then they'd have a right…
> …
> Margie: That's a bit frightening to think if you start to change things yourselves but other countries aren't going along with that, why would you do it?
> Facilitator: So would you want to ask Kirsty have they thought about that?
> Margie: Yeah 'cause really you've got to be united in it altogether (Nottingham).

With regards to sharing information with public there seemed to be two spatial scales at which dissemination was needed: the national public and the local publics who may be in close spatial proximity to either the test-bed site or the receptors of any as yet, unnamed impacts of the test-bed occurring. The former was deemed important to maintain/build trust or at the very least prevent a public backlash:

> Roger: I think if you do an experiment people must know the results.
> Facilitator: People as in everyone?
> Roger: The public. I think too many things are done in secret, we don't hear about it until it's too late
> …
> Roger: Make people aware. There are lots of times if you go right the way back to testing the atom bomb, we were involved in that but we didn't know what was happening then. (Nottingham).

However, transparency does not guarantee that trust will be formed. For some, previous betrayals of trust in adjacent arenas by stakeholders will affect how publics engage and assimilate information given in relation to geoengineering and the test-bed:

> Cath: ...I don't trust 'cause you read so many things don't you, this has happened and that's happened and you get shocked that those who seem to know have put us in anger or well with all the politicians now where they're lying and you put your trust don't you, you just realise you just can't trust anybody particularly so it's probably me [laughs].
> Facilitator: Well what information would you want or would you just not trust any information that they gave you?
> Cath: Well you'd want all the information. I suppose it would be up to the individual to trust that information. There's no more that they can do or say.
> Facilitator: Well what sort of information would you personally want Cath if it [test-bed] was gonna happen?
> Cath: That it was 100% safe; that the pipe is not going to burst, that if it did that it was in the middle of nowhere, that there would be no effect.
> ...
> Morgan: They need to make sure everyone publicly [is] aware don't they before they do it wherever they're gonna put it, everyone around and who it's gonna affect, they all need to know about it, whether you have a leaflet through your door explaining everything or whether it's on the news or someone knocking on your door. (Cardiff).

4.2.6 Uniformed view – Apathy and Affect: Local consultation

We asked our participants, what their or their friends'/families' reactions might be to finding an article on the test-bed in their newspaper, news programme or media of choice, without drawing upon, their experiences of

our deliberative event. Many of our participants suggested that their reaction would be one of at most mild idle curiosity, but principally lack of interest:

> Jane: I probably wouldn't pay much attention to it to be honest.
> Cecil: I was about to say to be honest I don't think I'd read it.
> Wilma: I'd think "what are they doing now?"
> Cecil: Probably look at the picture and just turn the page.
> Jane: If it looked good and it was local I might go and see it but other than that I probably wouldn't be interested. (Nottingham).

Other participants suggested that their initial reaction would be disbelief:

> I think I would have disbelieved it to tell the truth because it looks so *Heath Robinson* that it's not very believable is it really? (William, Norwich).

Some though, suggested that no prior knowledge of the test-bed could engender impact including but not limited to anxiety. This could be the result of, in part, knowledge of previous catastrophic risk events and in part anger/frustration over lack of consultation over the test-bed. Indeed some felt that such surprise could lead to vociferous local public contestation:

> I think a lot of people would look at it without a priori knowledge, when you think back to Chernobyl and things like that, where something happens in Russia, completely out of their control and it affects the whole of this country (Henry, Norwich).

> Morgan: People probably protest and all that and just cause riots wouldn't they unless they were informed then I suppose they've got time to get round it then haven't they and sink in but otherwise it probably would be a bit of a shock. If I had a newspaper poster through my door and I seen this thing and it said they were starting the next day on the mountain outside my house...[laughs]
> Meredith: Well that's it, that's their way of telling you. It's not asking you, "Do you want it?" that's "This is happening". (Cardiff).

However, that is not to say that participants necessarily wanted the final say in the decision, interestingly Meredith and Morgan continue their discussion and outright reject the notion that they should make the decision:

> Meredith: I wouldn't wanna be asked. I wouldn't wanna have any involvement in it. I wouldn't wanna have an opinion on it. What if they done like a ballot vote and 80% decided yeah and something went wrong? I don't wanna be to blame if it goes wrong.
> Morgan: It could cause conflict as well especially if we were asked. (Cardiff).

Clearly, these participants feel that there are a plethora of ways that the test-bed could cause contestation. It would also be fair to say that these participants also felt distinctly unqualified to actually make the decision, that they lacked the foresight to make strategic decisions about the test-bed and research in general. Furthermore, some felt that to reject such research may be symptomatic of a knee-jerk reaction, not because of specific fears or concerns regarding <u>this</u> research, but more because of a reluctance to embrace something new/different:

> But who am I to say? I haven't got all that research and knowledge and think "oh this is gonna progress us years down the line" or whatever. I wouldn't wanna have an opinion to be honest (Meredith, Cardiff).

Despite the above, for many participants, consultation was desirable. However, many also suggested it was not necessarily something they expected. Other participants believed that a news article on the local test-bed would engender curiosity and interest. For some this would translate into a desire for more information regarding any potential risks and impacts of both the test-bed and wider proposal.

Despite the recognition of difficulties that could arise from consultation, there was a strong general consensus that local publics should be involved. However, to engage properly with local publics our participants suggested it would need to be a multi-staged strategy. First, numerous forms of media would need to be utilised including perhaps repeated articles in local papers, leaflets, radio station broadcasts and perhaps even local TV. Of course, over-reliance on media was also cautioned against given the potential for manipulation and sensationalism. Second, it was felt very strongly that the SPICE team should engage openly and be seen to engage as early as possible in local democratic processes, including consulting with local councillors, planning offices and in other local democratic forums, or with other local representatives:

> ...as individuals we have very little power and we channel our power as a people through our local representatives, the councillors and MPs and they are the people who on our behalf take decisions. That's the basis of our democracy I think (Rowan, Nottingham).

Our participants were not naive to the potential ramifications of early consultation with local publics. As discussed above, some did feel that it could cause local opposition to the test-bed. Equally in all the workshops, participants could envisage how the release of too much information could enable opposition groups from outside the local area, to infiltrate and cause potentially serious disruption to both local life and the test-bed through direct action. Participants acknowledge that getting the balance right would be extremely challenging for the SPICE team and could not offer a strategy to assist with this.

Despite all of the difficulties in executing a balanced consultation with local publics, most participants did feel that this was the safest option to avoid a potentially large backlash. Whilst some did idly suggest doing the test-bed in a covert manner (one participant suggested putting an advertisement on the balloon to disguise its true purpose!), the overall consensus was that this would be an extremely dangerous and unwise strategy which would ultimately be exposed leading to extremely damaging misconceptions:

> Cath: I think you'd wanna know about the safety of it. That would be the main concern; why didn't they tell us that? That type of thing. Is there anything gone into the air that we should be concerned about?
> Gwen: Yeah it's like a conspiracy theorists dream isn't it?
> Cath: Yes.
> Gwen: What were they really pumping into the atmosphere?
> Cath: Yeah so if it was only fresh water why didn't they tell us? (Cardiff).

Equally, whilst under the guise of humour, the following quote also strongly urges that the SPICE team continue to keep local publics informed of any changes to their plans. This does not mean (as the quote suggests) to react literally to the obviously implausible idea that the test-bed site would become the stage for the main deployment, rather, the notion that extensions to the test-bed are plausible (e.g. due to bad weather) and if the publics are not informed this in itself could cause alienation and controversy:

KP: If there was – I don't know where you live, but the field over from you, suddenly they start building this thing; do you think you'd have any reaction?
Rhobert: Well it's only gonna be there for four or five weeks testing isn't it? It won't there forever. I wouldn't mind.
Iowerth: Ah you don't know that mate. They might think, "This is a good area, this we'll do here".
Morgan: No you never know that do you because –
Rhobert: I'll get my air rifle out!
Iowerth: Get your air gun out! (Cardiff).

5.0 Conclusion

Research per se is interesting and I'm quite happy for scientists all over the world to be pursuing research into an awful lot, wonderful and quirky ideas, because you never know what good will come out of them and an awful lot of good has come from an awful lot of research over the years. So research in itself is absolutely fine, but scaling up would then be where I'd start to have reservations (Riley, Norwich).

In relation to the test-bed, the main conditions and recommendations we wish to highlight from our analysis as a whole are as follows:

- Broad level strategic conditions and recommendations:
  - Overall almost all of our participants were willing to entertain the notion that the test-bed as an engineering test – a research opportunity – should be pursued. Equally very few were fully comfortable with the notion of stratospheric aerosols as a response to climate change. As we have tried to indicate, their discourses operated, often simultaneously, within several frames and therefore it is essential that these findings are NOT misconstrued as unconditional acceptance of, or support for, either stratospheric aerosols or indeed geoengineering more generally. It is more accurate to characterise this as a highly 'conditional' or 'reluctant acceptance' (Bickerstaff et al., 2008) of pursuing a research agenda such as the test-bed, as part of a carefully developed research strategy. There remain significant concerns regarding any activities with stratospheric aerosols beyond the test-bed, including justification, efficacy, equity, ethics and governance.
  - A key concern was that international governance and regulatory structures be under development now, and not only in the event of full scale deployment, to help govern and co-ordinate research such as the test-bed and SPICE. Whilst not dismissing the importance of developing technical knowledge and proving efficacy in relation to geoengineering methods and stratospheric aerosols in particular, it was clear that our participants felt that funding decisions for both the test-bed and research stemming from the test-bed should be based as much on issues of governance and ethics, as on the science, engineering and technical knowledge. In addition, that such decisions should be made through or as part of international governance mechanisms was also considered desirable and necessary. Finally, the ambivalences of our participants are indicative of their desire to ensure that strategic research decisions are made in the light of, and hence do not lose sight of, the end result of scaling up to potential full deployment.
  - Public(s) desire to understand the context for funding such research. An obvious response here would be for the SPICE team to delineate how the SPICE project and test-bed sit in relation to other geoengineering research.
  - Related to the last point, there was a desire that Research Councils themselves should make transparent their strategy for funding and supporting geoengineering research. Specifically regarding the test-bed, RCUK should clarify their objectives and reasons for funding such a project emphasising how this fits within their strategy for supporting research more widely and specifically that connected to responses to climate change. The SPICE team should be able to draw upon such justifications/reasoning together with their own, when communicating their goals with and to the publics.
  - Our participants were keen to know how both the SPICE team and other stakeholders including RCUK are communicating with other scientists and governments with regards to this research. That such research does not occur in research silos and that every effort is made to ensure dissemination and

communication occurs beyond the conventional forms was also a key desire. It would be useful if both parties outlined their communication strategy.

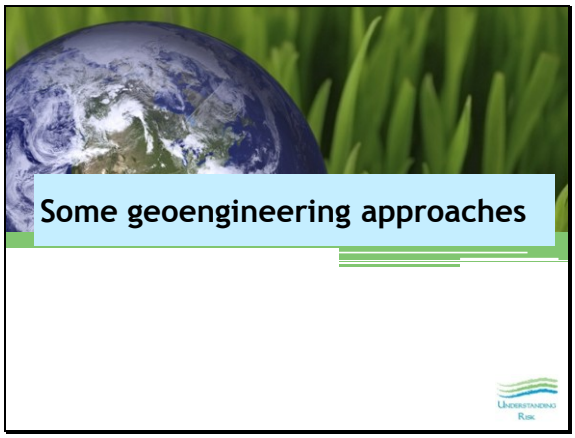
- Specific test-bed recommendations to the SPICE team:
  - The SPICE team should operate in a transparent and open manner engaging with those publics living in close proximity to the test-bed site through a variety of means. This includes directly through for example, leaflets and other forms of information provision, and through actively engaging in local democratic processes. Engagement should be ongoing with the objectives for engagement being clear (e.g. is the goal information provision and/or consultation). The SPICE team may wish to consider inviting community representatives onto an advisory panel of sorts to proactively maximise the insights and information exchange. Ideally such engagement would occur before key decisions are made to ensure, as much as is feasible, publics are active participants rather than receptors of decisions. Clearly though this can only be one part of a multi-pronged strategy as there could be sensitivities over responsibility and culpability for decisions.
  - The test-bed can only proceed if it is safe for both local inhabitants and the local environment, and information relating to the safety and impacts of the test-bed should also be made publically available in summarised accessible form. This includes key results and provisions stemming from any risk assessment and environmental impact assessment.

6.1 Appendix 1: Format & Tasks Overview

Main Task	Extra Information
DAY 1	
Intro presentation Climate Change thought listing task & feedback	Thought-listing: "Please list what comes to mind when you hear the term 'climate change'". Participant (dis)engagement and (dis)belief in climate change were able to be probed here.
CC overview presentation	A crash course in climate change, potential effects and scientific (un)certainty.
Group discussion – Climate Change	
World Café 1 – Societal responses to climate change	Split into two small groups, each group discuss each topic in turn: 1: reduction (mitigation) ▪ Materials provided: CO2 reduction target, Map of CO2 emissions per capita (Bangladesh, China, UK, USA), Foresight Scenarios. 2: adaptation ▪ Materials provided: Two case studies of adaptation (Flooding in London & Coastal Erosion) 3: climate control (geoengineering) ▪ Materials provided: Very broad intro to geoengineering and two approaches & comparison of what CR/RA can(not) do. • Introduce material – 5 mins to review • A facilitator joins table but only enters discussion if needs guidance/stimulation • Encourage to record (via sticky notes) pros & cons for each, & comparisons between the three
4 techniques of Geoengineering presentation and Q&A by EXPERT	Participants reasons for asking questions probed before expert answered
World Café 2 – Carbon Removal (Biochar & Air Capture) & Reflective Approaches (Stratospheric Aerosols & Cloud Whitening)	Split into two small groups Topic 1: CR & Topic 2: RA (35 mins per topic) ▪ Materials provided: reminder of 4 different techniques with advantages & disadvantages, & ethics/governance prompt statements (5 mins review) • A facilitator joins table but only enters discussion if needs guidance/stimulation • Aim to record concerns/benefits & create conditions and rules for approaches using governance and ethics prompt sheets
Homework: To describe Geoengineering to a friend/family member & write down their responses.	
DAY 2	
Group feedback on homework including their reflections on family responses and if their own opinions had changed.	
Presentation: Introduction to SPICE	By Cardiff University
Initial group responses to SPICE	**ALL EXPERTS (including SPICE rep) LEAVE ROOM** • Initial thoughts, discuss & questions for experts created and recorded on Flipchart. • Finally probed as to what participants' or friends' responses to a media article/programme would have been if "uninformed".
Experts answer questions (primarily directed to Dr Kuo)	
Two small group discussions – SPICE	Encourage to reflect upon previous rules/conditions/concerns created on previous day & create ones for SPICE • Probe as to why • Probe locality • Probe if notice switch in opinions
Small group feedback and whole group discussion	Representative from each small group reports back from their small group – whole group discussion stemming from these reports (on SPICE, geoengineering and so forth)
Anonymous last thoughts SPICE	Participants fill out a form and drop it into a box without telling anyone what is on it.

6.2 Appendix 2: Slides used by Dr Naomi Vaughan to introduce the geoengineering techniques.

1



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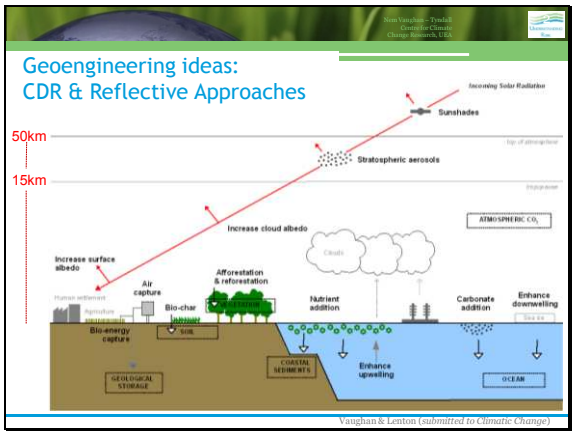

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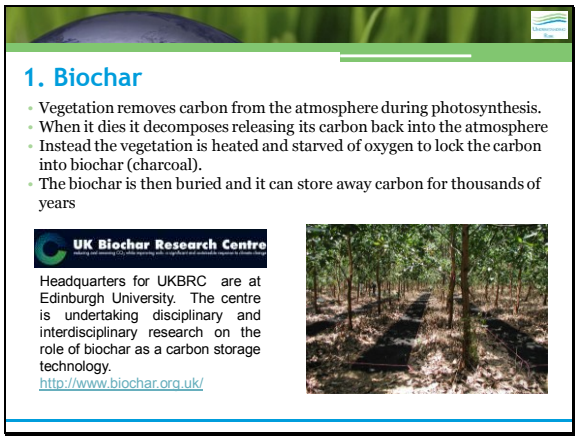

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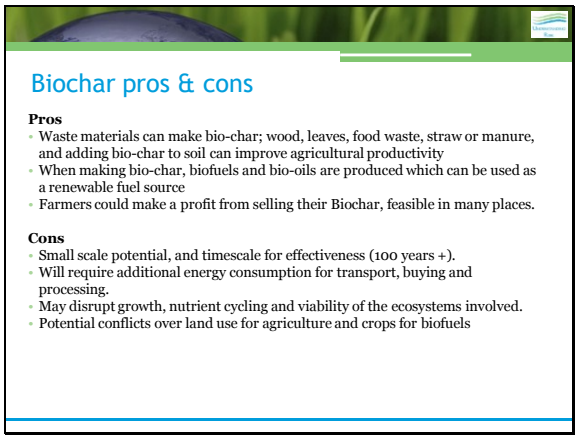

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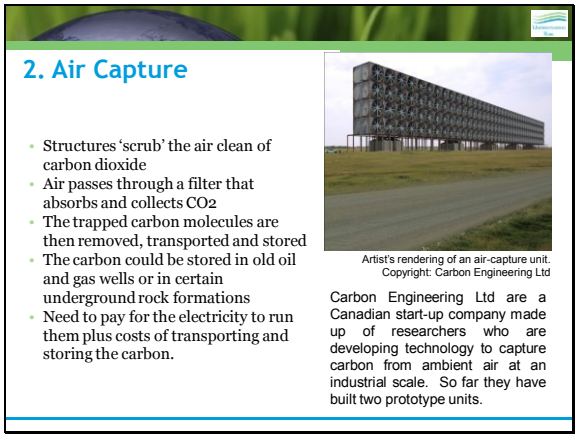


7

Air capture pros & cons

Pros

- Very efficient as can remove many more times carbon dioxide than a tree
- Placed anywhere
- Capture is very safe and shouldn't have any bad side effects
- Would operate 24 hours a day but could be switched off easily if something went wrong
- Easy to measure the amount of carbon captured

Cons

- They would be slow to reduce global temperatures
- The capture devices may be an eyesore and would take up land space
- There will be a limit on places to store CO_2 underground

8

Some techniques to reflect heat & light back into space that scientists & others are considering

There are more we have just selected some!

9

3. Cloud whitening

- Clouds reflect sunlight.
- Clouds appear brighter when they are made of many tiny droplets than fewer bigger droplets.
- By spraying small seawater droplets into the air over the sea, it is possible to create more cloud droplets and so increase the reflectivity of the clouds
- One idea is to use specially designed automated ships to spray the seawater
- The most effective places in terms of cooling are over sea on the west coast of North and South America and the west coast of Africa

Artist's Impression - (copyright J. MacNeill 2006). There are researchers based at Edinburgh University & the National Center for Atmospheric Research (USA) who are investigating the 'Cloud Brightening Geoengineering Idea' & the hardware needed to do it (see Salter et al., 2008).

10

Cloud whitening pros & cons

Pros

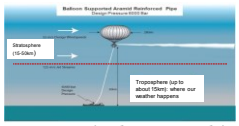
- Could start reducing temperatures in a short time period
- Easy to turn off if there's a fault

Cons

- It may not be as effective at reducing temperatures as predicted.
- Effects may only last a few days or weeks so it would need to be carried out repeatedly which would cost money and take time
- It would cause a lot of cooling in a very localised area
- It may have unwanted effects on the weather and sea life
- May reduce or change the patterns of rainfall in other regions
- Other impacts of rising carbon emissions still remain e.g. increasing ocean acidification

11

4. Stratospheric Aerosols



Researchers at universities in the UK (e.g. Bristol, Cambridge, Reading) are investigating whether aerosols can be injected into the atmosphere via a 20km pipe.

- Some particulates are shiny so scatter the sun's rays back into space, preventing them from reaching Earth and so cooling the earth (e.g. sulphates, clay…)
- One idea is to use very large balloons connected to a pipe to disperse aerosols (or aircraft, missiles, platforms).
- Computer modeling has been carried out
- If using sulphates, the amount involved is quite modest and so would not significantly add to acid rain.

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Sulphate particles pros & cons

Pros

- Works fast could start lowering temperatures within a year
- Would reduce the global average temperature in a fairly uniform way

Cons

- If you suddenly stopped the world get warmer more quickly
- Effects would only last about 1-3 years so have to be repeated
- Difficult to get the aerosol up that high and to release it
- Very uncertain side effects may affect the climate/rainfall and lead to droughts
- Could damage the ozone layer and high altitude clouds
- Other impacts of rising carbon emissions still remain e.g. increasing ocean acidification

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