Ipsos MORI

Experiment Earth?

Report on a Public Dialogue on Geoengineering

August 2010

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Public Dialogue on Geoengineering

Contents

Summary

Executive Summary

‘Experiment Earth?’ was a public dialogue conducted for the Natural Environment Research Council (NERC) on geoengineering − technologies that involve the deliberate and large scale manipulation of the Earth’s climate system to reduce the extent and impact of climate change.

The dialogue was supported by the NERC, the Sciencewise Expert Resource Centre (supported by the Department for Business, Innovation and Skills), the Royal Society, and the multi-agency Living With Environmental Change (LWEC) programme. The aim was to identify and understand public views on geoengineering research and deployment, including its moral, ethical and societal implications. The dialogue was run by Ipsos MORI along with Dialogue by Design and the British Science Association.

The dialogue process gave members of the public the chance to inform future NERC decision-making on geoengineering. The discussions provided insights into the public’s priorities and how their opinions were formed. Such information can be used by NERC and other funding bodies when considering the future planning, conduct and communication of geoengineering research. It may also be of value to science users, such as industry and policymakers, who may play a role in further research and deployment of geoengineering, and to science communicators both of geoengineering and climate science more generally.

It should be noted, however, that the results were qualitative and indicative, rather than quantitative, and may not fully represent UK public opinion. However, detailed deliberative research such as this does have the advantage (over quantitative surveys) of giving some indication of the range of opinions present when members of the public are presented with information, and allowed participants the time to deliberate about the issues in question.

Key findings

- Awareness and knowledge of geoengineering were low prior to the sessions. During the dialogue, views on geoengineering became more sophisticated and discriminating. Support for some geoengineering approaches increased, while support for others declined, although the changes were almost all statistically insignificant. None of those participating were vehemently against all geoengineering approaches as a matter of principle, although there were serious concerns with specific technologies.
- Participants’ views of the seriousness of climate change affected their views on geoengineering. Most accepted the potential need for geoengineering on the basis that mitigation (through reductions in greenhouse gas emissions) might not be effective enough.
- Participants believed it would be both ethically and practically important to link any new climate change solutions to continued mitigation, recognising that one solution might not be enough to tackle climate change. The majority wanted to combine several different international geoengineering approaches with international, national

and individual mitigation efforts. This evidence is contrary to the 'moral hazard' argument that geoengineering would undermine popular support for mitigation or adaptation, although it cannot give any indication of whether moral hazard would be more significant for other stakeholders.

- Some technologies were considered more acceptable than others, *see table below.*

Carbon Dioxide Removal (CDR)	**Solar Radiation Management (SRM)**
Consistently highlighted as preferred method of geoengineering. ***Afforestation*** and ***Biochar*** were seen as "natural" approaches and preferred for this reason.	Less support for SRM overall, as it was perceived not to tackle the root cause of climate change (which participants considered to be greenhouse gases).
Level of support for ocean based methods such as ***Iron Fertilisation*** and ***Liming*** was low, though at the reconvened event participants became more prepared to consider these.	***Cloud Whitening*** and ***Sulphate Particles*** were the most positively received of the SRM technologies, but were not endorsed by a majority.
Support for ***Air Capture*** increased through the events. Participants welcomed the fact that this CDR technology could be carried out on a local level without the need for international regulation required, and that results may be seen more quickly than with afforestation.	***Mirrors in Space*** were seen as expensive and risky, and ***White Roofs*** were viewed as likely to be ineffective and not feasible. Both received little support.

Attitudes to future research into geoengineering

In this dialogue the public gave cautious support to research in geoengineering, provided their principles and caveats were addressed in future decision making.

Participants came up with key questions which they suggested should be applied to geoengineering research. These questions reveal the issues which were most important to participants in the dialogue, and some of their gaps in knowledge about the climate.

What effect might this have on mitigation efforts? It was important to participants that geoengineering should not conflict with mitigation, and wherever possible should augment mitigation efforts.
How far does the proposed research support "natural processes"? Most participants took a particular view of the natural world, believing that natural systems were balanced and self-contained. This was an emotional rather than rational perspective, not necessarily backed up with scientific evidence. Nevertheless, it provided an important context for their opinions on geoengineering. Most believed that geoengineering should be considered in terms of how well it preserves "natural systems".
How controllable is it? Participants stressed that nature contains complex systems. They did not support scientists "interfering" with these complex systems unless detailed assessments of

the consequences were carried out first.
How reversible is it? Because participants were keen to ensure scientists retained control of the effects of geoengineering, they wanted to make sure that effects of research and deployment could be reversed if necessary. They called for research to progress in small stages, to reduce the likelihood of irreversible consequences. They felt that this would make it easier for scientists to 'switch off' a project.
How effective is it? Participants wanted scientists to weigh up core *benefits* against *costs*. They recommended that scientists should take into account the two related benefits of *amount of CO_2 removed from the atmosphere*, and *overall global temperature reduction*. This was because they were more cautious about SRM technologies (which might reduce global temperature, but would not reduce CO_2) and wanted to ensure that the benefits of CDR technologies were appreciated. They suggested that the following different kinds of costs were important:- **Carbon cost** (in terms of the amount of CO_2 generated by the geoengineering process itself) **Direct financial cost** (of research and implementation) **Future cost** (to lifestyle, environments, future generations) **Opportunity cost** (by focussing on geoengineering, opportunities to spend money and resources elsewhere would be reduced) **Investment burden for the UK**
When should it be done? Participants thought that government and other authorities should set a timetable for action, and should establish when the need for action to tackle climate change becomes urgent (e.g. define a 'climate emergency'). The public should be kept informed, and need to be given data on the efficacy, costs and side effects of any technologies that are researched, as such information becomes available, so they can give or withdraw support.
How can it be regulated / done fairly? Where geoengineering would affect international resources and systems, participants recommended that international governments come together to decide on regulation, to ensure that geoengineering effects and benefits are distributed equitably across the globe. They also recommended that the UK government should think about geoengineering in terms of its long term consequences, rather than its short-term political consequences. They also wanted to ensure that the voices of those in the developing world are heard in the process.

Most of these questions combine ethical principles with other practical considerations. This reflects the fact that participants in this dialogue did not see ethical issues as inherently separate from scientific and economic ones.

Communicating Climate Science

The dialogue also revealed much about how participants viewed climate science, the scientific method and scientists. Some of the issues to emerge for the dialogue include:

- Some members of the wider public may have low levels of awareness of how the climate works, and may need further information.
- Participants found it difficult to envisage the scale of likely climate change impacts. In the dialogue, imagery linking large-scale effects to the human scale helped participants envisage this. This imagery could be used in future engagement.

- Participants found it difficult to form firm views on the issues given the levels of uncertainty about climate change. Scientists and communicators may need to present information to the public in terms of pros and cons, and be clear about what is unknown.
- Public attitudes towards government, science and institutions form an important context for communication of climate issues.
- Public awareness of the scientific process and the role of research in developing knowledge often contains gaps. Future engagement activities may need to explore these aspects in more detail.
- Participants drew a distinction between deliberately manipulating the climate (through geoengineering), which they saw as less acceptable, and manipulating the climate accidentally as a consequence of industrialisation, which was seen as regrettable, but more acceptable. An appreciation of this point of view may help scientists communicate with the wider public.

Lessons for research funders, science users and communicators

Recommendations from this study for NERC and other research funders and decision-makers are to:

1. Take account of the results of this study when discussing geoengineering priorities in future. In particular, recognise that information about the public's opinions and understanding of a subject can complement and support information from scientists and policymakers in the decision-making process.
2. Ensure future plans for geoengineering research and deployment take place in the context of the continuing need for mitigation, considering the moral hazard and opportunity costs faced in research decisions.
3. Consider participants' concerns around perceived '*naturalness'* in discussions about future geoengineering research and deployment.
4. Take account of participants' specific concerns that geoengineering research and deployment as shown in the table above, should be assessed in terms of *controllability; reversibility; effectiveness in terms of costs and benefits; timeliness; and potential for fair regulation.*

Recommendations for future public engagement on geoengineering research:

5. Continue to engage the public with geoengineering research, as requested by participants in this dialogue. Dialogue should be an on-going process, as public opinion is dependent on context and will change over time. Dialogue may also be required at different stages of research and deployment, to engage the public on specific issues relating to different technologies.
6. Keep the public informed about the efficacy, costs and side effects of any technologies that are researched, as research progresses and as such information becomes available. This helps the public to stay involved in the decision-making process, and ensures that their views are based on the most up to date information.
7. Further dialogue activity should include people from the developing world, and scientists from all over the world.

Recommendation for communicating climate science:

8. Future science communication activities on climate change, including further geoengineering dialogue, should take account of the 'Communicating Climate Science' findings, including: the range of public awareness of climate change, particularly its scale, urgency and levels of uncertainty: trust in science: awareness of how science is done, and differences between the 'scientific' view and the public view of issues.
9. There is also a need for further dialogue on the subject of 'naturalness' to establish what this term means to the public (see recommendation 3, above) and explore public attitudes to, and scientific understanding on, the role of humans in natural systems and interactions between humans and the environment.

How the dialogue worked

Three groups comprising members of the general public (each up to 30 people; 85 in total) were recruited in Cardiff, Birmingham and St Austell, Cornwall. Each group met for two full days, one week apart. A final event was held in Southampton, to which a subset of participants from all three locations were invited. During the workshops, the public met with scientists and science ethicists to debate the issues.

Nine geoengineering technologies were discussed, drawn from those identified in the Royal Society report 'Geoengineering the Climate'[1] and covering both Carbon Dioxide Reduction (CDR) and Solar Radiation Management (SRM). This approach enabled participants to think through their priorities, principles and concerns about geoengineering. Their understanding of the subject developed as the dialogue went on.

In addition to the core dialogue workshops, other members of the public had the opportunity to give their views on the geoengineering technologies through:

a) two discussion groups. The first with people at risk of flooding, to test whether their potential proximity to the effects of climate change made a difference to their views. The second with young people (aged 16-18), to test whether younger people had a different view on the long term implications of climate change than their elders;

b) a qualitative online survey about attitudes to geoengineering technologies, eliciting 65 responses and

c) open access events at science centres in Cardiff, Birmingham and Oxford, which included science demonstrations, and discussions between the public and scientists.

The core dialogue provided in-depth evidence while the additional strands gave further data, which broadly supported the core dialogue's findings. Evidence from all the strands was synthesised for the report.

The dialogue process was overseen by a steering group made up of academics and representatives from business, government and Non-Governmental Organisations (NGOs). Material for the dialogue was developed in consultation with stakeholders, including a small group of NGOs, who met early in the process to discuss the aims of the dialogue and the format it should take.

[1] Available from http://royalsociety.org/Geoengineering-the-climate/

1. Background & objectives

1. Background

SUMMARY

1.1 Geoengineering technologies involve the deliberate and large-scale manipulation of the Earth's climate system to reduce the impact of climate change.

NERC and Sciencewise-ERC, together with LWEC and the Royal Society, came together in Spring 2010 to run a **public dialogue** that will inform the direction, conduct and communication of research in geoengineering. The complex technical, ethical and social issues around geoengineering made a public dialogue the most appropriate way to understand public views.

This report provides the findings from the dialogue process.

1.2 The dialogue covered **nine potential geoengineering technologies**. Through discussing these technologies, participants expressed their priorities, principles and concerns about geoengineering research overall.

1.3 Dialogue aims: To identify the public's preferences around the future of research into geoengineering, in particular the moral, ethical and societal implications of funding decisions. This, in order to influence NERC's strategic decision making, and the decision making of other funders and policy makers.

1.4 Method:

- **Three general public groups,** comprising 85 people in total, were recruited in Cardiff, Birmingham and St Austell, Cornwall. Each group of around 30 people met for a full day, then were reconvened for a second full day a week later. Participants from all three locations were invited to a final event. Scientists also attended the events, to discuss the issues with the public.
- **Two long discussion groups**, one with people at risk of flooding, the other with young people (16-18).
- **Qualitative online survey**, 65 responses from stakeholders in community groups.
- **Three open access events** at science centres in Cardiff, Birmingham and Oxford.

The core dialogue provided in-depth evidence while the additional strands gave further data, which broadly supported the core dialogue's findings. Evidence from all the strands was synthesised for the report.

1.5 The results will inform NERC and LWEC's decisions on the future of research into geoengineering, and in particular the moral, ethical and societal implications of funding decisions. It will also contribute to a wider body of knowledge and insight within NERC about public views on science, and the principles and priorities relating to geoengineering.

1.1 Background to the project

1.1.1 The climate change challenge

International scientific consensus agrees that the global climate is changing as global temperatures rise, driven by increasing levels of greenhouse gases in the atmosphere.

It is, however, proving difficult to establish global political action on tackling climate change – the outcome of the recent Copenhagen summit was seen to have fallen short of agreeing decisive commitments.

The disagreement on national and global commitments to policy interventions has led some scientists and commentators to suggest exploring 'Plan B' solutions, in case these should become urgently necessary.

1.1.2 Geoengineering

These potential 'Plan B' solutions are **geoengineering** technologies - the **deliberate and large scale manipulation of the Earth's climate systems** to reduce the progression of climate change and the impact of global warming.

Geoengineering could offer, potentially, large-scale solutions to some of the problems caused by rising concentrations of atmospheric CO_2, if carbon emissions cannot be cut speedily enough to avert disastrous climate change.

However, there are still significant technological and scientific uncertainties around geoengineering. To progress geoengineering to the point where it could be used, investment in research is urgently required. The Royal Society report *Geoengineering the Climate*[2].recommended research investment of £10m per year for the next 10 years. However, deciding on which research to fund is a challenge. Even to weigh up the costs and benefits of research into geoengineering may require more information than is currently available about the potential effects of geoengineering on people and ecosystems.

The Royal Society report also points out that technical and scientific issues may not be the dominant ones when it comes to the actual deployment of geoengineering technology. Social, legal, ethical and political issues would be of equal significance, as geoengineering could potentially affect the lives of people around the world. Implementing global-scale projects would require international agreement.

Given this, the Royal Society asserted that **public attitudes towards geoengineering** should be a critical factor in considering the future of geoengineering -.specifically how (and if) the public think these technologies should be taken forward. One of the Royal Society report's key recommendations, therefore, was to engage the public on these issues.

[2] http://royalsociety.org/Geoengineering-the-climate/

1.1.3 Public dialogue

The **Natural Environment Research Council** (NERC)and Sciencewise-ERC[3], together with LWEC[4] and the Royal Society, came together in Spring 2010 to run a **public dialogue on geoengineering**, to inform the direction, conduct and communication of research in this area.

NERC already supports a wide range of research relevant to geoengineering. In the near future, the Council will need to take decisions on its priorities around geoengineering so that it can make informed investment decisions in this area. Taking account of the Royal Society's recommendations for public involvement, NERC wanted to understand public opinion on how, and to what degree, geoengineering-related research should go forward, and where priorities should lie.

A public dialogue was considered the most appropriate way to engage people with geoengineering. Public dialogue is useful where the public know little, initially, about the issue under discussion, and where the themes involve complex political, social, ethical and technical considerations. Geoengineering satisfied both of these conditions.

The kinds of outputs that public dialogues produce can be used to create insight and understanding for policy makers. The next chapter explains more about public dialogue, and how its findings can be interpreted.

The Royal Society's report also acknowledged the requirement for knowledge exchange between the science community and the public. This could also effectively be facilitated through a dialogue.

Ipsos MORI, **Dialogue by Design** and the **British Science Association** ran this project as a consortium and this report represents the findings of the project.

This dialogue has been independently evaluated by **Collingwood Environmental Planning**.

1.2 Nine geoengineering technologies covered

This public dialogue focused on nine geoengineering technologies. The technologies chosen for discussion broadly reflected those discussed in the Royal Society's report. The dialogue did not provide exhaustive coverage of all geoengineering techniques. For practical reasons, most notably the time available to discuss the technologies with participants and to avoid information overload, a selective list was necessary.

The technologies can be divided into two main categories, **Carbon Dioxide Removal (CDR)** and **Solar Radiation Management (SRM).** Both sets of techniques have the ultimate aim of lowering global temperatures, but approach the task in different ways. The dialogue project included a selection of both CDR and SRM techniques.

CDR techniques address the root cause of climate change by removing CO_2 from the atmosphere. During the dialogue, the following techniques were discussed:

[3] The Sciencewise Expert Resource Centre is an expert resource centre supporting public dialogue in policy making involving science and technology issues and supported by the Science and Society unit of the Department for Business, Innovation and Skills (BIS).

[4] Living With Environmental Change, a partnership of Research Councils and government.

- **Biochar:** Vegetation, which uses CO_2 from the atmosphere for growth, is heated and starved of oxygen to lock the carbon into biochar (finely grained charcoal) rather than releasing the stored CO_2 back into the atmosphere when the vegetation decays. The biochar is then buried and can store away carbon for thousands of years.

- **Liming the Ocean:** 'Lime' ($Ca(OH)_2$) would be created from limestone carbonate rocks and added to the oceans to make them more alkaline, which makes them absorb more CO_2 from the air.

- **Iron Fertilisation:** Adding nutrients such as iron to certain areas of the ocean to promote 'blooms' of algae. As the algae grow they soak up carbon dioxide from the atmosphere. When they die they sink out of the upper ocean, taking the carbon with them potentially for hundreds of years.

- **Air Capture:** 'Artificial trees' would be made that remove carbon dioxide from the air. The air passes through chemical solutions or compounds that absorb and collect CO_2, which can then be removed, transported and stored.

- **Afforestation:** Planting more trees and managing land use would help reduce CO_2 levels as the newly-planted trees would absorb more from the atmosphere as they grow.

SRM technologies attempt to offset effects of increased greenhouse gas concentrations by reflecting a small percentage of the sun's light and heat back into space. The following were included in the dialogue discussions:

- **Sulphate Particles:** These would mimic what happens when large volcanoes erupt, sending sulphate particles up into the air. Sulphate particles scatter the sun's rays back into space, preventing them from reaching Earth and so cooling the Earth. Military planes or hot air balloons would disperse sulphate particles in the upper atmosphere.

- **Mirrors in Space:** Many small mirrors or reflective mesh put high up in space, acting as a sunshade to reflect some sunlight away from the Earth, and preventing it from warming the atmosphere.

- **White Roofs:** Painting surfaces white or making them more reflective means that less heat from sunlight is absorbed by the Earth, so lowering temperatures.

- **Cloud Whitening:** Some clouds cool the Earth by reflecting sunlight back into space. By spraying small seawater droplets into the air over the sea, it is possible to increase the reflectivity and (possibly) longevity of existing clouds. The seawater could be deployed using normal ships, radio controlled vessels or aeroplanes.

1.3 Project aims

To identify the public's preferences around the future of research into geoengineering, in particular the moral, ethical and societal implications of funding decisions, in order to influence NERC's strategic decision making, and the decision making of other funders and policy-makers. To contribute to knowledge and insight on public views of climate science and principles and priorities relating to geoengineering.

To achieve these aims, the dialogue organisers:

- Engaged upstream, and throughout, with a **range of different stakeholders**, to ensure:
    - Content and focus of the public discussion reflected the breadth of scientific and other opinion.
    - Stakeholders input into design and process of dialogue.
    - Researchers, research council staff, social scientists, business, policymakers and relevant Non-Governmental Organisations (NGOs) all played a part in the dialogue itself.
    - Steering group received useful outputs from the dialogue.
- Exposed the public to a **well balanced range of facts and expert opinions** about geoengineering, and helped them to interrogate these resources for themselves.
- Facilitated **debate and discussion** among members of the public, including representation from a wide diversity of population groups.
- Identified **key areas of concern, perceived trade-offs and risks**, areas where more knowledge is required, and helped the public come to conclusions on their preferences. The dialogue covered the spectrum from small lab-based research, to field trials, to larger projects which have some of the attributes of full implementation, through to implementing geoengineering solutions themselves. Considering:
    - Research funding: whether it's appropriate, how it should work, and what kinds of projects should be funded.
    - Research management.
    - Research governance.

1.4 Method and structure of dialogue

1.4.1 Stakeholder engagement & materials development

Before the dialogue began, a steering group of scientists, science communicators, and representatives from government, business and the third sector was appointed. Meetings were held with the steering group and separately with a group of NGO representatives to

discuss the terms of reference of the dialogue, and the appropriateness and accuracy of stimulus materials for the dialogue workshop. A wider group of stakeholders was also asked to comment on the materials as they were developed.

Comments from all of these discussions were collated and worked up into final materials by NERC and Ipsos MORI. All the materials presented to dialogue participants were signed off by the steering group.

1.4.2 Public Workshops – Events 1, 2 and 3 (Reconvened Event)

The main focus of the dialogue project was on a series of workshops for three groups of the general public.

Around 30 people were recruited in each of Cardiff, Birmingham and St Austell, Cornwall (eighty-five people were involved in total). Each group of approximately 30 people met for a day (Event 1), then went away for a week to deliberate on what they had heard, before coming back to meet the next week for a second full day (Event 2).

At Event 1 the public met with scientists and learned about climate change and geoengineering approaches. At Event 2 the public discussed values, principles and ethics and viewed contributions from science ethicists.

The table below shows a simple breakdown of the dialogue participants by gender and age:

Location	Male	Female	Age range
Birmingham	15	15	19-69
Cardiff	15	13	18-70
Cornwall	16	11	18-72

At the point of recruitment participants were asked about their belief in, and concern about, climate change. The vast majority were both convinced that climate change is currently affecting the planet and concerned about it (87% in both cases). This compared to 10% saying they were unconvinced and 11% saying they were unconcerned.

A higher proportion of participants at the dialogue events were more likely to be both convinced and concerned about climate change than the general public overall (about 16% difference in reported concern[5]). This was to be expected, as participants were likely to have some interest in the subject to agree to take part.

Following Event 2, a smaller group from each of the three areas attended a final day-long event, which was held at NERC's National Oceanography Centre at the University of Southampton. Here, representatives from each area met with NERC staff, scientists and other stakeholders to discuss their thoughts and findings from the earlier events.

Other streams, outlined below, supplemented these core public events.

[5] Ipsos MORI's most recent survey on climate change was conducted with Cardiff University and published on Friday 11th June 2010. 71% of respondents said they were either 'very' or 'fairly concerned' in response to the question: How concerned are you, if at all, about climate change, sometimes referred to as 'global warming'? A nationally representative quota sample of the British population aged 15 years and older (1,822) were interviewed in their own homes in 315 sampling locations.

Materials for all of the supplementary events were based on the materials used in the dialogue Event 1 workshops and redesigned to make them suitable for each event.

1.4.3 Discussion groups

Targeted discussion groups were held with specific groups within the general public. In Cardiff a three hour discussion was held with ten residents living in an area considered to be at-risk of flooding. These participants were explicitly included to test whether people with greater exposure to the reality of the impacts of climate change differ in their attitudes towards potential solutions, including geoengineering.

A three hour discussion was also held in Birmingham with 10 young people, aged 16 to 18, to ensure the views of the future generation were captured in the dialogue. Both groups covered a shorter version of the first public event encompassing all nine technologies.

1.4.4 Online qualitative survey

A qualitative online survey was also conducted, with responses received from 65 people and organisations. Invitations for the survey were sent out to stakeholders in community groups such as Green drinks, Community Action Network, Women's Institute, and were posted on various websites such as Living With Environmental Change, ScienceOxfordLive, Sustainable Development Research Network as well as the websites of all the organisations directly involved in conducting this research. The survey website was also publicised at a public evening event at the Science Museum.

The survey question pages contained a brief summary of each technology, a link to a document outlining the pros and cons of the technology, and questions on what participants liked and disliked about the technology. This report references findings from the online survey, comparing and contrasting how these fit alongside wider public attitudes towards geoengineering. However, for a full report on this stream of the dialogue please see the separate report prepared by Dialogue by Design (DbyD)[6].

1.4.5 Open Access Events

Three open access events were held in Cardiff, Birmingham and Oxford.

In Cardiff sessions were held with school children: one group of around 20 children in Year 8 and one group of 20 children in Year 9. Sarah Castell (Ipsos MORI) and Amy Lothian (British Science Association) ran the sessions, which involved a demonstration of some techniques such as dissolving CO_2 in water and reflecting light from the sun back into space. The children were given some of the materials used to explain a range of technologies and worked in small groups to decide on the 'pros and cons' of each. They completed 'Have your say' cards answering the question 'What should scientists studying climate research be doing to save the environment?'

The open access event in Birmingham took place in the city's science museum, Thinktank. Carl Reynolds (DbyD facilitator) and local STEM ambassador Madaser Iqbal ran the two hour drop-in event from 12-2pm on Sunday 14 March, which was during National Science &

[6] Geoengineering online survey from 5 March to 12 April 2010, Summary Report. Prepared by Dialogue by Design. Information about the survey, and the findings, can be accessed at the following link: http://geoengineering.dialoguebydesign.net/

Engineering Week. Participants completed the 'Have your say' cards as above. Information on the various geoengineering technologies was available via handouts and through informal discussions with the two staff. Also, a series of busks were developed by Thinktank and performed by explainer staff in the science museum on Saturday 27 March and 1 and 8 April.

The final open access event took place at Science Oxford on Wednesday 14 April from 7.30-9pm. Dominic McDonald, Head of Public Engagement at Science Oxford facilitated a discussion with scientist Andy Ridgwell from Bristol University. The event was free to attend and was advertised on both the British Science Association and Science Oxford websites, the local Oxford newspaper and through a number of e-newsletters. Notes were taken of participant questions and they also filled in comment cards. Findings from the open access events have been woven into this report to complement the outputs from the other strands of the project.

1.4.6 Analysing these materials together

The findings from the dialogue form the main part of this report, with additional information as noted above from the other strands. Because the participants in the main dialogue had the most time to consider their views, data from this stream was given most weight in the analysis when it came to defining key themes and drawing conclusions. The findings from the other strands were used to check whether all the different themes mentioned by the public had been drawn out and explored. Where there were differences between audiences (such as young people, present in the additional discussion group and the Cardiff open access events) it has been noted where views differed markedly from those in the main dialogue. Overall, the open access events, shorter groups and surveys played an important role – they helped the analysts to calibrate their sense of what were the most important ideas coming out of the main dialogue. This is important in a qualitative study and allows for more confidence in the conclusions drawn.

1.4.7 Expert involvement

Scientists and STEM ambassadors from a range of academic institutions participated in the events. A detailed list of those involved is included in Appendix B. Observers from Sciencewise-ERC and from the evaluation team were present at all the events. NERC participants were also present at the majority of events. Further stakeholder participants attended the reconvened event, including senior NERC representatives, project steering group members, and other interested scientists from Marine Resource Management, a private company with an interest in geoengineering.

1.5 Use of the findings

This final report on the dialogue will enable NERC to consider at the earliest stage the ethical, moral and societal implications of geoengineering research funding, helping to ensure that public research funds are used in ways that reflect the broader concerns and hopes of society.

The dialogue's steering group was chaired by a member of NERC Council and had members from senior NERC decision makers, scientists and representatives from NGOs, business and government. NERC's Chief Executive, Alan Thorpe, is the Research Council's champion in

public engagement and there was a subsidiary objective for this dialogue to help NERC to build its own experience and capability in dialogue activity. A large number of NERC representatives have participated in the dialogue by observing events and attending the reconvened events, which has helped NERC achieve this aim.

Other Research Councils may also fund geoengineering research in future. In particular EPSRC[7] has made funds available for geoengineering research and sponsored a workshop on geoengineering research in October 2009. Arising from this workshop a 'sandpit' event took place in March 2010, to develop a research programme in this area. NERC also contributed to this sandpit (through both additional funding and participation), which had LWEC accreditation.

Early results of the dialogue fed into the sandpit, as both the events in Birmingham had taken place before the sandpit convened, as well as the first event in Cornwall – which some sandpit participants attended. Emerging findings were shared at the sandpit with all participants. As a direct result of this, both research proposals which were ultimately approved for funding from the sandpit, had significant public engagement components and will build on NERC's public dialogue, with further dialogue and related activities.

Key government departments, such as DECC and Defra, and agencies such as the Environment Agency, are maintaining a watching brief on the issues and the response to this dialogue. There were members from DECC and the Environment Agency on the steering group. Other government sponsored bodies with a watching brief include the Committee on Climate Change, the All Party Parliamentary Group on Climate Change (APPGCC), the House of Commons Select Committee on Climate Change, and the Parliamentary Office of Science and Technology.

[7] Engineering and Physical Sciences Research Council.

2. Interpreting the findings

2. Interpreting the findings

SUMMARY

2.1 What this report gives: The results of this dialogue process identify **insights** about the public's likely priorities, and the underlying principles which are important to them. The report qualitatively identifies **themes** which research funders and policy makers can take into account when making decisions or developing communications strategies.

2.2 Technical notes on using the results:

- Qualitative results such as those in this report do not give statistically significant quantitative evidence of public views.
- Views expressed in the dialogue do not necessarily represent views of the public at large. Other people may hold different views.
- This dialogue is not an indication of the way these particular participants might react to similar stimulus outside the context of the dialogue. There are many other variables which influence views in everyday life.
- Views of participants in future in-depth dialogues may not be the same as the views expressed here, given a different political or media context.
- A wide range of data has been synthesised here (including facilitator notes, written exercises from participants, homework tasks, and numerical indications of views from questionnaires). Numerical data presented are not statistically significant but indicative of views in the context of the rest of the analysis.

2.3 The way that issues were framed had an effect on the discussion. Participants were given the following information:

  - Climate change is a problem involving atmospheric temperature rise, caused by a mixture of CO_2 and other gases. Geoengineering seeks to reduce or reverse its effects or extent.
  - Whether humans have caused this problem or not was outside the scope of the dialogue.
  - There is a wide range of different opinions on the level of impact climate change might have. This leads to many different predictions as to how widespread the impacts might be, and how long it may be before different impacts are felt.
  - The detail of mitigation plans was also outside the scope of the dialogue. Geoengineering was presented as a new element that could be added to the mixture of approaches to tackle climate change, which includes mitigation and adaptation. It was not explicitly stated that geoengineering was a 'Plan B' that could be implemented if mitigation 'failed', but such an implication could be inferred.
  - Commitment to mitigation could potentially be put at risk by investment in the technological solutions proposed by geoengineering.

2.4 Types of data collected: Many different forms of data were collected during the course of this qualitative study. A full list of these is included in Appendix H, which also contains a note of assumptions in data collection and analysis processes.

2.1 The purpose of public dialogue

This report provides decision makers and others who use the findings with qualitative **insight** into the emotions, thoughts and feelings with which the public approach geoengineering.

Public dialogue is a qualitative research method which aims to explore how people conceptualise issues and trade-off different ideas and priorities. It is most appropriately used when:

- The question to be discussed is complex.
- There are a range of disputed points of view on an issue, or a range of different ways of framing a question. These may all be valid, but where different stakeholders may express the core questions or issues differently.
- The public know little about the area under discussion before the dialogue, or, specific technical knowledge is needed before a truly informed view can be expressed.

Key to dialogue is capturing how public perceptions of an issue mutate and shift, as more, and different, information is provided. This enables dialogue to capture both spontaneous, and mostly uninformed, views towards an issue as well as more considered responses and trade-offs. Information can be delivered through the dialogue in a variety of ways, including hard-copy fact-sheets, scenarios, face-to-face contact with scientists and expert-witness films.

Dialogue differs from more traditional deliberative research approaches by bringing scientists, and other experts, directly into conversation with public participants. In practical terms this means scientists sitting around the same table as small groups of participants rather than presenting a one-way flow of information to the room: experts become an ongoing resource for participants. The aim is for participants, as far as possible, to lead the direction of the dialogue and seek answers to the questions they pose so that they can come to their own understanding of the issue.

Many different approaches are used to capture views during such a dialogue. These include small group sessions and presentations, larger discussions, plenary presentations, exercises to complete, homework tasks and questionnaires to gather individual thoughts.

By providing a picture of views of a general public group in the context of the dialogue, it illustrates the principles and priorities which are present in public discourse on the topic. In this way, themes are uncovered which are likely to be important to the public as a whole. These can inform decision making and inspire communications strategies.

2.2 Technical notes on using the results

This report reflects the views of a group who have focused on an issue and been through a range of complex arguments. Their views changed during the process – some shifted and remained shifted at the end, while others moved between different points of view and returned to their original views later. It can be reasonably assumed that the concerns, priorities and principles they express as they go through this process would reflect those of other general public groups, had they the time and space to interrogate the issues.

However, this does not necessarily mean that if particular decisions on geoengineering are taken (for instance, funding certain technologies) that the wider public response will play out exactly as has been seen here, nor is it possible to extrapolate that public views in the wider world are identical to those expressed in the dialogue. This is because, beyond the environment of a dialogue, the context for views is determined by a complex range of factors.

This report does not include quantitative data of a representative sample of the public and is not evidence for the wider general public's views.

It is also important to bear in mind the views expressed by these individuals might change, given a different set of circumstances – for instance, future media and political contexts around geoengineering may create a different context for response.

However, detailed deliberative research such as this does have the considerable advantage (over quantitative surveys) of illustrating the range of opinions present when members of the public are presented with information, and allowed the time to deliberate about an issue.

2.3 Framing the debate: how material was presented

2.3.1 The materials

Appendix C provides details of how and when various pieces of information about climate change, geoengineering and the issues of risk, research and ethics were shared with participants. Appendix C also provides the exercises that facilitators went through with participants. The information given for each technology is shown in chapter 5.

Facilitators did not present materials in order to seek consensus. The discussion was not designed to identify a simple choice of favourite technologies. The aim throughout was to prompt participants to think through and debate some of the issues involved, so that the underlying principles on which they made judgements about geoengineering would emerge.

The technologies were presented in a certain order to the groups and this may have had some impact on how participants viewed them. This is worth taking into account when considering the findings. SRM and CDR technologies were presented with similar levels of emphasis and the same amount of discussion of advantages and disadvantages.

Also, as only four of the nine technologies were discussed in detail at Event 2, this may have had an impact on participants' views and be partly responsible for some changing views between the end of Event 1 and the end of Event 2. The fact that participants were asked to explore a technology of their choice in detail in between the two events may also have had an impact.

2.3.2 Information frames

When interpreting the results from any deliberative research or public dialogue it is vital to consider the way in which information is presented to participants, and most crucially the way in which the content of the information is framed. This has an effect on the ensuing discussions by setting the context for response.

It is important therefore to bear in mind the following ways in which geoengineering was positioned for participants at the start of this dialogue.

- Climate change is a problem involving atmospheric temperature rise, caused by a mixture of CO_2 and other gases. Geoengineering seeks to reduce or reverse its effects or extent.
- Whether humans have caused this problem, or not, was outside the scope of the dialogue.
- There is a wide range of different opinions on the level of impact climate change might have. This leads to many different predictions as to how widespread the impacts might be, and how long it may be before different impacts are felt.

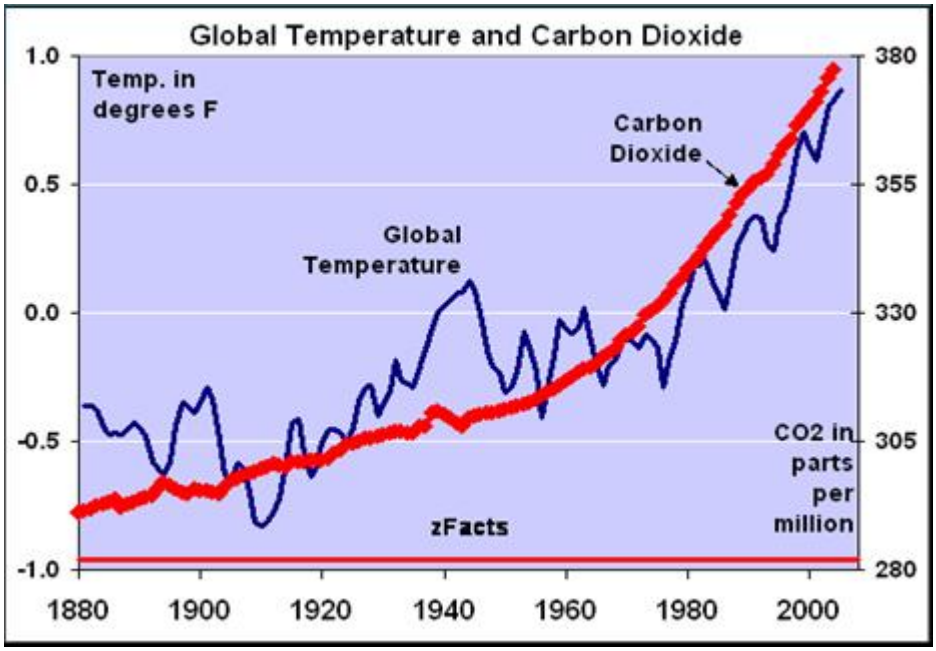
- The detail of mitigation plans was also outside the scope of the dialogue. Geoengineering was presented as a new element which could be added to the mixture of approaches to tackling climate change, which includes mitigation and adaptation. It was not explicitly stated that geoengineering was a 'Plan B' which could be implemented if mitigation 'failed' – but such an implication could be inferred.

- Commitment to mitigation could potentially be threatened by technological solutions proposed by geoengineering.

The presentation and reporting of climate change data is important for the formation of public attitudes about both the severity of the issue and the attribution of responsibility.

Participants were presented with temperature data showing post-industrial warming (see chart below). The absence of longer-term temperature trends on this chart, for instance including the Medieval Warm Period or previous interglacial phases, could potentially have reduced debate about natural cycles and encouraged support for man-made climate change.

Nevertheless, there was challenge and discussion around this chart and participants asked the scientists at their tables in Event 1 many questions about ideas which might contradict the information, such as the concept of global cooling, and questions around recent media discussions of allegedly misrepresented climate data.



The aim of presenting the chart was to point out that both temperature and CO_2 have risen since the Industrial Revolution and to highlight the fact that scientists have concerns about an increase beyond 2°C above pre-industrial temperatures, while avoiding a discussion of the causes of climate change[8]. The majority of participants accepted these pieces of information after discussing it at their tables.

Information frames, however, do not automatically set the direction of debate. Participants are free to choose how far they accept what is offered. For instance, participants partly accepted but partly rejected another frame on information. There was discussion around the idea that mitigation might be threatened by geoengineering. Some participants suggested

[8] Facilitators explained the graph to participants, directing them to note that the graph shows two y-axis scales which do NOT illustrate a causal relationship between the rise in temperature and CO_2, but show that they have both risen over the same period of time.

that mitigation could feasibly increase and become more effective as a result of research into geoengineering.

Also, though facilitators framed all the technologies as equally valid, a large number of participants rejected SRM due to its ineffectiveness at addressing the root of atmospheric temperature rise (i.e. increasing concentration of carbon dioxide).

All other context and frames for the discussion were generated by participants themselves.

2.4 Types of data collected

A vast range of different forms of data were collected during the course of this qualitative study. A full list of these is included in Appendix H, which also contains a note of assumptions in data collection and analysis process.

This report presents the synthesis of all these data. In some cases numerical indications of views from pre- and post-dialogue questionnaires have been included. These are illustrative of the views of a very small sample, rather than statistically valid quantitative findings.

3. Key findings

3. Key findings

SUMMARY

3.1. Awareness of geoengineering was low prior to the sessions. Support for some forms of geoengineering rose during the sessions. The public expressed no absolute reactions against geoengineering approaches in principle.

3.2 CDR technologies were preferred by participants; especially Afforestation and Biochar, which were seen as more natural approaches. Support for Air Capture grew through the events. Support for ocean based methods such as Iron Fertilisation and Liming was low, though after the reconvened event participants were more prepared to consider these.

3.3 SRM was less supported overall, as it was seen not to tackle the root cause of climate change (i.e. increasing atmospheric CO_2). White Roofs were seen as not very feasible, Mirrors in Space as very expensive and risky. Cloud Whitening and Sulphate Particles were more positively received, but were still not preferred by the majority.

3.4 Views of geoengineering were affected by views of climate change and perceptions of the role of mitigation in meeting the climate challenge.

Most participants accepted the need for geoengineering because when they considered climate change in detail, they became concerned that mitigation might not be effective enough.

The reasons why participants became concerned about mitigation were:

- They saw no political consensus on mitigation
- They suspected that individuals would find it hard to play their part if lifestyle changes should be required (themselves included)
- They believed a growing population meant that emissions were likely to rise; hence climate change might progress faster than it can be mitigated.

Participants believed that it is both ethically and practically important to link any new climate change solutions to the continued practice of mitigation.

They asserted that one climate solution would not be enough to tackle climate change. The majority wanted to combine, potentially, several different international geoengineering approaches with international, national and individual mitigation efforts.

3.1 Overall attitudes

Awareness of geoengineering among participants prior to the dialogue was low. On realising the low levels of awareness and knowledge among their peers, some participants mentioned that the general public is unlikely to have heard of geoengineering because it had not been discussed in the media.

Once facilitators introduced the concept of geoengineering to the groups, participants were interested in the idea and were willing to consider the different technologies. There were no initial ‘absolutist’ reactions stating that geoengineering should not be explored. Indicative views taken from questionnaires suggest that support for geoengineering ‘in principle’ rose during the course of the deliberations and this numerical shift is supported by comments made by participants during the process, as demonstrated below.

Table 1 below shows how the participants felt about each of the nine technologies described briefly in chapter one at the end of Event 1 (after they had been given some basic

information about each) and after Event 2 (in which they considered specific scenarios involving one or more of the technologies, and the moral and ethical impacts of geoengineering more widely).

Table 1: Levels of support for geoengineering technologies amongst participants

% strongly / tend to support	End of event 1	End of event 2	Diff
	%	%	+/-%
Afforestation	93	91	-2
Air Capture	**61**	**82**	**+21**
Biochar	**66**	**78**	**+12**
Cloud Whitening	40	41	+1
Sulphate Particles	**21**	**28**	**+7**
Iron Fertilisation	**31**	**18**	**-13**
White Roofs	29	17	-12
Liming the Ocean	23	13	-10
Mirrors in Space	13	13	0

(Note: not statistically valid as base size of c.82 respondents. Movement should be viewed as indicative, only in the case of Air Capture is the increase statistically significant.) Highlighted technologies were those discussed in detail at event 2.

Air Capture became more popular by the end of the second event, with 82% stating that they would 'tend to' or 'strongly' support it. **Biochar** and **Sulphate Particles** also became a little more popular as time went on. Support for **Afforestation** began high, and remained high through the whole process. **Cloud Whitening** remained the most liked of the consistently unpopular SRM methods.

These broad trends also played out in the other strands of the project. In the discussion groups and at open access events, views were very similar to those in the dialogue overall. In the online survey, CDR technologies were much preferred to SRM technologies.

3.2 Views of Carbon Dioxide Removal (CDR)

CDR was preferred overall. The technologies associated with this were preferred at the beginning of Event 1 and support strengthened during the two sessions.

The popularity of CDR options was partly because they were seen as tackling the root cause of climate change, returning the environment to its "*natural*" balance, and because they avoided the termination problem[9] of Solar Radiation Management. The concept of naturalness was a key principle for participants: it will be discussed in detail in Chapter 4.

> "Great value for money, and better for the planet." **Birmingham, Event 1**

However, some misunderstandings persisted which may have skewed perceptions in favour of two of the CDR approaches, **Afforestation** and **Biochar.** In particular, the majority did not fully take on board the land use trade-offs that large-scale deployment of Biochar or Afforestation might require, nor the length of time required for these to make a difference to global CO_2 levels. Scientists and facilitators explained the land use question and the

[9] The 'termination problem' occurs when SRM technologies are switched off, which would lead to a very rapid rise in global temperatures. Therefore, once SRM technologies are deployed they must be maintained until greenhouse gas levels have been significantly reduced.

timescale, but participants preferred to focus on the benefits of this "*natural*" process of carbon sequestration and identified many more positives than they did challenges. This was apparent throughout Event 1 and 2, and in the shorter sessions with other participants, as well as in the online survey.

> "Have more trees in roads and on top of houses." **Birmingham, Event 1**

> "Natural processes so less likely to have unintended consequences on ecosystems." **Online Survey**

Air Capture was also popular. Key benefits for participants were that it could be carried out in a controllable way, on an individual or local level, alongside mitigation, and without presenting global governance issues. However many participants criticised this technology for being "*over-engineered*" compared to more natural processes of tree growth. Some felt it was potentially storing up more problems for the future in the literal sense of capturing and storing CO_2 rather than tackling the cause of emissions.

> "If we are capturing CO_2 are we not just capturing something that will need letting out in the future?" **Cornwall, Event 1**

Participants were wary of **Iron Fertilisation** and **Liming the Ocean**, as they were considered to be risky and unpredictable. The ocean was seen as a sophisticated and fragile system under considerable stress. Participants underlined the need to minimise the 'unknown unknowns' before large scale trials could take place.

By the end of the reconvened event participants were less positive towards Biochar and Afforestation after discussing some of the land use issues around these technologies. Attitudes to Iron Fertilisation and Liming the Ocean softened slightly as participants saw the potential for taking large amounts of CO_2 from the atmosphere with both of these technologies. However, participants continued to stress the unknown elements in these ocean-based technologies and wanted to ensure that any research progressed in slow and cautious steps. It should also be noted that the location and mix of scientists present for the reconvened session (at the National Oceanography Centre) could have contributed to this reduction in opposition.

3.3 Views of Solar Radiation Management (SRM)

SRM was less widely supported than CDR. Participants found it harder to understand the aims of SRM technology and many did not initially believe these approaches would bring benefits. For example, some participants struggled throughout the events to understand not only that SRM does not take CO_2 out of the atmosphere, but that it is not designed to do so. Across all the dialogue events, in the young people's group, and in some of the open access events, many participants objected to SRM on the basis that it did not reduce high atmospheric CO_2 concentrations, but simply masked the cause of climate change.

> "One element is to extract CO_2 and the other is to put a reflective mirror on sunlight. The second one is a waste of time. The problem is CO_2." **Cardiff, Event 1**

Some participants who appreciated the rationale for lowering temperatures were concerned that it would be difficult to calibrate how far the temperature should be lowered using SRM techniques. They argued that lowering temperatures too far could be harmful to agriculture and the environment.

Of the four SRM technologies put forward in the groups, only a small number of participants supported **Mirrors in Space** and **White Roofs**. These technologies were seen by many as unfeasible or unrealistic and participants suggested that both might turn out to be ineffective and poor value for money. White Roofs was not liked because it might not impact climate change enough to be worth the administrative effort of adopting it. Mirrors in Space was criticised because it would require very high financial investment and international cooperation to take it even as far as the field research stage.

Sulphate Particles were considered more seriously as they were seen as one of the more predictable technologies of those presented. Participants were informed that scientists had evidence on the potential effects of sulphates in the atmosphere from volcanic eruptions (such as Mount Pinatubo). This reassured participants that the components had been, to some extent, researched, and made this technology appear less risky. Although the questionnaires filled out by participants before and after the events did not show a statistically significant increase in support for sulphate particles, the tone of the discussions held over the course of the two days suggested support for this technology increased slightly during the events. Many of the facilitators who shared the analysis commented on this during the analysis process. It should be noted, however, that sulphate particles were never the main preference of the majority.

Among the four SRM technologies, **Cloud Whitening** was the best received. Participants found it easy to imagine implementing the technology on a small scale, but with potentially impactful results over a large scale. They felt that the components were natural (for example not changing the ecosystem of the sea by adding additional substances) and it would be easy to turn off. They envisaged that the effect on weather locally would not be dramatic, but that there would be global climate benefits. However many raised questions about the efficacy and feasibility of doing it on a large scale.

These themes were also reflected in the additional sessions and online survey.

3.4 Contextual views of climate change

Participants' overall views on, and understanding of, climate change set the context for how they perceived the case for mitigation. In turn, their views on mitigation, (e.g. how far they felt this solution could meet the challenge of climate change) provided the background for their views on geoengineering. Therefore it is important to understand participant's initial knowledge of climate change, and how their understanding developed during the sessions.

3.4.1 Climate change beliefs

At the start of discussions many participants claimed to be concerned about climate change. For this reason, the geoengineering debate was a welcome topic as participants were eager to think about alternative ways to tackle the problems climate change could cause. The fact that they had been invited to the dialogue appeared to reinforce the idea that climate change is a serious challenge facing the planet.

During event 1, participants heard that climate change is occurring and considered that it already has noticeable effects. The majority of participants accepted the information that was presented to them. A minority in each sub-group disagreed that climate change existed (as might be expected from the balance of views identified at recruitment). These people argued that long-term natural trends might be responsible for global

> "With the weather in our own country, the tsunami, in Chile and the amount of pollution in China, we know something is happening." **Birmingham, Event 1**

temperature changes and considered that the Earth had a natural ability to re-calibrate its systems. There was also some debate about the extent to which anthropogenic activity contributes to climate change.

Judging from the questionnaires, those who were more sceptical about climate change were also less inclined to support geoengineering. Those that believed climate change to be a serious issue were much more positive about geoengineering.

The basis on which participants accepted climate change varied, and views were not always based on scientific data. Participants often formed attitudes towards climate change through personal experience of certain weather events, sometimes conflating weather and climate concepts in their comments. For instance, some mentioned unusually heavy snowfall as evidence of climate change, while others refuted claims of global temperature rise due to 2009's cold winter. People also referred to media coverage of high profile natural disasters, such as the Boxing Day tsunami in 2004 or the recent Chilean earthquake, as evidence for climate change.

3.4.2 Views change when the potential scale of climate change impacts was appreciated

Most participants stated early in the discussions that they believed mitigation would be an effective way to combat climate change. They had heard information about mitigation over many years and from a number of different sources, and for the majority the need for mitigation was an accepted truth.

Most considered that they were already contributing to the mitigation effort. However, there were some gaps in knowledge. It was apparent that many had not considered the scale and scope of the systems that will need to be affected by the sum total of individual actions for mitigation to be successful on a global scale.

The scope of climate change and the potential scale of effects were discussed. Participants' views shifted as they developed a deeper understanding of climate change and had time to reflect on what they heard. Most came to feel that climate change was a very serious challenge. Several views then emerged, paraphrased here:

- **Mitigation might not be enough** so some form of geoengineering might be necessary.
- Mitigation remains essential. So, if the task is so significant as to require geoengineering in addition to mitigation, **geoengineering should be closely linked with mitigation**. This is *ethically* important (so that people do not lose sight of mitigation) and *practically* important (as both strategies should work together and not counteract each other). The implications of this are discussed further in Chapter 6 (6.1.2).
- **One climate change solution is unlikely to be sufficient** (whether mitigation or geoengineering). Many different approaches may be necessary to solve the planet's problems.

These views then shaped the advice that the dialogue participants ultimately gave on geoengineering research and deployment. The majority wanted to **combine (potentially several) international geoengineering approaches with mitigation at international, national and individual levels**. This represents the considered views of dialogue participants after deliberation and also reflects the views expressed in the online survey.

> "Although it is important that we reduce our greenhouse gas emissions, this alone will not be sufficient to prevent the serious effects of climate change, since it will take many decades for this to have an effect on temperatures." **Online Survey**

"We should do both – mitigate and use the geoengineering system. People still need to remember to cut CO_2." **Cardiff, Event 1**

At the open access events, participants did not tend to discuss the issues in such depth, but the same underlying themes emerged in conversations at these events - support for mitigation, yet concern that about its limitations.

"They should increase the use of renewable energy and decrease the use of fossil fuels. This would lower carbon emissions and prevent global warming" **Birmingham Open Access Event**

3.4.3 Beliefs about mitigation

Dialogue participants came to agree fairly quickly in Event 1 that mitigation alone would not be enough. But why were they so quick to believe this?

The information they were given is likely to have contributed to this thought process. Facilitators used background information, which they provided at different points throughout the events, about the potential damage climate change could cause to different aspects of the environment. Presentations in Event 1 included the following points:

- Political will may be needed to create mitigation on a large scale.
- Mitigation may be a challenge for developing nations as it can be costly, and if their economies are reliant on fossil fuels.
- Mitigation may involve lifestyle changes in the developed world.

This may have helped participants appreciate the scale of the issue. However, it was not simply hearing these points that caused participants to doubt whether mitigation will work in time, rather these points seemed to chime with some of the concerns they already had about mitigation.

Some explained that they saw no political consensus, globally, on mitigation, and so believed that it could not happen before large-scale climate catastrophe had already occurred.

Some said that they were keen to make a difference, but they suspected other individuals wouldn't want to make the effort required or did not know enough about the problem. One participant in Cardiff had taken her homework task back to her family, after spending Event 1 thinking a lot about mitigation. She believed her family had been sceptical because they hadn't been exposed to the information she had. Her family also told her that they believed most others were "*even less interested than they were*" in mitigation.

"Head in the sand and maybe a bit selfish." **Cardiff, Event 2**

Others felt an internal tension: while wanting to make a contribution through personal action (e.g. turning off the light) they were concerned that such actions would not make a difference on a global scale.

"It's difficult to know what we can do in our little way." **Birmingham, Event 1**

For some, support for mitigation had limits where personal freedoms would be sacrificed, and many did not want to give up travel by car or by aeroplane.

There were felt to be other challenges facing the world which will make mitigation more difficult. A vocal minority in every dialogue location, and at the open access events, suggested that **overpopulation** is the world's main problem, with varying solutions suggested (with varying levels of seriousness!). These included more birth control (from Birmingham), a 'Chinese policy' of limiting population growth suggested in various places, and taxes on children (suggested by one participant in Cardiff). Participants at the Oxford open access event suggested compulsory birth control for Americans, who were thought to consume more resources than others.

> "The main cause of CO_2 is individuals using CO_2, breathing, cooking. When do we start dealing with population, the main cause of global warming?" **Cornwall, Event 1**

4. Underlying principles

4. Underlying principles

SUMMARY

4.1 The public in these dialogues gave **cautious support to research in geoengineering**, providing their principles and caveats are addressed in future decision-making.

4.2 Naturalness was an important theme underpinning many of the principles. Most participants believed that natural systems are balanced and self-contained and that geoengineering should be considered in terms of how well it preserves natural systems.

4.3 Participants suggested key questions to be applied to geoengineering research:

- **What effect might this have on mitigation efforts?** It was important to participants that geoengineering should not conflict with mitigation and, wherever possible, that it should add to mitigation efforts.
- **How far does the proposed research support "natural processes"?**
- **How controllable is it?** Participants stressed that nature contains complex, amorphous systems (sea, sky, space) in which scientists do not have the right to interfere deliberately without knowing the full consequences.
- **How reversible is it?** The public would support research which progresses in small stages, both to minimise uncertainty, and to ensure scientists retain the ability to 'switch off' a project.
- **How effective is it?** To judge the efficacy of geoengineering, participants asked that scientists weigh up core benefits against costs. They considered two benefits to be most important: the amount of CO_2 removed from atmosphere and the overall global temperature drop. The following different kinds of costs were important:
    - **Carbon cost** (in a cradle-to-cradle [what does this mean?] analysis of the carbon cost of the geoengineering process)
    - **Direct financial cost**
    - **Future cost** (to lifestyle, environments, future generations)
    - **Opportunity cost** (money and energy which could have been spent elsewhere)
    - **Investment burden on UK.**
- **When should it be done?** Participants thought that government and other authorities should set a timetable for action, and should establish when the need for action to tackle climate change becomes urgent (e.g. define a 'climate emergency'). The public should be kept informed, and need to be given data on the efficacy, costs and side effects of any technologies that are researched, as such information becomes available, so they can give or withdraw support.
- **How can it be regulated / done fairly?** Participants recommended an international governance approach and shared responsibility. They stressed that short-term political thinking should be avoided so that geoengineering effects and benefits are distributed equitably across the globe.

4.4 It is important to note that most of these questions combine **ethical** principles with other practical considerations. This reflects the fact that in this dialogue, participants did not see ethical issues as separate from scientific ones.

4.1 Overview

The public participants who attended these dialogue events gave cautious support to further research in geoengineering, providing that their underlying principles and caveats were addressed in future decision making.

In both Event 1 and Event 2, participants suggested the key questions they believed should be asked of geoengineering technologies before researching or deploying them. The themes they chose here revealed their underlying principles.

This chapter synthesises the most important criteria participants felt should be applied to the discussion of geoengineering. This has been done by drawing together all the findings from the project as a whole into the chart in 4.3, below, which shows four aspects:

- **Key criteria:** the questions participants wanted to ask, in their own language,
- **Beliefs:** on which the questions were based and which support the different criteria,
- **Ethical principles:** where these criteria and beliefs overlap with, and were informed by, ethical principles.

These criteria are relevant whether geoengineering *research* or *deployment* is being considered.

Before this synthesis is presented, it is worth considering the key theme of **naturalness** which underpinned many of the principles.

4.2 Naturalness – an important underlying theme

Participants saw nature as a set of balanced systems, which operate together without wastage. They believed the Earth has a natural ability to calibrate these systems. They strongly preferred technologies that enhanced or mimicked processes they saw as natural, such as Afforestation, Biochar and to some extent, Cloud Whitening. These were perceived to work in harmony with the planet, using the self-contained systems which already exist on the Earth, and would not have many side effects. It was felt that "*natural*" technologies would be easier to 'sell' to the wider public because of their natural features. Conversely, ideas which reduced the Earth's temperature by using "*unnatural*" processes (such as Mirrors in Space) were liked less.

Overall, those in Cornwall were most keen to avoid altering natural systems. A larger proportion of participants came from rural areas than was the case in Cardiff or Birmingham, which may partly explain these views.

Across the dialogue events, processes were seen more positively when they were thought to be natural. For example, some felt that fertilising the ocean to grow algae was a less invasive process than adding lime because growing algae mimicked natural biological processes. For others, adding lime was seen as more natural as the chemical reaction used in the technology already exists within nature. The key point here is that the same criterion, naturalness, was used to back up each case, though the arguments were different.

Participants also called for a limit on population, (as discussed in section 3.5.3). These comments reflected the importance of naturalness in their worldview, as they were based on the assumption that there is a natural balance of man with the environment, and that humanity is straining the ability of the environment to cope.

Another understanding of "natural" was in terms of the preservation of a natural environment. Here, aesthetic and environmental criteria tended to become conflated under the heading of naturalness. For example, some participants were concerned that White Roofs were unnatural because birds would not be able to navigate in their natural way (an environmental question). Others felt they were unnatural because traditional or diverse human landscapes would be affected (an aesthetic question).

One participant in Cardiff pointed to a NERC poster and commented that the landscape displayed there was not natural, but the product of centuries of husbandry and agriculture. Nevertheless, the participant argued, it should be preserved. The group agreed that traditional land use, and the ecosystems this creates, should be preserved for both practical and aesthetic reasons.

In the case of Liming the Ocean participants raised aesthetic concerns about the visual impact of new or expanded quarries. The online survey also raised concerns about where technologies would be located and whether they would be eyesores.

Protecting nature was seen as an ethical principle. The range of ethical principles are discussed in more detail in section 4.4.

The theme of naturalness also occurred regularly in the online survey.

Scene described by participant as "not natural"…but still valuable.

However, participants rarely referred to their own lifestyles or life choices and how these may impact on nature.

> "More natural offset methods should be considered i.e. those that mimic natural processes like: reforestation, enhanced ocean mixing, enhanced weathering." **Online Survey**

4.3 Criteria for assessing technology

Key questions to ask of any technology	Participants' underlying beliefs, ethical principles	What they said…
How controllable is it?	**Beliefs:** Nature contains complex systems (oceans, sky, space). We don't fully understand these mysterious systems. Therefore clearly bounded, contained experiments in these environments are easier to imagine and feel safer. **Ethical principles:** We don't have the right to interfere with fantastically complex and delicate ecosystems, if we don't really understand all the variables which might be affected. This could be the start of a slippery slope – interference with natural systems for geoengineering might legitimate other interference in natural systems later.	"Temperamental environment, the ocean, we don't know how to push the iron or lime in, it's hard to know what will happen." **Reconvened Event** "Space is a dangerous environment." **Cornwall, Event 1** "Air Capture is slow to reduce CO_2 but this is a good thing because you can monitor and control it more easily." **Cardiff, Event 2** "Our whole earth depends on sunlight – if we start interfering here, where do we stop?" **Cardiff, Event 1**
How reversible is it?	**Beliefs:** Fear that geoengineering could cause long-term damaging side effects, and that once implemented, nothing could be done to change that. This relates to safety, timeliness and also how controllable the results might be. **Ethical principles:** We don't have the right to act if we don't know the consequences of action into the future (nuclear weapons in the 1940s were given as an example of this, in Cardiff). The longer term the potential impact on people or on the natural world, the less right we have to act. We don't have the right to create uneven consequences across the world so that other people suffer more than us.	"What would the possible side effects be on the oceans...and if it were drastic consequences how easily could it be reversed?" **Reconvened Event, written exercise** "We could stop it, see if weather patterns continue, and research it." **Birmingham, Event 2**

Key questions to ask of any technology	Participants' underlying beliefs, ethical principles	What they said…
How effective is this?	To judge the efficacy of geoengineering, participants asked that scientists weigh up the core benefits against costs. **Benefits** were considered to be the amount of CO_2 removed from atmosphere, or the overall global temperature drop. Participants identified the following different kinds of **costs** as being important:	"The solar management options might help cool the planet down but they don't help solve the problem of taking away the carbon dioxide." **Cardiff, Event 2** "We are all living on this planet so you have to think about everybody, you have to look at what the effects will be not just for us but for people in Africa, the Brazilian rainforest, every inch of the planet." **Cardiff, Event 2** "We should not be making choices for developing countries. They should be involved in making the decision." **Cornwall, Event 2**
Carbon cost	**Beliefs:** Participants assumed that all the technologies they saw would be *somewhat* effective in tackling the key problems of CO_2 and rising temperatures, but that some would be more effective than others. The most important aim of geoengineering was believed to be reversing atmospheric CO_2 across the whole world. Participants wanted a cost-benefit analysis of how effective each technology would be at doing this, in a 'cradle-to-grave' carbon cycle. **Ethical principles:** *not a specifically ethical issue*.	
Direct financial cost, Opportunity cost, and Investment burden on UK	**Beliefs:** Benefits should be considered against both direct financial cost, and also the opportunity cost (i.e. by focussing on geoengineering, opportunities to spend money and resources elsewhere would be reduced) of us carrying out other mitigation measures. We should consider the benefit to the UK of the technology's efficacy set against any investment burden. (Though this is seen as less important than the overall global carbon reduction benefits.) **Ethical principles:** We should value things in different ways, not just take into account economic value, e.g. find ways of valuing social goods or natural environments.	
Future cost	**Beliefs:** We should consider the cost to lifestyle, environments, future generations. **Ethical principles**: We don't have the right to create uneven consequences across the world, so that other people suffer more than us. We don't have the right to act if we don't know the consequences of action into the future. The longer term the impact on people or on the natural world, the less right we have to act. We should value things in different ways, not just take into account economic value, e.g. find ways of valuing social goods or natural environments. We don't have the right to affect others' living environments or animals' ecosystems (or, we don't have the	

	right to do this simply because we want to change them).	

Key questions to ask of any technology	Participants' underlying beliefs, ethical principles	What they said…
When should this be done?	**Belief:** Government or other authorities should provide a clear steer on when we need to *prepare for climate emergency.* Despite the lack of scientific consensus, participants felt that authorities should take the lead on creating a timescale. **Ethical principles:** We don't have the right to act if we don't know the consequences of action into the future. The longer term the potential impact on people or on the natural world, the less right we have to act. Public should be given data on the efficacy, costs and side effects of any technologies which are researched as such information becomes available, so they can give or withdraw support. We should inform people in this country as much as possible about what is being done so that they can get involved in decision making to the best of their abilities.	"Only in a climate emergency – well, what's a climate emergency?" **Cornwall, Event 1**
How can this be regulated / done fairly?	**Beliefs:** Need for international governance and shared responsibility. Need to avoid short term UK political capital made out of geoengineering (programmes changed or stopped in the event of a change of government, for example). Geoengineering research would be likely to have an impact on the taxpayer. Protect research from vested political interests and ensure decisions were made on the basis of the other, important, criteria. Especially at Event 2, participants were somewhat sceptical about the motivations of commercial interests and governments to ensure that the fairest outcomes were achieved. A strong theme in the online survey was the need to create equity across the globe in the way geoengineering effects and benefits are felt. **Ethical principles:** We should include as much of the population of the world as possible in decisions affecting them (though in practice, realpolitik makes this difficult). The rich do not own the planet – and should not be allowed to use all the planet's resources for their own gain. We should inform people in this country as much as possible about what is being done so that they can get involved in decision making to the best of their abilities.	"We need to focus on this as a global problem, it needs to be addressed for the good of the world. We need an apolitical, scientific executive to treat the problem on a global scale." **Reconvened Event**

4.4 Ethical implications

Participants drew on both ethical arguments and practical considerations as they discussed the principles set out in 4.3. Ethical and other criteria were considered as all part of the same discussion by participants. Ethical themes, however, can be drawn out of the discussions. The ethical criteria and themes of most importance to participants can be paraphrased as follows.

Uncertainty of outcomes

1) We don't have the right to interfere with complex and delicate ecosystems if we don't really understand all the variables which might be affected.
2) We don't have the right to act if we don't know the consequences of action into the future. The longer term the impact on people or on the natural world, the less right we have to act.

Inequitable outcomes

3) The rich do not own the planet and should not be allowed to use all the planet's resources for their own gain.
4) We don't have the right to create uneven consequences across the world so that other people suffer more than us.
5) We should value things in different ways, taking into account more than just economic value, such as the value of social goods or natural environments.

Informed, and inclusive, decision making

6) We should include as much of the population of the world as possible in decisions affecting them.
7) We should give the UK population as much information as possible about what is being done so that they can get involved in decision making to the best of their abilities.
8) Scientists undertaking geoengineering need a public mandate to move forward. However, the public who give them the mandate should be informed and be given data on the efficacy, costs and side effects of technologies which are used.

Interference with natural systems

9) This could be the start of a slippery slope as interference with natural systems for geoengineering might legitimise other interference later.
10) We don't have the right to affect others' living environments or animals' ecosystems.

This last principle was contested, however, because the participants pointed out that human living arrangements continually violate this principle. On further discussion, a more nuanced ethical position emerged. This could be stated as – we don't have the right to change the living environment of people or animals, *simply with the aim of deliberately changing them*[10]. If environments are changed or damaged as collateral in the service of another higher aim (for instance, tackling climate change), this is seen as more morally acceptable than setting out overtly to change an ecosystem or living environment.

[10] See note on the morality underpinning attitudes to geoengineering, and the reference to 'trolley problems' in section 6.3.2.

A note on religion

Religious arguments were not used throughout the events as an overt rationale for supporting (or not supporting) geoengineering. While a few participants mentioned in private discussions that faith played an important role in their lives, religious arguments were not brought up spontaneously in the general discussion. In Event 2, a video was shown including a speaker from the Catholic Agency For Overseas Development (CAFOD). On seeing this, a few vocal participants in each group brought up, then immediately disagreed with, the idea that human intervention in planetary ecosystems was against the will of God. *"If there was a God, wouldn't he sort this mess out?"* (Cornwall, Event 2*).*

Some religious participants across the groups then suggested that God was encouraging humanity to take action on climate change, but this discussion tended to end at this point, as participants turned to other questions.

Most participants agreed that people have a responsibility to other people. The ethical arguments which carried most sway from the CAFOD contribution were those around social justice and helping those in poverty. Both religious and non-religious participants agreed that these questions of equity of outcome would be important considerations for geoengineering decision-makers.

5. Technologies in detail

5. Technologies in detail

SUMMARY

This chapter summarises for each technology:-

- Information participants were given by facilitators
- Information which was added by scientists.
- Ideas and concerns generated by participants.

5.1 Shifts in response during the dialogue

Levels of support for individual technologies changed during the dialogue process. Questionnaires administered at the start and end of each event revealed how views changed. They provide an additional strand of data alongside the qualitative analysis and to some extent reflect and support the kinds of comments participants made during discussions at the events. Care should be taken when using this numerical information as the numbers are for illustrative purposes only, and are indicative of the views of a very small sample, rather than reliable quantitative findings.

Participants' changes in opinion are outlined in table 2, below (with those discussed in detail at Event 2 in bold).

Table 2: Changes in opinion amongst workshop participants between Events 1 and 2

	Support Post-event 1 (%)	Support Post-event 2 (%)
CDR		
Air capture	**61**	**82**
Iron fertilisation	**31**	**18**
Liming the ocean	23	13
Biochar	**66**	**78**
Afforestation	93	91
SRM		
White roofs	29	17
Mirrors in space	13	13
Cloud whitening	40	41
Sulphate particles	**21**	**28**

Note: not statistically valid as base size of c.82 respondents. Changes should be viewed as indicative, only in the case of Air Capture is the increase statistically significant. Highlighted technologies were those discussed in detail at Event 2.

In addition to considering each technology on its merits, participants may also have changed their views due to ethical considerations discussed at Event 2, which may not have arisen during Event 1. For example, the decrease in support for Iron Fertilisation and Liming the Ocean may have been due to discussion of international agreements for geoengineering technologies during event 2. Many participants concluded that these would be particularly difficult to achieve when it came to ocean-based technology research and deployment, which might have affected their views of the ocean-based technologies.

Overall, individuals expressed different views at different times. While each participant went on his or her own journey through the materials, there were some typical 'stages' or thought processes. Not everyone went through every stage – and not everyone went through the stages in the same order. Further details of this are noted in Appendix D, which describes how participants communicated and behaved during the three Events.

Those attending the group discussions or open access events did not have the time and space to go through all of these stages.

In the remainder of this chapter, the response to each technology is taken in detail.

5.2 Afforestation (CDR)

"We are balancing the environment rather than unbalancing it with flawed technology." **Online Survey**

Information given

Advantages

- Very cheap
- Addresses the cause of climate change directly.
- Could be implemented in a very short timescale (but would need permission – who from?).
- Process understood so less risk of unwanted side effects.
- Integrated land-use planning, as well as reducing carbon can have benefits for the economy, water regulation, biodiversity conservation and agriculture.

Disadvantages

- Not enough land available to carry out this process on sufficient scale (particularly since global population likely to double) to make a massive difference to global temperatures.
- Political conflicts over land: would compete with agriculture and growing crops for bio fuels.
- Biodiversity may change which may be bad for some species

"It feels like you're doing something good when you're planting a tree." **Cornwall, Event 1**

Participants' questions to scientists

- Scale required: how much land needed to bring down temperatures or make a noticeable effect on global CO_2?
- Feasibility of creating land space needed - where would trees go?
- Would there be local climate impacts, for example greater humidity?

Overall support for research into this technology

Positive initial response as fits with key principle of perceived naturalness. The public would like more political pressure to make afforestation a reality. However, during Event 2 (and even more so at the reconvened event), participants started to consider the land use argument more fully and hence became slightly more negative towards this.

Reasons for support:

- Natural, reversible, good ratio of carbon costs to benefits and little sense of opportunity costs.
- Can be done by individuals as part of mitigation effort. Also can tie in with other geoengineering approaches, such as biochar. Some suggested planting "useful trees" or crops to create multiple beneficial effects. This was very important to participants; afforestation suggests solutions which did not stand alone, but involved individual action from citizens, local effort, mitigation, as well as global solutions.
- Local; individuals and communities could get started immediately, so no regulatory issues.

Concerns: effect on wildlife and biodiversity; potentially ineffective unless done on a very large scale; potentially very slow to remove CO_2

5.3 Biochar (CDR)

"Land will be the biggest problem; we don't have enough spare now."
Birmingham, Event 1

Information given

Advantages

- Lots of waste materials can make biochar; wood, leaves, food waste, straw or manure.
- Adding biochar to soil can improve agricultural productivity.
- When making biochar, bio fuels and bio oils are produced which can be used as a renewable fuel source.
- Relatively cheap.
- A natural process so not much risk of unintended side effects.
- Addresses the cause of climate change directly.
- Farmers could make a profit from selling their biochar.
- Everyone could do it and it can be implemented everywhere.

Disadvantages

- Will require additional energy consumption for transport, burying and processing.
- May disrupt growth, nutrient cycling and viability of the ecosystems involved.
- Doesn't make a massive difference to global temperatures but can be used on a small scale to remove some CO_2.
- May be conflicts over land use with agriculture, timber production and growing crops for bio fuels.
- Not enough land available to carry out this process on sufficient scale (particularly since global population likely to double).

"Natural processes so less likely to have unintended consequences on ecosystems."
Online Survey

"Cheap, like a form of recycling, it's a natural process."
At risk of flooding group

Participants' questions to scientists

- How is it made? How much energy is required?
- Are there any dangerous or volatile emissions? Will it have a detrimental impact on soil?
- Can it be done on a small scale?
- There is a need to store the biochar – where would the space be found for this?
- It is a more high-tech (and therefore more expensive) method than planting trees, but does it have greater benefits to make the increased cost worthwhile?

Overall support for research into this technology

Ultimately, the majority would favour further research into biochar. For some participants, support decreased as land use trade-off was discussed, but the majority would welcome investment in biochar, to be used alongside other approaches.

Reasons for support:

- Natural and high-tech too – helping nature's own processes.
- Good value for money, reversible, and controllable
- Ties in with mitigation efforts and afforestation
- Individuals and local communities can do it themselves without the need for regulation.

Concerns:

- Not enough land available, especially for storage.
- Role of commercial interests and distribution – who profits from this?
- There could be competition between land for biochar and land for other crops – potential for loss of biodiversity.
- If it adds to agricultural activity, this may increase CO_2 emissions.

5.4 Liming the Ocean (CDR)

Information given

Advantages

- Making the water less acidic would benefit marine life and help save coral reefs.
- Will remove some CO_2 from the atmosphere.

Disadvantages

- Expensive and uses a lot of energy - need to pay for mining the limestone, processing and transporting it, all of which also produce CO_2.
- Initial release of CO_2 when limestone is converted to lime.
- Difficult to verify how much carbon has been 'permanently' removed.
- Slow to reduce global temperatures.
- May have unintended effects on ocean ecosystems.
- Would require international agreement and substantial infrastructure building.
- Limestone quarries would be an eyesore.

Participants' questions to scientists

- Would the CO_2 produced by quarrying and transporting the limestone be outweighed by the CO_2 sequestered?
- Is there enough limestone to make this an effective solution?
- What are the adverse effects of lime on people and the oceans? Would sea water continue to be safe?
- Could liming be contained in one place or would it spread throughout the oceans?
- To what extent has this technique been researched to date? How much is known about the impacts on marine life?

"We've already wrecked the atmosphere; we don't want to wreck the ocean too." **Birmingham, Event 1**

"Damage likely to be experienced disproportionately by those directly dependent on marine ecosystems." **Online Survey**

Overall support for research into this technology

Initial concerns were expressed; these were not allayed through the events.

Concerns:

- Potential unknown effects on marine life.
- Would require international regulation, which would be difficult to achieve.
- For most, feels engineered and industrial rather than natural.
- Need to do a lot of it to have an effect; poor cost benefit ratio.

5.5 Iron Fertilisation (CDR)

Information given

Advantages

- Initial small scale effectiveness has been demonstrated using iron.
- Process itself not too expensive.
- Could help increase marine productivity as zooplankton and fish would feed off the algae.

Disadvantages

- May not be that effective in long term since most CO_2 taken up by algae is returned to the atmosphere within a year. Expensive and difficult to quantify how much carbon has been 'permanently' removed.
- Unknown side effects on sea life.
- Effects on marine ecosystems not necessarily beneficial; could result in release of other greenhouse gases.
- Legal framework under development; research currently restricted under international law.
- Results of early tests suggest it may not be as effective as hoped.

"Who would give permission? Who owns the ocean?" **Birmingham,**

"We don't know enough about m life." **Cardiff, Event 1**

Participants' questions to scientists

- Would harmful gases be produced, such as methane?
- Could the iron or algae harm humans?
- Is this the same algae that get out of control in local ponds and lakes?
- Would this process have to go on forever?
- Where would the iron come from?
- Would the CO_2 produced from mining the iron outweigh the carbon benefits of the process?

Overall support for research into this technology

Initial response was very cautious; more positive than liming oceans, but ultimately there are many concerns and participants were very cautious about the idea of large scale field trials.

Reasons for support:

- Slightly more natural than liming as using biological not chemical processes.
- There are potential benefits to marine ecosystem. However these are outweighed, ultimately, by perceptions of unknowns and risks to a complex, uncontrollable system.

Concerns:

- Not easily reversible once begun.
- Difficult to calculate a cost: benefit ratio because the effectiveness of the process is unknown.
- Needs international regulation which is difficult to achieve.
- Could be a slippery slope to tampering with many other areas of nature.

5.6 Air Capture (CDR)

Information given

Advantages	Disadvantages
▪ Potentially could remove thousands of times more CO_2 than a real tree. ▪ Can be placed anywhere, even underground, and would not require international agreement. ▪ Safe and should not have any bad side effects (although CO_2 storage has risks). ▪ Would operate 24 hours a day but could be switched off easily if something went wrong. ▪ Easy to measure the amount of carbon captured.	▪ A lot of infrastructure is required for construction, maintenance and removal, with energy needed to drive the process. Could be more efficient to use that energy to meet primary needs, and not to release the CO_2 in the first place. ▪ Would be slow to reduce global temperatures. ▪ The capture devices may be an eyesore and could take up land space. ▪ There are not many places to store CO_2 underground.

Participants' questions to scientists

- How long will the 'trees' last and what maintenance/monitoring is required?
- How much energy would be required to power the 'trees'?
- What is the process by which CO_2 is captured?
- Where should these be sited? Would there be health benefits for those living near them? Would it be better to have them next to large emitters of CO_2, e.g. factories?
- How big would they be? What would they be made out of?

"Seems less likely to affect biodiversity in contrast with other ideas such as cloud or ocean seeding with particles." **Online Survey**

"The landscape will be ruined...It's rather like wind farms – they make a mess of the countryside, stick them out at sea." **Birmingham, Event 1**

Overall support for research into this technology.

The public warmed to this technology during the course of the events. There was a very clear call for air capture and carbon capture and storage to be connected to mitigation efforts.

Reasons for support:

- Individuals or nations could do this alone – no need for regulation.
- Focuses attention on mitigation; by having this on every street corner, it helps us see that the problem and solution is all-pervasive.
- For some, the idea of replacing CO_2 in mines has a natural feel. Although some discussion of whether it would be better to plant real trees rather than create artificial ones.
- Controllable solution which can be easily turned on and off within minimal impact on the natural environment.

Concerns:

- Visual appearance and potential noise.
- Safety of CO_2 storage.
- Seems a rather wasteful or 'end of pipe' solution; allowing carbon to escape and then capturing it again.

5.7 Sulphate Particles (SRM)

Information given

Advantages	Disadvantages
▪ Effective at lowering temperatures. Injecting sulphate particles every one to four years would have the same effect as a volcanic eruption. ▪ Works fast - could start lowering temperatures within a year. ▪ Relatively inexpensive. ▪ Computer models suggest that the sulphate layer would reduce temperatures. ▪ Can be turned off quickly - in one to two years.	▪ Requires constant input - If you suddenly stopped the world could get hotter very quickly. ▪ Effects would only last a few years so have to be repeated which would cost more. ▪ Uncertain side effects- may affect the climate/rainfall and lead to droughts. ▪ Requires international agreement. ▪ Could damage the ozone layer and high altitude clouds. ▪ Does not solve the problem of ocean acidification.

Participants' questions to scientists

- Where does the sulphur come from and where does it go afterwards?
- Given the expense of obtaining the sulphate, transporting it and then dispersing it, is this a financially viable option?
- Is there a risk of cooling too much? What if a volcano erupts at the same time?
- Would this increase acid rain?
- Would this affect human health?

"It's not a solution it's a sticking plaster." **Birmingham, Event 1**

"What happens if a volcano erupts as well?" **Cornwall, Event 1**

Overall support for research into this technology.

Some gradual increase in approval for this technology as events progressed, though it was never popular among participants**.**

Reasons for support:

- Potential for this to be a very useful technology to bring temperatures down suddenly, a "quick fix".
- It was felt to be controllable compared to other SRM technologies, as easy to switch off.
- Would be effective.

Concerns:

- This, as with all SRM, is seen as less effective than CDR as it does not address the cause of temperature rise, i.e. rising atmospheric CO_2 concentrations.
- Moral hazard – if this is in place, it may stop people mitigating.

5.8 Cloud Whitening (SRM)

Information given

Advantages

- Could start reducing temperatures in a short time period.
- Easy to turn off if there's a fault.
- Cloud formation occurs naturally so this enhances a natural process that is fairly well understood.
- Not too expensive.

Disadvantages

- We do not know how expensive it is likely to be.
- It may not be very effective at reducing temperatures.
- Effects may only last a few weeks so it would need to be carried out repeatedly which would cost money and take time.
- It may have unwanted effects on the weather and sea-life, particularly in areas where cloud spraying occurs as it can cause a large local drop in temperatures.
- If regional weather patterns are adversely disrupted, who pays compensation?
- Does not solve the problem of ocean acidification.

Participants' questions to scientists

- Will we need to use carbon to generate this – in which case is there a negative carbon benefit?
- Who would be in control of it and who would pay for it?
- How quickly could we get this up and running; could it be able to help us avoid a climate emergency? Can it be switched off once the process is started?
- Impact on sea life and potential knock-on effects on plants and wildlife on land?
- Effect on the weather? Will there be uneven consequences, for example monsoon season changes?

"Would this lead to an increase in rainfall?"
Birmingham, Event 1

"Sea water is more natural than other things, rather than chemicals."
Cornwall, Event 1

Overall support for research into this technology

Ultimately participants felt it would be worth investigating in small scale trials; but were concerned about progressing to large scale trials in case of unexpected and complex effects on global weather patterns.

Reasons for support:-

- Sea water is natural so is not introducing pollutants to an ecosystem.

Concerns:-

- Expensive approach.
- Uncertain about effectiveness.
- Increased clouds would block out sunlight.
- Many were concerned about the effect on daily life, agriculture and tourism.

5.9 Mirrors in Space (SRM)

Information given

Advantages

- Would work immediately once implemented, so could be used in a climate emergency.
- Would be effective, making a big change to global temperatures.

Disadvantages

- Relatively expensive.
- Would take at least several decades to develop the technology and to put the reflectors into orbit.
- May have an uneven cooling effect where the tropics get cooler but the polar regions get warmer.
- Could have unpredictable and undesirable effects on weather systems.
- May reduce plant production (crops and natural ecosystems).
- May not be easily reversible.
- Fears over weaponisation.
- Requires international agreement.
- Does not solve the problem of ocean acidification.

Participants' questions to scientists

- Could it change global temperatures too much? Is it dangerous to block out the sun? Would the effect be like an eclipse?
- How reversible is it? Could the mirrors be moved?
- Who would own the mirrors, and what would happen if a rogue state decided to use these as weapons?
- How fair would the cooling effect be – would it be uneven?
- What would be the effect of reduced sunlight on crops?
- How much energy would it take to produce the mirrors and launch them into space?

"I think this could be a last ditch solution if all else fails but it does smack of desperate measures." **Online Survey**

"How do you get everyone, all countries, to agree?" **Cornwall, Event 1**

Overall support for research into this technology.

Initial interest in this very high-tech solution gave way to concern over high costs and a high degree of uncertainty over potential effectiveness.

Concerns:

- Sounds "scary", dangerous and certainly not natural.
- It would require international regulation which would be extremely difficult to secure.
- Does not reduce CO_2 levels so no carbon benefit.
- Would take a long time to develop making it inappropriate for helping us avoid climate emergency.
- Expensive.

5.10 White Roofs (SRM)

Information given

Advantages

- Quick to implement.
- Technically easy to do.

Disadvantages

- Global-scale effect insignificant.
- Only effective if scaled up thousands of times (e.g. cover the Sahara desert).
- In temperate regions more heating would be required in winter.
- Better to capture solar energy – to replace fossil fuels.
- Does not solve the problem of ocean acidification.

Participants' questions to scientists

- Would this make much difference in the UK?
- Would this be left to individuals to do? How would it be regulated?
- Would it be safe? Would there be repercussions on sight?
- How would this effect the natural world? What would be the impact on animals?

"Would this just be in hot countries? Where would it be most effective?" **Cornwall, Event 1**

"Lots of reflection, would we all need to wear goggles?" **Birmingham, Event 1**

Overall support for research into this technology.

Seen initially by some as a simple but ingenious idea, however as this was discussed further the majority found many reasons why this would not be feasible (practically, financially and politically).

Concerns:

- Regulation could be difficult – how would individual homeowners be incentivised to do this?
- As it is an SRM technique, it does not reduce CO_2 levels.
- Lack of certainty about effectiveness - participants believe that this either will not work at all and be inappropriate in the UK – or would work too well, and we will spend more money, and produce more CO_2, heating our houses.
- Not cost-effective.
- Global effects on natural ecosystems such as desert animals.
- Safety concerns – glare could cause traffic accidents.
- Will need renewing regularly.
- Aesthetics – not appropriate for the traditional landscape in the UK.

6. Recommendations

6. Recommendations for research funders, science users and communicators

Recommendations from this study for NERC and other research funders and decision-makers are to:

1. Take account of the results of this study when discussing geoengineering priorities in future. In particular, recognise that information about the public's opinions and understanding of a subject can complement and support information from scientists and policymakers in the decision-making process.
2. Ensure future plans for geoengineering research and deployment take place in the context of the continuing need for mitigation, considering the moral hazard and opportunity costs faced in research decisions.
3. Consider participants' concerns around perceived '*naturalness'* in discussions about future geoengineering research and deployment.
4. Take account of participants' specific concerns that geoengineering research and deployment, as shown in Table 3 (page 56) above, should be assessed in terms of *controllability; reversibility; effectiveness in terms of costs and benefits; timeliness; and potential for fair regulation.*

Recommendations for future public engagement on geoengineering research:

5. Continue to engage the public with geoengineering research, as requested by participants in this dialogue. Dialogue should be an on-going process, as public opinion is dependent on context and will change over time. Dialogue may also be required at different stages of research and deployment, to engage the public on specific issues relating to different technologies.
6. Keep the public informed about the efficacy, costs and side effects of any technologies that are researched, as research progresses and as such information becomes available. This helps the public to stay involved in the decision-making process, and ensures that their views are based on the most up to date information.
7. Further dialogue activity should include people from the developing world, and scientists from all over the world.

Recommendation for communicating climate science:

8. Future science communication activities on climate change, including any future geoengineering dialogue, should take account of the 'Communicating Climate Science' findings in this report. These include: public awareness of climate science and the scale of climate systems, communicating uncertainty, trust in science, awareness of how science is done, and differences between the 'scientific' view and the public view of issues.
9. There is also a need for further dialogue on the subject of 'naturalness' to establish what this term means to the public (see recommendation 3, above) and explore public attitudes to, and scientific understanding of, the role of humans in natural systems and interactions between humans and the environment.

6.1 Recommendations for NERC and other research funders and decision makers

6.1.1 Take account of public attitudes

Research funders and decision makers (including those from industry and government) should take account of the public attitudes expressed in this dialogue. During the discussion, while preferences for one technology or another changed, the principles that participants used to think about the benefits of geoengineering did not. So, decision makers can use the principles set out in chapter 4 of this report as a way of structuring thinking about geoengineering technologies in future. This may help scientists and others understand how the public see the question of geoengineering.

At the end of the day, participants were happy to leave the actual decisions on geoengineering to the experts. Participants felt they lacked the necessary technical knowledge to make final decisions and, as participants became more aware of the complexity of the issue, the more they felt experts should take ultimate responsibility for decisions. This may be why, in their homework tasks, many considered 'public acceptability' the *least* important criterion to consider when scientists are making decisions on geoengineering.

If the public did need to be involved in decision making, participants suggested that decisions be taken democratically, to share the weight of the decision across society as a whole.

> "We're depending on the scientists; we don't have enough information today to make up our minds." **Cornwall, Event1**

> "Are they going to ask the public to vote on this? We don't have enough information." **Cornwall, Event1**

Some respondents who identified themselves as scientists in the online survey also cautioned that the role of the public should be to inform the gathering of information rather than to take a more active role in decision making.

> "Working now in science communication I think there is good value to this method, engaging and empowering the public, but whilst I hope it does feed into funding decision making, I hope it won't limit blue-sky research too much. There is a limit as to how well the general public can understand very specific research areas and their value." **Online Survey**

Recommendation 1: Research funders and decision-makers should take account of the results of this study when discussing geoengineering priorities in future. In particular, recognise that information about the public's opinions and understanding of a subject can complement and support information from scientists and policymakers in the decision-making process.

6.1.2 Set geoengineering in the context of mitigation

Participants wanted mitigation and geoengineering to be closely linked. They were keen for new technologies to work with existing ones to maximise efficacy. They also wanted to avoid a particular moral hazard - that investing in geoengineering activities might distract attention from mitigation.

For participants, the ideal project was one where geoengineering and mitigation were designed to interact together, for instance Bio fuels and Biochar; or Solar Panels and Air Capture. A further example was that Air Capture should be incorporated into the design of new 'cleaner' factories.

Participants felt that the wider public are now aware of mitigation. They felt that most people see reducing emissions as something they can take part in. On the other hand, participants believed there is still a need to increase public support for mitigation.

Poster designed by participants at the Reconvened Event.

Several key benefits of linking geoengineering with mitigation were identified by participants.

Support for geoengineering might be increased by drawing on already-established public goodwill towards mitigation.

Efficacy of mitigation might be increased by technologies that draw new attention to it.

Linking geoengineering and mitigation would ensure that we are using the most effective method to solve climate change, rather than doing counter-productive things. For example, participants found the idea of emitting greenhouse gases, then expending more energy to remove them again, very wasteful, and said that it would not be sensible to put effort into removing them without also putting effort into mitigating them.

> "[Air capture without mitigation] is like getting a rabbit, letting it go, and then catching it again. Why not just not let it out in the first place?" **Cardiff, Event 2**

Support for Biochar and Afforestation was strong partly because these were seen as the closest geoengineering could get to mitigation. Participants could imagine how these approaches could help people move towards more sustainable lifestyles.

This also emerged strongly in the online survey:

> "Geoengineering should not be an alternative to living more sustainably, this is the only real long term solution." **Online Survey**

Some participants at the events even recommended that geoengineering projects should incorporate a mitigation element as a *condition* of obtaining funding. While participants did not necessarily expect this level of regulation to be achieved, the fact that they suggested this underlined how strongly they felt about mitigation.

This was echoed in the open access events, where comment cards often linked geoengineering research with individual action on mitigation.

> "International consortium for geoengineering overseeing it. Research into technologies. Education for joe public as to what they can do."
> **Oxford, Open Access Event**

This all means that the public may not be supportive of geoengineering projects which seem to contradict or ignore mitigation efforts.

Recommendation 2: Ensure future plans for geoengineering research and deployment take place in the context of the continuing need for mitigation, considering the moral hazard and opportunity costs faced in research decisions.

6.1.3 Consider the way the public thinks about "Naturalness"

As discussed in section 4.2, the idea of "naturalness" was one of the most important considerations for the dialogue participants, and underpinned many of the other principles they used. Scientists who wish to communicate with the public on geoengineering may need to consider the language of naturalness, and the underlying worldview it implies.

The public seemed to place a different value on efforts to change the climate carried out *deliberately*, and changes to the climate which have happened *accidentally* as a result of other human activity. While accidental changes to the climate are not seen as 'natural', they still feel more 'natural' than deliberately changing the climate. It will be important to understand this thinking when engaging with the public in future discussions of geoengineering.

Not everyone explicitly referred to the difference between accidental and deliberate changes, but this idea underpinned a range of arguments used in the discussions.

Participants seemed to be drawing on an ethical framework which has been best expressed in 'trolley problems'[11]. Trolley problems are ethical thought experiments in which the majority of people tend to draw a distinction between two sorts of harm. The first is causing deliberate harm, which is seen as immoral, and the second is causing accidental harm as an unfortunate side-effect of helping others. This second kind of harm is seen as more morally acceptable.

One view of 'naturalness' expressed in the dialogue was that it reflected the world pre-industrial revolution, but also reflected the world of today (after some industrialisation, but before any geoengineering efforts to change the planet). Participants saw a difference between pollution from industrialisation, which was seen as accidental harm, inevitable, and part of the 'natural' process of working the land and humanity's life on the planet. Deliberately intended climate change felt very different. It was seen as morally worse.

[11] First introduced by Philippa Foot and further developed by Judith Jarvis Thomson, these thought experiments posit situations where bystanders can act to save lives of five people stuck on the track in front of a runaway train. In the first instance, the bystander can switch the points, but thereby killing one other person who is standing on the second track to which the train is diverted. In a development, the bystander can push a fat man onto the track and save the five. The majority of people, when presented with this, are comfortable with turning the switch, indirectly killing one to save five but refuse to push the fat man themselves as this would be causing deliberate harm.

"Doing something deliberately is different from doing it accidentally."
Cardiff, Event 2

This perception of the world is interesting for those wishing to communicate with the public about geoengineering. It is interesting because it is, potentially, different from the way scientists might make the case for geoengineering. Participants at the events tended to assume that the world as it is today is the (natural) norm, and that geoengineering would destabilise that norm. The scientists and other experts who engaged with the public took a different line. Many believed that some current existing 'geoengineering' effects are caused by industrialisation, and so they saw the world as already changed by human activity – not 'natural' any more.

Similar discussions were heard in each location, where scientists explained that we have been manipulating the climate for a long time only to be contradicted by participants, who claim that this is not the issue, or deny that this provides a rationale for geoengineering. Even at the reconvened event, two or three exchanges of this sort were noted, where it appeared that scientists and the public were speaking at cross purposes – even, sometimes, frustrating each other.

Gen public: We shouldn't do experiments which will leave the planet in a state.
Scientist: How about when we burned all that coal and oil - that was a geoengineering experiment in itself!
Gen public: That wasn't an experiment, that was necessity.
Scientist: But we have been changing the climate...
Reconvened Event

Geoengineering decision makers, and communicators, should take these underlying ideas into account when working with the public.

Recommendation 3: Consider participants' concerns around perceived 'naturalness' in discussions about future geoengineering research and deployment.

6.1.4 Take account of participants' specific concerns

While debating the principles, participants gave many examples of ways these could be applied in practice. Their suggestions are summarised in table three below. Participants did not necessarily expect decision-makers to implement these ideas wholesale. However it is useful to read these suggestions, as they will give decision-makers a sense of the kinds of constraints that participants felt should be placed on researchers and their projects.

Table 3: Participant suggestions for implementation of geoengineering

Key question to ask	What participants thought ought to happen
How controllable is it?	If field trials have to take place within a complex, unbounded system, such as the sea, it should be a condition of the research that as much learning as possible is taken from the findings before researchers are permitted to move on to any larger scale trials. Research in these unbounded systems should only be funded if as many uncertainties and risks as possible are removed before starting. This might involve, for example, requiring components to be tested separately before research progresses to field trials. Some participants suggested that individuals, governments and communities could take responsibility for a specific project with controllable effects, and monitor these effects carefully. This would be applicable to Air Capture and Biochar implementation at a local level, for example.
How reversible is it?	Researchers should set clear goals and expectations for the research before it takes place; setting out how long it might take to see effects, either positive or negative, and what the contingency plan would be in the case of negative effects. Researchers should identify any unintended consequences as soon as they occur, and make them public. Participants were concerned that negative effects from trials might be ignored, and felt that information should be shared openly. Where possible, research should be staged so that information to minimise uncertainty can be learned from smaller-scale projects and applied to larger scale projects.
How effective is it – what's the cost/benefit analysis?	Researchers and decision makers should calculate, as far as possible, costs and benefits before starting. They should consider the costs and benefits on the widest possible scale. In particular they should consider how long the effects of geoengineering approaches on ecosystems might last.
When should it be done?	Decision makers should gather as much information as possible about when climate emergencies might happen, to help them weigh up the risks and balances of research into geoengineering. Participants acknowledged that there is much uncertainty around predicting the future of climate change, but they wanted efforts in this area to continue.

How can it be regulated / done fairly?	There should be independent, global-level discussions about the pros and cons of geoengineering. Participants envisaged an ideal situation where an independent global group would draw up regulations and take decisions. They also felt that the UK government should lead the way in geoengineering, and would support bold investment decisions from the UK if decision makers can argue that such investment is timely and necessary.

Recommendation 4: Take account of participants' specific concerns that geoengineering research and deployment, as shown in the table above, should be assessed in terms of *controllability; reversibility; effectiveness in terms of costs and benefits; timeliness; and potential for fair regulation.*

6.2 Recommendations for future public engagement on geoengineering

6.2.1 Continue to engage the public

The participants enjoyed taking part in the dialogue events and felt they had learned something new (see box to right for views after Event 2). The vast majority of those at the reconvened event also gave very positive feedback. For example:

"Thoroughly enjoyed and most informative"
"A learning curve"
"The chance to talk with experts and get facts"
"A feeling that the general public's opinion will be very strongly considered"
"Very enjoyable, professional and interesting".

Enjoyed taking part: 97% agree
Agree strongly 71%
Tend to agree 26%
Neither agree/disagree 3%
Tend to disagree 0%
Disagree strongly 0%

Learnt something new: 99% agree
Agree strongly 63%
Tend to agree 36%
Neither agree/disagree 1%
Tend to disagree 0%
Disagree strongly 0%

Scientists also found the public dialogue useful and several stakeholders and scientists mentioned during and after the events that they had absorbed some different ways of looking at the issues, from speaking with the public. They felt they had picked up overarching themes which were important to the public, specific learnings relating to different technologies and, importantly, a general feel for how the public understood the issues.

"I've never seen this kind of event before – I found it really interesting and am very impressed by the speed and effectiveness with which you've come to terms with the issues. I am struck by lack of faith in the governance institutions and humbled by the faith in scientists." **Birmingham, Event 1**

"There is always an opportunity cost, for example to choose to have a dialogue about geoengineering or to do another piece of research. I am more convinced it is worth doing after sitting in on today." **Stakeholder participant, Reconvened Event**

Wider public acceptance, both for geoengineering and for other climate change solutions, may depend on how the challenge of climate change is framed in the media at the time of the discussion. This framing is not entirely within the control of policymakers as it exists partly in the media and the general social discourse on the topic. It is important for those talking about climate science and geoengineering to understand the impact these frames will have on public views.

Participants acknowledged that the way they are engaged might have to evolve and change over time. For instance, they suggested negative side effects from geoengineering technologies might create a 'backlash' in public opinion which would affect the way the discussion might unfold. While opinion was split on the best way to handle this, most eventually agreed that a policy of honest transparency would be the best approach, giving the public information about new findings from research as it emerged. Scientists involved in geoengineering should be clear about the potential benefits and detriments of research and deployment, and should give the public the chance to comment on this as more information becomes available.

"Cautious progression, with lots of media coverage so we can see what's going on." **Cardiff, Event 2**

Recommendation 5: Continue to engage the public with geoengineering research, as requested by participants in this dialogue. Dialogue should be an on-going process, as public opinion is dependent on context and will change over time. Dialogue may also be required at different stages of research and deployment, to engage the public on specific issues relating to different technologies.

6.2.2 Keep the public informed as things change

Overall, participants were keen that the public should continue to be involved in the discussion of geoengineering. As mentioned in the table above, they wanted to be informed when additional scientific information is discovered and given the opportunity to discuss risks and uncertainties of projects as they progress.

Recommendation 6: Keep the public informed about the efficacy, costs and side effects of any technologies that are researched, as research progresses and as such information becomes available. This helps the public to stay involved in the decision-making process, and ensures that their views are based on the most up to date information.

6.2.3 Engage the whole world

Public consultation was felt by participants to be an important future strand for ongoing discussion. In particular, it was mentioned throughout the dialogue - in events, at open access events, and in the online survey - that the field of consultation should be wider than just participants in the UK, drawing in and consulting more groups globally. This was felt to be important in order to promote social equity – given the global effects of climate change and geoengineering - by empowering and including people whose voices may otherwise not be heard. Scientists who take part in a public dialogue including people from the developing world may be better equipped to take into account issues of global "*unevenness*".

"Comments on the exploration of the issues need to be far more wide, embracing far more dialogue/ survey perspectives than are available to scientists based in developed nations." **Online Survey**

Secondly, and of equal importance, participants were keen to ensure that global scientific knowledge is drawn together to avoid *"reinventing the wheel"* and to ensure that global governance develops at the same pace as technological capability.

"[At Event 3 will we be talking to] British scientists... or is there an international element? If it's just British scientists will their findings be shared with other countries?" **Birmingham, Event 2**

"I think you should talk to China and Russia and India who have clever scientists." **Oxford, open access event**

Recommendation 7: Further dialogue activity should include people from the developing world, and scientists from all over the world.

6.3 Communicating climate science

The geoengineering dialogue gave some evidence of the range of views which exist across the general public about issues to do with science and climate change. While it is impossible to generalise about how far these views are prevalent in the public as a whole, or to quantify them, it seems likely that some of these issues may come up for those who wish to communicate on science. This last section, then, has some useful thoughts and themes for science communicators.

Recommendation 8: Future science communication activities on climate change, including any future geoengineering dialogue, should take account of the 'Communicating Climate Science' findings, set out below.

These include: the range of public awareness of climate change, particularly its scale, urgency and levels of uncertainty, trust in science, awareness of how science is done, and differences between the 'scientific' view and the public view of issues.

Participants had questions around how, ultimately, scientific research can "prove" things, or how it can minimise uncertainties. Communicators may need to explain scientific timescales and processes.

For example, many participants did not know, at the start of the events, how it would be possible to interrogate atmospheric data from beyond 200 years ago. They therefore lacked trust in the accuracy and robustness of climate models and projections. Many of these attitudes were rooted in a gap in understanding of the scientific method itself.

> "There are always new theories coming along to discredit past theories, you never know what's right" **Cornwall, Event1**

As a result participants tended to start the discussion about geoengineering at the point of *deployment* rather than thinking through the practical, moral and ethical implications of *researching* these technologies. When prompted to consider the initial research phase, many participants struggled to understand the distinction between different scales of field trial. Some participants assumed that computer modelling would be sufficient.

The reconvened event was structured differently to attempt to address these issues. At this event, the public could hear scientists present different types of research scenario. This allowed the scientists to explain more about how scientific research is conducted. Following this, participants found it easier to grasp the scale of the problem and tended to leave the event more aware of the various different stages of scientific research.

This highlights the fact that for the general public, scientific research itself may need explaining if geoengineering research is to be discussed.

It should be noted that some participants at each dialogue location claimed they were shocked that the technologies presented were *"all that scientists had come up with*". This implies that some of the general public may have significant expectations of science and might expect idealistic solutions. For example, with regards to Air Capture, some participants questioned why the captured CO_2 could not be released outside of our atmosphere. Others questioned why we could not capture more energy from the sun from space, or why we could not use energy from volcanoes to power our society.

There may be a need to manage public expectations of scientists at the same time as explaining the expert knowledge that scientists have, and the rigorous processes that science demands.

From the small number of people in this dialogue, some had high levels of scientific education and knowledge, and interrogated the resources they were given very rationally and comprehensively.

> "The graph showed 100 parts per million in 200 years and a 1 degree increase in temperature. How will it affect us? Should we really be concerned...2 degrees?" **Cardiff, Event 1**

On the other hand, others held different 'mental models' of how the world works. These models were often internally consistent, but sometimes not supported by accurate scientific information.

> "My degree is in Environmental Science and I don't feel it's a subject that's accessible unless you are in the academic area... I would like to think I look at specialist websites but I don't! I came here today as I wanted to learn about it and immerse myself." **Cardiff, Event 1**

> "When you say CO_2 what does that mean? And what's carbon dioxide?" **Cardiff, Event 2**

The general public who have not been to these sessions, may start from a comparably wide range of viewpoints. Because levels of education and knowledge about science are likely to vary across the public, there may need to be a range of different ways to communicate about science overall, to make sure everyone can access the information.

6.3.2 Varied levels of understanding of how the climate works

Starting with the very basics of the components of the climate system, a large number of participants at the dialogue events did not have a complete understanding of what carbon dioxide (CO_2) is, and where it comes from. Future engagement activities may need to discuss this with the public before considering more complex issues.

Participants understood that human activities such as burning fossil fuels produce carbon dioxide but they did not understand the role of CO_2 in the atmosphere and what 'sequestering' it really involved.

> "I can't see how we're going to get rid of CO_2, if we are capturing, holding CO_2 are we not just creating waste that has to be dealt with in the future?" **Cornwall, Event 1**

This lack of understanding led to questions about why excess CO_2 could not simply be destroyed or 'neutralised' so that it no longer posed a threat to the atmosphere. When participants then considered the merits of different geoengineering technologies, this left them seeking an ultimate solution which entirely removed CO_2 from the system. If the wider public have similar gaps in their knowledge, this may lead to misinterpretation of some of the proposed benefits of SRM approaches.

Certain processes within the climate system needed careful explanation during the dialogue, such as the link between temperature rise and CO_2. The concept of an equilibrium point (at which CO_2 concentrations are at an appropriate level to sustain life, but are not sufficiently high to increase temperatures to an unstable level), was not immediately comprehended by everyone. Many participants raised concerns around removing "too much" atmospheric CO_2 and wanted to understand the risks and impacts associated with that.

> "How do you make sure it doesn't go too far? It's not an instant thing it takes a while, how do you know down the line if you've gone too far?" **Birmingham, Event 1**

The rationale for focusing efforts on reducing CO_2 emissions was also, therefore, not well understood. Many were not familiar with the relative importance of different greenhouse gases in terms of their atmospheric concentrations and their irradiative forcing potential. This led to queries around the absence of methane, and in a few instances water vapour, in discussions around greenhouse gas emission reduction targets.

These details of the most commonly-misunderstood aspects of climate science may be useful to communicators.

6.3.2 Varied language used when climate change is discussed

Throughout the dialogue, the term "global warming" was more familiar for participants than "climate change" as global warming was associated with negative changes to the climate, driven by human activities. Climate change seemed a more abstract concept, and also tended to be associated more with long-term natural fluctuations, so seemed a less urgent issue for participants.

The issues of pollution and ozone layer depletion were also seen as synonymous with climate change. This was particularly apparent in the Cardiff open access event, where children immediately called out "pollution!" when asked what they associated with climate change.

The young people's group in Birmingham explained that at school they use the expression "global warming" rather than "climate change", gathered from science and geography lessons. When asked to give examples of climate change, they mentioned polar bears and other animals becoming extinct, the ice caps melting, and the greenhouse effect. Their language assumed the role of humankind in this.

Though this dialogue included only a small number of children and young people, the results suggest that young people may be more inclined to recognise man-made climate change. This would make an interesting topic for further reseach.

Overall, this report recommends that language should be carefully considered when science communicators address climate change.

6.3.3 Varied levels of understanding of climate change scale, impacts, risks and uncertainties

Although there was a general acceptance of the existence of climate change, the likely scale of its impact seemed more difficult to communicate.

Many participants found it hard to envisage the scale of elements of the climate system, and the implications of change in that system. For example, changes to parts per million of gas were hard to imagine, as was the impact of a two degree temperature rise on life in Britain.

> "What is the impact, 2° temp change doesn't sound too bad?"
> **Birmingham, Event 1**

> "Birmingham is landlocked so the chance of ocean rising doesn't really affect us here. It's one of the places least affected."
> **Birmingham, Event 1**

Overall, participants tended not to relate climate change impacts to their own personal lives. And when people did perceive the problem as a personal threat, their attention turned to similarly personal ways of tackling the problem (i.e. everyone should recycle, reduce car use and take fewer flights).

The potential urgency of the issue was also not immediately obvious for participants. Many people mentioned a concern for future generations if climate change was allowed to continue unchecked, however some did question the extent to which this was a likely outcome.

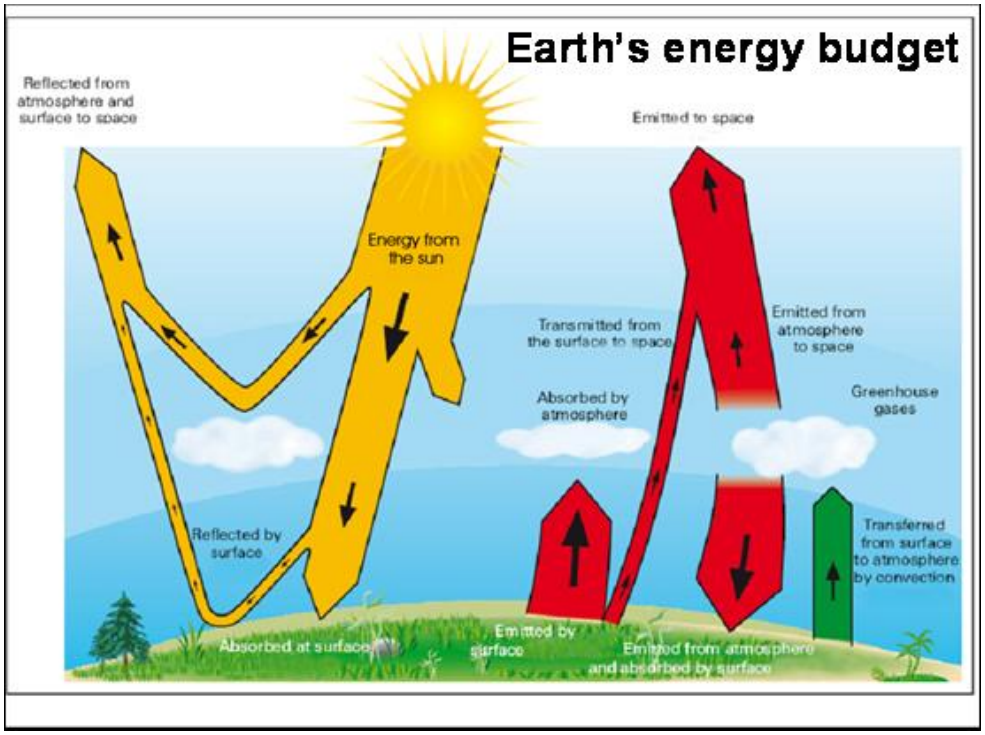
Participants' views changed once they became aware of the size and scope of the challenge (through conversations with scientists and an introductory presentation and group discussion at the start of Event 1). The most relevant example is that the participants did not envisage how much land would be required by Biochar – a method perceived as relatively natural -if it was to be used widely enough to have an effect on climate change. Without this understanding, most underestimated the trade-offs necessary. In the reconvened event, scientists divided up the Earth's usable land between individual families and demonstrated how much land per household would need to be taken over by Biochar. Participants saw the real trade-off for individuals, towns, and countries and the debate changed.

Recommendation 9. There is a need for further dialogue on the subject of 'naturalness' to establish what this term means to the public and explore publc attitudes to, and scientific understanding of, the role of humans in natural systems, and interactions between humans and the environment.

In the wider debate, imagery and metaphor could make hard-to-grasp concepts and scales more accessible to non-specialist audiences, as will concepts which are 'human scale' rather than planetary scale. In the dialogue, an image of a person planting a tree had more emotional resonance than information about an abstract change to the stratosphere.

Imagery can also explain the complex processes that occur within the climate system. It is important to simplify discussion of climate systems. For example, participants found this map of how heat from the sun can be trapped by the atmosphere helpful.

However, images should be used with a degree of caution. Photographs have the potential to take people down the wrong track (for example the Biochar image used in the dialogue materials suggested it was a very space-effective way of geoengineering, which may have been misleading).



When participants saw video vox pops during Event 2, by far the best-liked and best-understood was the Guardian journalist. Participants felt he explained complex issues in a simple, concrete way. Participants gave more negative feedback on commentators they felt were taking a more philosophical or abstract line.

This all illustrates the importance of piloting materials which are aimed at a wider public, to ensure that materials explain climate issues clearly. The recommendation here is that imagery and scales should be clear, powerful, easily understood and salient.

Poster designed by participants at the Reconvened Event.

Through the dialogue, participants came to understand that substantial climate change is a genuine risk, but at the same time they learned that scientists cannot accurately predict the timescale or level of impact, nor the likely spread of effects across different parts of the world.

> "What is the tipping point and when will we know we've reached it? When will we get to a point with the climate when we really have to worry?" **Cardiff, Event 1**

Most understood that there was no consensus over 'tipping points' and that the risk story was not a simple one. However, participants found it difficult to weigh up the need for new technologies (such as geoengineering) in the absence of specific predictions as to when climate change impacts might occur. A minority continued to ask throughout the dialogue for more information on when the 'tipping point' would be.

Most wanted a clearer explanation of the risks of climate change, and felt that the wider public would also require this in order to debate the issues. Participants acknowledged that in the absence of hard information about risks, the next best thing was a transparent acknowledgement of the areas of uncertainty.

Behavioural economic theory tells us that individuals find it hard to relate statistical risks to real-world choices. This behaviour was apparent in the dialogue discussions. Some participants found it hard to engage with the ultimate decisions (research / not research geoengineering) that the scientific community has to make, simply because of the high level of uncertainty around the effects and consequences of decisions. This may need to be considered carefully in future public engagement.

> "We need more statistics and more simple stats. One concrete set of figures, not many" **Cardiff, Event 2**

The dialogue participants also reported finding it difficult to engage with and interpret data and statistics. They were overwhelmed by the range of evidence and, while accepting that this is not something that is necessarily possible, were keen to be offered more certainty by reading one set of 'correct' data rather than multiple scenarios, each with a range of likelihoods attached to the impacts of climate change.

The results from this dialogue do suggest, however, that the public are more likely to trust information when it presents pros and cons, rather than only putting one side of the argument. Participants were particularly impressed that the information they had been given during the events presented both advantages and disadvantages, and this gave them more faith that their views were genuinely being sought. Participants also appreciated the effort that had been made to convey complex ideas in simple terms, and said that scientists should do this wherever possible.

> "I'm impressed because the language used is easy. Scientists need to use language we can all understand." **Birmingham, Event 2**

6.3.4 The context for communications – trust in government and in science

The trust the public place in different institutions and sectors is key to shaping their attitudes towards issues to which they have very little regular exposure. In terms of climate change, this means that public attitudes towards government, scientists and the media set the context for any information they are given.

> "Government says there should be change, but you don't see their actions support their claims. They still drive cars, fly around. They don't practice what they preach...They are just creating revenue from tax."
> **Birmingham, Event 1**

Many participants in these events and discussion groups raised the issue of trust in the sources disseminating evidence about climate change. It was assumed that information and statistics could easily be manipulated to meet specific agendas.

Overall, participants were keen to hear that climate change is being taken seriously by scientific authorities and by government. This reflects other public dialogue findings, particularly DECC's Big Energy Shift public dialogue[12,] where participants simply wanted government to tell them clearly what tackling climate change will involve and what steps government is taking.

Communication about geoengineering will need to fit into the overarching strategy for the UK's climate change policy, to ensure that the public support it.

There was a great deal of scepticism about the commitment of politicians to addressing climate change. For some participants, apparent contradictions between what politicians are doing about environmental issues and what they say about them, lessens the urgency of the climate change agenda. The upcoming (at the time of the dialogue events) General Election featured in people's discussions of political commitments. Participants raised queries about the extent to which policies on climate change are unilateral across political parties or whether these are subject to change when a new party is in power.

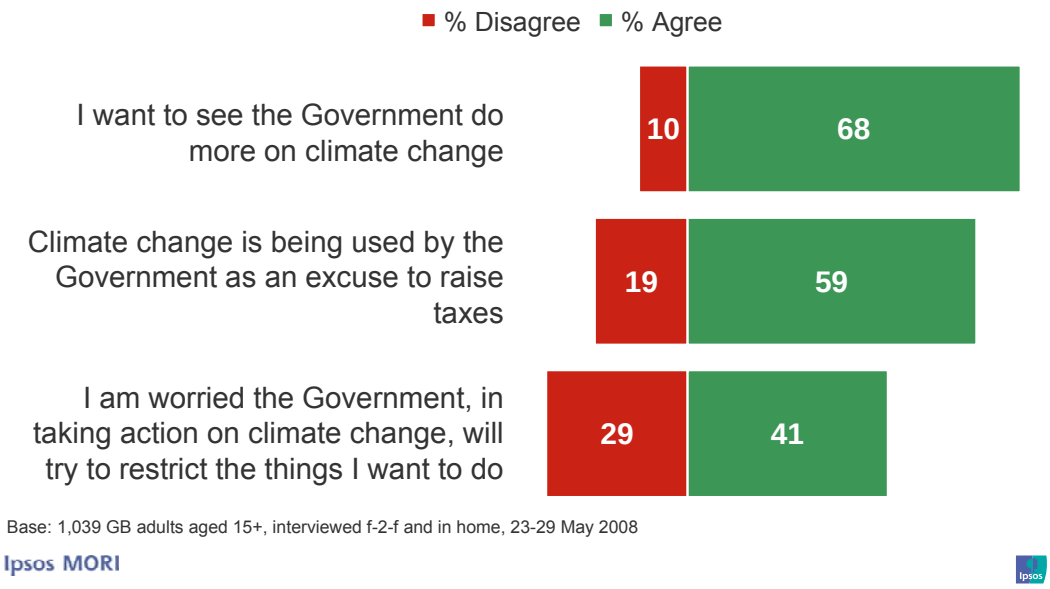
This possibly contributed to participants' beliefs that mitigation would be unlikely to succeed alone. However it also contributed to some scepticism about the likelihood of implementing some of the geoengineering technologies, as participants questioned how likely it was that politicians would commit to such projects.

[12] 2009 The Big Energy Shift, report by Ipsos MORI, http://www.big-briefs.com/big_energy_shift/Big_Energy_Shift_Final_Report_300609.pdf

Looking at the wider context of attitudes towards the government's commitment to climate change, these comments from participants resonate with opinions expressed by the general public more widely (collected through other research by Ipsos MORI as shown in the chart below): they too question the motivations of government, and the lack of visible evidence of action being taken by government, to tackle climate change.

Attitudes to Government

Q. To what extent do you agree or disagree that……?



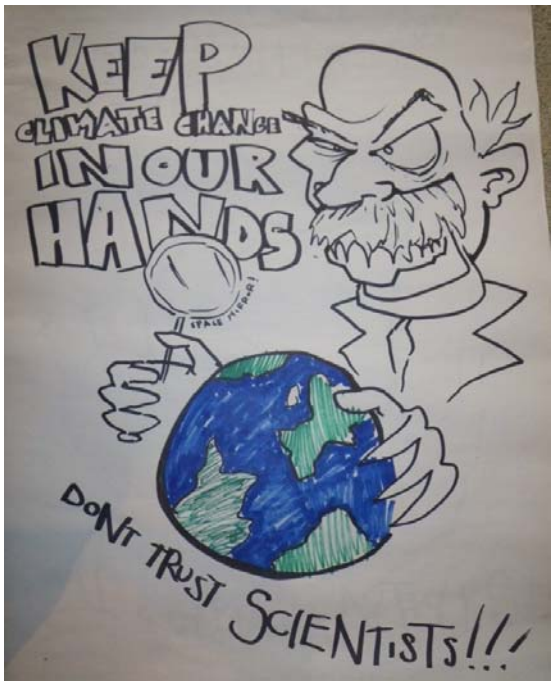
There was also some distrust in scientific authorities expressed throughout the dialogue. Some participants questioned the extent to which scientific research is ever truly independent of the organisation and by association the agendas, which fund it. It is worth noting that these attitudes may, to an extent, have been influenced by recent media coverage of the disclosed emails episode at the University of East Anglia.

Comments such as those below revealed that some participants did not know how scientists search for information, how they input data, or how they ensure robustness of findings.

"When you're doing computer modelling, surely you are putting in the figures yourself, so how do you know you're not manipulating it?" **Reconvened event**

"How miffed would you be if you did all the research and then it did not go ahead?" **Reconvened event**

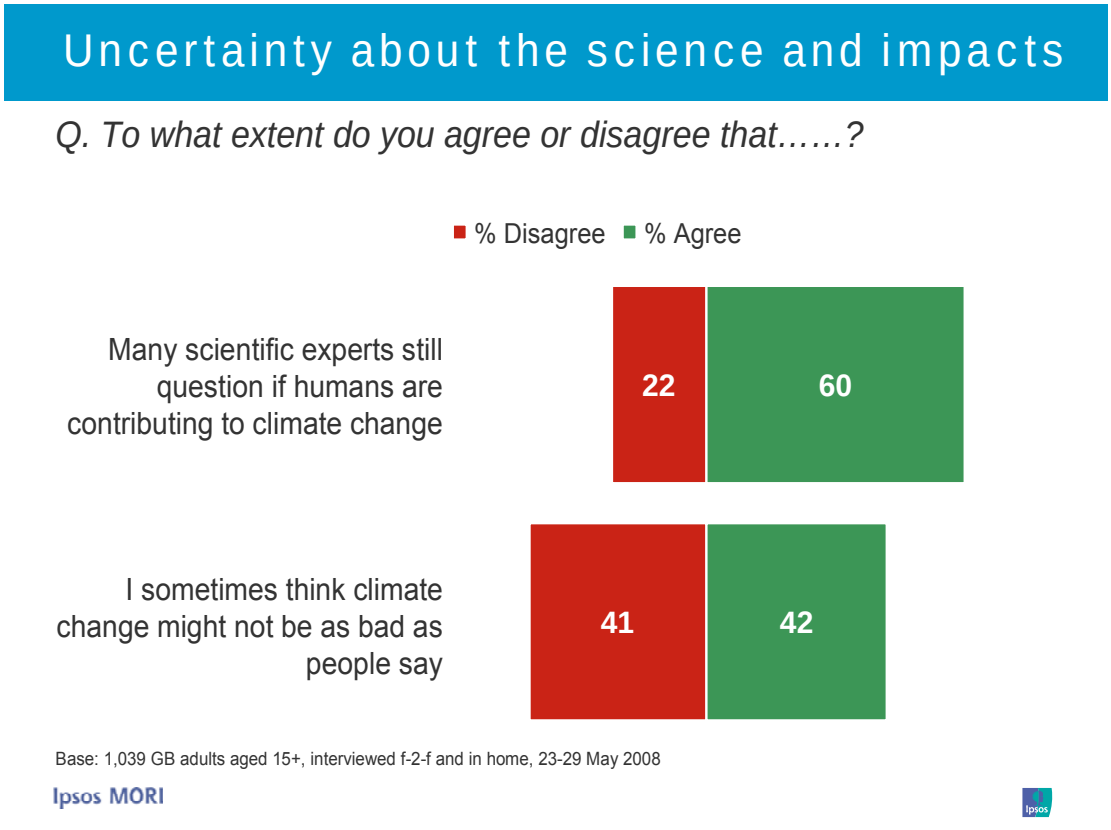
"In the current political climate is your research biased in favour of things to support climate change?" **Cardiff, Event 1**



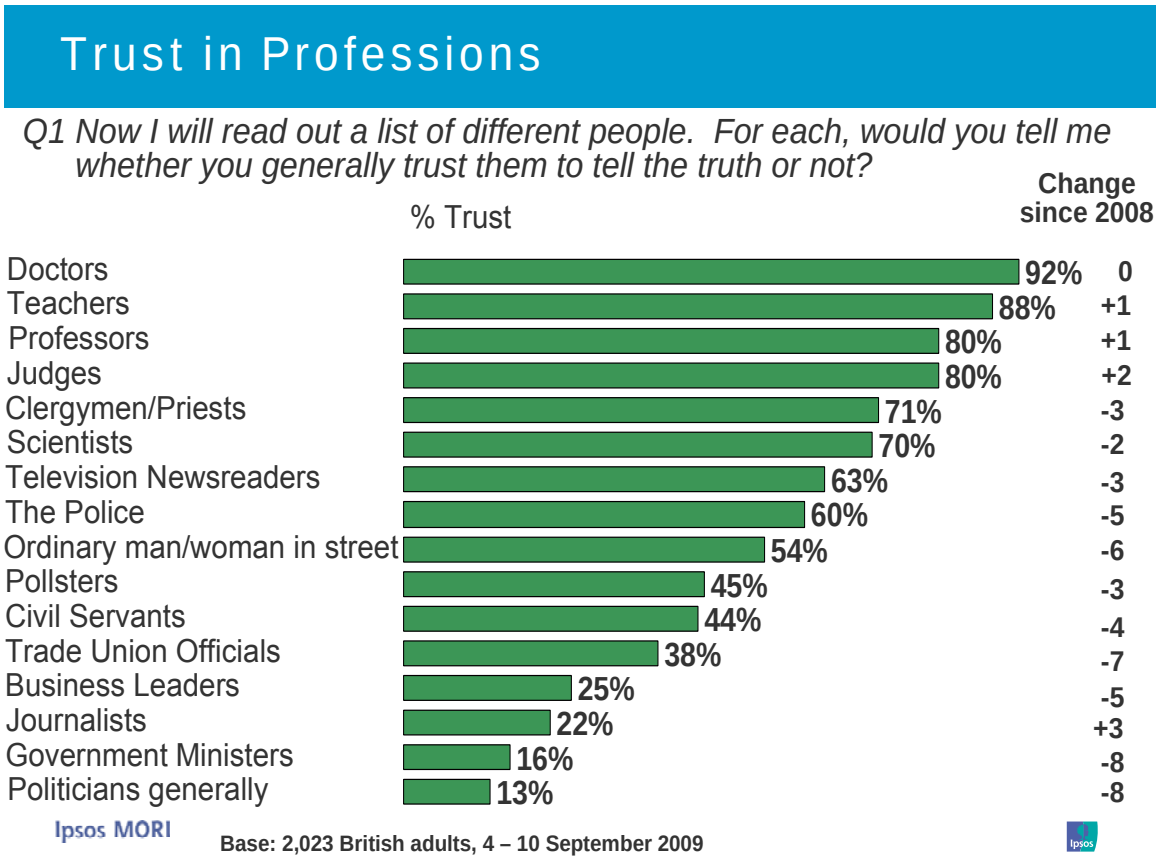
Poster designed by participants at the Reconvened Event.

Dialogue participants expressed some surprise when they were told of the scientific consensus around anthropogenic climate change. Participants were told, in accordance with the IPCC 4th Assessment Report, that scientists were 90% certain of the connection between post-industrial warming and human activity. A few participants said they would have estimated this to have been more like 50% certain.

This lack of acknowledgement of the scientific consensus which surrounds anthropogenic climate change is something which is replicated across the public as a whole according to Ipsos MORI's other research (see chart below).



Ipsos MORI regularly track public attitudes towards a range of sectors through the Trust in Professions Survey. The latest data (shown below) highlights the very low levels of confidence placed in politicians by the public, and the similarly poor perceptions of journalists. Scientists are rated more favourably, although research has suggested levels of trust can depend on the source of funding: government scientists are less-well trusted.



The implication of this lack of trust is that the source of the climate change message makes a difference to how the public receive the information. Communicators will need to take this into account.

Media-friendly science communicators may be valuable to those seeking to communicate geoengineering and climate change more generally. During the dialogue, participants mentioned that they had been impressed by some recent media treatments of science. In particular, participants liked Professor Brian Cox's BBC documentary series Wonders of the Solar System, which succeeded in communicating vast planetary phenomena in an accessible way, and Radio 4's Countryfile, a programme which discussed geoengineering.

Appendices on method

Appendices

A: Recruitment

Dialogue events

All recruitment for the events was carried out face-to-face in the local area (i.e. Birmingham, Cardiff and St Austell in Cornwall). Thirty participants were recruited in each area to allow a drop-out rate of three people. Quotas were set to ensure a representative group of participants. These were based on age, gender, social grade, ethnicity, work status, and whether participants were parents or not. It was also an aim to have participants from a range of life stages.

People were also recruited according to their views on climate change and the extent to which it is an anthropogenically-induced phenomenon. This was done to ensure a range of views of climate change were brought to the dialogue. The recruitment was not designed to be representative of the general public's views on climate change, but it was designed to be illustrative of these and ensured both climate change believers and sceptics were included. It is worth considering that this sample of participants may be more likely to accept climate change is happening than the population at large as they are people with an interest in attending a dialogue on geoengineering.

All participants recruited had to be able to attend both events in their area, and recruiters were instructed not to recruit relatives or more than one person per household. All participants received a fee of £50 for attending event 1 and £125 for event 2. Participants who attended the reconvened event received £100.

Discussion groups

Recruitment for the discussion groups was also carried out face-to-face in the local area. Two discussion groups were recruited, one in Birmingham with young people and one in Cardiff with people who lived in areas perceived to be at greater risk of flooding. For the group with young people, quotas were set on age (participants had to be aged 16-18), gender and ethnicity. For the group with people affected by flooding, quotas were set on age, gender and whether they lived in an area impacted by flooding (all were required to fit into the latter category). For both discussion groups, recruiters were instructed not to recruit relatives or more than one person per household. All participants received a fee of £50 for attending the discussion group.

Discussion guides were designed for the deliberative events and discussion groups with the input of stakeholders. The discussion guides used in the discussion groups were very similar to those from 'event 1' – essentially these were condensed to allow for less time.

B: Experts

The following scientists were involved at each of the events:

Event 'experts'		
Birmingham Event 1	Peter Irvine	University of Bristol
	Jacob Baker	University of Birmingham
	John Thornes	University of Birmingham
Cardiff Event 1	Peter Irvine	University of Bristol

	Dan Lunt	University of Bristol
	Gideon Henderson	University of Oxford
Cornwall Event 1	Naomi Vaughn	University of East Anglia
	Dan Lunt	University of Bristol
	Malcolm Hart	Plymouth University
	Peter Melville-Shreeve	STEM ambassador
Birmingham Event 2	Tim Jickells	University of East Anglia
Cardiff Event 2	Phil Williamson	University of East Anglia
	Nick Pidgeon	University of Cardiff
Southampton Reconvened Event	Damon Teagle	Southampton University
	Richard Lampitt	National Oceanography Centre
	Andrew Parker	Royal Society
	Ed Hill	National Oceanography Centre
	Nick Pidgeon	University of Cardiff
	Charles Godfray	University of Oxford
	Alan Thorpe	NERC
	Tim Jickells	University of East Anglia

C: Materials

The table below outlines the order, and manner in which, participants were exposed to information about geoengineering.

Dialogue process and presentation of materials to participants

EVENT	CONTENT	OBJECTIVE
Event 1	*Presentation*: Climate change context • Earth's Energy Budget • scientific consensus on anthropogenic climate change • anticipated impacts of increased atmospheric CO_2 • principles of geoengineering, mitigation and adaptation • introduction to geoengineering technologies	Set the context for the discussion: - address potential scepticism around scientific consensus - address the necessity to consider geoengineering within the context of mitigation and adaptation
	Exercise: Rotations around each technology - participants presented with facts and pros and cons of nine technologies at three facilitated stations - groups discuss instant reactions to each technology (what they like, dislike and what questions they have about each one)	Introduce participants to each technology Build a growing list of questions for scientists to address later on

	Presentation: consider trading-off different technologies according to their effectiveness, safety and value for money	Introduce idea of needing to trade-off relative pros and cons of different technologies
	Exercise: Mapping exercise to judge technologies against criteria (impact on people, impact on future generations, impact on animals and plants, safety, value for money) - participants indicate most important risks associated with each technology, and preferred technology, on completed map	Determine weighting participants give to each criteria
	Exercise: Post-task homework - participants choose one technology to research further, or talk about with a friend - decide on most important questions to ask before initiating research into geoengineering	Ensure participants continue to think and reflect on geoengineering
Event 2	*Presentation*: Summary of technologies and climate context	Recap on Event 1
	Presentation: Ethics in science, what ethics means in relation to science, and how it is used • introduce questions about environmental, social, political, legal and economic repercussions of researching geoengineering • show participants Royal Society map of technologies according to safety, affordability and effectiveness	Set up debate for the day, establish discussion around morals and ethics rather than technical capability Enable participants to have a sense of how the technologies trade-off in terms of the key issues of safety and effectiveness and importantly cost.
	Exercise: Scenarios of the future - Four technologies chosen in agreement with stakeholders – reflected those raising most debate in Event 1, e.g. Sulphate Particles. Technologies which generated a uniform response in Event 1, e.g. Afforestation, Mirrors in Space, were not re-considered through the scenarios - Participants presented with potential futures for four technologies (Sulphate Particles, Iron Fertilisation, Biochar, Air Capture) including the model of governance, the associated impacts and public opinion	Get participants thinking about different questions relevant around governance, winners and losers, compensation, commercialisation

	Presentation: Expert witness films – short films highlighting different points of view: • David Adams, Environment Correspondent, *The Guardian* • Michael Edwards, Climate Change Advisor, CAFOD • Adam Corner, Research Associate, Cardiff University Psychology Department • Catherine Redgwell, Professor of International Law, University College London • Chris Groves, Research Associate, Cardiff University	Show participants the range of moral arguments surrounding geoengineering, prompt discussion of this
Re-convened Event	*Participants given a guided tour of National Oceanography Centre (NOC)*	
	Presentation: Thank you and welcome by Professor Ed Hill, Director of NOC and Professor Alan Thorpe, Chief Executive of NERC	Welcome participants back, assure them their views are being listened to
	Presentation: Dialogue themes	
	Exercise: Research projects Each group hears presentation on a research project scenario from scientist: • Liming the Oceans – Professor Damon Teagle • Ocean Fertilisation – Professor Richard Lampitt • Sulphates – Andrew Parker, Royal Society	Tackle issue of participants finding it difficult to think about the world of research and the questions that need to be asked before research can take place – put focus back on research and not on deployment
	Participants shown a slide outlining research possibilities • Modelling – Small-scale/test components – Field trials – Deployment *Presentation*: • Professor Charles Godfray: how NERC makes funding decisions • Tim Jickells: how the public dialogue will influence NERC's plans • Nick Pidgeon: how the sandpit was influenced by the dialogue and what projects might emerge Followed by questions from the floor and discussions in groups	
	In groups: *Exercise*: Poster creation or further discussion of technologies Biochar with Professor Charles Godfray Carbon Capture and Storage, Air Capture and Weathering with Profs Damon Teagle and Richard Lampitt, and Cloud Whitening with Prof Alan Thorpe	

D: Dialogue process

Participants developed their ideas during the dialogue in various ways. A **typical or aggregate thought process** was something like this:

Event 1: Questioning and absorbing information, challenging, coming to some fairly clear preferences. For many, a feeling that CDR is the way forward.

Event 2: Having reflected further on mitigation and geoengineering, concern that the problem is very complex. More awareness of the challenge of bringing ethical principles into the process, particularly ensuring equity for developing world and setting up good international governance. At the end of this event, participants were keen that decisions should be made by those with high levels of knowledge and little political bias.

Event 3: (Smaller) reconvened group were more confident in their questions and decisions, pursuing lines of enquiry with individual scientists and coming up with clearer ideas. However most stopped short of advocating large-scale field trials for any technology and suggested a range of lab and smaller scale field trials.

Event 1: Learning phase

Questioning and absorbing

- What are these technologies? What does the terminology mean? How do they work?
- Why is it important to consider them? What's the climate challenge all about? Where does the evidence come from?
- Why is mitigation not enough? Reflection, and some confusion as participants wrestle with a concept opposite to one they have heard before (i.e. that individuals putting effort into mitigation is the only way to tackle climate change).

Challenging

- Who pays the scientists? Where are the vested interests?
- Some not convinced by the evidence of climate change even at end of Event 1
- Most go through a 'quiet period' during some of Event 1 as they reflect and absorb
    - For some, this prefaces speaking up again, coming to a clear conclusion by the end of Event 1
    - For others, this means they are not convinced geoengineering is needed, but would rather not say in the main session while some take facilitators aside privately at lunchtime
    - Some simply feel out of their depth with the scope of the issue and don't feel qualified to hold an opinion, they also remain quiet until the end of Event 1.

Coming to some conclusions, expressing clear preferences

- Most come to the view that CDR is their preferred solution (alongside mitigation)
    - Some enjoy a 'false honeymoon' thinking that there are some easy solutions to climate change.
    - Many not really aware of size of problem, size of solution needed on global scale *"biochar and afforestation are the most suitable approaches".*

- Others express wonder at the scope of science, enthusiasm for inventiveness, and confidence that a solution can be found.
- Others are somewhat frustrated, looking to science to give us clear answers – why is there not a clear solution being presented? Little sense of how research progresses and what stage the technologies are really at. *"Why have we not been given enough information to comment?"*
- Most feel that **ethical** and **practical** issues are intertwined. Most have identified ethical issues around equity and the implications of uneven climate effect over the world, effects on natural systems and traditional lifestyles, but global governance and legal frameworks tend to be left until Event 2.

Event 2: raising more questions

Homework and more sophisticated reflection and emerging concerns

- Identifies additional questions and problems with some technologies *"there are some problems with sulphates I was surprised we didn't hear about"* (Cornwall, Event 2)
- Have reflected on geoengineering and mitigation
    - Now worried about the scale of the mitigation challenge, and looking to lifestyle changes for humanity *"I'm not religious but maybe we should be more Buddhist and care about the environment more"* (Cardiff Event 2).
    - Better grasp of overall objective of geoengineering and some ethical issues around moral hazard *"At the moment it seems we're not going to keep down to the 2 degree rise without using geoengineering, but then the problem is that geoengineering might make people take their eye off the ball"* (Cardiff, Event 2).
- Some concern about focusing on sulphates and ocean technologies today and some **challenge**. Will our views be used to support research into technologies even though we don't support them?

Ethical questioning

- Engaging with the commercial, regulatory and governance aspects of the scenarios.
    - Some recoil from the idea that people might make money from geoengineering and fear that political will might overtake scientific knowledge *"In that scenario the EU ignored the scientists…"* (Cardiff, Event 2) "Are we talking about politicians making decisions, or experts, or experts advising politicians?" (Birmingham, Event 2)
    - How will cost and deployment be shared across the world?
    - Who will make decisions and police this?
    - Social equity – how will the voices of the poor be heard?

More sophisticated conclusions

- We need to combine several technologies, mitigation and geoengineering to have an effect (especially as people thought more about the range of problems within climate change – ocean acidification, atmospheric gases, shifts in weather patterns, temperature rise, unexpected weather events...).

- More awareness of governance issues and opportunity costs.
- More prepared to "research" some technologies they were unfavourable towards such as sulphates, *"Nothing wrong with research"* (Cornwall, Event 2).
- Many now say that the solutions they thought would work earlier are more complex than they first imagined. *"I've learnt a lot over the two weeks – I'm still going away with uncertainty and think there's still a lot of uncertainty within the science community and government as to whether these things will work*" (Birmingham, Event 2).
- Keen to ensure ultimate decisions are made by scientists or other informed, unbiased people.

Event 3: Understanding the research process

More confident behaviour

- Comparing notes from different locations and surprise at similarity of views across locations.
- More 'huddles' and two- or three-way conversations with scientists at break times following up on particular themes and questions.
- Challenge to some emerging findings in plenary. Some still concerned that views will be co-opted in service of an agenda. *"To get information we need research, but before you do research you want a steer from us what is okay"* (Reconvened Event).

By the end, clearer advice

- Greater grasp of the status of different geoengineering technologies – which hypotheses need to be explored in order to take them further.
- Would support a range of stages of research for each technology (e.g. lab trials and small-scale trials for liming, larger scale trials for sulphates) but stop short of advocating largescale field trials for any geoengineering technology, today.
- From feeling that they had covered all the technologies exhaustively at the end of Event 2, a feeling now that they had reached 'another level' and didn't have time to cover them at this level in enough depth.
- More focus on political side and NERC's task in considering research – questions emerge around cost of commissioning, opportunity cost, and the need for "*world agreement*" to be developed alongside technologies.

E: Group dynamics and the role of experts

The role of group dynamics is likely to have had an impact on participants' views. For example, if one person in the group is particularly vocal and opinionated and/or provides new information on the subject, this can sway others' views, particularly those who have a less formulated opinion prior to the discussion. Additionally, the information imparted by facilitators may also cause participants to change their views over time (all the materials used during the course of the dialogue are listed in Appendix C and the information provided about each of the technologies is detailed in Chapter 5).

Scientists and other experts may also have been influential. Like the facilitators, the scientists imparted new information which may have influenced the participants. Additionally, the

participants were very enthusiastic to have the opportunity to speak with scientists and are likely to have been influenced by the scientists' views, especially at Event 1, where scientists were presented as experts – not necessarily expert in every geoengineering technique, but with a grounding of knowledge in climate change and the subject area. This meant that participants took the information given by the scientists seriously. Examples of interactions between scientists and public participants are provided below.

In **Event 1**, scientists tended to respond in the following ways:

- Points of clarification on materials.

> Gen Pub: Are geoengineering techniques proven methods, or just concepts?
> Scientist: Nearly all haven't been trialled and are at the drawing board stage. **(Cardiff, Event 1)**

- Adding additional information to contextualise materials.

> Scientist: The level of CO_2 now hasn't been seen since the Ice Age began.
> Gen Pub: So is the period we're in now between ice age periods?
> Scientist: Yes, we have gone from a very icy period where CO_2 levels were lower, but now we're in a warmer period. **(Cardiff, Event 1)**

- Giving their professional opinions on how they felt participants should weigh the materials.

> Gen Pub: The CO_2 climate graph was interesting but what if you don't believe it?
> Scientist: Scientific evidence shows that climate change is happening. **(Cornwall, Event 1)**

- Explaining aspects of scientific research, their working life, or funding.

> Gen Pub: In the current political climate is your research biased in favour of things to support climate change?
> Scientist: There could be an argument for it, but who benefits from climate change not existing? **(Cardiff, Event 1)**

During the course of an informal day's conversation, some of these comments are likely to have been more considered than others, and scientists revealed (whether consciously or unconsciously) their own opinions about the technologies under discussion.

It is not impossible that some remarks changed the direction of conversation for some participants, at some points closing off some avenues of discussion. The scientists may also not have been in possession of all the facts, or have simply got it wrong when asked to give details of different experimental findings, for example.

The different points of view brought by different scientists may well have altered opinions; for example, stated preferences on which technologies were the most preferred, written in questionnaires. However, it is important to note that the aim of this discussion was not simply

to gather participants' views on what technologies they preferred, but to understand the values and principles they brought to the table. The scientists were there partly to stimulate discussion among participants, hence allowing the research analysts to hear and understand their principles and values. It is unlikely that the comments made altered the participants beliefs, or the value judgements that they brought with them to the events.

Furthermore, the analysis takes account of the range of different comments made across the events. The day was designed to look at the same technologies in a number of different ways, plus participants worked in small groups during the day and not everyone heard every comment by every scientist. Furthermore, at most events more than one scientist was present, so participants were able to hear views expressed in different ways. This analysis has brought together the main concerns from many conversations between different groups and over the course of the days. Individual comments from individual scientists are unlikely to carry more weight than they deserve.

At **Event 2**, experts asked more questions than they gave information, and encouraged participants to think through the ethical implications of geoengineering. Some also continued to add points of clarification, and other observers (from NERC) answered questions about the role of NERC.

Gen Pub: So it will stay where you put it?
Scientist: Yes, the algae will sink and the deep ocean current will keep it deep for hundreds of years. **(Birmingham, Event 2)**

At the **reconvened event (Event 3)**, a mixture of NERC observers, scientists and other experts asked questions of each other and of participants. The comments here tended to take the arguments further and scientists could turn questions back to participants and to each other.

Gen Pub: Wouldn't cloud whitening be less harmful?
Scientist: It depends what you mean by harmful. There are a number of effects, like monsoon. **(Reconvened Event)**

F: Homework exercise

In this particular project, participants also had time between the first and second events to research a technology of their choice, and to talk to friends and family outside the project, which may also have caused them to reassess their previously held opinions.

In the homework tasks in between Events 1 and 2 participants were asked what they felt would be the most important questions to ask, inviting them to choose from a set of questions (see below) using a question ranking system. Here is what they replied (note that only 63 people completed their homework).

The chart below shows the average ranking of the questions, revealing that **overall effect on climate change** is considered most important, followed by a raft of issues around managing side effects and termination, whereas **public acceptability** is considered least important. This may reflect the finding that participants did not feel that they were best qualified to judge what decisions scientists should make.

Question	Score
How big an effect will it have on the climate?	585
How effectively will it reduce CO_2?	575
How effectively will it reduce temperature?	472
How manageable are the side effects?	466
How difficult will it be to stop, once we have started using it?	387
How quickly will we see results?	359
How expensive will it be to set up, use and maintain?	332
How easy is it to regulate?	301
How quickly can we start using it?	275
Who will design, build, and run this system?	209
How acceptable will this be to the public?	197

G: Demographic factors influencing opinions

Below are the differences in responses to the pre- and post-dialogue questionnaires according to participants' gender, age and level of education. These figures are for illustrative purposes only. It is important to stress that these are indicative of the views of a very small sample, rather than reliable quantitative findings.

Gender

Discussion groups were not split according to gender so male and female opinions will not be split out in detail. However, the questionnaires do indicate some interesting differences in views. Firstly, they suggest that women are more likely to be supportive of geoengineering approaches to tackling climate change. Women also appear to have been more likely to increase their levels of support between the end of Event 1 and the end of Event 2.

Topline findings from questionnaires

Support geoengineering approaches to tackling climate change (Event 1):
Men: 65%
Women: 74%

Support geoengineering approaches to tackling climate change (Event 2):
Men: 68%
Women: 83%

Anecdotally, facilitators also reported that women during the discussions were more likely to advocate nature-based approaches that respect the environment. There is no more specific way to evidence this, however.

There are also some differences apparent in men and women's support of the different types of technologies. Although men and women expressed similar levels of support for SRM technology by the end of Event 1 (27% and 31% respectively), women appeared very slightly more likely to favour SRM approaches *prior* to Event 1 and also by the end of Event 2.

In terms of the nine technologies discussed, by the end of Event 2 men and women had similar views on all except for Cloud Whitening (which 50% of women supported vs. 33% of men) and Sulphate Particles (which 35% of men supported vs. 22% of women).

Topline findings from questionnaires (post-event 2)

Support for CDR options:	Support for SRM options:
Air Capture Men: 80% Women: 86%	**White Roofs** Men: 18% Women: 14%
Iron Fertilisation Men: 18% Women: 19%	**Mirrors in Space** Men: 13% Women: 14%
Liming the Ocean Men: 15% Women: 11%	**Cloud Whitening** Men: 33% Women: 50%
Biochar Men: 78% Women: 80%	**Sulphate Particles** Men: 35% Women: 22%
Afforestation Men: 93% Women: 92%	

Age

Age is another factor that appears to have some influence on attitudes towards geoengineering. For example, when comparing the post-event 2 questionnaires of participants aged 18-35 with the over 35s, it is apparent that younger people appear more positive about CDR technology (overall) and Cloud Whitening as potential solutions to climate change. Over 35s appear slightly more supportive of SRM technology (overall).

Topline findings from questionnaires (post-event 2)

Support for CDR options:	Support for SRM options:
CDR overall: 18-35s: 81% Over 35s: 72%	**SRM overall:** 18-35s: 23% Over 35s: 39%
Air Capture 18-35s: 83% Over 35s: 82%	**White Roofs** 18-35s: 16% Over 35s: 16%
Iron Fertilisation 18-35s: 23% Over 35s: 13%	**Mirrors in Space** 18-35s: 10% Over 35s: 16%
Liming the Ocean 18-35s: 13% Over 35s: 13%	**Cloud Whitening** 18-35s: 58% Over 35s: 27%
Biochar 18-35s: 81% Over 35s: 77%	**Sulphate Particles** 18-35s: 26% Over 35s: 30%

Looking at the questionnaires from the young people's group (aged 16-18) in Birmingham allowed us to see a snapshot of this age group's views in isolation (though, again, not in a statistically valid way). The participants in this group were particularly easy to engage as they were more familiar with climate change and the science behind it when compared to the 'average participant' across the groups. As discussed in the previous chapter, they also more readily accepted the argument that climate change exists and is a problem for the planet. This group were particularly favourable towards Air Capture, Afforestation and Sulphate Particles.

Level of education

Participants' level of education and ability to engage with the complexity of the discussions also had an impact on their attitudes. For example, many participants struggled to understand the reasoning behind SRM technologies – such as the fact that these did not take CO_2 out of the atmosphere – and this led some people to question their use. As mentioned above, the young people who participated in the research, and were currently in school or college, were particularly easy to engage as they were more likely to have discussed such subjects recently and in an educational environment.

Interestingly, the questionnaire responses indicate that participants with lower education levels are, in fact, more likely to support geoengineering approaches overall. These are outlined in the following table[13].

Topline findings from questionnaires (post-event 2)

Support geoengineering approaches to tackling climate change:
No qualifications/Level 1: 100%
Level 2 or 3: 65%
Level 4 or 5: 64%

H: Analysis

Public dialogue can encompass a range of different processes of involvement. These are summarised in the Sciencewise report on widening public involvement in dialogue[14] as:

- *Communications/campaigning*: for government to influence citizens
- *Research*: for government to find out what citizens think
- *Upstream dialogue or 'true engagement'*: for citizens and government to influence each other.

Because public dialogue sometimes includes elements of all of these, best practice involves practitioners drawing techniques from a range of different research and engagement traditions. At the beginning of this project it was important to carefully consider which assumptions to use at different times to ensure that the way in which data were collected and analysed suited the purpose of the study, and would lead to the right kinds of results.

[13] This raises some interesting questions, which other research into the process of dialogue could investigate. The hypotheses which could be generated from this are numerous, and this project does not allow us to investigate them in depth. For example, could it be that participants who are less used to the academic treatment of a subject are more likely to assume that the facilitator is looking for a positive response to subjects under discussion? Or, perhaps, that those who have not understood some of the arguments are 'bluffing' by expressing a more positive view? Or that those with higher than average educational attainment will be less likely to agree, when they have heard a number of complex arguments? Or simply varying levels of trust in scientists The possibilities are considerable.

[14] Hyam, Pippa, *Widening Public Involvement in Dialogue* http://www.sciencewise-erc.org.uk/cms/assets/Uploads/TrackedDocuments/Publications/Widening-Public-Involvement-in-DialogueFull-report.pdf

Design and facilitation

This dialogue drew on some of the traditions of *research*, in that it was designed to identify how participants would respond to information about geoengineering. This meant that in order to report on participant response, design needed to capture information as clearly and comprehensively as a qualitative research process. 'Focus group' style sessions were included in which participants shared their views, first spontaneously, at other times after reflection. Members of the groups were asked not to talk over each other and, while the facilitator drew everyone into the discussion, it was accepted that some would talk more than others. Essentially, these parts of the session were 'moderated' as a focus group would be.

Flip chart notes taken by facilitators summarised emergent themes from the groups as a support for the discussion rather than as a complete record of what was said. Note takers took notes as close to transcript as possible, but with an element of summary as the note taker used their qualitative skills to identify emergent themes. Examples of this approach included the first sessions in Event 1 where participants discussed what they knew about climate change, and the second session where facilitators shared the pros and cons of different techniques and summarised views on flip charts. Different facilitators used their flip charts in different ways according to personal style – just as would happen if a project of qualitative group discussions was run which included different moderators on different evenings.

The dialogue was not a pure research process, however, but also included elements of *upstream dialogue or 'true engagement'*. When the aim is for citizens to influence the agenda, there is more of a need for exercises to create space and time to think about what they would recommend, and the emphasis is on analysing what they eventually conclude, rather than on capturing every phrase as they say it for later analysis. So, exercises where participants worked in smaller groups and wrote their own feedback were also included, an example being the post-it exercise in the afternoon at Event 1. This ensured that quieter participants could talk to one another or ask the science experts individual questions. In some sessions, for example in Event 2 participants were asked to draw final conclusions, which utilised a technique closer to consensus-building in that facilitators made sure that all members of the group were happy with the final outputs.

Data

The following types of data were collected during the course of this dialogue, and its complementary streams:

Stakeholder engagement	Notes from stakeholder meeting and comments on all materials
Events 1 and 2 and Reconvened Event	Audio recordings of groups Real-time transcripts taken by note takers Some additional ad hoc notes taken by facilitators during and after events Facilitator summaries on flip charts Other flip charts and wall exercises where content was written by participants Small number of 'vox pops' from reconvened video Pre- and post-event questionnaires Post-task exercises from after Event 1

	Individual handout exercises from reconvened event Cartoon posters drawn at the reconvened event by some participants
Open Access Events	Flip charts designed by students at Cardiff Postcards from Cardiff, Birmingham and Oxford
Additional group discussions	Audio recordings of groups Facilitator summaries on flip charts Some additional ad hoc notes taken by facilitators during and after events Audio recordings of groups Real-time transcripts taken by note takers Pre-group questionnaires
Online Survey	Responses 65 people

Analysis

When it came to analysing these different forms of data note was taken of whether the information came directly from participants (e.g. post-its, homework tasks, posters they'd created) or from transcribed notes (near-verbatim comments) or from facilitators' notes or flip charts. The insights that each facilitator gained were then shared during analysis meetings after the day was completed so that the final report reflects the synthesis of all.

The different types of event in the process were also accorded different status in the analysis. The open access events, from a research perspective, were most useful in that they enriched the main part of the dialogue with additional spontaneous thoughts.
Analysts looked at the open access event materials *after* analysing the materials from the main dialogue events. When interesting themes came out of these which were not already within the main part of the analysis, the dialogue findings were revisited to see if these themes were also present in the dialogues. For the most part, however, because the comments from the open access events were so brief, the views expressed tended to chime with the earlier or more spontaneous views expressed by participants in the dialogues. This was also the case with the additional discussion groups; though particular analysis took place of the Cardiff open access group and the young person's discussion group as they both dealt with younger participants.

Overall, because the participants in the main dialogues had more time to consider their views, conclusions were drawn largely on the basis of these and *supplemented* with information from the other streams.