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Science and Technology Committee

The Regulation of Geoengineering

Fifth Report of Session 2009–10

Report, together with formal minutes, oral and written evidence

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Summary

Geoengineering describes activities specifically and deliberately designed to effect a change in the global climate with the aim of minimising or reversing anthropogenic (that is human caused) climate change. Geoengineering covers many techniques and technologies but splits into two broad categories: those that remove carbon dioxide from the atmosphere such as sequestering and locking carbon dioxide in geological formations; and those that reflect solar radiation. Techniques in this category include the injection of sulphate aerosols into the stratosphere to mimic the cooling effect caused by large volcanic eruptions.

The technologies and techniques vary so much that any regulatory framework for geoengineering cannot be uniform. Instead, those techniques, particularly carbon removal, that are closely related to familiar existing technologies, could be regulated by developing the international regulation of the existing regimes to encompass geoengineering. For other technologies, especially solar refection, new regulatory arrangements will have to be developed.

There are three reasons why, we believe, regulation is needed. First, in the future some geoengineering techniques may allow a single country unilaterally to affect the climate. Second, some—albeit very small scale—geoengineering testing is already underway. Third, we may need geoengineering as a "Plan B" if, in the event of the failure of "Plan A"—the reduction of greenhouse gases—we are faced with highly disruptive climate change. If we start work now it will provide the opportunity to explore fully the technological, environmental, political and regulatory issues.

We are not calling for an international treaty but for the groundwork for regulatory arrangements to begin. Geoengineering techniques should be graded with consideration to factors such as trans-boundary effect, the dispersal of potentially hazardous materials in the environment and the direct effect on ecosystems. The regulatory regimes for geoengineering should then be tailored accordingly. The controls should be based on a set of principles that command widespread agreement—for example, the disclosure of geoengineering research and open publication of results and the development of governance arrangements before the deployment of geoengineering techniques.

The UN is the route by which, eventually, we envisage the regulatory framework operating but first the UK and other governments need to push geoengineering up the international agenda and get processes moving.

This inquiry was innovative in that we worked collaboratively with the US House of Representatives Science and Technology Committee, the first international joint working of this kind for a House of Commons select committee. We found the experience constructive and rewarding and, we hope, successful. We are enthusiastic supporters of collaborative working between national legislatures on topics such as geoengineering with international reach. Our Report covering the regulation of geoengineering will now dovetail into a wider inquiry that the House of Representatives Committee is carrying out on geoengineering. Science, technology and engineering are key to solving global challenges and we commend to our successor committee international collaboration as an innovative way to meet these challenges.

1 Introduction

1. There were two spurs to this Report. First, in what we believe was a first for scrutiny by a legislature we examined geoengineering as one of the case studies in our Report, Engineering: turning ideas into reality.[1] We wished to follow-up that earlier work. Second, during our visit to the USA in April 2009 we met the Chairman of the House of Representatives Science and Technology Committee, Representative Bart Gordon, who suggested that the committees might find it beneficial to coordinate their scrutiny on a subject. Later in the year we agreed that geoengineering was an area where we could pool our efforts and complement each other's work, particularly as it has a significant internal dimension—a large geoengineering test could have global repercussions, deployment certainly would.

Previous scrutiny of geoengineering

2. In our earlier Report, Engineering: turning ideas into reality, we carried out a wide examination of geoengineering. The Report provided us with an opportunity to consider the implications of a new engineering discipline for UK policy-making. The broad definition of geoengineering that we used in the earlier Report holds good: we use the term "geoengineering" to describe activities specifically and deliberately designed to effect a change in the global climate with the aim of minimising or reversing anthropogenic (that is, human made) climate change.[2] A more succinct definition was provided by one of the witnesses to the current inquiry, Professor Keith: the intentional large-scale manipulation of the environment.[3]

3. To set the scene for this inquiry it is worth recalling some of our earlier findings, conclusions and recommendations from the earlier inquiry which informed our approach to this inquiry.

- We noted that unlike mitigation and adaptation to climate change, the UK had not developed any policies relating to geoengineering research or its potential role in mitigating against climate change.[4]

- We did not consider a narrow definition of geoengineering technologies to be helpful and took the view that technologies to reduce solar insolation[5] and to sequester carbon should both be considered as geoengineering options.[6]

1 Innovation, Universities, Science and Skills Committee, Fourth Report of Session 2008–09, Engineering: turning ideas into reality, HC 50–I, chapter 4

2 HC (2008-09) 50–I, para 160

3 DW Keith, "Geoengineering the climate: history and prospect", Annual Review of Energy and the Environment, (2000) 25:245–284

4 HC (2008–09) 50–I, para 159

5 Insolation is the offsetting of greenhouse warming by reducing the incidence and absorption of incoming solar (short-wave) radiation.

6 HC (2008–09) 50–I, para 182

- We were of the view that the Government should give the full range of policy options for managing climate change due consideration and that geoengineering technologies should be evaluated as part of a portfolio of responses to climate change, alongside mitigation and adaptation efforts.[7]

- The decision not to consider any initiative other than "Plan A"—mitigation—could be considered negligent, particularly since uncertainties in success of "Plan A—for example, climate sensitivity—could be greater than expected. Geoengineering should be considered "Plan B".[8]

- In order to identify those geoengineering options it might be feasible to deploy safely in the future, it was essential that a detailed assessment of individual technologies was conducted. This assessment had to consider the costs and benefits of geoengineering options, including their full life-cycle environmental impact and whether they were reversible. We welcomed the efforts of the Royal Society to review the geoengineering sector.[9]

- We considered that support for detailed modelling studies would be essential for the development of future geoengineering options, and to the construction of a credible cost-benefit analysis of technological feasibility. We urged the UK Research Councils to support research in this area.[10]

- We recommended that the Government engage with organisations including the Tyndall Centre, Hadley Centre, Research Councils UK and the Carbon Trust to develop a publicly-funded programme of geoengineering research.[11]

- Before deploying any technology with the capacity to geo-engineer the climate, we considered that it was essential that a rational debate on the ethics of geoengineering was conducted. We urged the Department for Energy and Climate Change (DECC) to lead this debate, and to consult on the full range of geoengineering options.[12]

- We were of the view that it was essential that the Government support socio-economic research with regard to geoengineering technologies, in order that the UK could engage in informed, international discussions to develop a framework for any future legislation relating to technological deployment by nation states or industry.[13]

7 HC (2008–09) 50–I, para 185

8 HC (2008–09) 50–I, para 187

9 HC (2008–09) 50–I, para 197

10 HC (2008–09) 50–I, para 203

11 HC (2008–09) 50–I, para 217

12 HC (2008–09) 50–I, para 226

13 HC (2008–09) 50–I, para 229

4. The Committee's Report was published in March 2009 and the Government replied in June 2009.[14] The main points relevant to this inquiry that the Government made were as follows.

- Geoengineering options currently did not represent viable alternatives to reducing greenhouse-gas emission. However, it recognised that it was important to keep such options under review as some might ultimately have a role to play in helping to ameliorate climate change, if emissions reductions were not achieved quickly enough. The Government therefore saw a need for some research on the potential of geoengineering technologies, to determine whether any of them could be used as an additional (Plan B) policy option for managing climate change, to complement the conventional mitigation and adaptation approaches.[15]
- The Government agreed that a detailed (and independent) assessment of geoengineering options was needed and welcomed the study that the Royal Society had been undertaking into climate engineering. It said that it would consider carefully the findings of this study and use it to inform its policy development on geoengineering.[16]
- The Government agreed with the Committee's view that support for detailed modelling studies would be essential, to help evaluate the feasibility and suitability of different geoengineering options. As indicated in the Committee's report, the nature of geoengineering research meant that much of it would need to be done on a "virtual" basis and the use of climate models would also enable a risk assessment of individual options.[17]
- Geoengineering technologies raised a number of very significant and difficult socio-economic issues and the Government agreed that some publicly-funded research on this aspect would also be needed, to inform and underpin its policy position in any future international negotiations that might take place on the possible deployment of individual geoengineering options.[18]

5. In September 2009, the Royal Society published its report, Geoengineering the climate: science, governance and uncertainty.[19] The report aimed "to provide an authoritative and balanced assessment of the main geoengineering options" but made the point that "far more detailed study would be needed before any method could even be seriously considered for deployment on the requisite international scale".[20] The report emphasised that geoengineering was not an alternative to greenhouse gas emission reductions and that, although geoengineering might hold longer-term potential and merited more research, it

14 Innovation, Universities, Science and Skills Committee, Fifth Special Report of Session 2008–09, Engineering: turning ideas into reality: Government Response to the Committee's Fourth Report, HC 759

15 HC (2008–09) 759, pp 11–12

16 HC (2008–09) 759, p 13

17 HC (2008–09) 759, p 13; see also Ev 36 [British Geophysical Association], para 1.

18 HC (2008–09) 759, p 14

19 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009

20 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, p v

offered "no quick and easy solutions that should distract policy-makers from working toward a reduction of at least 50 percent in global carbon dioxide [...] emissions by 2050".[21]

6. We welcomed both the Government's response to our Report—albeit we consider some parts to be too cautious—and the Royal Society's report. Both are constructive and show that further work needs to be done. We considered therefore what part we could play in moving geoengineering policy on in the limited time left in this Parliament. One of the recommendations in the Royal Society's report was that:

> The governance challenges posed by geoengineering should be explored in more detail, and policy processes established to resolve them.[22]

The report explained:

> A review of existing international and regional mechanisms relevant to the activities and impacts of [geoengineering] methods proposed to date would be helpful for identifying where mechanisms already exist that could be used to regulate geoengineering (either directly or with some modification), and where there are gaps.[23]

We considered that the national and international regulation of geoengineering was an issue we could examine in more detail by means of a short inquiry.

Coordinated working with US House of Representatives Science and Technology Committee

7. When the Innovation, Universities, Science and Skills Committee, as we were until October 2009, visited the USA in April 2009 we met Representative Bart Gordon, Chairman of the House Science and Technology Committee. Representative Gordon suggested that the two Committees might wish to identify a subject on which they could work together. The Commons Committee (now the Science and Technology Committee) discussed the proposal after its return from the USA and explored possible topics and arrangements for coordinating work. During the summer geoengineering emerged as an attractive subject, particularly as geoengineering has a large international dimension. In addition, the two Committees were at different stages in examination of the subject with the Commons Committee having, as we have noted, already produced a report and the House Committee about to embark on its first examination of the subject. This meant that each could cover different ground and complement each other's work.

8. In October 2009 the Committees agreed a timetable and working arrangements within the procedural rules of their respective legislatures. The text of a joint statement agreed between the Committees is the Annex to this Report.

9. The House Committee began its examination of geoengineering with a hearing in Washington DC on 5 November 2009, in which testimony was provided by a panel of

21 Ev 51, para 2

22 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, rec 6.1

23 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, para 5.4

expert witnesses that included Professor John Shepherd, who chaired the working group that produced the Royal Society's report, and leading US climate scientist Professor Ken Caldeira, Carnegie Institution, from whom we took evidence in our earlier inquiry. That session assessed the implications of large-scale climate intervention. On 4 February 2010 the House Committee took evidence on the scientific basis and engineering challenges from Professor Klaus Lackner, Columbia University, from whom we took evidence for our earlier inquiry, and from Professor David Keith, who gave evidence to this inquiry. The third hearing is planned for 18 March 2010 and will cover issues of governance.[24] It is planned that our Chairman will give testimony to that session. Ultimately, the hearings may lead to the formation of legislation authorising US government agencies to undertake certain geoengineering research activities and establish intergovernmental research agreements with other nations.

10. It is our intention that this report will assist members of the House Committee in their deliberations on the regulation of geoengineering. We also see our work on geoengineering as a pilot for future collaborative scrutiny between select committees of the House of Commons and the committees of other national legislatures, which is an issue we examine further in this Report.

The inquiry

11. In our call for evidence on 5 November 2009 we stated that the inquiry would focus on the regulation of geoengineering, particularly international regulation and regulation within the UK. The following were the terms of reference of our inquiry.

- Is there a need for international regulation of geoengineering and geoengineering research and if so, what international regulatory mechanisms need to be developed?
- How should international regulations be developed collaboratively?
- What UK regulatory mechanisms apply to geoengineering and geoengineering research and what changes will need to be made for the purpose of regulating geoengineering?[25]

12. We received 13 written submissions (excluding supplementary memoranda) in response to our call for submissions, which we accepted as evidence to the inquiry and which are appended to this Report. We are grateful to all those who submitted written memoranda. We are especially pleased that with the international dimension to this Report we received submissions from across the world.

13. On 13 January 2010 we took oral evidence from three panels consisting of:

a) Dr Jason J Blackstock, Centre for International Governance Innovation, Canada, Professor David Keith, Director, ISEEE Energy and Environmental Systems Group,

24 "Subcommittee Examines Geoengineering Strategies and Hazards", US House of Representatives Science and Technology Committee, Press Release, 4 February 2010

25 "The regulation of geoengineering", Science and Technology Committee press release 2008–09 no. 10, 5 November 2009

University of Calgary, and John Virgoe, an expert in geoengineering governance based in Australia;

b) Sir David King, Director of the Smith School of Enterprise and the Environment and former Government Chief Scientific Adviser in the UK, and Dr Maarten van Aalst, Associate Director and Lead Climate Specialist at the Red Cross/Red Crescent Climate Centre, who gave evidence in a personal expert capacity;[26] and

c) Joan Ruddock MP, Minister of State, DECC, Professor David MacKay, Chief Scientific Adviser, DECC, and Professor Nick Pidgeon, on behalf of Research Councils UK.

14. We are grateful to those who provided oral evidence. All three members on the first panel gave their evidence by video link from, respectively, the USA, Canada and Australia. The arrangements worked well and, other than a couple of blips, each witness was able to hear the others and to comment on their responses. There was almost no time delay in the transmissions which greatly facilitated the flow of the session. It would assist the operation of the facility if the visual quality was improved and all the witnesses could see each other as well as the Committee. We wrote to the Speaker and the Liaison Committee to commend the facility and its development and we were encouraged by the Speaker's response. He replied in February 2010 and said that some technical aspects have been improved and that the audio-visual facilities in all committee rooms were being reviewed. We welcome the review that the House is carrying out of the audio-visual facilities in committee rooms to enable the taking of oral evidence in committee by video link.

Structure of this Report

15. This report is in four parts. The second chapter examines categories of geoengineering, the third examines the need for regulation of geoengineering, the fourth considers the outline of future regulatory arrangements and the final chapter looks at collaborative working between committees in national legislatures.

26 Q 35

2 Categories of geoengineering

Introduction

16. This chapter examines what technologies and techniques could be classed as geoengineering and what can and should be regulated. As we explained in the previous chapter, we use the term "geoengineering" to describe activities specifically and deliberately designed to effect a change in the global climate with the aim of minimising or reversing anthropogenic climate change.[27] We are examining geoengineering exclusively in relation to climate change. Our starting point is again our earlier Report, Engineering: turning ideas into reality[28] along with the Royal Society's report, Geoengineering the climate: science, governance and uncertainty.[29]

Definition of geoengineering

17. Geoengineering is not, however, a monolithic subject.[30] Geoengineering methods are "diverse and vary greatly in terms of their technological characteristics and possible consequences".[31] They can be—and were by those who submitted evidence to us—classified into two main groups: Carbon Dioxide Removal (CDR) techniques; and Solar Radiation Management (SRM) techniques.

Carbon Dioxide Removal (CDR)

18. CDR techniques remove carbon dioxide from the atmosphere. Proposals in this category include:

a) techniques for enhancing natural carbon sinks (the oceans, the forests, rocks and soils); and

b) sequestration of carbon dioxide from the atmosphere ("atmospheric scrubbing") by chemical means, with the captured carbon deposited in the deep ocean or in geological structures.

Examples of CDR techniques

Bioenergy with carbon dioxide capture and sequestration (BECS) Biomass may be harvested and used as fuel, with capture and sequestration of the resulting carbon dioxide; for example, the use of biomass to make hydrogen or electricity and sequester the resulting carbon dioxide in geological formations.[32]

Biomass and biochar As vegetation grows it removes large quantities of carbon from the atmosphere during photosynthesis. When the organisms die and decompose, most of the carbon

27 HC (2008–09) 50–I, para 160

28 HC (2008–09) 50–I, paras 163–82

29 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, para 1.2

30 Q 8 [Dr Blackstock]

31 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, para 1.2

32 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, para 2.2.2

they stored is returned to the atmosphere. There are several ways in which the growth of biomass may be harnessed to slow the increase in atmospheric carbon dioxide—for instance, Biomass may be harvested and sequestered as organic material, for example, by burying trees or crop wastes, or as charcoal ("biochar").[33]

Enhanced weathering (land and ocean-based methods) Carbon dioxide is naturally removed from the atmosphere over many thousands of years by processes involving the weathering (dissolution) of carbonate and silicate rocks. Silicate minerals form the most common rocks on Earth, and they react with carbon dioxide to form carbonates (thereby consuming carbon dioxide).[34]

Ocean fertilisation Phytoplankton take up carbon dioxide and fix it as biomass. When the organisms die, a small fraction of this "captured" carbon sinks into the deep ocean. Proponents of ocean fertilisation schemes have argued that by fertilising the ocean it may be possible to increase phytoplankton growth and associated carbon "removal". Ocean fertilisation schemes involve the addition of nutrients to the ocean (soluble iron, for example), or the redistribution of nutrients extant in the deeper ocean to increase productivity (such as through ocean pipes).[35]

Ocean N and P fertilisation Over the majority of the open oceans the "limiting nutrient" is thought to be nitrogen. One suggestion therefore has been to add a source of fixed nitrogen (N) such as urea as an ocean fertiliser. Phosphate (P) is also close to limiting over much of the ocean.[36]

19. The table below, which draws from the Royal Society's report, compares the cost and environmental impact of CDR methods.[37]

Technique	Cost	Impact of anticipated environmental effects	Risk of unanticipated environmental effects
Land use and afforestation	Low	Low	Low
Biomass with carbon sequestration (BECS)	Medium	Medium	Medium
Biomass and biochar	Medium	Medium	Medium
Enhanced weathering on land	Medium	Medium	Low
Enhanced weathering—increasing ocean alkalinity	Medium	Medium	Medium
Chemical air capture and carbon sequestration	High	Low	Low
Ocean fertilisation	Low	Medium	High
Ocean N and P fertilisation	Medium	Medium	High

33 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, para 2.2.2

34 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, para 2.2.3

35 HC (2008–09) 50–I, para 174

36 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, para 2.3.1

37 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, table 2.9

Solar Radiation Management (SRM)

20. The second category of climate geoengineering methods aims to offset greenhouse warming by reducing the incidence and absorption of incoming solar (short-wave) radiation.[38] Proposals in this category include space-based shades or mirrors to block a portion of incoming solar radiation; and ways of increasing the Earth's albedo (that is, its surface reflectivity of the sun's radiation) by increasing cloud cover, whitening clouds or placing reflective particles or balloons into the stratosphere.[39]

Examples of SRM techniques

White roof methods and brightening of human settlements The purpose is to increase the reflectivity of the built environment by painting roofs, roads and pavements bright reflective "white". This would be most effective in sunny regions and during summertime where there might also be co-benefits through savings in air-conditioning.[40]

More reflective crop varieties and grasslands Land plants tend to absorb strongly in the visible photosynthetically active part of the solar spectrum, but are highly reflective in the near infrared frequencies. However, the albedo of plant canopies can vary significantly between different plant types and varieties, due to differences in basic leaf spectral properties, morphology and canopy structure. It may therefore be possible to increase significantly the albedo of vegetated surfaces through careful choice of crop and grassland species and varieties.[41]

Cloud Albedo It has been proposed that the Earth could be cooled by whitening clouds over parts of the ocean.[42]

Aerosol injection Large volcano eruptions result in the mass injection of sulphate particles—formed from the emitted sulphur dioxide—into the stratosphere. As these aerosols reflect solar radiation back to space, or themselves absorb heat, mass eruptions result in a cooling of the lower atmosphere. The eruption of Mount Tambora in present day Indonesia, for example, was thought to have produced the "year without a summer" in 1816. In the 1970s, Professor Budyko proposed that "artificial volcanoes" be geoengineered. That is, that sulphate aerosols be injected into the stratosphere to mimic the cooling effect caused by these "super-eruptions".[43]

Space mirrors Positioning a superfine reflective mesh of aluminium threads in space between the Earth and the Sun was proposed in 1997 by Dr Lowell Wood and Professor Edward Teller to reduce the amount of sunlight that reaches the Earth. It has been estimated that a 1% reduction in solar radiation would require approximately 1.5 million square kilometres of mirrors made of a reflective mesh.[44]

21. The table below, which again draws from the Royal Society's report, compares the cost and environmental impact of SRM methods.[45]

38 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, para 3.1

39 John Virgoe, "International governance of a possible geoengineering intervention to combat climate change", Climatic Change, vol 95 (2009), pp 103–119

40 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, para 3.3

41 As above

42 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, para 3.3.2

43 HC (2008–09) 50–I, para 168

44 HC (2008–09) 50–I, para 167; 1.5 million square kilometres is roughly the size of the land area of Alaska or six times the area of the UK.

45 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, table 3.6.

SRM technique	Possible side-effects	Risk (at max likely level)
Human Settlement Albedo	Regional Climate Change	L
Grassland and Crop Albedo	Regional Climate Change Reduction in Crop Yields	M L
Desert Surface Albedo	Regional Climate Change Ecosystem impacts	H H
Cloud Albedo[46]	Termination effect[47] Regional Climate Change	H H
Stratospheric Aerosols	Termination effect Regional Climate Change Changes in Stratosphere Chemistry	H M M
Space-based Reflectors	Termination effect Regional Climate Change Reduction in Crop Yields	H M L

Differences between CDR and SRM

22. The fundamental difference between CDR and SRM is that carbon sequestration addresses the root issue—that is, the concentration of carbon dioxide—while solar reflection "treats the symptom"—that is, global warming.[48] The Sustainability Council of New Zealand pointed out that problems arising from this include:

- reflection does not address the acidification of oceans that results from excess carbon dioxide in the atmosphere being absorbed by the sea;
- schemes that inject particles into the atmosphere are likely to alter the distribution of rainfall and also cause some reduction in the global quantity of rainfall; and
- many reflection techniques will need to be replenished constantly over their lifetime and, if this is not kept up, extremely rapid warming could ensue.[49]

23. The other difference is that some SRM techniques could substantially influence the climate within months but, as Dr Blackstock pointed out, with "much greater uncertainty about the net climatic effects".[50] Natural experiments caused by volcanoes have demonstrated the rapid impact potential of SRM, and recent reviews have shown such schemes should be technically simple to deploy at low cost relative to mitigation. But, as Dr Blackstock noted, these reviews also stressed that SRM would "at best unevenly ameliorate

46 See Ev 37 [Alan Gadian], which challenged the assessment of risk in the Royal Society's report.

47 "Termination effect" refers here to the consequences of a sudden halt or failure of the geoengineering system. For SRM approaches, which aim to offset increases in greenhouse gases by reductions in absorbed solar radiation, failure could lead to a relatively rapid warming which would be more difficult to adapt to than the climate change that would have occurred in the absence of geoengineering. SRM methods that produce the largest negative changes, and which rely on advanced technology, are considered higher risks in this respect.

48 Ev 45

49 As above

50 Ev 2 [Dr Blackstock], para 10

regional climatic change, and may generate serious unintended consequences. For example, SRM could produce droughts with severe implications for regional and global food production, and delay the recovery of the ozone layer by decades, while doing almost nothing to address ocean acidification."[51]

Weather modification techniques

24. While there was a measure of debate that some—CDR, in particular—technologies fell within the definition of geoengineering, there was greater disagreement about weather modification techniques should be included. The Action Group on Erosion, Technology and Concentration (ETC Group) considered that geoengineering should also encompass weather modification techniques such as hurricane suppression and cloud seeding.[52] Cloud seeding causes precipitation by introducing substances into cumulus clouds that cause condensation. Most seeding uses silver iodide, but dry ice (that is, solid carbon dioxide), propane, and salt are also used.[53]

25. These techniques are in use to precipitate rain and to suppress precipitation and hail.[54] Dr James Lee, from the American University, Washington DC, pointed out in his memorandum that cloud seeding was first scientifically demonstrated in 1946[55] and "is a geoengineering tool that is widely used by more than 30 countries" and that with climate change, fresh water resources will be in decline in many parts of the world and one "result may be an increase in the use of cloud seeding".[56] He cited the example of China, whose:

> cloud seeding program is the largest in the world, using it to make rain, prevent hailstorms, contribute to firefighting, and to counteract dust storms. On New Year's Day in 1997, cloud seeding made snow in Beijing, for probably no other reason than popular enjoyment. During the 2008 Olympics, China extensively used cloud seeding to improve air quality. China sees cloud seeding as part of a larger strategy to lower summer temperatures and save energy.[57]

26. Dr Lee drew a distinction between climate change and weather:

> since cloud seeding is more likely to affect the latter. Weather is a state of the atmosphere over the short-term and more likely at specific points and places. Climate is a long-term phenomenon expressed as average weather patterns over a long period. Cloud seeding could affect climate when carried out over a long period. Key measures of weather and climate are precipitation and temperature.[58]

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51 Ev 2 [Dr Blackstock], para 10

52 Ev 50, para 4

53 Ev 33, section 3

54 As above

55 As above

56 Ev 32, summary para 1; and see also Ev 33, section 3

57 Ev 34, section 3

58 Ev 32, section 1

27. Since 1977, cloud seeding and environmental techniques have been subject to international regulation. In 1977 countries agreed to the "Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques" (ENMOD). The treaty, as well as forbidding the use of environmental modification techniques in hostile circumstances, supported the use of weather modification for peaceful purposes. A re-confirmation of the ENMOD principles occurred at the Framework Convention on Climate Change (UNFCCC) and the 1992 Earth Summit in Rio de Janeiro.[59] Dr Lee pointed out that most techniques covered by the ENMOD treaty were "quite speculative"—for example, causing earthquakes or tsunamis which was far beyond the capacity of current technology—but that cloud seeding was a technology that was often used.[60]

28. At the oral evidence session we asked whether weather-changing techniques such as cloud seeding should be considered to be geoengineering. Mr Virgoe, Dr Blackstock and Professor Keith were clear that they should not.[61] Mr Virgoe considered that "one of the criteria [...] for geoengineering is that the effect needs to be at a global level, and cloud seeding is a weather modification technique."[62] Weather modifications such as cloud seeding which affect the weather for no longer than a season, in our view, do not fall within the definition of geoengineering. Moreover, these techniques are regulated by international conventions, ENMOD and UNFCCC. We conclude that weather techniques such as cloud seeding should not be included within the definition of geoengineering used for the purposes of activities designed to effect a change in the global climate with the aim of minimising or reversing anthropogenic climate change.

Conclusions on definition

29. We have set out the techniques that fall within CDR and SRM in some detail to show that there is a "very wide range of geoengineering methods, with diverse characteristics, methods of action and potential side effects".[63] John Virgoe, an expert in geoengineering governance based in Australia and who has conducted research into geoengineering governance and regulation, was of the view that CDR and SRM are

> so different in nature and implications that it is questionable whether it is helpful to describe both as geoengineering. Broadly speaking, the former might form an element within a package along with mitigation and adaptation [to climate change], while the latter might be deployed as an emergency response in the event of highly disruptive climate change.[64]

Dr Blackstock shared his view that SRM was "unsuitable as an alternative to mitigation".[65]

59 Ev 32, section 2

60 As above

61 Qq 16–17

62 Q 16

63 Ev 52 [Royal Society], para 4

64 Ev 5, para 5

65 Ev 2, para 10

30. Taking the CDR technologies as a whole, it is clear that the risk of a negative impact on the environment is less than those in the SRM category. But, as the Royal Society pointed out, ecosystem-based methods, such as ocean fertilisation—a CDR technology—carries the risk of having “much greater potential for negative and trans-boundary side effects”.[66] As Sir David King put it: “as soon as we move into capture from the oceans [...] we are dealing with an issue of long range pollution and impact problems, so cross-boundary problems”.[67] On the other hand, painting roofs white—an SRM technique—would have little adverse effect or consequences across national boundaries. In our view, geoengineering as currently defined covers such a range of Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM) technologies and techniques that any regulatory framework for geoengineering cannot be uniform. As the Government put it, to formulate an overarching governance framework covering all geoengineering research and deployment “will be challenging”.[68] In our view, it is neither practicable nor desirable.

Conclusions on grading for the purposes of regulation

31. A system to differentiate and grade geoengineering techniques is required. As Dr Jason Blackstock put it:

> When we think of developing regulatory structures for what we class as geoengineering, our primary concern should be about how large is the transboundary impact and how soon will that transboundary impact manifest.[69]

In more detail the Royal Society suggested that the fundamental criterion in relation to governance of geoengineering was whether, and to what extent, the techniques involved:

a) trans-boundary effects—other than the removal of greenhouse gases from the atmosphere;

b) dispersal of potentially hazardous materials in the environment; and

c) direct intervention in (or major direct side-effects on) ecosystems.[70]

32. Professor Keith preferred an approach based on leverage, which we understand to be large effect on the climate for a relatively small amount of resources, and timescale.[71] Mr Virgoe added that as well as environmental risks there were risks of things going wrong or risks of unintended side effects and that there “is clearly a risk that the techniques do not work and there are also risks around things like legal issues and liability”.[72]

33. We consider that geoengineering as currently used is a useful portmanteau definition encompassing CDR and SMR techniques but cannot be used as the basis for a single

66 Ev 52, para 5

67 Q 39

68 Ev 21, para 6

69 Q 18

70 Ev 52, para 7

71 Q 20

72 Q 21

regulatory regime. In our view the criteria suggested by the Royal Society provide a sound basis for building a grading system for geoengineering techniques for the purposes of regulation. They are intelligible and likely to command support. Other criteria such as leverage and risk could be included, though we would be concerned if the criteria proliferated or were drawn so widely as to bring techniques unnecessarily within tight regulatory control. We conclude that geoengineering techniques should be graded according to factors such as trans-boundary effect, the dispersal of potentially hazardous materials in the environment and the direct effect on ecosystems. The regulatory regimes for geoengineering should then be tailored accordingly. Those techniques scoring low against the criteria should be subject to no additional regulation to that already in place, while those scoring high would be subject to additional controls. So for example, at the low end of the scale are artificial trees and at the high end is the release of large quantities of aerosols into the atmosphere.

3 Need for regulation of geoengineering

34. The first question in our terms of reference for this inquiry was: is there a need for international regulation of geoengineering research and deployment and if so, what international regulatory mechanisms need to be developed? The answer we received split into two: some geoengineering techniques are already subject to regulation; and as regards the remaining techniques the position is not yet clear.

Geoengineering techniques currently subject to regulation

35. The Royal Society pointed out that:

> CDR technologies could mostly be adequately controlled by existing national and international institutions and legislation. Many of the technologies are closely related to familiar existing technologies. Air capture technologies are very similar to those of carbon capture and storage; and this is likely to be one of the most environmentally benign technologies. Ocean fertilisation techniques are currently being managed by the London Convention on ocean dumping, under the London Protocol. The Convention of Biological Diversity has also adopted a decision on ocean fertilisation which is mostly consistent with that of the London Convention. Biochar and BECS[73] face similar regulatory issues to that of biofuels including life cycle analysis, and land use management. Ecosystem impacts of enhanced terrestrial weathering would be contained within national boundaries. Methods of enhanced weathering involving oceanic dispersion of the products would have trans-boundary effects, but may also be able to be managed under the London Convention.[74]

36. John Virgoe in a recent article identified an important shortcoming of the existing international systems of regulation. He pointed out that "No existing treaty deals explicitly with geoengineering. None of these treaties was drafted with geoengineering in mind, and none of them clearly prohibits or regulates relevant activities" but he considered that they might provide "contexts in which a possible geoengineering intervention might be regulated—or challenged.[75] He pointed out that even the UNFCCC, the basic legal instrument on climate change, did not address the possibility of intentional attempts to change the climate, except for the "enhancement of sinks and reservoirs".[76] In our view this is not a defect that could or should be rectified by excluding geoengineering from the ambit of these protocols or erecting parallel arrangements for the purposes of regulating geoengineering.

37. Instead, the existing regimes could be developed to encompass geoengineering. Mr Virgoe could "see no good reason not to encourage (carefully supervised) research in these techniques" and "to ensure carbon accounting/trading rules are crafted in a way which

73 Biomass with carbon sequestration.

74 Ev 52, para 13; see also Q 8 [Dr Blackstock]

75 J Virgoe, "International governance of a possible geoengineering intervention to combat climate change", Climatic Change, 2009, 95:103–119, para 3

76 As above

might include such activities (once issues of safety, verification etc are taken into account)".[77] Research Councils UK made a similar point. On the assumption that geoengineering techniques, particularly CDR, were formally recognised as contributing to climate change mitigation (that is, as part of national commitments to international climate change agreements), "such techniques will need linking to emission trading schemes or other mechanisms that may evolve".[78]

38. **The existing international regulatory arrangements on climate change, such as UNFCCC, need to be developed to encompass geoengineering techniques. We see a role for the Government. Through its involvement in the existing international regulatory arrangements such as the UN Framework Convention on Climate Change and when these instruments come up for revision we recommend that the Government raise geoengineering, particularly those for Carbon Dioxide Removal (CDR), and seek to develop, in conjunction with other governments, the arrangements provided by these international instruments so that they address research on, and deployment of, CDR geoengineering techniques.**

Geoengineering techniques currently not subject to regulation

39. In contrast, regulatory regimes for many SMR techniques have yet to be developed. Again the Royal Society summarised the position:

> For SRM technologies there are fewer existing institutions that could manage research and development. Land surface albedo modification could be managed under national regulatory frameworks as there are unlikely to be major trans-boundary issues. The oceanic cloud brightening technologies would not fall under national jurisdiction and no existing international institutions have a clear mandate, so modifications and extensions of existing treaties (e.g. ENMOD) and institutions would be required. Existing treaties governing the atmosphere and space (CLRTAP[79] & OST)[80] would similarly not be adequate to regulate stratospheric aerosols and space mirrors. There is a risk that these methods could be applied by an individual nation or corporation which highlights the need for international regulation for deployment (and in some cases research).[81]

Dr Blackstock pointed out that for SRM "we do not have the appropriate regulatory mechanisms in place, and I do not believe we have even a forum in which that discussion has begun to occur".[82]

40. The Government appeared to share this view. It told us that geoengineering was an emerging policy area and there "were at present no international treaties or institutions with sufficient mandate to regulate the broad range of possible geoengineering activities"

77 Ev 5, para 8

78 Ev 24, para 16

79 The 1979 onvention on Long-range Trans-boundary Air Pollution

80 The 1967 Outer Space Treaty

81 Ev 53, para 14

82 Q 9

and that, while regulation of some of the technologies might be feasible by employing or amending existing treaties and protocols of international law, others—such as atmosphere and space-based methods—"may require new international mechanisms".[83] **We conclude that there is a gap in the regulatory framework for geoengineering techniques, especially for SRM techniques.**

41. But does this gap matter? There are three issues which we consider are relevant:

a) whether there is a need for urgency;

b) the state of the science; and

c) public attitudes.

Urgency

42. The Government considered that there was no urgency. The Minister, Joan Ruddock MP, did not see geoengineering as a priority for Government. She said that geoengineering techniques were "far from being developed to the point of viability at the moment".[84] But the Government was keeping a "watching brief" on the subject and did "things at a de minimis level".[85] What it considered as urgent was "reducing greenhouse gas emissions in this country, of legislating to that effect, and of participating in the international discussions about trying to arrive at a global deal".[86] Indeed, she saw a danger in adopting Plan B[87] (that is, research into geoengineering), "if that were even feasible, which I would question, but the danger in adopting a Plan B is that you do not apply yourself to Plan A, and the point of Plan A is it is all entirely do-able."[88]

43. As we explained in a previous chapter, we have disagreed strongly with the Government on the advisability of investigating geoengineering as a fallback option, Plan B. Sir David King directly addressed the concern that appears to inhibit the Government's view of geoengineering that it was a distraction from the reducing greenhouse gas emissions. He said that the major effort had to be around defossilising economies, as that would manage the anthropogenic (that is, human made) problem directly rather than indirectly through geoengineering.[89] He considered that, if "we [could] manage the transition over the next 40 years into a defossilised economy", geoengineering techniques might not be needed. It was, however, necessary:

> to factor in the probability distribution functions that the best science can deliver around what the temperature rise for the planet will be even at a level [...] of 450 parts per million of greenhouse gas CO_2 equivalent in the atmosphere. The best that science can tell us at the moment is that the eventual temperature rise is going to lie

83 Ev 19

84 Q 51; see also Q 58

85 Q 58

86 Q 51

87 See paragraph 3 above.

88 Q 56

89 Q 34

> somewhere between 1° Centigrade and 4° Centigrade with a peak in that probability distribution function above 2° Centigrade, and so we only have a 50 per cent chance of staying below a 2° Centigrade rise. There is still, for example, a 20 per cent chance that the temperature rise will be above 3.5° Centigrade, and I am putting to you the idea that the 450 parts per million figure is what we ought to aim for globally—it is the lowest figure that is manageable—but even there we have to manage risks by keeping in reserve an alternative way forward.[90]

Dr Maarten van Aalst took a similar view:

> we need to be cautious of investing at too large a scale to even give the impression that this is a suitable alternative in the short-term to mitigation or [...] much more extensive capacity building and adaptation, especially among the most vulnerable groups [...] On the side of the risks, I agree that it is something that we might want to have up our sleeves, and we are nowhere near the level of certainty about what these different options are that we could consider these options that we have at this stage, so further research, in that sense, on a small scale to get slightly further in our understanding would be important.[91]

44. Sir David saw a need to manage the acidification of the oceans as the increase in carbon dioxide levels meant that more carbonic acid formed in the oceans. The oceans were "part of the ecosystem services for humanity. It is the oceans that provide the beginning of the food chain" and he saw a need to invest research in carbon dioxide removal from the oceans and for prior regulation particularly on ocean removal.[92]

45. Dr Blackstock considered that in spite of the limitations and risks "avoiding SRM research would be a mistake".[93] He pointed out that the ability to influence rapidly the climate meant SRM might be the only recourse should a climate crisis materialise. Since severe climate change could bring about such national or regional crises within decades, he considered that "prudence suggests we should improve our understanding of the likely feasibility, effectiveness and dangers of SRM interventions" and that without prior research "uninformed and rash unilateral action by less responsible actors becomes more likely".[94] Moreover, near-term authoritative research would help "discredit ungrounded fringe claims that SRM could provide an alternative to dramatic near-term emission reductions" and he added that "establishing good governance of SRM requires good understanding of the schemes and risks to be governed, which first requires research".[95]

46. Both Professor Keith[96] and Dr Blackstock made the point that SRM technologies appeared to be relatively cheap and therefore relatively technically simplistic.[97] Dr Blackstock explained that this was:

90 Q 34; see also Ev 45 [Sustainability Council of New Zealand]

91 Q 35

92 Q 39

93 Ev 2, para 11

94 As above

95 As above

96 Q 17

> because most of the technologies required to actually deploy solar radiation management are things that are available to numerous countries already. These are not technologies that require huge technological progress from where existing technologies are at. The idea that we can potentially regulate and control the technology underlying solar radiation management, like we do, or attempt to do, with nuclear technologies, is not a good analogy for this. The technology is going to proliferate and be accessible to a large number of individuals or countries and, therefore, we have to look at controlling behaviours in this case, not just access to technology.[98]

47. The Sustainability Council of New Zealand put to us a scenario for unilateral action where one region was significantly affected by climate change and felt the international community was responding too slowly. The Council pointed out that developing nations would in general suffer soonest from the more serious effects of climate change and it envisaged that a small group of developing countries could deploy reflection schemes shifting the balance of power such that the pace of climate change responses in general would tend to better align with those countries' preferences.[99]

48. Nor is geoengineering confined to modelling and the distant future. Professor Keith told us that the Russians were already carrying out testing,[100] though Dr Blackstock added that the Russian tests were "extremely subscale".[101] Professor Keith also explained that it was becoming urgent to undertake tests into stratospheric geoengineering as it had become clear that the main method that had been considered did not work. He explained that if sulphur was put in the stratosphere the way scientists have been assuming, it did not do what they expected. Tests were necessary and these would have "no detectable climate effect, but they would be subscale tests, and if we want to actually understand whether this technology works or it does not, we need to do those tests relatively soon".[102]

49. The Government's focus on Plan A—the reduction of the emissions of carbon dioxide and other greenhouse gases—is an approach that is becoming increasingly untenable as geoengineering testing is already beginning and SRM techniques are within the reach of a growing number of nations. Nor is its aversion to geoengineering on the grounds that it will distract from Plan A evidence-based. An equally plausible view is that, if the Government were to focus more than at present on geoengineering, it would persuade more people that the threat of global warming was serious and needed to be addressed. In this regard Sir David King made a telling point that "knowing the nature of the possible challenges in the future—[for example one country using geoengineering to divert another's monsoon]—is a very sobering way of managing the business of defossilising".[103] **We recommend that the Government review its policy on geoengineering to give it greater priority.**

97 Q 18 [Dr Blackstock]

98 Q 18

99 Ev 45

100 Q 27; see also Ev 3 [Dr Blackstock], para 15

101 Q 27

102 As above

103 Q 40

Geoengineering is too unpredictable

50. An argument made by some against geoengineering is that climate systems are already unpredictable and contain much “noise” and that, as the ETC Group stated, “for any research activities on geoengineering techniques to have a noticeable impact on the climate, they will have to be deployed on a massive scale, and thus any unintended consequences are also likely to be massive”.[104] John Virgoe weighed up the issues:

> The state of knowledge about geoengineering, both on the technical side but also on the political, ethical and regulatory sides, is simply not at a point where I think any sensible person would be able to recommend that we should be implementing a geoengineering technique at this point. I think, however, there is increasing reason to think that we may be heading that way in the future. [It] depends to some extent on your degree of optimism about whether the world will actually get on top of global warming through the mitigation methods and through international negotiations. If we believe that we may be heading in that direction and that in some years from now [...] we may be looking seriously at a geoengineering intervention, I think it does make sense for us to be starting, at this point, not only to research the science and the technology, but also to think through some of these issues around the politics and the regulation so that when we do get to the point [...] we are in a position to take a mature, measured and informed decision.[105]

51. Dr Blackstock considered that because stratospheric aerosols and cloud whitening were the only category of techniques that could be used with a rapid impact on the climate system there was a need to get regulatory structures in place before large scale field tests were started.[106] He said that field experiments designed to have demonstrably negligible environmental and trans-boundary risks were valuable for feasibility testing deployment technologies, and for exploring local-scale physical, chemical and biological interactions that could damage the environment when scaled up.[107] Dr Blackstock explained that once “you start running into the potential for transboundary impacts, or at least a perception of transboundary impacts, and so international mistrust, international concern of what another country will do with that technology can come up very rapidly”.[108] Professor Keith added that “governance is central at the point where we lock it, and the reason is that it is so cheap that the challenge for the international system will be to restrain unilateral action”.[109]

52. Beyond the small test, Dr Blackstock said that robust understanding of SRM would eventually require tests with demonstrable climatic impacts and that confidence in SRM climate model predictions could only come from “poking” the climate system and comparing the predicted and observed responses. But due to the natural complexity and variability of the climate system, “signal-to-noise issues will plague the attribution of

104 Ev 50, para 13

105 Q 6

106 Q 8

107 Ev 3, para 15

108 Q 8

109 Q 12

climatic impacts and unintended consequences to a particular test" and that for "any SRM scheme it might prove impossible to test for most impacts with 'pokes' below a scale considered (at least politically) to constitute deployment of a low-level climatic intervention".[110]

53. There is a wider issue. For understandable reasons there is a tendency to approach regulation of geoengineering as we do reducing emissions of greenhouse gases, which requires action by many parties. Reduction of emissions requires global action with a global impact. By contrast, as John Virgoe has pointed out, some geoengineering techniques only require local action to have a global impact—one possible example, would be the release of stratospheric aerosols. The regulatory regime applying to a geoengineering technique does not need to be so extensive as that for the reduction of emissions. It could focus on setting targets, managing a process and cost-sharing. This reduces the complexity of the governance task, while simultaneously reducing the need for a universal process, though wide participation would remain strongly desirable on ethical and political grounds.[111]

Conclusions on the need for the regulation of geoengineering

54. The science of geoengineering is not sufficiently advanced to make the technology predictable, but this of itself is not grounds for refusing to develop regulatory frameworks, or for banning it. There are good scientific reasons for allowing investigative research and better reasons for seeking to devise and implement some regulatory frameworks, particularly for those techniques that a single country or small group of countries could test or deploy and impact the whole climate.

55. We conclude that there is a need to develop a regulatory framework for geoengineering. Two areas in particular need to be addressed: (i) the existing international regulatory regimes need to develop a focus on geoengineering and (ii) regulatory systems need to be designed and implemented for those SRM techniques that currently fall outside any international regulatory framework.

Public attitudes

56. The Royal Society said in its report that the acceptability of geoengineering would be determined as "much by social, legal and political issues as by scientific and technical factors".[112] The Minister told us that it was not for the Government to encourage a debate on the social acceptability of geoengineering, because that presumed that the Government had taken a view that geoengineering was a good thing, and that it should be deployed. The Government had not, however, taken that view. The Minister considered it was "important to involve the public in discussions as these things develop".[113] She was "alive to the fact that there would need to be public engagement" and pointed out that the Natural

110 Ev 3, para 17

111 J Virgoe, "International governance of a possible geoengineering intervention to combat climate change", Climatic Change, 2009, 95:103–119, para 2.2

112 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, p ix

113 Q 65

Environment Research Council "have a public dialogue programme that they are about to launch. So it is important to talk with the public and to avoid ignorance and prejudice, but at the same time, it is not for the Government to persuade the public of the need for this."[114]

57. Dr Adam Corner and Professor Nick Pidgeon, on behalf of the Understanding Risk Research Group at Cardiff University, said that a key consideration would be the public acceptability of both specific geoengineering proposals themselves and the governance arrangements set in place. They explained that

> Research in the UK and elsewhere on the public acceptance of the risks of new technologies (such as nuclear power or biotechnology) shows clearly that people raise a range of generic concerns about new technologies. These include concerns over: long-term uncertainties; who will benefit; arrangements for control and governance; and who to trust to regulate any risks. Geoengineering is unlikely to be any different in this regard.
>
> [W]ork on the technical feasibility of geoengineering should not begin prior to a thorough evaluation of governance arrangements for research. Our most fundamental concern is that a programme of public engagement should be an important component feeding into governance and research priorities. Thus, the first challenge for geoengineering governance is to pursue an international programme of upstream public engagement.[115]

58. While we welcome the work that NERC is doing on public engagement on geoengineering, we find the Government's approach unduly cautious. In part this appears to be a product of its view that geoengineering is a distraction from reducing carbon emissions, which, as we have already discussed, is not an evidence based approach and does not recognise some of the alternatives in pay-off of government support for geoengineering. **We recommend that the Government give greater priority to public engagement on geoengineering by, for example, showing how it relates to its policy on the reduction of carbon dioxide emissions. We welcome the work of Natural Environment Research Council (NERC) on public engagement on geoengineering and we request that, when the work is completed, the Government provide our successor committee with an explanation of how it will inform its policy on geoengineering.**

114 Q 65

115 Ev 41, paras 1–2

4 Future regulatory arrangements

59. Having concluded in the previous chapter that there is a need to develop the regulatory regimes for geoengineering, we examine in this chapter what regulatory principles and arrangements should apply and how they might operate.

The formulation of a regulatory regime

60. The first stage in establishing a regulatory regime (or regimes) is to decide on principles and common procedures. The experts who gave us oral evidence favoured a "bottom-up generation of norms"[116] rather than a "top-down" approach from an organisation such as the UN. John Virgoe wished to develop and "socialise" the norms "among the community of nations, the community of scientists and other stakeholders".[117] He considered that the state of international understanding and also the knowledge base was currently so weak that the outcome from a top-down approach could be unsatisfactory. He explained:

> it is very possible to imagine, if this is put on the table in some sort of UN forum, you could end up with a decision [...] to make geoengineering a taboo, to outlaw it, and that would be a mistake, for a couple of reasons. One is that it may be that we actually need to be doing this research and that, some decades down the line, we will be very sorry if we have not started thinking through these techniques. The second is that I think there are a lot of actors out there [...] with the capacity to research and implement these techniques. Some of them may not feel bound by that sort of international decision, some of them may not be as responsible, and it would be very unfortunate if what geoengineering research was happening was going on under the radar screen, if you like. What we need is an open process which builds on some of the principles that are already out there around similar issues; for example, principles developed to deal with long-range air pollution or weather modification: principles around openness, transparency and research, notifying a neighbouring country or countries which might be affected. We probably develop these through maybe a slightly messier process than an international negotiation. Individual countries will have a role; communities of scientists will certainly have a role.[118]

61. While accepting that the "bottom-up" approach could work well for developing deployment technologies, laboratory research and computational modelling, Dr Blackstock had reservations whether it would be sufficient when it came to field tests, particularly high leverage SRM technologies and those with trans-boundary impact. He said that as well as the technical risk and the environmental risk there was the political risk in the perception of the test.[119] He cited the recent case of the ocean fertilisation experiment in 2009—Lohafex—an Indo-German collaboration. He said that the test would have had very small impacts in terms of the ecosystems and trans-boundary.[120] But it demonstrated the political

116 Q 23 [Professor Keith]

117 Q 22; see also Q 23

118 Q 22; see also Q 28

119 Qq 23 [Dr Blackstock] and 24

120 Q 23

sensitivities any geoengineering experiments could evoke. He said that at the core of this controversy was also the "difficulty of defining politically acceptable (national and international) scientific standards and oversight mechanisms for ensuring the environmental and transboundary risks of nominally subscale geoengineering field tests were in fact 'demonstrably negligible'".[121] DECC explained that a moratorium had been placed on large-scale ocean fertilisation research under the Convention for Biological Diversity while a regulatory agreement was being developed under the London Convention/Protocol.[122]

62. Dr Blackstock took the view that "the consideration of the norms is partly necessary but not sufficient to address the sort of political issues that will raise".[123] In his view it was necessary to have a "mechanism of legitimacy", to define subscale (that is, small) experiments "before we start pushing the boundaries of [...] subscale, that is [...] where we really need to have, not just scientific, but political agreement".[124] Where nation states were starting to fund research, particularly if it went to funding subscale experimentation, Dr Blackstock considered that "we need to ask what preventive commitments, what precautionary commitments nation states need [...] up front in order to avoid exacerbating all the mistrust that already exists within the international climate arena".[125]

63. Research Councils UK took a more cautious view than Dr Blackstock. It was concerned that even small-scale actions could generate negative environmental, social and economic consequences if undertaken without appropriate controls in place or a sufficient level of expertise. It cited, as an example, a field trial involving atmospheric SRM manipulations that might temporally—but perhaps coincidentally—be linked to extreme weather events resulting in high economic consequences. Research Councils UK also considered that some highly controversial techniques could be applied at relatively low cost and with relative ease, opening up geoengineering as a feasible unilateral activity to a wide range of actors with different knowledge, skills and motivations. Such actions might be linked to political as well as, or even instead of, environmental concerns. This suggested to Research Councils UK that "regulation might be best monitored at the level of supra-national governance structures such as the UN".[126]

64. Dr van Aalst was anxious that if geoengineering was raised at a high political level too early, it could be sending the "wrong signals".[127] He considered that there were more technically oriented UN bodies that would be more appropriate, such as the Intergovernmental Panel on Climate Change (IPCC). He hoped that, along with some conscious efforts at consultation focussed primarily on looking at risks, it "might actually be then guiding us towards more investments on the mitigation and adaptation sides".[128] He hoped that discussions in "UN bodies would then trigger a much wider debate,

121 Ev 3, para 16

122 Ev 21, para 9

123 Q 24

124 Q 27

125 As above

126 Ev 23, para 12

127 Q 46

128 As above

involving a larger range of stakeholders, and a more diverse set of stakeholders than have been taking part in this discussion so far".[129]

65. In our view, there is a case for starting to develop the international framework for geoengineering now as opposed to waiting for the state of international understanding and the knowledge base for geoengineering to grow. Characterising the development of an international framework as top-down may be exaggerated as development will not be uniform for geoengineering techniques and the development of geoengineering regulatory arrangements is likely to take years. Nor does it preclude the building of bottom-up practices and approaches to geoengineering. While accepting that the development of a "top-down" regulatory framework may have risks and limitations, we consider that these are outweighed by the benefits of an international framework: legitimacy; scientific standards; oversight mechanisms; and management of environmental and trans-boundary risks.

Principles to be applied to geoengineering research

66. In a submission to our inquiry a group of academics set out five key principles by which they believed geoengineering research should be guided.[130] We welcome the production of the principles by a group of academics which provide a basis to begin the discussion of principles that could be applied to the regulation of geoengineering. We consider that the proposed principles could be useful both to the "top-down" approach and, to a lesser extent, to a "bottom-up" approach. (It could, for example, inform the drafting of the code of practice on research suggested by the Royal Society—see paragraph 89.) We therefore examine the principles in detail. The principles and part of the explanatory text are set out in the box below.

Principle 1: Geoengineering to be regulated as a public good
While the involvement of the private sector in the delivery of a geoengineering technique should not be prohibited, and may indeed be encouraged to ensure that deployment of a suitable technique can be effected in a timely and efficient manner, regulation of such techniques should be undertaken in the public interest by the appropriate bodies at the state and/or international levels.

Principle 2: Public participation in geoengineering decision-making
Wherever possible, those conducting geoengineering research should be required to notify, consult, and ideally obtain the prior informed consent of, those affected by the research activities. The identity of affected parties will be dependent on the specific technique which is being researched—for example, a technique which captures carbon dioxide from the air and geologically sequesters it within the territory of a single state will likely require consultation and agreement only at the national or local level, while a technique which involves changing the albedo of the planet by injecting aerosols into the stratosphere will likely require global agreement.

Principle 3: Disclosure of geoengineering research and open publication of results
There should be complete disclosure of research plans and open publication of results in order to facilitate better understanding of the risks and to reassure the public as to the integrity of the process. It is essential that the results of all research, including negative results, be made publicly available.

129 Q 46

130 Ev 42: Professor Steve Rayner (University of Oxford), Professor Catherine Redgwell (University College London), Professor Julian Savulescu (University of Oxford), Professor Nick Pidgeon (Cardiff University) and Mr Tim Kruger (Oxford Geoengineering Institute)

Principle 4: Independent assessment of impacts
An assessment of the impacts of geoengineering research should be conducted by a body independent of those undertaking the research; where techniques are likely to have trans-boundary impact, such assessment should be carried out through the appropriate regional and/or international bodies. Assessments should address both the environmental and socio-economic impacts of research, including mitigating the risks of lock-in to particular technologies or vested interests.

Principle 5: Governance before deployment
Any decisions with respect to deployment should only be taken with robust governance structures already in place, using existing rules and institutions wherever possible. [131]

67. In putting forward these principles the academics said that transparency in decision-making, public participation, and open publication of research results were key elements of the framework, designed to ensure maximum public engagement with, and confidence in, the regulation of geoengineering research. Alone or in combination, many of these principles were already applied in the regulation of hazardous substances and activities such as the trans-boundary movement of hazardous wastes and pesticides, radioactive substances and Genetically Modified Organisms (GMOs).[132]

68. Most debate and reservations focused on the regulation of geoengineering for the public good and public participation in geoengineering decision-making.

Principle 1: Geoengineering to be regulated as a public good

69. Commenting on Principle 1—geoengineering to be regulated as a public good—Mr Virgoe asked who was the public—the global public? He pointed out that geoengineering interventions affected the planet as a whole and that there were number of publics. Some publics were suffering very badly, or would be suffering very badly, from the effects of climate change. But some populations might benefit from climate change and, therefore, would not be happy to see climate change being put into "reverse gear", if that could be achieved. He said that the impact of some of the techniques was likely to be heavily differentiated. Some areas might continue to warm, whereas other areas cooled faster and there might be unintentional side effects. He considered that below the surface of the public good "you get into some difficult ethical territory".[133]

70. Sir David King raised the treatment of intellectual property rights (IPR). He pointed out that

> if we are going to go down the route of carbon dioxide capture from oceans or atmosphere, and this is going to be a good thing, we also need to know, where is the investment going to come from, to take the research into demonstration phase and into the marketplace, and there will be a marketplace with a price of carbon dioxide. That is going to be the private sector companies. If we do not allow protection of IPR, are we going to actually inhibit that process of investment? So I think I am a

131 Ev 44, para 17

132 Ev 43, para 6

133 Q 26

little hesitant to simply back the pure public good argument without IPR protection.[134]

71. We conclude that Principle 1 of the suggested five key principles on how geoengineering research should be guided—"Geoengineering to be regulated as a public good"—needs, first, to be worked up in detail to define public good and public interest. Second, the implied restriction suggested in the explanatory text to the Principle on intellectual property rights must be framed in such a manner that it does not deter investment in geoengineering techniques. Without private investment, some geoengineering techniques will never be developed.

Principle 2: Public participation in geoengineering decision-making

72. One of the principles international law suggests might be used in developing a regulatory regime for geoengineering is the requirement to inform or consult (Principle 10 of the Rio Declaration).[135] In the context of geoengineering, however, Mr Virgoe questioned what the principle meant at the global level, specifically, how public participation was achieved at the global level and how to ensure that certain parts of the public, or the public in certain countries, did not have privileged access compared with other countries, publics or other parts of the global public.[136]

73. Dr Blackstock said that some countries already had populations marginalised in terms of climate change or were on the edge of suffering from climate change impacts, because those marginalised populations were likely to be the ones most sensitive to geoengineering experiments and a high level of solar radiation management experiments and particularly implementation. He saw a risk that without directive public engagement, an attempt to reach out and provide the information proactively, "we end up with them inevitably being surprised later on by rapid climate change impacts [and] that requires international public consultation, not just domestic".[137] Dr van Aalst voiced a similar concern that the more vulnerable felt "threatened by the possibility that the winners will protect their wins, and the losers, which clearly are mostly them, will not get anything".[138] He wished to see an international debate fostered and to "include attention for [the] human dimension, and to try and involve that side of the debate early on".[139]

74. We conclude that Principle 2—"Public participation in geoengineering decision-making"—is to be supported but it needs to spell out in the explanatory text what consultation means and whether, and how, those affected can veto or alter proposed geoengineering tests.

134 Q 43

135 Ev 6 [Mr Virgoe], para 12

136 Q 26

137 Q 30

138 Q 44; see also J Virgoe, "International governance of a possible geoengineering intervention to combat climate change", Climatic Change, 2009, 95:103–119, para 2.3.

139 Q 44

Principle 3: Disclosure of geoengineering research and open publication of results

75. On Principle 3—disclosure of geoengineering research and open publication of results—we would add that as well as publishing plans and results the agency carrying out the test should also publish any modelling relevant to the test.

76. The one concern that was expressed to us which has a bearing on this principle was the effect of classifying or restricting access to SRM research on grounds of national security. Dr Blackstock commented that it "would dangerously provoke [...] international perceptions [...] that national or corporate interests might try (or just be perceived as trying) to control or profiteer from nascent SRM technologies".[140] He added that non-public SRM research would

> exacerbate international mistrust about unilateral control, provoking such disputes and potentially sparking a proliferation of similarly closed programs. This could even encourage the development and unilateral testing of SRM schemes targeted to benefit specific regional climates, regardless of other impacts. And any such developments could prejudice many countries against cooperation on broader climate issues—including mitigation."[141]

77. **We endorse Principle 3—"Disclosure of geoengineering research and open publication of results". The requirement to disclose the results of geoengineering research should be unqualified. We recommend that the Government press for an international database of geoengineering research to encourage and facilitate disclosure.**

Principle 4: Independent assessment of impacts

78. On Principle 4—independent assessment of impacts—we regard independent review of the results of geoengineering research not only to be good scientific practice but also good politics. In the final resort decisions weighing the benefits and risks of a geoengineering intervention will be made by those most affected by climate change and those affected by the geoengineering. Those affected and those taking the decisions on their behalf will need to be confident that the scientific assessment is the best that can be provided in the circumstances.

79. It is also important to link any decision to develop, and eventually to deploy, geoengineering to global warming. Sir David King reminded us that research into impacts, both in terms of the physical and economic impacts, would also need to take into account the impacts from rising temperature. In other words, geoengineering interventions would be deployed against a temperature rise of, say, 3.5 degrees centigrade.[142]

80. Consideration of impact raised the question of compensation for those affected by geoengineering interventions. Research Councils UK said that "approval-based

140 Ev 3, para 14

141 Ev 4, para 19

142 Q 48

mechanisms should [...] include protocols for the assessment of fair compensation; should adverse impacts occur, who would meet the costs of such impacts" but acknowledged that in some cases it would be difficult to attribute climatic impacts to particular acts of geoengineering and "research on how this should be done is essential".[143] Dr van Aalst cautioned against purely economic impact assessments as they tended "to lose out on the perspective of the most vulnerable groups, which do not count much on the economic analysis side".[144]

81. Distributional issues—between countries, and between groups—is likely, in our view, to raise questions of compensation, as well as political and legal issues of liability, which, as Mr Virgoe pointed out, will need to be addressed by a governance regime or through litigation. These issues would be particularly problematic in the case of a geoengineering intervention by one country, or a group of countries. We agree with him that this strengthens the case for seeking the explicit agreement of all countries through a UN-led, multilateral process.[145]

82. We also endorse Principle 4—"The independent assessment of impacts". But it too needs to be worked up in more detail in the explanatory text to: (i) define impacts; (ii) produce agreed mechanisms for assessing impacts, including for assessing the impact of global warming; and (iii) determine whether and how compensation should be assessed and paid. The agreement of these arrangements will need to command the broadest level of support across the globe and we consider that UN-led, multilateral processes are the best way to secure concurrence.

Principle 5: Governance before deployment

83. The sponsors of the principles were clear that it was imperative that governance structures were in place to "guide research in the short term and to ensure that any decisions taken ultimately with respect to deployment occur within an appropriate governance framework".[146] Others took the same view[147] and we consider that this is a sensible approach. It does not mean that research, including tests, the regulation of which we consider below, has to be halted until regulatory frameworks are in place. It does mean that research must be carried out in parallel with discussions on the legal, social and ethical implications of geoengineering, and its regulation and governance.[148]

84. We endorse Principle 5—"Governance before deployment of any geoengineering technique". We recommend that the Government carry out research, and press for research to be carried out through international bodies on the legal, social and ethical implications, and regulation and governance of geoengineering.

143 Ev 23, para 11

144 Q 48

145 J Virgoe, "International governance of a possible geoengineering intervention to combat climate change", Climatic Change, 2009, 95:103–119, para 2.3

146 Ev 43, para 6

147 Ev 53 [The Royal Society], para 15, and Ev 21 [DECC]

148 Ev 21 [DECC], para 14

The precautionary principle

85. One principle of international law not included in the suggested list is the precautionary principle (Principle 15 of the Rio Declaration).[149] In his recent article Mr Virgoe pointed out that the

> precautionary principle would be likely to influence debate, particularly as the side-effects of geoengineering techniques are not yet well understood. But it is unlikely that it could act as a legal, as opposed to rhetorical or moral, constraint on geoengineering: as noted by Weiss (2006), "no non-European international court has thus far accepted the Precautionary Principle as a binding principle of international law."[150]

He said that it would be necessary to be cautious in the way international debate on geoengineering was initiated. Geoengineering was so far from the current mitigation-adaptation paradigm, and raised so many concerns, "that a premature discussion might well see geoengineering banned in line with the precautionary principle".[151] Already, in June 2008, the Conference of the Parties to the Convention on Biological Diversity cited the precautionary principle in calling for a moratorium on ocean fertilisation activities. While he had sympathy for that decision on the specific issue of ocean fertilisation, Mr Virgoe said that it was "important that genuine research into geoengineering techniques are subjected to an appropriate, cautious regulatory regime rather than a blanket ban".[152]

86. The precautionary principle is an issue that our predecessor committee considered in 2006. In its Report on Scientific Advice, Risk and Evidence Based Policy Making, the Committee noted that, while the precautionary principle was "valuable in dealing with uncertainty",[153] it believed that it was

> best to use the term precautionary approach, but with a consistent explanation of the degree and nature of the risks, benefits and uncertainty and an explanation of the concept of proportionality. It should never be considered a substitute for thorough risk analysis which is always required when the science is uncertain and the risks are serious.[154]

This approach holds good for geoengineering. To go further and make the precautionary principle predominant risks not only halting geoengineering research and small tests being carried out by those states playing by the rules to develop a Plan B but it could also force

149 The Precautionary Principle has been endorsed internationally on many occasions. At the Earth Summit meeting at Rio in 1992, World leaders agreed Agenda 21, which advocated the widespread application of the Precautionary Principle in the following terms: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." (Principle 15)

150 J Virgoe, "International governance of a possible geoengineering intervention to combat climate change", Climatic Change, 2009, 95:103–119, para 3

151 Ev 6, para 16

152 As above

153 Science and Technology Committee, Seventh Report of Session 2005–06, Scientific Advice, Risk and Evidence Based Policy Making, HC 900–I, para 165

154 Science and Technology Committee, Seventh Report of Session 2005–06, Scientific Advice, Risk and Evidence Based Policy Making, HC 900–I, para 166

from international and public scrutiny any research carried out by other bodies or states not playing by the rules. In our view the five Principles as drafted contain a precautionary approach and that to go further is unnecessary. **We conclude that the key principles should not include the precautionary principle as a discrete principle.**

Conclusion on principles

87. In our view the principles as drafted provide a good starting point for either a bottom-up or a top-down approach to building a regulatory arrangements for geoengineering research. **While some aspects of the suggested five key principles need further development, they provide a sound foundation for developing future regulation. We endorse the five key principles to guide geoengineering research.**

Research

88. In our earlier Report on engineering we supported research into geoengineering. The research that is most controversial is that into SRM technologies. Dr Blackstock supplied the table below which summarises the stages of SRM research that could be undertaken, along with the environmental risks and political issues each raises.[155] In this Report we have examined three stages of research: modelling; development and subscale (that is, small) field testing; and climate impact testing.

155 Ev 2, para 13

The Stages, Status and Political Issues for *Solar Radiation Management* (SRM) Geoengineering Research				
Environmental Impacts	Stages of Research	*Description*	International Political and Governance Issues	*Current Status*
No Environmental Impact	**Theory and Modelling**	*Paper and computational studies of the anticipated climatic impacts of SRM.*	**May reduce or enhance public motivation to rapidly mitigate carbon emissions. (7)**	*Limited climate model studies of SRM are ongoing. Much more comprehensive modelling is called for by recent studies. (6,7)*
	Technology Development	*Laboratory development of SRM deployment technologies.*	**Could create international tension over technology control and subsequent decisions regarding testing and use.**	*Initial research on deployment technologies for the SRM schemes of stratospheric aerosol and cloud brightening have recently begun to emerge, including the first sub-scale field testing of aerosol deployment. (7,14)*
Negligible Environmental Impacts	**Subscale Field Testing**	*Feasibilty testing of SRM deployment technologies at levels posing 'demonstrably negligible' environmental and transboundary risks.*	**Could exscerbate these international tensions, particularly regarding decisions on acceptable scale of testing.**	
	Internationally Agreed Definition of 'Demonstrably Negligible' Risks if Required			
Increasing Transboundary Environmental Impacts	**Climatic Impact Testing** ? **Low-Level Climatic Intervention**	*Testing of the climatic impacts of SRM deployment, nominally at scales below actual deployment, but with notable transboundary environmental impacts.*	**Could spark a "crisis of legitimacy" (13) if conducted without international approval. Presents challenging liability issues.**	*No experiments have been seriously proposed or planned at this stage.*

Depiction of the level of environmental impacts and the type international political issues associated with each progressive stage of SRM research

Research: modelling

89. The Minister did not seek to put any constraint on modelling work and pointed out that the Royal Society had suggested there should be a code of conduct for research[156] at a certain level. In her view "a code of conduct is probably entirely appropriate, and we would very much support that".[157] Professor Keith considered that the "crucial thing" was to start from the

> bottom up through the management of a research programme in an international and transparent way. From the bottom up does not mean just that the scientists decide—that is certainly not the right answer—but it means, I think, that it would be premature to start a full UN scale EU Court treaty process, because it is simply not clear yet what the capacities are and states, individuals, have not had long enough to consider seriously what the trade-offs are.[158]

Mr Virgoe said that countries commencing geoengineering research prior to an internationally agreed framework being in place needed to make voluntary commitments

156 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, rec 7

157 Q 62

158 Q 12

to full international collaboration and transparency. Otherwise national geoengineering research that failed to make or meet such commitments "could spark international mistrust over future intentions, and disrupt the already inadequate progress toward essential mitigation".[159]

90. We agree with DECC and Professor Keith and see no reason to develop the panoply of international regulation to cover modelling of geoengineering interventions. Provided those carrying out research follow a code of practice along the lines of that suggested by the Royal Society, incorporating in particular Principle 3 on the disclosure of geoengineering research and open publication of results, we see no reason for an international regulatory regime applying to paper and computer modelling of geoengineering techniques.

Research: development and field testing

91. The ETC Group in a graphic phrase wanted to draw a "'line in the sand' at the lab door". It did not believe that it was "warranted to move geoengineering out of the laboratory and the most urgent questions of governance concern keeping that 'lab door' closed against the pressures from industrial players to move to open air geoengineering research and deployment".[160]

92. Sir David King took that view that there should be a temporary ban on solar radiation management as "the unintended consequences of that are extremely difficult to foresee".[161] He was

> not happy about smaller experiments being conducted at this stage in time before the unintended consequences have been fully evaluated. We are dealing with an extraordinarily complex issue here, and we all know scientifically that complex phenomena, as complexity increases, we get emergent properties that are not always easy to predict. So I do think we need to watch the stratosphere very carefully, but at the same time, in terms of regulation of the others, get ahead of the game, precisely because firstly, you want to keep the public on side, if we lose the public, then we lose the game; and secondly, we want to see that the regulation encourages the right behaviour.[162]

93. While cautious also, Dr Blackstock did not go quite as far as Sir David. To encourage international climate cooperation, he considered that countries beginning SRM research needed to take early steps to encourage the collective international exploration of SRM as a possible means for insuring global public welfare in the face of highly uncertain climate change. This, he suggested, meant making several preventive commitments. First, to foreswear climatic impacts testing—and very conservatively limit field testing—until approved by a broad and legitimate international process. Second, to keep all SRM

159 Ev 1, para 4

160 Ev 50, para 10

161 Q 39

162 Q 40

research, including generated knowledge and technologies, in the public domain. Third, to integrate all SRM research into any subsequent international research framework.[163]

94. While we understand Sir David's concerns, we consider that a temporary ban on SRM may not be the way forward. First, it would have to be negotiated through an international agreement which will take time and may not be achieved. Second, as we noted in the previous chapter, small scale testing may already be underway. Third a ban on all testing could inhibit laboratory development of geoengineering techniques. Instead, we consider that the approach suggested by Dr Blackstock may be the way forward. Much of the focus in the previous chapter on the need for regulation was on testing. For the reasons we set out in that chapter, we are of the view that there are good scientific reasons for allowing investigative research and for seeking to devise and implement some regulatory frameworks, particularly for those techniques with the potential to allow a single country or small group of countries to test or deploy, in order to affect the global climate. We consider that a ban, even a short-term ban, on all SRM geoengineering testing would prevent work on geoengineering as "Plan B". It may well also be unenforceable and be counter-productive as those carrying out tests do so in secrecy.

95. As we have indicated we favour international regulation of SRM technologies. But we recognise that it is going to take time to devise, agree and implement regulatory frameworks for the testing of SRM technologies. In the meantime, in order to encourage research into geoengineering techniques and to foster public understanding of geoengineering, we conclude that development and small tests of SRM geoengineering should be allowed provided they:

a) are fully in accordance with an internationally agreed set of principles such as those we have considered in this Report;

b) have negligible or predictable environmental impact; and

c) have no trans-boundary effects.

Research: climate impact testing

96. As tests increase in scale and impact they need to be regulated. We consider that any testing that impacts on the climate must be subject to an international regulatory framework.

Research: international confidence and cooperation

97. Mr Virgoe pointed out that given the pre-existing mistrust on global climate issues, further steps should also be taken to foster international confidence and cooperation. He considered that national SRM programmes should involve international scientists, particularly including those from vulnerable developing countries and "more importantly, these programmes should give priority to research on SRM schemes that may preserve global public welfare, rather than focusing on narrowly defined national interests".[164]

163 Ev 4, para 21

164 Ev 4, para 22

98. We agree with both points and consider that the UK Government should lead by example. We recommend that any UK SRM programmes should involve international scientists, particularly including those from vulnerable developing countries, and that these programmes should give priority to research on SRM schemes that may preserve global public welfare. We further recommend that the UK Government press the governments of other countries to a adopt similar approach to SRM research.

Formulating international regulatory arrangements for geoengineering

99. As we noted at paragraph 39, regulatory regimes for most SMR techniques have yet to be developed. As Mr Virgoe noted in his recent article,[165] there are important arguments in favour of a UN process. It would give the implementation of geoengineering legitimacy, in the form of a multilateral mandate. Most multilateral environmental regimes tend to operate by consensus, at least where major decisions are concerned, whatever their formal decision-making rules. We would add that it would give a voice to those likely to be most likely to be affected by the direct environmental consequences of the use of geoengineering technology. The problem he noted was that the UN process complicated and slowed down the decision-making process and any serious geoengineering proposal would certainly lead to vigorous international debate. He considered that the chances of achieving a multilateral agreement to deploy geoengineering were “not good”. He identified the following difficulties.

- The UNFCCC/Kyoto process was committed to the mitigation/adaptation paradigm. Institutional inertia, and the commitments already made by states, would make it hard to argue for a complete change in approach under this process—and equally difficult to establish a separate multilateral process.
- The introduction of a whole new approach would raise developing country suspicions that it would divert attention and funds from adaptation; other countries and communities would be concerned that it would reduce pressure to mitigate climate change.
- In the absence of a substantial political community in its favour, international discussion of geoengineering would be likely to result in its prohibition in line with the precautionary principle.[166]

100. But he identified a way forward. The dynamics might be different if a powerful country, or a group of countries, “were to act as a policy entrepreneur, pressing for serious consideration of, or research into, geoengineering” and that “growing global concern over global warming might also create more fertile soil for such a proposal, particularly among developing countries which are likely to be hit earlier, and harder, by the negative impacts of climate change”.[167] None of the alternative approaches—waiting for events, individual action or regional or interested groups—would have the legitimacy that action through the

165 J Virgoe, “International governance of a possible geoengineering intervention to combat climate change”, Climatic Change, 2009, 95:103–119, para 4.1

166 As above

167 As above

UN would provide. **We consider that the way forward for the regulation of geoengineering is through the UN and we recommend that the UK Government and other interested countries develop proposals for the regulation of not only CDR but also SRM techniques and begin to press them through the UN.**

101. The starting point for the formulation has to be the five key principles which we have discussed in this chapter. In addition, as Mr Virgoe pointed out, it will be important to ensure evidence based decision-making.[168] It will also be crucial that regulatory measures are able to respond rapidly, if necessary, following the application of geoengineering techniques. A key criterion for geoengineering to be taken forward will be the facility to withdraw applications quickly in case of negative consequences.[169] The Royal Society considered it was essential that mechanisms for the regulation of geoengineering were imbued with a high level of flexibility because:

> First, regulatory controls will need to adapt to the evolution of environmental, scientific, technological, geo-political, economic and social risks. Major uncertainties remain about geoengineering and it is impossible to foresee how technologies will develop, their public confidence, and the measures that will be needed to shape and respond to such developments. In addition, environmental, geo-political, economic and social factors that will influence the development of geoengineering are also in a constant state of flux and must therefore be accounted for through flexible regulatory arrangement.[170]

102. As we have noted at paragraph 27, the ENMOD treaty requires members "not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party". **We consider that it is crucial to the development of geoengineering that this principle is applied comprehensively to all geoengineering technologies.**

103. **We recommend that the UK Government is proactive in persuading and working with other governments to press for regulatory arrangements for geoengineering through the UN. They should do this on the basis of the following principles and objectives:**

a) **geoengineering to be regulated as a public good;**

b) **public participation in geoengineering decision-making;**

c) **disclosure of geoengineering research and open publication of results;**

d) **independent assessment of impacts;**

e) **governance arrangements to be clear before deployment;**

168 J Virgoe, "International governance of a possible geoengineering intervention to combat climate change", Climatic Change, 2009, 95:103–119, para 4.1

169 Ev 24, para 19

170 Ev 24, para 17; see also J Virgoe, "International governance of a possible geoengineering intervention to combat climate change", Climatic Change, 2009, 95:103–119, para 2.4

f) decisions to be based on the best scientific evidence, including social science;

g) regulatory measures to be able to respond rapidly;

h) regulatory measures imbued with a high level of flexibility to be able, for example, to encompass new technologies as they emerge; and

i) prohibition of the use of geoengineering techniques for military purposes.

Suitability of existing bodies to provide regulation of geoengineering

104. We received evidence on the suitability of existing international bodies to provide a model for the regulation of geoengineering, particularly SRM.[171] In the time available we have not been able to examine the operation of the bodies sufficiently to reach a view on whether:

a) any organisation would provide a model for a regulatory regime for SRM; or

b) existing bodies could be adapted to encompass SRM.

105. We were therefore attracted to the proposal of the Royal Society that a suitable international body, not exclusively a UN body, should commission a review of existing international and regional mechanisms to:

- consider the relevant roles of the following bodies such as UNCLOS,[172] LC/LP,[173] CBD,[174] CLRTAP,[175] Montreal Protocol,[176] Outer Space Treaty,[177] Moon Treaty,[178] UNFCCC/KP,[179] ENMOD[180] the regulation of geoengineering;

- identify existing mechanisms that could be used to regulate geoengineering research and deployment activities, if suitably extended as necessary; and

- (for geoengineering in general) identify where regulatory gaps exist in relation to geoengineering methods proposed to date, and establish a process for the development of mechanisms to address these gaps.[181]

106. We recommend that the Government press for a suitable international body to commission a review of existing international and regional mechanisms to: (i) consider

171 For example, Ev 53 [Royal Society], para 21

172 1994 United Nations Convention on the Law of the Sea

173 1972 London Convention with the 1996 Protocol of the London Convention

174 1992 Convention on Biological Diversity

175 1979 Convention on Long-Range Transboundary Air Pollution

176 1987 Montreal Protocol on Substances That Deplete the Ozone Layer

177 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies

178 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies

179 1997 United Nations Framework Convention on Climate Change/ Kyoto Protocol

180 1977 Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques

181 Ev 53, para 21

the relevant roles of the existing international bodies in the regulation of geoengineering; (ii) identify existing mechanisms that could be used to regulate geoengineering research and deployment activities, if suitably extended as necessary; and (iii) identify where regulatory gaps exist in relation to geoengineering methods proposed to date, and establish a process for the development of mechanisms to address these gaps.

107. The next stage, which DECC suggested, was that a suitable organisation needed to be identified, whose mandate would enable it to take the lead in facilitating the collaborative development of international regulations.[182] The Royal Society has suggested that an international consortium is formed to explore the safest and most effective geoengineering options while building a community of researchers and developers,[183] and we, like DECC,[184] consider that this is worth pursuing.

108. As the cost, effectiveness, timeliness and risk of putative geoengineering approaches vary substantially, Research Councils UK considered that it was therefore important that international collaboration was sought at an early stage. It explained that:

> An international geoengineering advisory group may well be an appropriate body to help address these challenges. With representation from the scientific, policy, commercial, regulatory and non-governmental communities, such a group would provide independent oversight of evolving regulatory issues concerning geoengineering. It would be tasked with the coordination of existing research, and the identification of a new research agenda, as well as the development of an effective and objective assessment framework to inform the regulation of geoengineering. This would involve making informed judgements about the weight of different environmental, social and economic costs and benefits and striking an appropriate balance between short-term and long-term effects.[185]

109. We recommend that, in parallel with the development of an international regulatory framework, the UK Government press for the establishment of an international consortium, to explore the safest and most effective geoengineering options, while building a community of researchers and developers.

Role of the UK

110. Dr van Aalst pointed out that there was probably a difference between the sort of debate taking place on geoengineering in the UK and the debate in other countries, including in several different states which may already be at the stage of small scale testing of some geoengineering techniques. He considered that the UK was "in a way also operating as an international arena, and in a way setting moral standards and setting an

182 Ev 21, para 12

183 The Royal Society, Geoengineering the climate Science, governance and uncertainty, September 2009, rec 4.2

184 Ev 21, para 13

185 Ev 25, para 24

example for how globally we should be approaching this, which is a very important side effect for your own considerations, I think, at this stage".[186]

111. We were disappointed to be told by the Minister that she could not recall any ministerial involvement in discussions on geoengineering and that it was "unlikely that we have had any ministerial discussions on regulation, but we are aware, our officials are alive to the issue, and it is something that we know needs to be done".[187] She continued:

> Of course, the IPCC is going to be reporting itself, and we have taken a lot of our leads from reports from the IPCC. It is clear that if there is to be regulation, it is going to have to be in some international body, whether a scientific body, or whether the UN itself, but clearly, this is something that will have to be developed over time.[188]

112. **We recommend that the UK should take the lead in raising geoengineering within international bodies such as the EU and the Commonwealth.**

186 Q 40

187 Q 64

188 As above

5 Collaborative working with the US Congress

Introduction

113. As we have explained in chapter 1, the suggestion for collaborative working came during our visit to Washington DC in April 2009, when Representative Bart Gordon, Chairman of the House of Representatives Science and Technology Committee, suggested that the two Committees might wish to identify a subject on which they could work together. When drawing up our joint programme with the House Committee, we took the recommendations in the Royal Society's report into consideration. The House Committee would conduct an inquiry on geoengineering—its first exploration of the topic—while we would run a complementary short inquiry on the regulatory aspects of geoengineering. The text of a joint statement agreed between the Committees is the Annex to this Report. The House Committee is examining issues regarding the research and development of geoengineering proposals, focusing its inquiry on the following questions:

- Under what circumstances would the US consider initiating research or the actual deployment of geoengineering?
- Which, if any, of the proposed geoengineering activities warrant further evaluation through coordinated, government-sponsored research, and which activities should be removed from consideration due to unacceptable risks or costs?
- Which US Federal Agencies have either the legal jurisdiction or technical resources to address geoengineering and, of those, which should lead a coordinated US effort?
- To inform international decision-making processes regarding the deployment of geoengineering activities, what level of investment in research is appropriate?
- Which existing international frameworks would govern research, development and deployment of geoengineering? And what new models for international cooperation must be developed to address the unique challenges of geoengineering deployment?
- How could these international frameworks for research and development serve to inform the regulation of deployment of geoengineering activities?

Ultimately, the hearings may lead to the formation of legislation authorising US government agencies to undertake certain geoengineering research activities and establish intergovernmental research agreements with other nations.

114. The evidence we have gathered and our Report will form part of the House Committee's evidence and our Chairman plans to give oral testimony to the House Committee when it takes testimony on issues of governance on 18 March 2010. When the US House Committee publishes its Hearing Record, it will include our Committee Report.

Arrangements for collaborative working

115. The House of Commons has specific procedural arrangements for joint working with the National Assembly for Wales but not the national legislatures of foreign countries. In these circumstances we adopted straightforward arrangements. We each ran discrete but dovetailed inquiries. We discussed and agreed areas to cover and an outline timetable with the House Committee.

116. The two Committees could not sit or take evidence together—which would anyway be difficult to arrange in practical terms—but within the procedural constraints we worked together sharing publicly available papers and kept in close contact. The following arrangements were adopted:

- the staff of each Committee were in regular contact with one another and shared information on geoengineering;
- all Commons Committee memoranda and transcripts were sent to the US Committee once reported to the House of Commons;
- all House Committee papers were sent to the Commons Committee once reported to the Committee Clerk;
- the Commons Committee's report was to contain a chapter drawing on the experience of two Committees working together with, if necessary, recommendations on arrangements for future coordination; and
- the Chairman of the Commons Committee would testify in March 2010 on the conclusions and recommendations in the Commons Committee report to the House Committee, which would be treated as testimony to the House Committee.

Review of procedural arrangements

117. We have seen the collaborative working with the House Committee as part of our search for innovative methods of working. From our point of view, we regard it as a success and we hope that the House Committee will regard it similarly. Having seen the way the House Committee organises its business and with its focus on producing draft federal legislation it is clear that full joint inquiries and hearings with members from both Committees sitting together in joint session may not be practicable at this stage. From our discussions with colleagues on the House Committee we understand that they feel the same way. That said, we must put on record that we are enthusiastic supporters of collaborative working between national legislatures on topics with international reach such as geoengineering and we consider that there are a range of measures that could be taken to streamline the process of collaborative working.

118. In administrative terms, many processes employed by the House Committee were familiar to us and we found that coordination of these processes was essential to successful collaborative working. These "basics" between the two committees include:

a) agreeing terms of reference for inquiries and hearings along with an indicative timetable and the collaborative arrangements at the outset;

b) sharing of background papers and submissions received once made publicly available;

c) regular contact to discuss progress; and

d) once our Report is published the Chairman conveying its conclusions and recommendations to the House Committee.

119. Beyond the basics, as we have carried out the inquiry it became clear to us that there was room to employ and, if necessary, develop House of Commons procedures to improve the collaborative process. First, one of the processes select committees can use is the witness who attends all public evidence sessions.[189] Given the improvements we noted in video communications we see scope for such a witness being available via video link from the "collaborating" legislature. It would therefore be possible for a witness from the collaborating legislature to be available by video link throughout the oral evidence sessions with other witnesses. The nature and circumstances of the inquiry would determine whether such a person was an official, a member of the collaborating committee or a specialist adviser appointed for the length of the inquiry. While we were able to draw on the papers available to the House Committee, it would have given an increased US perspective to our work if such an arrangement had been in place. Such a person would have been treated as witness to our inquiry with their contributions on the published record. We would be content to put in place a reciprocal arrangement, if the committee with which we were collaborating wanted it. We conclude that in future collaborative working between legislatures House of Commons committees should request the committee with which collaboration is taking place to provide a "permanent" witness—either an official or member of the committee—to provide oral evidence via video link at all oral evidence sessions.

120. Second, we received enquiries about the possibility of joint submissions to both committees. We are keen to encourage such submissions: they reinforce the collaborative nature of the committees' work and encourage members of both committees to focus on the same issues. We consider that in future when House of Commons committees participate in collaborative work they should include a statement in the call for submissions that, subject to the appropriate considerations of privilege, memoranda received may be passed to the committee in the other legislature. Reciprocal arrangements should be sought from the other committee. It should also be agreed that the committee receiving the memorandum will arrange and lead on publication.

121. The third area raises more significant procedural issues. When considering our Report, the collaborative nature of the inquiry highlighted the need for an American perspective. As we have said, the papers supplied by the House Committee went some way to filling this gap but we would have found it beneficial to have included a member of the House Committee or a special adviser based in the USA. This was highlighted when it came to framing our recommendations to the UK Government to initiate international action in that we refrained from suggesting similar action to the US Federal Government. We consider that the House of Commons should consider procedural changes to the effect that, where a select committee resolves to carry out collaborative working with a

189 Used predominately by select committees carrying out pre-legislative scrutiny where the witness is a Government official who can assist the committee when requested.

committee in another national legislature, a member of that committee attend—or communicate via video link—private sessions of the House of Commons committee. Although extending the power for joint working to the legislatures of foreign states would be a straightforward step, in many ways the issue of principle involved has already been taken by the House's decision to allow joint working of this kind between the Welsh Affairs Committee and the relevant committees of the National Assembly for Wales.

Conclusion on collaborative working

122. Science, technology and engineering are key to solving global challenges. Only through international collaboration will these challenges be met with success. We suggest that the next Science and Technology Committee should re-establish the working relationship with the US House of Representatives Science and Technology Committee. It should also consider making working connections with other international committees.

6 Conclusion

123. We are clear that serious consideration for the regulatory arrangements for geoengineering needs to start now, not once highly disruptive climate change is under way. If we start now it will provide the opportunity "to explore the technological, environmental, political and regulatory issues in a measured, science-led process".[190] The UN is the route by which eventually we envisage the regulatory framework operating but first the UK and other governments need to prime the UN pump. As Mr Virgoe pointed out, such "an approach would encourage enhanced awareness of the options and help ensure that, if and when a crisis arrives, there is a reasonable chance of getting multilateral agreement to a geoengineering deployment through the UN.[191]

124. We found collaborative working with the House Committee to be constructive and rewarding and, we hope, successful. We have commented on the process to made a number of suggestions for improvements which should assist future select committees embarking on collaborative working. Science, technology and engineering are key to solving global challenges and we commend to our successor committee international collaboration as an innovative way to meet these challenges with success.

190 J Virgoe, "International governance of a possible geoengineering intervention to combat climate change", Climatic Change, 2009, 95:103–119, para 5

191 As above

Conclusions and recommendations

House of Commons video conferencing facilities

1. We welcome the review that the House is carrying out of the audio-visual facilities in committee rooms to enable the taking of oral evidence in committee by video link. (Paragraph 14)

Definition of geoengineering

2. We conclude that weather techniques such as cloud seeding should not be included within the definition of geoengineering used for the purposes of activities designed to effect a change in the global climate with the aim of minimising or reversing anthropogenic climate change. (Paragraph 28)

3. In our view, geoengineering as currently defined covers such a range of Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM) technologies and techniques that any regulatory framework for geoengineering cannot be uniform. (Paragraph 30)

4. We conclude that geoengineering techniques should be graded according to factors such as trans-boundary effect, the dispersal of potentially hazardous materials in the environment and the direct effect on ecosystems. The regulatory regimes for geoengineering should then be tailored accordingly. Those techniques scoring low against the criteria should be subject to no additional regulation to that already in place, while those scoring high would be subject to additional controls. (Paragraph 33)

Regulatory framework

5. Through its involvement in the existing international regulatory arrangements such as the UN Framework Convention on Climate Change and when these instruments come up for revision we recommend that the Government raise geoengineering, particularly those for Carbon Dioxide Removal (CDR), and seek to develop, in conjunction with other governments, the arrangements provided by these international instruments so that they address research on, and deployment of, CDR geoengineering techniques. (Paragraph 38)

6. We conclude that there is a gap in the regulatory framework for geoengineering techniques, especially for SRM techniques. (Paragraph 40)

7. We recommend that the Government review its policy on geoengineering to give it greater priority. (Paragraph 49)

8. The science of geoengineering is not sufficiently advanced to make the technology predictable, but this of itself is not grounds for refusing to develop regulatory frameworks, or for banning it. There are good scientific reasons for allowing investigative research and better reasons for seeking to devise and implement some regulatory frameworks, particularly for those techniques that a single country or

small group of countries could test or deploy and impact the whole climate. (Paragraph 54)

9. We conclude that there is a need to develop a regulatory framework for geoengineering. Two areas in particular need to be addressed: (i) the existing international regulatory regimes need to develop a focus on geoengineering and (ii) regulatory systems need to be designed and implemented for those SRM techniques that currently fall outside any international regulatory framework. (Paragraph 55)

Public engagement

10. We recommend that the Government give greater priority to public engagement on geoengineering by, for example, showing how it relates to its policy on the reduction of carbon dioxide emissions. We welcome the work of Natural Environment Research Council (NERC) on public engagement on geoengineering and we request that, when the work is completed, the Government provide our successor committee with an explanation of how it will inform its policy on geoengineering. (Paragraph 58)

The formulation of a regulatory framework

11. While accepting that the development of a "top-down" regulatory framework may have risks and limitations, we consider that these are outweighed by the benefits of an international framework: legitimacy; scientific standards; oversight mechanisms; and management of environmental and trans-boundary risks. (Paragraph 65)

12. We welcome the production of the principles by a group of academics which provide a basis to begin the discussion of principles that could be applied to the regulation of geoengineering. (Paragraph 66)

13. We conclude that Principle 1 of the suggested five key principles on how geoengineering research should be guided—"Geoengineering to be regulated as a public good"—needs, first, to be worked up in detail to define public good and public interest. Second, the implied restriction suggested in the explanatory text to the Principle on intellectual property rights must be framed in such a manner that it does not deter investment in geoengineering techniques. Without private investment, some geoengineering techniques will never be developed. (Paragraph 71)

14. We conclude that Principle 2—"Public participation in geoengineering decision-making"—is to be supported but it needs to spell out in the explanatory text what consultation means and whether, and how, those affected can veto or alter proposed geoengineering tests. (Paragraph 74)

15. We endorse Principle 3—"Disclosure of geoengineering research and open publication of results". The requirement to disclose the results of geoengineering research should be unqualified. We recommend that the Government press for an international database of geoengineering research to encourage and facilitate disclosure. (Paragraph 77)

16. We also endorse Principle 4—"The independent assessment of impacts". But it too needs to be worked up in more detail in the explanatory text to: (i) define impacts; (ii) produce agreed mechanisms for assessing impacts, including for assessing the impact of global warming; and (iii) determine whether and how compensation should be assessed and paid. The agreement of these arrangements will need to command the broadest level of support across the globe and we consider that UN-led, multilateral processes are the best way to secure concurrence. (Paragraph 82)

17. We endorse Principle 5—"Governance before deployment of any geoengineering technique". We recommend that the Government carry out research, and press for research to be carried out through international bodies on the legal, social and ethical implications, and regulation and governance of geoengineering. (Paragraph 84)

18. We conclude that the key principles should not include the precautionary principle as a discrete principle. (Paragraph 86)

19. While some aspects of the suggested five key principles need further development, they provide a sound foundation for developing future regulation. We endorse the five key principles to guide geoengineering research. (Paragraph 87)

Regulation of research and testing

20. Provided those carrying out research follow a code of practice along the lines of that suggested by the Royal Society, incorporating in particular Principle 3 on the disclosure of geoengineering research and open publication of results, we see no reason for an international regulatory regime applying to paper and computer modelling of geoengineering techniques. (Paragraph 90)

21. We consider that a ban, even a short-term ban, on all SRM geoengineering testing would prevent work on geoengineering as "Plan B". It may well also be unenforceable and be counter-productive as those carrying out tests do so in secrecy. (Paragraph 94)

22. We conclude that development and small tests of SRM geoengineering should be allowed provided they:

    a) are fully in accordance with an internationally agreed set of principles such as those we have considered in this Report;

    b) have negligible or predictable environmental impact; and

    c) have no trans-boundary effects. (Paragraph 95)

23. We consider that any testing that impacts on the climate must be subject to an international regulatory framework. (Paragraph 96)

24. We recommend that any UK SRM programmes should involve international scientists, particularly including those from vulnerable developing countries, and that these programmes should give priority to research on SRM schemes that may preserve global public welfare. We further recommend that the UK Government

press the governments of other countries to a adopt similar approach to SRM research. (Paragraph 98)

International regulatory arrangements

25. We consider that the way forward for the regulation of geoengineering is through the UN and we recommend that the UK Government and other interested countries develop proposals for the regulation of not only CDR but also SRM techniques and begin to press them through the UN. (Paragraph 100)

26. We recommend that the UK Government is proactive in persuading and working with other governments to press for regulatory arrangements for geoengineering through the UN. They should do this on the basis of the following principles and objectives:

    a) geoengineering to be regulated as a public good;

    b) public participation in geoengineering decision-making;

    c) disclosure of geoengineering research and open publication of results;

    d) independent assessment of impacts;

    e) governance arrangements to be clear before deployment;

    f) decisions to be based on the best scientific evidence, including social science;

    g) regulatory measures to be able to respond rapidly;

    h) regulatory measures imbued with a high level of flexibility to be able, for example, to encompass new technologies as they emerge; and

    i) prohibition of the use of geoengineering techniques for military purposes. (Paragraph 103)

27. We recommend that the Government press for a suitable international body to commission a review of existing international and regional mechanisms to: (i) consider the relevant roles of the existing international bodies in the regulation of geoengineering; (ii) identify existing mechanisms that could be used to regulate geoengineering research and deployment activities, if suitably extended as necessary; and (iii) identify where regulatory gaps exist in relation to geoengineering methods proposed to date, and establish a process for the development of mechanisms to address these gaps. (Paragraph 106)

28. We recommend that, in parallel with the development of an international regulatory framework, the UK Government press for the establishment of an international consortium, to explore the safest and most effective geoengineering options, while building a community of researchers and developers. (Paragraph 109)

29. We recommend that the UK should take the lead in raising geoengineering within international bodies such as the EU and the Commonwealth. (Paragraph 112)

Collaborative working with the US Congress

30. We must put on record that we are enthusiastic supporters of collaborative working between national legislatures on topics with international reach such as geoengineering and we consider that there are a range of measures that could be taken to streamline the process of collaborative working. (Paragraph 117)

31. We conclude that in future collaborative working between legislatures House of Commons committees should request the committee with which collaboration is taking place to provide a "permanent" witness—either an official or member of the committee—to provide oral evidence via video link at all oral evidence sessions. (Paragraph 119)

32. We consider that in future when House of Commons committees participate in collaborative work they should include a statement in the call for submissions that, subject to the appropriate considerations of privilege, memoranda received may be passed to the committee in the other legislature. Reciprocal arrangements should be sought from the other committee. It should also be agreed that the committee receiving the memorandum will arrange and lead on publication. (Paragraph 120)

33. We consider that the House of Commons should consider procedural changes to the effect that, where a select committee resolves to carry out collaborative working with a committee in another national legislature, a member of that committee attend—or communicate via video link—private sessions of the House of Commons committee. (Paragraph 121)

34. Science, technology and engineering are key to solving global challenges. Only through international collaboration will these challenges be met with success. We suggest that the next Science and Technology Committee should re-establish the working relationship with the US House of Representatives Science and Technology Committee. It should also consider making working connections with other international committees. (Paragraph 122)

Conclusion

35. We are clear that serious consideration for the regulatory arrangements for geoengineering needs to start now, not once highly disruptive climate change is under way. (Paragraph 123)

Annex: Joint Statement of the U.K. and U.S. Committees on Collaboration and Coordination on Geoengineering

Introduction

A joint inquiry on geoengineering was initiated in 2009 by the Science and Technology committees of the U.S. House of Representatives and the U.K. House of Commons. Geoengineering is the deliberate, large-scale modification of the Earth's climate systems for the purposes of counteracting climate change. This document serves as an explanation of the committees' coordination and collaboration on the topic.

Background

In April 2009, the U.K. Committee with the remit for science visited Washington D.C. Its Members met with Representative Bart Gordon, Chairman of the U.S. House of Representatives Science and Technology Committee, and the chairmen of both committees—Phil Willis MP was the Chairman of the House of Commons Committee—discussed topics of mutual interest and potential collaboration. Representative Gordon suggested that there would be value in the two Committees collaborating on an emerging science and technology subject with important international implications.

The committees explored several potential topics and arrangements for coordinating activities. Geoengineering emerged as an attractive subject for the collaboration, particularly as most geoengineering projects will have international implications and require international collaboration. The two committees were at different stages of examination on the subject, with the U.K. Committee having already produced a report and the U.S. Committee initiating a series of preliminary hearings on the subject. This would allow the committees to leverage each other's experience by covering distinct aspects of subject.

Geoengineering

In its report, Engineering: turning ideas into reality, (HC (2008–09) 50–I, March 2009) the U.K. Committee recommends that the Government develop a publicly-funded programme of geoengineering research (para 217). Following the Committee's report the U.K. Royal Society published, on 1 September 2009, the findings of a major study into geoengineering, Geoengineering the climate: science, governance and uncertainty. This study provided a detailed assessment of the various methods and considered the potential efficiency and unintended consequences they might pose. The U.S. Committee is drawing on the Royal Society's report and its contributing scientists and policy experts, including Professor John Shepherd, who chaired the working group that produced the report.

The U.S. inquiry

The U.S. Committee is examining issues regarding the research and development of geoengineering proposals, focusing their inquiry on the following questions:

- Under what circumstances would the U.S. consider initiating research or the actual deployment of geoengineering?
- Which, if any, of the proposed geoengineering activities warrant further evaluation through coordinated, government-sponsored research, and which activities should be removed from consideration due to unacceptable risks or costs?
- Which U.S. Federal Agencies have either the legal jurisdiction or technical resources to address geoengineering and, of those, which should lead a coordinated U.S. effort?
- To inform international decision-making processes regarding the deployment of geoengineering activities, what level of investment in research is appropriate?
- Which existing international frameworks would govern research, development and deployment of geoengineering? And what new models for international cooperation must be developed to address the unique challenges of geoengineering deployment?
- How could these international frameworks for research and development serve to inform the regulation of deployment of geoengineering activities?

The U.S. Committee began its inquiry by convening a series of hearings and they will publish a final report as a capstone to the joint inquiry. The final report will include materials from all three hearings as well as the UK Commons Committee report. The hearings serve both to form the foundation for an informed and open dialogue on the science and engineering of geoengineering, and to provide a Congressional record to underpin the formation of legislation authorizing the United States to engage in geoengineering research at the Federal and international level.

The first hearing provided an introduction to the concept of geoengineering, including the science and engineering underlying various proposals, potential environmental risks and benefits, associated domestic and international governance issues, research and development needs, and economic rationales both supporting and opposing the research and deployment of geoengineering activities. The second hearing explored the science, engineering needs, environmental impacts, price, efficacy, and permanence of solar radiation management and carbon dioxide removal strategies for geoengineering. The third and final hearing in this series will explore issues relevant to the both the domestic and international governance of geoengineering research, with Phil Willis, Chairman of the U.K. Science and Technology Committee, testifying at this hearing.

The U.K. inquiry

One area which the Royal Society's report identified as requiring examination was the need to develop adequate international mechanisms to regulate geoengineering. It noted the importance of identifying where regulatory gaps existed in relation to geoengineering methods and to establish a process for the development of mechanisms to address these gaps. Taking its cue from the Royal Society's report, the British Committee settled on the following terms of reference for an inquiry into the regulation of geoengineering:

- What UK regulatory mechanisms apply to geoengineering and what changes will need to be made for purpose of regulating geoengineering;
- Is there a need for international regulation of geoengineering and, if so, what international regulatory mechanisms need to be developed; and
- How should international regulations be developed collaboratively?

The outline timetable for the inquiry is:

Nov 2009 Call for evidence

Dec 2009 Deadline for written submissions to the Committee

Jan 2010 Hearing—experts, international organisations and the UK Government.

Mar 2010 Report published and Chairman gives testimony on Committee's report to the U.S Committee.

Committee co-ordination

Due to procedure, the committees will not sit jointly; therefore, the committees are working together by sharing publicly available papers and the evidence and testimony that each has received. In addition, the committees are coordinating inquiry-related activities. The following arrangements have been agreed:

- All U.K. Committee memoranda and transcripts (i.e., papers) will be sent to the U.S. Committee once reported to the House of Commons;
- All U.S. Committee papers will be sent to the U.K. Committee once reported to the Committee Clerk;
- The staff of each Committee are in regular contact with one another and sharing information on geoengineering;
- The U.K. Committee's report will contain a chapter drawing on the experience of two Committees working together with, if necessary, recommendations on arrangements for future coordination; and
- The Chairman of the U.K. Committee will testify in March 2010 on the conclusions and recommendations in the U.K. Committee report to the U.S. Committee, which will be treated as testimony to the U.S. Committee.

Formal Minutes

Wednesday 10 March 2010

Members present:

Mr Phil Willis, in the Chair

Mr Ian Cawsey
Dr Brian Iddon
Dr Doug Naysmith
Graham Stringer

1. The Regulation of Geoengineering

The Committee considered this matter.

Draft Report (The Regulation of Geoengineering), proposed by the Chair, brought up and read.

Ordered, That the draft Report be read a second time, paragraph by paragraph.

Paragraphs 1 to 124 read and agreed to.

Annex and Summary agreed to.

Resolved, That the Report be the Fifth Report of the Committee to the House.

Ordered, That the Chair make the Report to the House.

Written evidence was ordered to be reported to the House for printing with the Report.

2. Science Question Time

The Committee considered this matter.

[Adjourned till Wednesday 17 March at 9.00am.

Witnesses

Wednesday 13 January 2010

List of written evidence

List of Reports from the Committee during the current Parliament

The reference number of the Government's response to each Report is printed in brackets after the HC printing number.

Session 2009–10

First Report	The work of the Committee in 2008–09	HC 103
Second Report	Evidence Check 1: Early Literacy Interventions	HC 44 (HC 385)
Third Report	The Government's review of the principles applying to the treatment of independent scientific advice provided to government	HC 158-I (HC 384)
Fourth Report	Evidence Check 2: Homeopathy	HC 45
Fifth Report	The Regulation of Geoengineering	HC 221

Session 2008–09

First Report	Re-skilling for recovery: After Leitch, implementing skills and training policies	HC 48–I (HC 365)
Second Report	The Work of the Committee 2007–08	HC 49
Third Report	DIUS's Departmental Report 2008	HC 51–I (HC 383)
Fourth Report	Engineering: turning ideas into reality	HC 50–I (HC 759)
Fifth Report	Pre-appointment hearing with the Chair-elect of the Economic and Social Research Council, Dr Alan Gillespie CBE	HC 505
Sixth Report	Pre-appointment hearing with the Chair-elect of the Biotechnology and Biological Sciences Research Council, Professor Sir Tom Blundell	HC 506
Seventh Report	Spend, spend, spend? – The mismanagement of the Learning and Skills Council's capital programme in further education colleges	HC 530 (HC 989)
Eighth Report	Putting Science and Engineering at the Heart of Government Policy	HC 168–I (HC 1036)
Ninth Report	Pre-appointment hearing with the Chair-elect of the Science and Technology Facilities Council, Professor Michael Sterling	HC 887
Tenth Report	Sites of Special Scientific Interest	HC 717 (HC 990)
Eleventh Report	Students and Universities	HC 170–I (HC 991)

Session 2007–08

First Report	UK Centre for Medical Research and Innovation	HC 185 (HC 459)
Second Report	The work and operation of the Copyright Tribunal	HC 245 (HC 637)
Third Report	Withdrawal of funding for equivalent or lower level qualifications (ELQs)	HC 187–I (HC 638)
Fourth Report	Science Budget Allocations	HC 215 (HC 639)
Fifth Report	Renewable electricity-generation technologies	HC 216–I (HC 1063)
Sixth Report	Biosecurity in UK research laboratories	HC 360–I (HC 1111)
Seventh Report	Pre-legislative Scrutiny of the Draft Apprenticeships Bill	HC 1062–I (HC (2008–09)262)
First Special Report	The Funding of Science and Discovery Centres: Government Response to the Eleventh Report from the Science and Technology Committee, Session 2006–07	HC 214

Session 2007–08 (Continued)

Second Special Report	The Last Report: Government Response to the Thirteenth Report from the Science and Technology Committee, Session 2006–07	HC 244
Fourth Special Report	Investigating the Oceans: Government Response to the Science and Technology Committee's Tenth Report of Session 2006–07	HC 506 [incorporating HC 469–i]

Oral evidence

Taken before the Science and Technology Committee (Science and Technology Sub-Committee)

on Wednesday 13 January 2010

Members present

Mr Phil Willis, in the Chair

Mr Tim Boswell	Dr Brian Iddon
Mr Ian Cawsey	Graham Stringer

Memorandum submitted by Dr Jason Blackstock (GEO 12)

THE INTERNATIONAL POLITICS OF GEOENGINEERING RESEARCH

Executive Summary

1. The recent scientific reviews of geoengineering found existing concepts to be fraught with uncertainties and potential negative side eVects, making geoengineering unsuitable as an alternative to dramatic emission reductions.

2. As the global risk of unabated climate change could prove far worse than the risk of geoengineering, expanded research into geoengineering as a possible recourse for limiting at least the most severe potential climate change impacts is recommended.

3. A broadly accessible, transparent and international political process—one that particularly engages vulnerable developing countries—is needed to develop international regulation and coordination of geoengineering research. Such a process will necessarily take many years to develop and evolve, and should be informed by further scientific and socio-political research conducted in the interim.

4. Countries commencing geoengineering research prior to an internationally agreed framework being in place need to make voluntary commitments to full international collaboration and transparency. National geoengineering research that fails to make or meet such commitments could spark international mistrust over future intentions, and disrupt the already inadequate progress toward essential mitigation.

5. This remainder of this memorandum describes the two main categories of geoengieering, the main stages of research that may be undertaken for solar radiation management (SRM) geoengineering, and the international political issues each stage of SRM research might raise. The focus on SRM has been chosen because the international political issues it presents are more accute than for carbon dioxide removal (CDR) geoengineering (though the general issues raised should be considered for both categories).

About the Author

6. Jason Blackstock is a scientist and international aVairs scholar whose research presently focuses on evaluating the climatic and international political implications of geoengineering. He is a lead author of the report "Climate Engineering Responses to Climate Emergencies" (2009), a prominent scientific review study of solar radiation management geoengineering via stratospheric aerosol injection. Jason has received his Master of Physics (Edinburgh, 2001), his PhD in physics (Alberta, 2005), his Graduate Certificate in International Security (Stanford, 2006), and his Master of Public Administration (Harvard, 2008).

Background Context

7. Despite mounting evidence that climate change could be more severe and rapid than estimated by the IPCC Fourth Assessment Report (AR4), progress toward globally reducing carbon emissions remains alarmingly slow. Concern over the global failure to act on climate change has been the dominant motivation behind scientists' recent convening of several prominent reviews of geoengineering—the intentional, large-scale alteration of the climate system—as a potential recourse for moderating the impacts of climate change. These scientific reviews (particularly the Royal Society and Novim reports on geoengineering in 2009) found existing geoengineering concepts to be fraught with uncertainties and potential negative side eVects, making them unsuitable as an alternative to dramatic emission reductions. Nevertheless, they recommend greatly expanding research, as the risks of unabated climate change could prove far worse than the risks of geoengineering.

8. As geoengineering schemes are now attracting national political attention and research funding in several developed countries, the implications for international climate politics need to be carefully considered.[1] Similar to climate change, for many geoengineering schemes both the benefits and the potential risk of severe unintended consequences would be unequally distributed between regions or nations. As a result, national geoengineering research programs could spark international mistrust over future intentions, and serve to further disrupt the already inadequate progress toward essential mitigation commitments. To limit such tensions and preserve options for future cooperation, countries starting geoengineering research should make early preventive commitments to full international collaboration and transparency, and avoid any appearance of pursuing national interests at the expense of global public welfare.

Geoengineering Concepts

9. Geoengineering schemes can be divided into two categories, with very diVerent characteristics: carbon dioxide removal (CDR) and solar radiation management (SRM). By removing the cause from the atmosphere, CDR schemes such as direct air capture or ocean fertilization would be eVective at diminishing climate change impacts. But technical challenges and large uncertainties surrounding large-scale CDR deployment, along with the long delays in the climatic response to carbon forcing, mean it would take at least decades for CDR to have notable climatic eVect. While important for long-term negative emission scenarios, CDR cannot oVer rapid climatic influence if severe climate change manifests too quickly for adaptation to avoid substantial damages.

10. Conversely, SRM could substantially influence the climate in months—but with much greater uncertainty about the net climatic eVects. SRM schemes such as stratospheric aerosols and cloud brightening aim to cool the planet by reflecting a fraction of the incoming sunlight away from Earth. Natural experiments caused by volcanoes have demonstrated the rapid impact potential of SRM, and the recent reviews show such schemes should be technically simple to deploy at low cost relative to mitigation. But these reviews also stress that SRM would at best unevenly ameliorate regional climatic change, and may generate serious unintended consequences. For example, SRM could produce droughts with severe implications for regional and global food production, and delay the recovery of the ozone layer by decades, while doing almost nothing to address ocean acidification. This makes SRM unsuitable as an alternative to mitigation.

Geoengineering Research

11. In spite of the limitations and risks, avoiding SRM research would be a mistake. The ability to rapidly influence the climate means SRM might be the only recourse should a climate crisis materialize. Since severe climate change could bring about such national or regional crises within decades, prudence suggests we should improve our understanding of the likely feasibility, eVectiveness and dangers of SRM interventions. Without prior research, uninformed and rash unilateral action by less responsible actors becomes more likely. Moreover, near-term authoritative research will help discredit ungrounded fringe claims that SRM could provide an alternative to dramatic near-term emission reductions. Finally, establishing good governance of SRM requires good understanding of the schemes and risks to be governed, which first requires research.

12. But who should conduct this research, how should it be managed and who would control any generated technologies? These are politically loaded questions with international significance, particularly given that the rapid impact, easy implementation and low cost characteristics of SRM schemes make unilateral deployment a very real possibility for a large number of countries.

13. The table below summarizes the stages of SRM research that could be undertaken, along with the environmental risks and political issues each raises. Until recently, SRM research had been limited to model studies published in the open literature. With no environmental impact and the generated knowledge being transparent and public, such research raises minimal political issues. The main critique of this research is that it could encourage complacency on mitigation by suggesting an illusory alternative. However recent research suggests the opposite may occur; by appearing frighteningly risky to the public, SRM might reduce such complacency by creating a desire to avoid needing it. But emerging stages of research may not prove so politically innocuous.

[1] To the best knowledge of the author, as of the date of this memo, only the EU and (separately) the UK have formally announced national level funding for geoengineering research. Through its framework-7 programme, the EU has funded a multi-institutional research consortium for × 3yrs to computationally model the science and potential economics of solar radiation management concepts (see http://implicc.zmaw.de/for details). Through the Engineering and Physical Sciences Research Councils' Energy Programme, the UK has publicly announced £3 million research funding for geoengineering research.

The Stages, Status and Political Issues for Solar Radiation Management (SRM) Geoengineering Research

Environmental Impacts	Stages of Research	*Description*	International Political and Governance Issues	*Current Status*
No Environmental Impact	Theory and Modelling	*Paper and computational studies of the anticipated climatic impacts of SRM.*	May reduce or enhance public motivation to rapidly mitigate carbon emissions. (7)	*Limited climate model studies of SRM are ongoing. Much more comprehensive modelling is called for by recent studies. (6,7)*
	Technology Development	*Laboratory development of SRM deployment technologies.*	Could create international tension over technology control and subsequent decisions regarding testing and use.	*Initial research on deployment technologies for the SRM schemes of stratospheric aerosol and cloud brightening have recently begun to emerge, including the first sub-scale field testing of aerosol deployment. (7,14)*
Negligible Environmental Impacts	Subscale Field Testing	*Feasibility testing of SRM deployment technologies at levels posing 'demonstrably negligible' environmental and transboundary risks.*	Could exacerbate these international tensions, particularly regarding decisions on acceptable scale of testing.	
	Internationally Agreed Definition of 'Demonstrably Negligible' Risks is Required			
Increasing Transboundary Environmental Impacts	Climate Impact Testing ? Low-Level Climatic Intervention	*Testing of the climatic impacts of SRM deployment, nominally at scales below actual deployment, but with notable transboundary environmental impacts.*	Could spark a "crisis of legitimacy" (13) if conducted without international approval. Presents challenging liability issues.	*No experiments have been seriously proposed or planned at this stage.*

Depiction of the level of environmental impacts and the type international political issues associated with each progressive stage of SRM research.

14. The increased scientific attention stratospheric aerosols and cloud brightening have been receiving has recently sparked the development and subscale field testing of SRM deployment technologies. Even lab-based development of SRM technologies raises the prospect that national or corporate interests might try (or just be perceived as trying) to control or profiteer from nascent SRM technologies. And a national security framing of emerging SRM research, especially if classified, would dangerously provoke such international perceptions. Nonetheless, in 2009 the U.S. Defense Advanced Research Projects Agency (DARPA) held a meeting to consider pursuing geoengineering research highlights the potential for such developments.

15. As technology development graduates to the stage of subscale field tests, these same issues could be further exacerbated—and the first such tests have very recently been conducted in Russia (Izrael, 2009). Field experiments designed to have demonstrably negligible environmental and transboundary risks are valuable for feasibility testing deployment technologies, and for exploring local-scale physical, chemical and biological interactions that could damage the environment when scaled up. But the signals that unilateral subscale tests, no matter how environmentally benign, might send to the international community need to be very carefully considered.

16. The controversy surrounding an Indo-German ocean fertilization (CDR) experiment conducted in early 2009 demonstrates the political sensitivities any geoengineering experiments can evoke (Nature Geoscience Editorial, 2009). At the core of this controversy was also the diY culty of defining politically acceptable (national and international) scientific standards and oversight mechanisms for ensuring the environmental and transboundary risks of nominally subscale geoengineering field tests are in fact "demonstrably negligible."

17. Robust understanding of SRM will eventually require tests with demonstrable climatic impacts. Confidence in SRM climate model predictions can only come from "poking" the climate system and comparing the predicted and observed responses. But due to the natural complexity and variability of the climate system, signal-to-noise issues will plague the attribution of climatic impacts and unintended consequences to a particular test. For any SRM scheme it might prove impossible to test for most impacts with "pokes" below a scale considered (at least politically) to constitute deployment of a low-level climatic intervention. And the testing of multiple SRM schemes by diVerent groups would only further complicate the situation.

18. Attribution challenges also underlie another international political challenge facing SRM—that of liability for real or perceived damages. For example, if the Asian or African monsoon were to have a weak year following an SRM test—a year at the edge of natural variability, but still inducing droughts and food shortages—scientific uncertainty about causation may just exacerbate accusations of responsibility. There would almost certainly be a global "crisis of legitimacy" (Victor, 2009) should a SRM climatic impacts test be conducted without international approval. And since by definition any test would be an intentional act, even nominally subscale field tests could open the door for spurious diplomatic, political or legal disputes (however unscientific) over liability for alleged nonlocal damages.

Creating Norms and Regulation for Geoengineering Research

19. Anticipation of unevenly distributed benefits and damages could easily steer any international discourse on development and testing of SRM technologies into disputes over national interests. Nonpublic SRM research would exacerbate international mistrust about unilateral control, provoking such disputes and potentially sparking a proliferation of similarly closed programs. This could even encourage the development and unilateral testing of SRM schemes targeted to benefit specific regional climates, regardless of other impacts. And any such developments could prejudice many countries against cooperation on broader climate issues—including mitigation.

20. A valuable first step for addressing some of these issues will be the creation of international norms and best practices for scientists conducting geoengineering research. The upcoming Asilomar conference on Climate Intervention Technologies in March 2010 will bring together × 150 scientists to begin this process. However, for most political issues the truly relevant actors are not scientists, but rather the decision makers representing national (or corporate) interests. Questions regarding acceptable risks for subscale field tests, if/when/where climatic impacts testing should begin, or how and by whom SRM technologies should be managed, cannot and should not be answered by scientists alone. A broadly accessible, transparent and international political process is needed to address these issues—one that particularly engages vulnerable developing country perspectives thus far absent from SRM discussions. Whether existing frameworks could facilitate this, and what the target products should be (eg new treaties, organizations, etc), are open questions that urgently need both research and international stakeholder consideration.

21. To encourage international climate cooperation, countries beginning SRM research need to take early steps to encourage the collective international exploration of SRM as a possible means for insuring global public welfare in the face of highly uncertain climate change. This means making several preventive commitments. First, to foreswear climatic impacts testing—and very conservatively limit subscale field testing—until approved by a broad and legitimate international process. Second, to keep all SRM research, including generated knowledge and technologies, in the public domain. Third, to integrate all SRM research into any subsequent international research framework.

22. Given the preexisting mistrust on global climate issues, further steps should also be taken to foster international confidence and cooperation. National SRM programs should explicitly involve international scientists, particularly including those from vulnerable developing countries. More importantly, these programs should give priority to research on SRM schemes that may preserve global public welfare, rather than focusing on narrowly defined national interests.

23. As national geoengineering research emerges, these preventive steps cannot guarantee future climate cooperation. But they would at least limit the new problems this research heaps on the already strained global climate agenda.

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Memorandum submitted by John Virgoe (GEO 05)

Summary

1. Technical research into geoengineering techniques should be accompanied by consideration of regulatory, legal, and decision-making frameworks, and potential distributional and political impacts. Techniques to remove CO_2 from the atmosphere could usefully supplement conventional mitigation activities, and it is probably unhelpful to describe these as geoengineering. Solar radiation management techniques ("true" geoengineering) raise much more diYcult issues, including the potential to foster international tension, but may provide a useful emergency response to dangerous climate change. No existing international legal instrument exists which clearly regulates or prohibits such activities, though there are relevant international legal principles. An international regulatory regime will need to address a number of important issues. Work should begin on such a regime as early as possible, but it will need to be approached in a careful manner.

Declaration of Interest

2. I conducted research into geoengineering governance and regulation at the Woodrow Wilson School of Public and International AVairs, Princeton University, in 2006–07. I subsequently entered the employ of the Foreign and Commonwealth OYce, but this evidence is submitted in my private capacity and does not represent HMG policy.

Remarks

3. I support early discussion of the complex regulatory, governance and legal issues thrown up by geoengineering. Calls for some sort of geoengineering intervention are likely to grow as climate disruption becomes more apparent, and particularly if mitigation eVorts prove inadequate. It is important that we start thinking through the consequences of such an intervention as early as possible if we are to take mature, informed decisions. Moreover, the development of an international regulatory regime would help reduce the risk that an individual country (or sub-national actor) might decide to deploy geoengineering techniques on a unilateral basis.

4. The opposing argument—that even raising the possibility of geoengineering creates a moral hazard, reducing the incentive to cut emissions—is not without merit. But geoengineering is already being touted by some as a magic bullet. I believe serious analysis will actually underscore what a problematic option it is—for a range of technological, ethical and political reasons—and show that there is no attractive alternative to radical emissions cuts. Equally, we are so far from achieving climate stabilisation through conventional mitigation that it would be unwise to ignore any serious option, even at the risk of creating a degree of moral hazard.

5. There was an important new contribution to the debate in September, in the form of a report from the Royal Society "Geoengineering the climate: Science, governance and uncertainty". This is an excellent evaluation of technological options. In particular, the report highlights a key distinction between two broad types of geoengineering: those which remove CO_2 (or other greenhouse gasses) directly from the atmosphere; and those which seek to balance the warming eVects of excess greenhouse gasses by blocking a proportion of solar radiation reaching the earth ("Solar Radiation Management"). Apart from their technological diVerences, the two have quite diVerent non-technological characteristics, with implications for their regulation. Indeed, they are so diVerent in nature and implications that it is questionable whether it is helpful to describe both as geoengineering. Broadly speaking, the former might form an element within a package along with mitigation and adaptation, while the latter might be deployed as an emergency response in the event of highly disruptive climate change.

6. Removing CO_2 from the atmosphere—eg through enhancing natural weatherisation processes or biochar—is arguably not wholly distinct from accepted mitigation approaches. Carbon capture and storage (CCS) from the atmosphere is conceptually similar to CCS from power stations; biochar is really an extension of reaVorestation. As such, it could conceivably be managed through a similar regime, as a supplement to conventional mitigation action. The carbon price would determine whether countries decide to meet their emissions targets though energy eYciency, changing their energy mix—or CO_2 removal. But this would require the rules on carbon trading to permit the creation of oVsets through such activities; alternately, they would need to be treated as credits in national greenhouse gas accounts.

7. In practice, CO_2 removal on a large scale may prove expensive and environmentally destructive— the Royal Society report suggests that it would be necessary to mine, process and transport silicate rocks at a volume equivalent to twice the current rate of global coal mining to remove all the CO_2 currently emitted by human activity. In some countries, there may be room for such techniques to take place at scale. But it is likely to remain a niche contribution to global mitigation, and one which only makes a diVerence over a long period.

8. I can see no good reason not to encourage (carefully supervised) research in these techniques, and to ensure carbon accounting/trading rules are crafted in a way which might include such activities (once issues of safety, verification etc are taken into account).

9. Looking at Solar Radiation Management techniques, the most widely discussed is injecting sulphur particles into the stratosphere. We know this works—it is why large volcanic eruptions cool the climate for a year or two. But there are potential environmental side eVects (eg on the ozone layer). These techniques only address the warming eVect of increased CO_2, not ocean acidification. So it is not easy to equate them to a carbon price). The cooling eVect does not necessarily cancel out global warming equally strongly in every part of the globe—the poles could still warm, for example. That is just one of several reasons why they will be internationally controversial. They are also hard to test—by its very nature, an intervention is global. On the positive side, sulphur injection seems to be relatively low-cost, to be straightforward from a technical perspective, and would have an immediate eVect—making it the prime choice for an "emergency" intervention.

10. Solar Radiation Management techniques raise complicated political, ethical and regulatory issues, and are the main subject of my article "International governance of a possible geoengineering intervention to combat climate change" (Climatic Change, 2009, 95:103–119), which was, I think, the first discussion of the international politics of geoengineering from the perspective of international relations theory.

11. My article identifies non-technical characteristics of geoengineering which might influence regulatory models, and then discusses three broad approaches to managing a geoengineering intervention: through the United Nations, by one state unilaterally, and through a consortium of states. Rather than repeat my analysis here, I attach a copy of that article. However, I would draw attention to my conclusion that no existing international instrument exists which clearly prohibits or regulates geoengineering research or activity. It has been suggested that the 1977 UN Convention on the Prohibition of Military or any Other Hostile Use of Environmental Modification Techniques (the ENMOD convention) would make geoengineering illegal. However, article 3.1 specifically preserves the right to use such techniques "for peaceful purposes". It is true, however, that the international regimes for governing the atmosphere and the oceans might have an interest in specific geoengineering techniques—for example, injecting sulphur compounds into the stratosphere might aVect the ozone layer, the concern of the Montreal Protocol.

12. International law does suggest principles which might be used in developing a regulatory regime for geoengineering, including the precautionary principle (Principle 10 of the Rio Declaration), the requirement to inform or consult, the principle of common but diVerentiated responsibilities (Rio principle 7) and the polluter pays principle (Rio principle 16).

13. I should also like to highlight the potential for geoengineering interventions to lead to international tension, bearing in mind the likely distributional impacts. It is unlikely that the use of a Solar Radiation Management technique would exactly counter the eVects of global warming in every part of the world. It is more likely that some regions would experience relative warming and others would see relative cooling. Side eVects would also be likely to impact diVerently in diVerent regions. Any freak weather event could be blamed, plausibly or not, on the intervention. Countries or groups which felt they were being harmed by the intervention could seek legal recourse or exert diplomatic pressure. The risk of this would be reduced, though not eliminated, if a consensual international regulatory regime were in place.

14. There are a lot of international bodies with a potential interest, including the Framework Convention on Climate Change (UNFCCC), the UN Environment Programme (UNEP), the Intergovernmental Panel on Climate Change (IPCC), the World Meteorological Organisation (WMO), and—on specific techniques—the International Maritime Organisation (IMO), the Montreal Protocol and other parts of the atmospheric governance regime. The Royal Society report suggested that the Commission on Sustainable Development (CSD) might be the appropriate body to lead on geoengineering governance, but the remit and working practices of the CSD seem unlikely to make it a preferred option.

15. I draw attention to pages 114–115 of my article, which set out the key elements which would need to be addressed by an international regulatory regime for geoengineering.

16. It will be necessary to be cautious in the way international debate on geoengineering is initiated. It is so far from the current mitigation-adaptation paradigm, and raises so many concerns, that a premature discussion might well see geoengineering banned in line with the precautionary principle. Already, in June 2008, the Conference of the Parties to the Convention on Biological Diversity cited the precautionary principle in calling for a moratorium on ocean fertilisation activities. I have sympathy for that decision on the specific issue of ocean fertilisation, but it is important that genuine research into geoengineering techniques are subjected to an appropriate, cautious regulatory regime rather than a blanket ban.

17. In terms of international regulation, the first step might be to develop guidelines to govern such research. These might cover, for example, refraining from field experiments until certain conditions have been met. In all cases, it is important that research is conducted in an open fashion, to minimise suspicion.

18. The Royal Society report called for government funding for research into geoengineering techniques. I agree; but it is important that scientific/engineering research is accompanied by work on non-technical aspects. Those non-technical aspects should include the appropriate legal, regulatory and decision-making frameworks, and the distribution of risks and benefits.

December 2009

Witnesses: Dr Jason Blackstock, Fellow at the Centre for International Governance Innovation (CIGI) Canada and research scholar at the International Institute for Applied Systems Analysis (IIASA) Austria, Professor David Keith, Director, ISEEE Energy and Environmental Systems Group, University of Calgary, Canada, and John Virgoe, an expert in climate change policy, gave evidence via video link.

Chairman: Could I say a very warm welcome to our guests around the world and, indeed, thank you very much indeed for joining us at what must seem an unearthly hour. It is snowing here in London and I am sure you will tell us what it is like around the world. We are very tight to timescale, and I am going to ask each of you to introduce yourselves very, very briefly so that we know that our feed is up and live, but first I am going to introduce our Committee to you. I am Phil Willis, the Chairman of the Science and Technology Committee here in the House of Commons, and on my immediate right is?
Dr Iddon: Dr Brian Iddon, Member of Parliament for Bolton South-East, Labour.
Graham Stringer: Graham Stringer, Member of Parliament for Manchester, Blakely.
Mr Cawsey: Ian Cawsey, Member of Parliament for Brigg and Goole.
Mr Boswell: Tim Boswell, Member of Parliament for Daventry.

Q1 Chairman: And on my immediate left is Glenn McKee, the clerk. That is our panel this morning. I wonder if I could ask John Virgoe if you could identify yourself, please?
John Virgoe: I am John Virgoe. I am on the line here from Canberra, where we have been enjoying 38) today.

Q2 Chairman: Professor Keith?
Professor Keith: David Keith, University of Calgary, where it is around zero.

Q3 Chairman: What time in the morning is it?
Professor Keith: One-thirty. No, it must be two-thirty; sorry.

Q4 Chairman: Thank you very much indeed. Dr Blackstock?
Dr Blackstock: Yes, is the audio working at this point in time?

Q5 Chairman: It certainly is; yes.
Dr Blackstock: Wonderful. I am Jason Blackstock from the International Institute for Applied Systems Analysis and the Centre for International Governance Innovation. I am in Boston right now and it is four-thirty in the morning and about 0) Celsius as well.

Q6 Chairman: John Virgoe, I wonder if I could start with you. It has been suggested that there is a need for geoengineering intervention. First of all, do you think that there is and do you agree that it needs global regulation?
John Virgoe: On the need, I think it would be premature to make that judgment at this point. The state of knowledge about geoengineering, both on the technical side but also on the political, ethical and regulatory sides, is simply not at a point where I think any sensible person would be able to recommend that we should be implementing a geoengineering technique at this point. I think, however, there is increasing reason to think that we may be heading that way in the future. I suppose it depends to some extent on your degree of optimism about whether the world will actually get on top of global warming through the mitigation methods and through international negotiations. If we believe that we may be heading in that direction and that in some years from now (and I would not like to put a figure on it) we may be looking seriously at a geoengineering intervention, I think it does make sense for us to be starting, at this point, not only to research the science and the technology, but also to think through some of these issues around the politics and the regulation so that when we do get to the point, if we get to that that point, where we want to go ahead with these sorts of acts, we have thought about it and we are in a position to take a mature, measured and informed decision.

Q7 Chairman: Dr Blackstock, if we take John Virgoe's position as a sensible starting point, there is a huge number of international conventions with the potential to regulate geoengineering. Is there suYcient out there, or do we need to establish new positions? Dr Blackstock, can you hear me?
Dr Blackstock: Yes, I can.

Q8 Chairman: I was just saying that there is a huge number of international conventions with the potential to regulate geoengineering. Is that so, or do we need new ones?
Dr Blackstock: I think this depends in part on the types of geoengineering that you are talking about. Geoengineering is not a monolithic subject. The diVerences between carbon dioxide removal and solar radiation management and even, within carbon dioxide removal, the types that are engineered and, therefore, can be done on a global scale versus the ecosystem management, each of them requires diVerent types of regulation, diVerent regulatory structures. I think that for the engineering of carbon dioxide removal we do have methods in place that can fit largely within the local and national regulatory structures, but once you start getting into managing ecosystems or interventions into ecosystems at a larger scale across borders, we start to have more questions. CDR that is ecosystem-based, like ocean fertilisation, has already gone to the Convention on Biological Diversity and the London Convention and we have some regulatory mechanisms there. For solar radiation management I think we really lack the regulatory structure right now, and because solar radiation management—the sort of techniques of stratospheric aerosols, cloud whitening—are the only category of techniques that could be used with a rapid impact on the climate system if we were to intervene, I think that we need to get these regulatory structures in place before large scale field tests are implemented. Because even when you start talking about field testing solar radiation management techniques, you start

running into the potential for transboundary impacts, or at least a perception of transboundary impacts, and so international mistrust, international concern of what another country will do with that technology can come up very rapidly.

Q9 Chairman: Are you saying, Dr Blackstock, that the Convention on Biological Diversity would be a good starting point, or are you saying that that is suYcient?
Dr Blackstock: I am saying that for the diVerent techniques we need diVerent systems. There will not be (and I do not think we should think of there being) one framework which is suYcient to regulate geoengineering as a whole. If we diVerentiate the categories of geoengineering into the two broad categories of carbon dioxide removal and solar radiation management, I think those techniques that aim to remove carbon dioxide from the atmosphere, we largely have the appropriate regulatory mechanisms. There are some changes that could be made, but they largely exist. For solar radiation management, on the other hand, I believe we do not have the appropriate regulatory mechanisms in place, and I do not believe we have even a forum in which that discussion has begun to occur. I think we need more discussion at the international level of what type of regulatory mechanisms are needed, and that discussion should begin soon.

Q10 Chairman: Mr Virgoe, you disagree with that? You feel that we need a single regulatory body. I just wonder if you would let our Committee know how you think that that could work.
John Virgoe: In fact, I do not disagree with that; I agree with almost everything that Dr Blackstock said at that point. I certainly agree that when we are talking about CO_2 removal, the aspiration, at least, must be to make this part of a broader greenhouse gas management regulatory structure; that once we have addressed the issues around measurability, verification, the eYciency of some of these methods, then, ideally, we will be looking to see these methods implemented as part of a portfolio, if the price makes it sensible to do it that way. So that the countries faced with emissions reduction targets would have the option, and it would be a market-driven process, to what extent they wished to meet those. I agree with him entirely. We do not have the structures in place which would allow us to take the decisions and to regulate that process. The one area that I would diVer slightly with him on that is I would certainly agree that we need to start the conversations around these issues as soon as possible, but that does not mean that we should necessarily be jumping straight into an international negotiation. The state of knowledge around these techniques and the possible unintended consequences is such that I just do not think we have enough knowledge to get into that sort of international negotiation and that actually getting into that international negotiation could lead us to some unwanted consequences, but I certainly think that we need to start the discussion and we need to start the discussion, in particular, around how we are going to manage the process of researching these things.

Q11 Chairman: Professor Keith, we have just had a rather disappointing Copenhagen summit with, arguably, science coalescing around a clear understanding that the planet is warming up and that we need to take very, very drastic action. We have still failed to be able to get the sorts of compensation agreements to support countries that require a great deal of support in order to put in carbon mitigation measures. How do you feel? Do you feel that there would need to be significant compensation for geoengineering which might be deployed by one nation but have quite a significant eVect on another? Do you think it is possible to work that out?
Professor Keith: I cannot see the video. Can you hear me?

Q12 Chairman: We can hear you, so please carry on. We can see you now as well.
Professor Keith: Again, talking about geoengineering in general is almost meaningless, because there are completely diVerent things in that project. I think the question really refers to solar radiation management, and that is governance is central at the point where we lock it, and the reason is that it is so cheap that the challenge for the international system will be to restrain unilateral action. It is precisely the opposite, or the converse, of the kind of challenge we face to reducing CO_2 emissions, but the challenge is to incentive as a collective act. I think we will need methods to do that and, indeed, those may be some of the most challenging developments, some of the most challenging the international community has ever faced. I do not think it makes sense to begin now to develop the full mechanisms for managing full-scale deployment, because I think we simply do not know enough. I agree with what John Virgoe has said. The crucial thing now is to think about how to start doing this from the bottom up through the management of a research programme in an international and transparent way. From the bottom up does not mean just that the scientists decide— that is certainly not the right answer—but it means, I think, that it would be premature to start a full UN scale EU Court treaty process, because it is simply not clear yet what the capacities are and states, individuals, have not had long enough to consider seriously what the trade-oVs are.

Q13 Chairman: Very briefly, before I pass you on to Dr Iddon, it has certainly come to my attention that there is a real worry that the military use of geoengineering might become an attractive proposition for some countries. Is that something that worries you?
Professor Keith: Yes.
John Virgoe: I understand the concern. I am not a lawyer, but my understanding is that such action would actually be prohibited by the 1977 ENMOD Convention, which does outlaw the hostile or

military use of environmental modification techniques. That does not mean, however, that the development of these sorts of techniques would not give rise to concerns, and that is certainly the case if militaries or, indeed, powerful governments were seen to be involved in developing some of these techniques. If we decide to move ahead with researching and possibly deploying these sorts of techniques, I think one of the big challenges for the world will be how do you actually deal with those sort of concerns? As I say, I think the legal position is that this would not be allowed under the Convention, but that does not mean there would not be concerns about it.

Q14 Chairman: Professor Keith.
Professor Keith: I would echo Mr Virgoe's comments on this. Let us try getting a scenario on the table. If a very small state, right now, decided to go out and deploy geoengineering with no prior consultation and with no adequate margin to go on, then, whether or not we had some prearranged international regime, it is pretty clear that the great powers would stop that small state. On the other hand, if a large state—and that does not necessarily mean a rich first-world country—began a serious ten-year programme of geoengineering research, subscale testing, and if that programme has international transparency in the form of an advisory committee that had some of the world's best scientists, and then that state moved, after, say, a decade, to say, "We are going to begin slowly and incrementally subscale deployment because we feel it will protect our world's interests", it would be extremely hard to stop. That state would eVectively seize the initiative, especially if it was a nuclear power state. The reality here is that there are limits to what we can do in international law because, in the end, this gets to the core national interest. That is not to say we should not try, because, I think, in the end, the stability of the world is going to depend on this over time, but I would use this example to give you a sense of just how valuable it will be. Let us say China decided to do some modification that they think will improve their monsoon but make India's monsoon worse: that will not be directly, as John says, prohibited by an ENMOD treaty, but there is no question that will have a military response on all sides.
Dr Blackstock: I would build on Professor Keith's statement quickly and say that those two scenarios that he painted are the ends of the spectrum of possibilities, but as geoengineering research is developing, particularly on solar radiation management, somewhere in the middle ground seems more likely at this stage, where powerful nations begin research programmes on geoengineering and other states' perceptions of how transparent that is. For example, the EU, the UK and the US are all having these conversations about geoengineering; developing countries are not yet present. We need to consider the knock-on consequences of that middle ground perception that powerful countries are beginning to develop these technologies and may be pursuing not necessarily militaristic interests, but simply national climatic interests by developing these technologies. For example, on the next attempt at Copenhagen, the next attempt to get mitigation discussions going, there will be these arguments. I would agree with Mr Virgoe, we are not ready for international negotiations, but, I think, particularly by countries that are now starting serious geoengineering research, there needs to be an attempt to engage a broader dialogue with those countries which would otherwise feel marginalised on these subjects.

Q15 Mr Boswell: My specific question was about the regulation of these processes and what might be termed the international validation of them. It would seem to me (and this prompted my asking to intervene) that the UN Charter and the principle of self-defence, at one level, could actually be invoked by a nation state who wanted to do this by saying, "It is essential we do this in order to protect ourselves." Perhaps you would like to comment on that. Secondly, there is some analogy with the development of nuclear programmes, for example, in states which are not at the moment nuclear weapon states. There may be some suggestion that they are able to shelter under civilian regimes in order to develop what are essentially nuclear military programmes. Do you have any comments on those two?
Professor Keith: Let me pick up on the connection of nuclear weapons and point out that we do not just succeed on an international basis by formal treaties. Normal behaviour is very important, even if they are not formally within a treaty. So the norm that said no state should have that first use of nuclear weapons, no first use for them, had a profound role in the Cold War and yet it was not the core of any treaty. I think what we need to develop here are both norms and treaties and we should not look at necessarily getting through a written treaty.
Chairman: I am going to leave that there and bring in Dr Brian Iddon.

Q16 Dr Iddon: Good morning, gentlemen. Are we quite clear about the width of geoengineering? What I mean by that is that weather-changing techniques such as cloud seeding might be considered to be geoengineering. Do you encompass those techniques within your definition? Could we start with John Virgoe perhaps?
John Virgoe: I certainly would not encompass that. One of the criteria for me for geoengineering is that the eVect needs to be at a global level, and cloud seeding is a weather modification technique. We should not get hung up, though, on the precise definition of geoengineering for a couple of reasons. One is that the term is a very scary term and I think it does inhibit sensible debate around these techniques. The second is that the term has come to encompass at least two quite diVerent things which are both technically diVerent. I am talking about techniques for solar radiation management on the one hand and for taking CO_2 or other greenhouse gases out of the atmosphere on the other. They are quite diVerent

technically but also in terms of their non-technological implications. Currently I find it more helpful to think in terms of unconventional or complementary techniques and then to look at them one by one. I think the category of geoengineering is possibly starting to no longer be a particularly helpful one.

Q17 Dr Iddon: Professor Keith, do you agree or disagree with John Virgoe?
Professor Keith: I strongly agree. I think all three of us have said that in diVerent ways. Let us try and help this by being specific. If biochar is geoengineering, it certainly does not bring out the kinds of direct international security concerns that are brought out by the capacity to do stratosphere solar radiation management, and the reason is all about leverage and money. The fact is that with the right technology it may be cheap enough, through engineering the stratosphere, that literally individual human beings may have the wealth necessary to introduce an ice age. I say that to be deliberately provocative, but there is evidence that is in fact correct, and that enormous leverage—the concept being so cheap—means that the threat of unilateral action is real and the impacts could be very substantial. There is no comparable issue with, say, biochar, and for that reason the sort of regulation management we need is completely diVerent.

Q18 Dr Iddon: Dr Blackstock, do you have any comment?
Dr Blackstock: I would echo the comments that were just made and build on them, just saying that it is the transboundary impacts, the impacts that go beyond the boundary of one country, that are really going to drive the international regulatory frameworks that we need to develop, and so for a working definition of geoengineering there is obviously the question of intentional intervention requirements. As David Keith just raised, biochar does have the intent of keeping the global atmospheric concentrations of CO_2 down, but the near-term transboundary impacts are minimal. When we think of developing regulatory structures for what we class as geoengineering, our primary concern should be about how large is the transboundary impact and how soon will that transboundary impact manifest? This is what focuses a lot of the conversation that you heard on solar radiation management, the fact that that can impact the climate system in the near-term, whereas the CDR techniques, the carbon dioxide removal techniques, have a much longer time lag behind them. Just to echo the last question that was asked about nuclear technology and build-up—Professor Keith's point—as David mentioned a couple of times now, solar radiation management technologies appear relatively cheap, which also means relatively technically simplistic. Therefore, the analogy to nuclear technologies becomes much more challenging, because most of the technologies required to actually deploy solar radiation management are things that are available to numerous countries already. These are not technologies that require huge technological progress from where existing technologies are at. The idea that we can potentially regulate and control the technology underlying solar radiation management, like we do, or attempt to do, with nuclear technologies, is not a good analogy for this. The technology is going to proliferate and be accessible to a large number of individuals or countries and, therefore, we have to look at controlling behaviours in this case, not just access to technology.

Q19 Dr Iddon: My second question is about risk. Should we be categorising geoengineering techniques as low risk, medium risk and high risk? If you agree with that, should there be separate regulatory regimes for each risk area? Could I start with Dr Blackstock, please.
Dr Blackstock: Simply having three categories of low, medium and high risk, as all three of us have already echoed, there are slightly diVerent things that you would want to lump into categories, that you would want to define the technologies according to, and I think what you have heard echoed here already is an attempt to classify these things in precisely that way. The high risk technologies in this case that we have been discussing, high risk geoengineering methods, are those of solar radiation management because of the cheap and easy technology for implementation, the near-term impact it can have and, therefore, the potential for unilateral action. That creates a high risk category that does require a diVerent type of regulatory framework than, for example, is necessary for biochar or the other carbon dioxide removal techniques, that is a useful framework of low key and higher risk, but understanding why those classifications of higher risk versus lower risk are made will be a very important part of any regulatory framework. That echoes Mr Virgoe's comment that we need a lot more research to understand the science underlying these techniques before going for full-scale negotiations and real international regulation.

Q20 Dr Iddon: Professor Keith, do you agree?
Professor Keith: Yes, generally I agree with what Dr Blackstock has said. I think that categorising things like the amount of leverage might be more useful than boundaries. There are things like that, low leverage, where it is implausible for a small amount of money or a small stated eVective load and may have high or low risk, and those things do not need a kind of international governance that they will eventually need for these high leverage technologies like solar radiation management. I think actually that high, low, medium risk categorisation is not a particularly useful way to think about overall governance. We need to think about the specific, very diVerent timescale and leverage diVerences.

Q21 Dr Iddon: John Virgoe, finally?
John Virgoe: I would agree with both of those comments and just observe that I think we are talking about a number of diVerent sorts of risk here, and it is going to be important to pick these apart.

There are environmental risks, risks of things going wrong or risks of unintended side eVects. There are also political risks, and we have touched on some of these already, and I think there are a number of other potential political risks, risks to the international system, to multilateral or bilateral relations. It is something that particularly concerns me. There is clearly a risk that the techniques do not work and there are also risks around things like legal issues and liability. I think there is a whole range of diVerent risks, and we probably need quite a sophisticated framework for assessing those, but ultimately, you are right, we will be in the business of balancing risks and balancing them against the risk of runaway climate change essentially.

Dr Iddon: Thank you, gentlemen.

Q22 Mr Boswell: I will start with Mr Virgoe, if I may. In your paper, which is very helpful, you suggested developing guidelines that would apply to the whole area of research into geoengineering. My first question is: who should be formulating these? Should this be individual governments, international organisations or, possibly, some kind of consortia of academics or NGOs that does it?

John Virgoe: I think that is an extremely interesting question. I do think that the development of, I suppose, what might more appropriately be called norms or principles is the first task and is a particularly urgent task given the urgent need to restrain what we might call irresponsible entrepreneurial activity in this field. We need to develop these norms and we need to socialise them among the community of nations, the community of scientists and other stakeholders. How do we do that? As I suggested earlier, I do not see turning, in the early instance, to the international multilateral process, negotiating it a treaty, as the right way to go in this. I think the state of international understanding and also the knowledge base is currently so weak that you could get outcomes that would not be the right one. I think it is very possible to imagine, if this is put on the table in some sort of UN forum, you could end up with a decision, basically, to make geoengineering a taboo, to outlaw it, and that would be a mistake, for a couple of reasons. One is that it may be that we actually need to be doing this research and that, some decades down the line, we will be very sorry if we have not started thinking through these techniques. The second is that I think there are a lot of actors out there, as we have all already said several times, with the capacity to research and implement these techniques. Some of them may not feel bound by that sort of international decision, some of them may not be as responsible, and it would be very unfortunate if what geoengineering research was happening was going on under the radar screen, if you like. What we need is an open process which builds on some of the principles that are already out there around similar issues; for example, principles developed to deal with long-range air pollution or weather modification: principles around openness, transparency and research, notifying a neighbouring country or countries which might be aVected. We probably develop these through maybe a slightly messier process than an international negotiation. Individual countries will have a role; communities of scientists will certainly have a role. I think if you look at some analogues, for example, around genetic engineering, fusion physics or, indeed, carbon capture and storage, to come a bit closer to home, you can see examples where research norms and principles have been developed almost from the bottom up in that way involving groups of scientists, other stakeholders and interested countries.

Q23 Mr Boswell: That is very helpful. Would the other two, Professor Keith or Dr Blackstock, like to comment?

Professor Keith: Yes. I think there is a role for bottom-up generation of norms that has to start most of all with just transparency alone. I think there are parts of the international scientific community, such as the national academies and bodies that link the national academies, such as the InterAcademy Council, that can play an important role here. That is not to say that this should just be the domain of scientists, because it should not. It is vital that we find a way to get a larger set of witnesses in here, not have a reality or perception that the scientific community alone are deciding what to do purely based on research. One of the wonderful things about the global scientific community has been its ability to operate internationally and have some level of transparency even in the middle of the Cold War, and I think that building on that is a certain key way to start but it needs to be done in many places, and we need to have diVerent eVorts to develop these norms of behaviour going on, whilst I think it would be a mistake to go for a single, unified system too early.

Dr Blackstock: Could I just add one thing on top of what my colleagues have said, which is that when speaking about research on low scales where the research itself has no transboundary impact—for example developing the deployment technologies, laboratory research, computational modelling—for that the framework of developing norms within the scientific community as a bottom-up process, I think, is very political and will work well. I am more sceptical, however, when we start talking about field tests, particularly what Professor Keith has been referring to as high leverage geoengineering technologies, which are specifically the solar radiation management type. When we start talking about field tests, it is a question of—

Q24 Mr Boswell: I interrupt you. Typically crossing national boundaries at that level. The field test would be typical.

Dr Blackstock: Yes, at some scale you can do what you refer to as subscale field tests, which are tests of such a small scale that they do not have transboundary impact, but defining where that boundary is between subscale and actually having transboundary impact—and this goes a little bit to what Mr Virgoe has just said—there are two types of risk. There is the actual technical risk, the environmental risk, but then there is the political risk in just the perception. One can conduct what is nominally a subscale test, but the political perceptions of your neighbours can be diVerent to that, and so when talking about the types of research that begin to get into actual environmental testing of these technologies, I think we have to be more cautious about what we are seeing, based on norms alone, prior to a political agreement. We saw an example of this in this last year with the ocean fertilisation experiment, the Lohafex example, that was the Indo-German collaboration that ran it, and the political controversy that emerged surrounding that. Nominally that test would have had very subscale impacts in terms of the ecosystems and certainly in terms of transboundary, yet the political controversy agreed because of the perceptions and the fact that the Convention on Biological Diversity and the London Convention had already been discussing these issues. When you start doing field tests, you start raising more political issues. I think the consideration of the norms is partly necessary but not suYcient to address the sort of political issues that will raise.

Q25 Mr Boswell: The second question is really for all of you. By prefacing it, I think I would say that it sounds to me as if the words “norms”, “guidelines” and “principles” are pretty well interchangeable, and you might like to comment on that, but a group of leading academics have suggested five key principles—that is the word they use—for guiding research. Broadly, first of all, that geoengineering be regulated as a public good; secondly, the importance of public participation in decision-making; thirdly, disclosure of geoengineering research and open publication of results; fourthly, the independent assessment of impacts; and, fifthly, governance before deployment. I think that last one implies that you start the guidelines and you work on the governance at the stage where you need to perhaps develop specific research projects. They sound pretty good to me at first sight, but are they practicable as a basis for at least starting to consider the acceptability of research? Would Dr Virgoe like to start on that, or whoever?
John Virgoe: I am happy to go first, but I should say I am not a doctor.

Q26 Mr Boswell: I am sorry.
John Virgoe: On the five key principles, I also agree that they sound pretty good at first sight, or at least three of them do. I would absolutely agree with the principle of open publication and disclosure of research. I think this is absolutely key. The surest way to excite international suspicion about what you are doing is not to be open about it, and that applies whether you are a community of scientists or whether you are government, of course. Starting with governance first, independent assessment of impacts sounds like a good idea to me as well. The two that I have some question marks over are the first two, however. Implementation in the public good. Yes, it is motherhood and apple pie, but I think when you delve below that you have to ask: who is the public in this case? The global public. We are talking about interventions which will aVect the planet as a whole, and there are number of publics out there. There are some publics out there who are suVering very badly, or will be suVering very badly, from the eVects of climate change. There are some populations out there who may have seen some benefit from climate change and, therefore, not be very happy to see climate change being put into reverse gear, if we were ever able to achieve that. The impact of some of these techniques is likely to be heavily diVerentiated. It is not necessarily the case that we will simply be able to slow climate change or put it into reverse at the same rate across the world. You may find some areas were continuing to warm, other areas cooling faster and, of course, unintentional side eVects. I think once you peer below the surface of the public good, it becomes quite hard to define it and you get into some diYcult ethical territory. As far as public participation is concerned, again it sounds good, but I find it hard to imagine quite what that means at the global level. How do you actually bring about public participation at the global level and how do you ensure that certain parts of the public, or the public in certain countries, do not have privileged access compared with other countries, publics or other parts of the global public?

Q27 Chairman: Could I ask you to be as brief as you can, because I am desperately trying to get in another set of questions before we run out of our link. Can I ask you to be very brief in your answers, please. Dr Keith?
Professor Keith: I want to return to a previous conversation, because I think it got on to the key point where there is a little disagreement probably between us. Dr Blackstock was suggesting that we need to have political agreement before we do any subscale testing. I would submit that that is problematic. For one thing, the Russians are already doing subscale testing. For another thing, it has recently become clear that, despite all the talk about stratospheric geoengineering, the main method people talk about basically does not work. That is, if you put sulphur in the stratosphere the way we have been assuming, it does not do what we thought. You could do tests on this. These would have no detectable climate eVect, but they would be subscale tests, and if we want to actually understand whether this technology works or it does not, we need to do those tests relatively soon. If we say we are not going to allow them until we have a political agreement, essentially that gives a veto to any power that does not want to see that. I think we have to really think hard about whether that would be an appropriate strategy or whether the default outcome of that would be that there was no serious progress in our standard of understanding.
Dr Blackstock: I would quickly respond to Professor Keith’s point and say I agree with most of what he has just said. The issue that I am trying to raise is the question of how the politics play out. As he pointed out, Russia has begun doing subscale field tests, and they are extremely subscale, at a point where there will clearly be no transboundary impact. While I

would agree that we want to progress our science—and we will need to do some of this subscale testing to understand the feasibility of some of these technologies—we want some international mechanism, some mechanism of legitimacy, for defining what subscale actually means to begin with, and then, before we start pushing the boundaries of what questionability of subscale, that is, I believe, where we really need to have, not just scientific, but political agreement. As Professor Keith raised before, the international grouping of national academies could be the right body for being able to make a declared statement of a subscale test being actually subscale, but there will be cases where the politics will overrun that and individual scientists, and particularly nation states supportive of subscale testing, need to be very aware of the political issues it can raise and be proactive. In responding directly to this last question, norms, guidelines and principles are all, I feel, interchangeable words, but what I think needs to be considered are commitments. There are some debaters that have operationalised these principles, but I think that nation states who are now starting to fund research, particularly if it goes to funding subscale experimentation, we need to ask what preventive commitments, what precautionary commitments nation states need to make about the sort of research and transparency that they are going to want to commit to up front in order to avoid exacerbating all the mistrust that already exists within the international climate arena.

Q28 Mr Cawsey: Mr Virgoe, in your written submission to us, you make the point that it would be necessary to be cautious in the way international debate on geoengineering is initiated. Indeed, you went further to say it may well be banned in line with the precautionary principle if we do not. Why do you think this might happen? Should we prevent it and, indeed, can we?
John Virgoe: I think we can try to prevent it by being careful in the way that we raise the issue. To take a very crude example, if you were to take a proposal around geoengineering straight to the floor of the United Nations, in whatever format you liked, you have to think about the politics of how countries would respond to that. At the moment the state of knowledge around geoengineering, the state of understanding, is not great. I think a number of countries will be very alarmed by that proposal. A number of countries might see it as an attempt by the developed nations to escape from having to make cuts in their greenhouse gas emissions; others might be very excited to hear about this potential solution to climate change. I think the consequences of that sort of unprepared debate in that sort of format would be very unpredictable, but you might get a decision of one extreme or the other, either to ban geoengineering or to rush ahead with it when we are really not at the point where we can say that this is at all a sensible road to be going down. That is why I am arguing for a much more cautious and bottom-up approach to putting this on the international agenda.

Q29 Mr Cawsey: The UK's Natural Environment Research Council has launched a public consultation on geoengineering and it has asked for comments on two topics: what are your thoughts on the hopes and concerns about the potential use of geoengineering technology and what questions people should be asked about the future of geoengineering research? Is that going too far too quickly, or is that sensible? Do you support that consultation and what issues and options should be considered? I will start with Mr Virgoe, but I would be interested in what other witnesses have to say as well.
John Virgoe: I thought that was a very interesting initiative and seems to me to be a sensible way of starting to start debate.

Q30 Mr Cawsey: Professor Keith?
Professor Keith: For other consultations to really work, it requires more than just having an open door for the public to pour comments. I think that is a necessity but it is really not suYcient. Good public consultation requires help to give members of the public the tools to ask scientists what is going on and understanding the technical facts, and it typically is more eVective if a small group of representatives of the public get to debate and work issues out for themselves and then report. There are various methods of this kind of symmetrical democracy that can work, and I think that pure kind of classic consultation patterns may not be all that helpful.
Dr Blackstock: I agree. I would echo that statement from Professor Keith that a more active educational role or involvement in education about these ideas is essential. I would just build back up to something that Mr Virgoe raised in his framing of how we could go wrong by rushing forward in the international community. This programme of starting communications within the UK is a good start, but because of the truly international scope of these geoengineering technologies that we are talking about, we have to ask ourselves who are going to be some of the most sensitive communities within the international sphere who we definitely need to take a proactive role engaging in the conversation early. I can think particularly about countries who already have populations marginalised in terms of climate change or are on the edge of suVering from climate change impacts, because those marginalised populations are likely to be the ones most sensitive to geoengineering experiments and a high level of solar radiation management experiments and particularly implementation. There is that risk that without directive public engagement, an attempt to reach out and provide the information proactively and indeed in a conversation, that we end up with them inevitably being surprised later on by rapid climate change impacts for these technologies which can lead to the unilateral and rash actions that we have been trying to steer that by doing informed research and responsible research we can hopefully avoid, but that requires international public consultation, not just domestic.

Q31 Mr Cawsey: I was going to go on about the Engineering and Physical Sciences Research Council undertaking workshops and sandpit events and ask if you thought other countries should do the same or whether it should be internationally focused, but you are clearly saying you think this should be an international endeavour, not just done by individual states?
Dr Blackstock: That would be my opinion on this, yes.

Q32 Mr Cawsey: Mr Virgoe?
John Virgoe: Certainly I agree with all of that. I think you have to look at the political structures in some of the countries that I think we are referring to and ask yourself whether going straight to public consultation nationally would actually make sense, but the broad principle that we have to avoid anybody, any country, certainly any powerful country, feeling either threatened, or suspicious, or surprised by any action or discussions we may be having in this area: I absolutely agree with that principle.

Q33 Chairman: I will have to call this session to a halt. I am sorry, Dr Keith, not to bring you in there. Could I thank you all very much indeed for joining us on what is the beginning of a journey. It is a piece of work we are doing jointly with the US Congress Science and Technology Committee, but we thank you very much indeed, Dr Blackstock, Professor Keith and John Virgoe, for your help in answering our questions this morning. We wish you either a good night or a good morning. Thank you very much indeed.
John Virgoe: Thank you.

Witnesses: Sir David King, Director of the Smith School of Enterprise and the Environment and former Government Chief Scientific Adviser, and Dr Maarten van Aalst, Associate Director and Lead Climate Specialist at the Red Cross/Red Crescent Climate Centre, gave evidence.

Chairman: We welcome our second panel this morning, Dr Maarten van Aalst, who has flown in this morning from Holland—and we thank you very much indeed, Maarten, for doing that—and an old friend of the Science and Technology Committee, former Government Chief Scientific Adviser, Dr Sir David King. Sadly, we have lost our third panel member, Dr Kilaparti Ramakrishna, who should have been coming to us from India. Unfortunately, our video link has not worked, which is sad, but it means we have more time for our other two distinguished witnesses this morning. I wonder if I could start with you, Graham Stringer, in this round of questioning.

Q34 Graham Stringer: Should we be putting a lot of investment into geoengineering research at the present time?
Sir David King: Good morning. I am delighted to be here. Could I congratulate you on conducting much of this by video conference, which must have saved a lot of carbon dioxide, and in a sense that reply addresses this question: because, quite clearly, the major eVort has to be around defossilising our economies, and the point about defossilising our economies is that it manages a problem which is an anthropogenic problem directly rather than indirectly, which is what we have been discussing this morning. It gets right to the root of the problem. I think that, while there are real concerns about what the impact on economic growth might be, I do not really share those concerns. If we manage the transition over the next 40 years into a defossilised economy, I think we can manage it and, at the same time, even get a boost to growth through the innovation that follows from this necessity to move away from high-carbon technologies. The shorter answer to your question is, however (and it is a very important however), we need to factor in the probability distribution functions that the best science can deliver around what the temperature rise for the planet will be even at a level, let us say, of 450 parts per million of greenhouse gas CO_2 equivalent in the atmosphere. The best that science can tell us at the moment is that the eventual temperature rise is going to lie somewhere between 1) Centigrade and 4) Centigrade with a peak in that probability distribution function above 2) Centigrade, and so we only have a 50 per cent chance of staying below a 2) Centigrade rise. There is still, for example, a 20 per cent chance that the temperature rise will be above 3.5) Centigrade, and I am putting to you the idea that the 450 parts per million figure is what we ought to aim for globally—it is the lowest figure that is manageable—but even there we have to manage risks by keeping in reserve an alternative way forward.

Q35 Graham Stringer: Dr Aalst?
Dr Aalst: First of all, let me say that I am not speaking on behalf of either the British Red Cross or the International Federation of Red Cross/Red Crescent Societies but in a personal expert capacity. I would echo many of these remarks. I think we need to be cautious of investing at too large a scale to even give the impression that this is a suitable alternative in the short-term to mitigation or, I would add, much more extensive capacity building and adaptation, especially among the most vulnerable groups, so I would just add to that. On the side of the risks, I agree that it is something that we might want to have up our sleeves, and we are nowhere near the level of certainty about what these diVerent options are that we could consider these options that we have at this stage, so further research, in that sense, on a small scale to get slightly further in our understanding would be important. To give you my primary perspective on that right away, it is not about what is per square metre, it is about people. I think in looking at those options, those

distributional eVects (and, in particular, the eVects on the groups already most aVected by climate change as we see it progressing and the end of the probability distribution, not just in terms of the global temperature rise but also the impacts from there) would be crucial.

Q36 Graham Stringer: Sir David, when you were advising on the preparation for the Climate Change Bill—and one part of good regulation is that you look at diVerent alternatives to the proposals in the Climate Change Bill—did you seriously consider geoengineering and the costs and benefits of geoengineering as against CO_2 reduction?
Sir David King: I think the answer is, yes, seriously consider, but then, following the answer to your previous question, I do not see that what we are now discussing with geoengineering issues should be a high profile way forward. In other words, it is something, to repeat, that should be there, kept in reserve, there should be a significant eVort made both into research and into regulation at this stage, but I do not think that the eVort should match in any way.

Q37 Graham Stringer: I understand the arguments. I suppose what I am really asking is when you were doing the regulatory impact assessment on the Climate Change Bill did you quantify the costs and benefits of geoengineering against the mitigation of carbon dioxide?
Sir David King: A very simple answer is, no, simply because the cost of carbon dioxide capture from the top end of a coal-fired power station is already rather large and there is a much higher density of carbon dioxide at that point of the atmosphere than in the general atmosphere, where it is only 400 parts per million. The cost at our present estimate is already expensive from the top end of a coal-fired power station and, in my view, is prohibitive from the general atmosphere. It was not eliminated without examination.

Q38 Graham Stringer: Geoengineering is going up the agenda in a way: more people are talking about it. Where do you think the pressure is coming from for a greater investment in geoengineering? Is it from industry, NGOs, people who are profoundly sceptical about global warming?
Sir David King: I do not think it is any of the above. I think it is more pressure coming from people who (a) are concerned about us not managing the problem by defossilising, but (b) a group of people who do not wish to go down the defossilising route and would like to provide an alternative, and I fear that there may be quite a largish group emerging, particularly in the United States, which come from that particular line.
Dr van Aalst: Yes, that is my impression as well. I think on the scientific side, this debate was probably started by people with a genuine concern, wanting to map out these options for that tail end of distribution. I think we are now in a shift, and with political attention growing, there is also political attention from the other side. I would also be cautious, including the caution of establishing very large research programmes which might be interpreted as on a similar scale as the investments we are making in mitigation and adaptation.

Q39 Graham Stringer: I was going to say, do you think that the risks are too high to consider geoengineering, but in a sense, you have already answered that question by saying we should have it in reserve. It might be a more pertinent question to ask: what do you think the major risks of geoengineering are?
Sir David King: I think if I can now adopt the same approach as the previous group, we need to separate geoengineering into carbon dioxide capture and solar radiation management. In terms of solar radiation management, my own view is that there should be, if possible, a temporary ban on solar radiation management. I think the unintended consequences of that are extremely diYcult to foresee. I am all in favour of research that would examine possible consequences of putting aerosols up in the stratosphere to reflect radiation away. The concerns expressed by the previous group I would match as well, the total cost of managing to put sulphates into the stratosphere is relatively small, and the technology is there, and I do think that this is something that needs to be addressed immediately, but now moving on to carbon dioxide capture, carbon dioxide capture should be dealt with as well in two forms: one is capture from the atmosphere, and one is capture from the oceans. I think as soon as we move into capture from the oceans, then again, we are dealing with an issue of long range pollution and impact problems, so cross-boundary problems. So the simple categorisation of two is not in my view suYcient. Let me just go back and make a comment about solar radiation management. Let us suppose that we could all be persuaded that Crutzen is right, and we can reduce temperatures in this way. We would still not be managing the acidification of the oceans. In other words, carbon dioxide levels going up means that we would get more carbonic acid formed in the oceans, and why is this a problem? The oceans are part of the ecosystem services for humanity. It is the oceans that provide the beginning of the food chain, and if we do not understand what is going to happen to the oceans as they become more acidified, and there are questions about that already being examined by the scientific community, then I would also be very concerned about this, even as a potential solution. So I am focusing then on these two methods, carbon dioxide removal from the atmosphere and from the oceans, and I would say we should be investing in research in those areas, and we need prior regulation particularly on ocean removal.

Q40 Dr Iddon: Good morning, gentlemen. Earlier, we were talking about regulating geoengineering, and, of course, it goes from modelling by computer and in the laboratory through to pilot scale, you know, on diVering scales in the environment. At what stage do you think the regulation should kick in, assuming that we can get international agreements? Should it apply to the research throughout, or just to quite large scale applications in the environment?

Dr van Aalst: I should say, I am not an expert on research regulation per se, so with that qualifier, my impression is that there is probably some regulation in place for some of the experiments that would be considered. The risks are primarily on the trans-boundary implications, that is where we probably do not have the good structure in place, and we need to look much further; and then there is the moral side of where you invest and how you look at options, and particularly how you include all the distributional eVects there, which would probably kick in much earlier. So I think it is clear that we are in that stage, once we are in the stage of testing, once we are testing, and I support the previous views that you want regulation in place before you do large scale testing. For the earlier experiments, in general, I tend to be in favour of fairly free research, so that we can explore these options, and I think we are in too large uncertainty still about many of these options to be able to even design the right regulations.

Sir David King: I certainly believe that early regulation in any issue of this kind is essential. That does not mean that we leap straight into regulation, but examining what is the optimal form of regulation is well worth doing in advance. I think, however, that in terms of solar radiation management, I would move fairly swiftly, as I have suggested, into a temporary ban, and find the feasible way forward for that. I am not happy about smaller experiments being conducted at this stage in time before the unintended consequences have been fully evaluated. We are dealing with an extraordinarily complex issue here, and we all know scientifically that complex phenomena, as complexity increases, we get emergent properties that are not always easy to predict. So I do think we need to watch the stratosphere very carefully, but at the same time, in terms of regulation of the others, get ahead of the game, precisely because firstly, you want to keep the public on side, if we lose the public, then we lose the game; and secondly, we want to see that the regulation encourages the right behaviour. Car exhaust regulation has always been progressive, saying this is the way—the new cars have to meet that standard in three years' time, and it has produced the investment in the right direction. So if the regulatory system is set out there, everyone knows what the playing field looks like.

Dr van Aalst: May I just add a comment, just to clarify? On regulation, I think we definitely need that sort of regulation once we go towards testing, and I would agree with the suggestion to have a ban, even on relatively small scale testing of solar radiation management. I do not think we can go quickly towards regulation of, say, model experiments of stratospheric aerosol injection, that would not even be feasible. I would think that as an alternative, or as a complement to eventual development of regulations for deployment, the sort of consultations that were discussed in the end of the previous panel would be crucial, and those should be international consultations, it should be very pro-active and engaging the public, because I think that will be a crucial factor to understand the feasibility, the acceptability of these options. That discussion needs to take place much before political decisions about eventual deployment, and I think also much ahead of actual regulation, except for a regulation to say let us try and stop it for now. I also think that we need to be realistic here; there is probably a diVerence between the sort of debate now taking place here in the UK and the debate around the globe, including in several diVerent states which may already be at the stage of small scale testing of some of these options. So I think the UK is in a way also operating as an international arena, and in a way setting moral standards and setting an example for how globally we should be approaching this, which is a very important side eVect for your own considerations, I think, at this stage.

Sir David King: Can I come back very briefly, because I think there is an important scenario or set of scenarios that we do need to examine here. If we roll forward in time, and we reach the point where the worst impacts are happening, temperature rises are quite excessive, and we take on the notion that came up in the previous discussion about one country protecting its monsoon, and another country finding it is not acceptable, this discussion is critically important to have now, well ahead of time, for two reasons. One, because we want to avoid that being done; but the second reason is knowing the nature of the possible challenges in the future is a very sobering way of managing the business of defossilising. We need to really know what the potential disastrous eventualities will be, if nations start having to take matters into their own hands, and away from the international procedures.

Q41 Dr Iddon: Earlier, Tim Boswell read out five principles that have been laid down by the geoengineering community to guide their research. I will not read them out again, I will just read one: "Geoengineering is to be regulated as a public good." Do you think everybody understands what public good is, and who should define it? Who should decide what is in the interests of the general public?

Sir David King: I feel like saying "pass".

Q42 Dr Iddon: You leave that to us, do you not?

Sir David King: It is obviously a very important issue, and within this, I presume, comes the issue of intellectual property rights as well, so I think it is a critically important issue to understand what we mean by the phrase "public good". If we are saying that there should be no intellectual property rights capable of being awarded in this area, I think I would be a bit hesitant to back it.

Q43 Dr Iddon: What is your view on IPR?

Sir David King: I think it is a very complex issue, because if we are going to go down the route of carbon dioxide capture from oceans or atmosphere, and this is going to be a good thing, we also need to know, where is the investment going to come from, to take the research into demonstration phase and into the marketplace, and there will be a marketplace with a price of carbon dioxide. That is going to be the private sector companies. If we do not allow protection of

IPR, are we going to actually inhibit that process of investment? So I think I am a little hesitant to simply back the pure public good argument without IPR protection.

Dr van Aalst: Yes, I would support that. If these are good options, then we want the private sector to play a role in rolling them out, and then we might be excluding—but again, I think for many of these questions, we are so far from large scale deployment that it is diYcult to even imagine what we need, but I would say that in principle, good regulation of the deployment, not regulation of the early stage of research, but regulation of the deployment, but having the private sector play a role, might be more eVective, if we all agree that there are options in that whole range of potential techniques that we do want to use.

Q44 Dr Iddon: I just want to finish by looking at the developing countries, obviously some of the developing countries are already badly aVected by climate change, more so than some of the developed countries. How do you think the international community should involve the developing countries in the geoengineering debate?

Sir David King: Brian has the diYcult questions today! I think it is very clear that one of the positive things to come out of Copenhagen, and the transformation of the global community between Kyoto and Copenhagen, is the much fuller engagement of the emerging powers and of the poorer countries, and the recognition that we now have at least three categories of countries: the developed nations, the emerging powers and the poorer countries. If we talk about the emerging powers in your question, I would engage them as closely as the developed world, as part of the world that can aVord the investment that we are now talking about into geoengineering research as a possible way forward. The poorer countries of the world, I do not believe that this is the issue that they will be raising, and I am advising several governments in this category. I think the focus there has to be on adaptation and low carbon economic growth. I do not think this is an issue that comes to them.

Dr van Aalst: I would slightly disagree here. Your first point about the emerging powers is clearly right, they need to be involved, and I think if you want a good international regulatory framework, they are going to be crucial. I think they are going to be the ones very cautious once this is brought to the UN, because they want to keep all their options open. So it is also a strategic consideration, if you do want to move towards some sort of international mechanism. The more vulnerable ones, I think, are the more diYcult ones, I think they will feel threatened by the possibility that the winners will protect their wins, and the losers, which clearly are mostly them, will not get anything. So politically, they are already very worried. I think there is a second dimension to it, which is the distributional eVects within countries, and we have seen that in adaptation, which is, of course, much more local than some of the large scale solutions that we are talking about here, but these large scale solutions, let us not kid ourselves, we are talking globally average watts per square metre, but these options, particularly on the solar radiation management side, will have specific local impacts as well, and similarly to adaptation, we will need to manage those as well. On the adaptation side, we have seen so many examples, I just heard one last week of a little village in Senegal which was facing increasing flooding, so you think, go and do something about it; well the city further downstream was also facing increased flooding, so they made a little canal to spill some of that floodwater towards the Atlantic, and the little village got hurt. This is the sort of adaptation intervention, of which we know so many have side eVects, particularly on the most vulnerable populations, which are not paying for the solutions so they do not get to have a say. I am really afraid we will get similar parallels on the geoengineering side, and I would really like the international debate that will be fostered, and that we had a little discussion about at the end of the last panel as well, to really include attention for that human dimension, and to try and involve that side of the debate early on. They do not come to the table naturally, and certainly not based on a call for comments by the Research Council in the UK or anywhere else in the developed world.

Q45 Dr Iddon: With respect to the international discussion, where should that be carried on? Should it be in the United Nations, and if so, is it being carried on there, to your knowledge, or should it be going on in the scientific/engineering communities, or both?

Sir David King: I would have said, in terms of the scientific community, the intergovernmental panel on climate change ought to be addressing this issue. It is obviously something that has to become part of their four yearly report in my view, and that would be the proper focus for the international scientific community. In terms of the international community, again I would turn to the United Nations bodies, UNEP, it is a pity we have not got the UNEP person here, is an obvious body, but I think this is an issue that, in terms of regulation, would need to be addressed at a G20 heads of states meeting to have a real impact. I do think in terms of the solar radiation management, it is of suYcient importance that it ought to be raised at that level.

Q46 Dr Iddon: Dr van Aalst, do you have a view on this?

Dr van Aalst: Let me just be frank, and say that I hesitate, in the sense that I worry that if we elevate it to too high a political level too early, we may be sending the wrong signals, so that would be my concern, putting it that high on the agenda right away. I do think that there are more technically oriented United Nations bodies that would be more appropriate, certainly the IPCC, and I would hope that along with possibly some conscious eVorts at consultation, which should primarily be looking at risks, and at whether this is an appropriate thing, and might actually be then guiding us towards more investments on the mitigation and adaptation sides. I would hope that those discussions in those UN bodies would then trigger a much wider debate, involving a larger range of stakeholders, and a more diverse set of stakeholders than have been taking part in this discussion so far.

Q47 Mr Boswell: It is coming across to me, gentlemen, that it seems that witnesses are looking at this as being a contingency if defossilisation does not do the job, and I suppose it is the nature of a contingency that it needs to be ready to go fairly quickly if that situation arises, although we are not committing ourselves to that yet. I am really asking a little bit more, if I may, about research into the impacts, and the importance of doing that now, and also, and this has been touched on in evidence, in particular research into the diVerential impacts, either by nation states, and that may be a contingent matter, or regionally, or within quite small areas or diVerent categories of people. I can think of hill farming, for example, if one was looking at that. I just wonder if Sir David and Dr van Aalst could say something about the importance of that research, as it were, digging down into this, in terms of physical impacts, also possibly economic impacts, which I suspect spills back into public acceptability, and the final point would be, to bring all this together, what about having some prior understanding about whether or not there needed to be some compensation mechanism, so that if we did have to use these weapons at short notice, if I may call them that, would we have got the machinery in place, and we would not be bogged down in yet another round of international argument about who should compensate who, or what could be done to mitigate it in individual cases. Is that clear? So with the backdrop of possible need to deploy at short notice, and a need to keep the political debate going, it is really looking at what research do we need to do, and in particular, how do we need to handle the findings of that research in relation to smaller impacts on individual groups?
Dr van Aalst: I think these are the critical questions, and also the questions where we have to be quite honest, particularly for the solar radiation management techniques, we are now in a stage of such high uncertainty that we are not really yet doing risk management, it is dealing with vast uncertainties.

Q48 Mr Boswell: So we need to get on with that in some sense.
Dr van Aalst: Yes, getting on with that in some sense to get a slightly clearer picture on what we are actually looking at is important, so I also think we are not yet at a stage where we can do proper economic impact assessments, I think the uncertainties are probably too large for most of these techniques, although you can do some back of the envelope calculations possibly. I would caution against purely economic impact assessments, in the sense that they tend to lose out on the perspective of the most vulnerable groups, which do not count much on the economic analysis side sometimes, so that is something to consider. On the compensation side, again, my previous comment hints at the fact that I think we are very early in the game to be talking about that even, but if we were, the attribution question is going to be as diYcult or probably more diYcult as it is for mitigation, or for carbon dioxide emissions. So I think that is a critical one, that we need to consider in how we treat this as a risk management option in the end. If we would ever deploy these options, we would be throwing it out on the world, and the attribution would make it diYcult for anyone actually to take the blame, so there will be losers, but the losers will not be able to defend themselves in court possibly, to some extent, unless we go towards precautionary principles and so forth, but then from my perspective, at this stage in the game, we should be keeping them oV the table mostly.
Sir David King: I think the issue in terms of the research into impacts, both in terms of the physical and economic impacts, would need to take into account the impacts from rising temperature. In other words, we are talking about an issue that would come into play if we are in that piece of the distribution curve that we are hoping we are not going to move into. So this is going to be playing oV a temperature rise of, let us say, 3.5 degrees centigrade against the impacts of whatever might happen if we, for example, put up sulphates into the stratosphere.

Q49 Mr Boswell: There are always choices, are there not, between two diYcult scenarios?
Sir David King: Right. I think this is an enormously complicated series of questions. If we look at the impacts from temperature rise, whether it is purely temperature rise, whether it is the changes in weather patterns, rainfall patterns, and therefore food productivity, sea level rises, if you look at all those impacts against the possible impacts of an intervention of the kind we are now discussing, I think that this is an issue that we cannot really tackle in advance. We are now talking 40 years in advance of the situation arising. But we just need to remember that it is going to be a balance of impacts.

Q50 Mr Boswell: I am going to ask you a contingency question prompted by that, which is if we were into that position, or thinking ahead at least, to look at the scenario, what kind of mechanism would be the best one for looking at this? Because clearly, there are political feedback loops and inputs as well, and people will be trying to avoid a situation where they or their country or their region may lose out. I mean, how on earth do we keep the integrity of this process if we need it, and the management of it, because of its scale?
Sir David King: We are already seeing, Mr Boswell, the problems of trying to achieve equity in negotiations around dealing with CO_2 emissions, and the equity issues that would arise around what

we are now discussing would be much more severe. That is why I think that the most important thing is to recognise the problems associated with going down this route, so that we amplify the need to go down the route of defossilising our economy.

Chairman: On that note, we will bring this session to an end. Could I thank you very much indeed, Dr van Aalst, for coming and joining us this morning; and thank you, Professor Sir David King, for joining us too.

Memorandum submitted by the Department of Energy and Climate Change (GEO 13)

This submission provides written evidence for the Committee's enquiry into:

— The regulation of geo-engineering, particularly, international regulation and regulation within the UK.

It addresses the three questions contained in the Terms of Reference for this enquiry.

Summary

— Geo-engineering is an emerging policy area and there are at present no international treaties or institutions with suYcient mandate to regulate the broad range of possible geo-engineering activities. Thus there are no regulatory frameworks in place aimed specifically at controlling geo-engineering activities. The risk consequently exists that some methods could be deployed without appropriate international agreement or regulation.

— The 2009 Royal Society report has concluded that, "while it is likely that some existing national, regional and international mechanisms may apply to either the activities themselves, or the impacts of geo-engineering, they have yet to be analysed or tested with this purpose in mind".

— We agree with the Royal Society that appropriate governance mechanisms for regulating the deployment of geo-engineering methods, whether large-scale or contained (ie within national boundaries), should be established before they are needed in practice. Any regulatory framework for geo-engineering will need to be flexible, so it can be adapted to take account of new findings and developments in this emerging area of technology.

— We therefore consider that there is a need for international regulation of geo-engineering research and deployment, in particular for those technologies that have trans-boundary implications or take place beyond national jurisdiction, as soon as possible. There is currently insuYcient information to be specific about the tools and regulations that would need to be implemented. Regulation of some of the technologies may be feasible by employing or amending existing treaties and protocols of international law. However, others (such as atmosphere and space-based methods) may require new international mechanisms.

— We suggest that international regulations should also seek to diVerentiate between research and deployment activities, and that regulations concerning research should be developed first. We agree with the recommendation of the Royal Society report that a de minimis standard should be established for regulation of trans-boundary research. The appropriate level would need to be decided collectively, according to the type and scale of research.

— We do not have a clear view at this stage as to whether existing national regulatory controls are likely to be suYcient for geo-engineering technologies where the activities and their impacts are confined within national boundaries.

Department of Energy and Climate Change (DECC)

The Department of Energy and Climate Change (DECC) was created in October 2008, to bring together:

— energy policy (previously with BERR, which is now BIS—the Department for Business, Innovation and Skills), and

— climate change mitigation policy (previously with Defra—the Department for Environment, Food and Rural AVairs).

This new Department reflects the fact that climate change and energy policies are inextricably linked—two thirds of our emissions come from the energy we use. Decisions in one field cannot be made without considering the impacts in the other.

DECC has adopted seven specific objectives to help focus eVorts towards a low carbon future:

— to secure global commitments that prevent dangerous climate change;

— to reduce greenhouse gas emissions in the UK;

— to ensure secure energy supplies;

— to promote fairness through our climate and energy policies at home and abroad;

— to ensure the UK benefits from the business and employment opportunities of a low carbon future;

— to manage energy liabilities eVectively and safely; and

— to develop the Department's capability, delivery systems and relationships so that we serve the public eVectively.

The Regulation of Geo-engineering

1. Geo-engineering[2] solutions have been proposed as an emergency strategy to cool the planet. However, it is clear that geo-engineering technologies are currently incompletely understood, undeveloped and untested, and at present they remain a long way from being practical solutions to an urgent problem. It is, however, recognised that geo-engineering may have a possible role to play in aiding our mitigation eVorts to reduce greenhouse gas emissions in the future. Thus, it is essential that full and considered investigation of the risks and feasibility of geo-engineering solutions is performed before implementation.

2. This submission is informed by the Royal Society report "Geo-engineering the Climate", published in September 2009 which represents the most extensive study of geo-engineering issues to date and provides an initial assessment of a range of proposed geo-engineering solutions.

Q. Is there a need for international regulation of geo-engineering and geo-engineering research and, if so, what international regulatory mechanisms need to be developed?

3. The intended impact of any geo-engineering technique is, by definition, global and, as such, international agreement is crucial to ensure clarity and common understanding of the scientific, legal and ethical issues surrounding geo-engineering. While there may be benefits, there are also considerable associated risks. More specifically, there may be significant undesirable environmental eVects of geo-engineering solutions, particularly solar radiation management techniques or those that interfere with ecosystems. These factors point to the need for some form of international regulation of geo-engineering techniques.

4. International coordination is necessary to develop strategies to ensure that both research and development, and deployment of technologies are pursued responsibly. The Royal Society report highlights a number of specific issues of concern that should be considered in any future discussion of geo-engineering and with which we agree:

— There are a number of proposed geo-engineering technologies that may be suYciently low cost that they could be implemented by a single nation or wealthy individuals and, therefore, there needs to be agreement on how to guide their activities and guard against risky and irresponsible action.

— Distribution of the environmental impacts of geo-engineering solutions may not be uniformly beneficial across the globe and full consideration of unique national or regional sensitivities to these solutions will need to be made. Some countries may experience detrimental eVects due to geo-engineering solutions despite net global benefits. The legal and ethical framework for possible compensation arrangements are unlikely to be straightforward.

— A geo-engineering action taken by an individual country might be seen as an infringement on the territory of other nations. This may be particularly relevant to techniques that entail atmospheric manipulations, which aVect national airspace and need to be large-scale to have significant eVects.

— Regulation of technologies is generally developed on the basis of existing research and evidence. In this case, however, knowledge and understanding of the risks of these technologies is still at a very low level and any research must be conducted responsibly and with caution. While initial research on the risks and feasibility of diVerent solutions will focus on modelling studies and small-scale field or laboratory experiments, the extent to which these adequately answer questions of unintended and negative consequences is limited and plans should be in place to prepare for large-scale experiments.

— As geo-engineering technologies are presently at a very early stage of development, any regulatory framework must therefore feature flexible characteristics to allow for developments in light of new knowledge and evidence and evolving social and political perspectives.

5. Furthermore, diVerent geo-engineering technologies may need diVerent governance arrangements for research and deployment. The technologies can be broadly classified into two groups: Carbon Dioxide Removal (CDR) techniques which seek to remove CO_2 from the atmosphere and solar radiation

[2] This submission draws upon Royal Society report published in September 2009 to define geo-engineering as "the deliberate large-scale intervention in the Earth's climate system" in order to moderate global warming.

management (SRM) techniques which act to reflect sunlight out of the atmosphere. SRM is likely to oVer lower cost options than CDR where the investment lead-times are longer and the capital costs are far higher, but SRM entail significant risks and uncertainties. It is also is particularly subject to issues of reversibility and termination.

6. To formulate an overarching governance framework covering all geo-engineering research and deployment will be challenging. A possible approach is to disaggregate technologies and take into account the range in approaches, separating those technologies that focus on CO_2 reduction from SRM solutions, for example. Some solutions, such as injection of sulphate aerosol into the stratosphere, will require detailed discussion and development of specific regulations but for others, existing treaties may be applied, for example the Montreal Protocol. There are also existing international treaty instruments in place that may cover the broader issues relating to the trans-boundary impacts of many geo-engineering approaches, for example, the UN Framework Convention on Climate Change (UNFCCC) and the UN Law of the Sea Convention.

7. A specific example of the use of existing mechanisms to address geo-engineering research or deployment is the application of the London Convention and its Protocol to ocean fertilisation. At the October 2008 meeting of contracting parties (which includes the UK) to the London Convention and Protocol, a non-binding resolution on the regulation of ocean fertilisation was adopted. Under the Protocol, the disposal of wastes or other matter into the sea is considered "dumping" and is regulated. Where the intention is for a purpose other than mere disposal, such an activity is considered to be "placement" and is permitted provided that such placement is not contrary to the aims of the Protocol.

8. The resolution agreed that the scope of the London Convention and Protocol includes ocean fertilisation activities, and that in order to provide for legitimate scientific research, such research into ocean iron fertilisation should be regarded as placement of matter for a purpose other than mere disposal.

9. The resolution also agreed that, given the present state of knowledge, ocean fertilisation activities other than legitimate scientific research should not be allowed, and should be considered as contrary to the London Convention and Protocol. Contracting parties to the London Convention and its Protocol are considering all the available options identified, and have been requested, following the meeting of governing bodies in October 2009, to deepen understanding of the implications of legally binding options to enable informed consideration and discussion on this issue by the governing bodies in 2010. A moratorium has been placed on large-scale ocean fertilisation research under the Convention for Biological Diversity while a regulatory agreement is being developed under the London Convention/Protocol.

10. The UK supports the precautionary approach towards ocean fertilisation. Any change to the London Protocol to enable all forms of marine geo-engineering for research purposes needs careful consideration before certain techniques that might usually be considered to be "placement" are prohibited as "dumping". Thought needs to be given to whether the London Protocol is the right instrument for this purpose (ie to regulate all forms of marine geo-engineering).

11. There are already many international bodies that may have an interest in geo-engineering, for example, the World Meteorological Organisation, and the IPCC. The IPCC's Fifth Assessment Report will begin to explore the scientific issues and risks surrounding geo-engineering approaches. While this is not expected to discuss governance directly, we consider this work will be a useful contribution in helping to inform international discussions on the mechanisms and strategies that are needed. This would also help develop an international framework for consistently assessing the risks, benefits, costs and feasibility across diVerent geo-engineering approaches and technologies, as currently individual studies apply their own assessment criteria.

Q. How should international regulations be developed collaboratively?

12. We suggest a suitable organisation needs to be identified, whose mandate would enable it to take the lead in facilitating the collaborative development of international regulations.

13. The Royal Society have suggested that an international consortium is formed to explore the safest and most eVective geo-engineering options while building a community of researchers and developers, and we consider that this is worth pursuing. It would also be necessary to address the non-technological issues surrounding geo-engineering, including the legal, social and ethical dimensions, and agree a precautionary principle. One example of a successful group which seeks to address the regulation of an ethically contentious area is the Human Genome Project.

14. We agree that further research is required to understand the risks and feasibility of geo-engineering approaches. We also recognise that this research must be carried out in parallel with discussions on the legal, social and ethical implications, and regulation and governance. To this end, DECC proposes to set up a Working Group to explore and develop proposals for governance structures relating to geo-engineering research from Spring 2010.

Q. What UK regulatory mechanisms apply to geo-engineering and geo-engineering research and what changes will need to be made for the purpose of regulating geo-engineering?

15. The Royal Society report notes that issues of liability for some contained activities that remain within State jurisdiction such as air capture or surface albedo enhancements, under public or private initiatives, could largely be covered by domestic law. There is a range of existing national land-use planning and environmental controls that are likely to be applicable to geo-engineering and geo-engineering research.

16. At this stage, further work is needed to identify what, if any, existing regulations can be used to regulate geo-engineering research. This issue will be considered by the Working Group.

January 2010

Memorandum submitted by Research Councils UK (RCUK) (GEO 10)

Introduction

1. Research Councils UK (RCUK) is a strategic partnership set up to champion the research supported by the seven UK Research Councils. RCUK was established in 2002 to enable the Councils to work together more eVectively to enhance the overall impact and eVectiveness of their research, training and innovation activities, contributing to the delivery of the Government's objectives for science and innovation. Further details are available at www.rcuk.ac.uk.

2. This evidence is submitted by RCUK on behalf of the Economic and Social Research Council (ESRC) and the Natural Environment Research Council (NERC) and represents their independent views. It does not include or necessarily reflect the views of the Department for Business, Innovation, and Skills.

3. The ESRC and the NERC have contributed to the main text of this response. NERC input was provided by Swindon OYce staV, the Plymouth Marine Laboratory, and the Oceans 2025 programme. In the preparation of this submission it has been agreed that beyond the potential funding of high quality research there are no conflicts of interest to declare.

Geoengineering and Regulation

4. While the term "geoengineering" is useful to collectively refer to methods of large-scale intervention in the global climate, it is worth noting that technologies fall into two distinct categories; those which remove CO_2 (or other GHG) from the atmosphere (Carbon Dioxide Removal techniques—CDR); and those that mediate the level of sunlight and heat that is absorbed by the Earth (Solar Radiation Management techniques—SRM). DiVerent techniques oVer diVerent opportunities, have diVerent eVects and carry diVerent risks which raise diVerent questions about the regulation of geoengineering.

5. Given the limited geoengineering research undertaken to date, the major social, environmental and technological uncertainties associated with its developmental infancy, and the specificity of the various techniques and technologies collectively referred to as geoengineering, it is not yet appropriate to outline a definitive framework for its regulation. Indeed, given the levels of uncertainty it is essential that all mechanisms established to regulate geoengineering are able to adapt to the evolving technological, environmental, and socio-political context within which they operate.

6. Public confidence is an essential step towards generating appropriate and eVective geoengineering regulation. Building knowledge amongst the public including regulators and law makers is conducive to establishing a genuinely participatory approach which must be sought if geoengineering is to be successfully applied.

7. To better understand public views and concerns, NERC is carrying out a public dialogue on geoengineering. This will assess public opinion and concerns, which will inform the direction, conduct and communication of future research in geoengineering. This activity, which is due to deliver by April 2010, is in partnership with Sciencewise, which supports public dialogue activities in government.

Is there a need for international regulation of geoengineering and geoengineering research and if so, what international regulatory mechanisms need to be developed?

8. Many, but not all, potential geoengineering schemes involve winners and losers both nationally and internationally. Given geoengineering will manipulate the climate at a global level, all global citizens should in principle be considered stakeholders in the development and implementation of geoengineering techniques and their regulation. Nevertheless, the expertise and tools required for the research and application of such techniques are likely to be within the direct control of relatively few while the positive and negative eVects of geoengineering will be unevenly distributed, both geographically and socially.

9. The need for explicit approval-based regulatory mechanisms for geoengineering primarily arise when the actions of one stakeholder have or could have consequences for others. Where such action is not well-covered by existing legal or regulatory arrangements an initial framework for joint decision-making by all parties is required. This should be used to establish that a net (global) advantage and equitable distribution of those advantages from the geoengineering intervention can be achieved prior to any interventions.

10. Careful consideration is required of who is involved and consulted during the development of geoengineering regulation in order that an equitable consensus can be reached. DiVerent countries and groups will have very diVerent assessments of the balance of risks of unchecked climate change and the application of geoengineering, as well as the morality of intentional manipulation of the climate system. Any geoengineering activity will therefore bring a variety of ethical, legal and social, political and economic questions into sharp focus.

11. Irrespective of the regulatory controls implemented, geoengineering will entail costs (direct and potentially indirect) as well as benefits. This raises significant research questions about ownership of, and responsibility for, both negative and positive eVects of geoengineering action which have an international impact. Approval-based mechanisms should, for example, include protocols for the assessment of fair compensation; should adverse impacts occur, who would meet the costs of such impacts—the country or countries carrying out the geoengineering, or the companies involved? In some cases it will be diYcult to attribute climatic impacts to particular acts of geoengineering and new, early-stage research on how this should be done is essential. Such research will have to address how to measure and attribute any changes and how to value their impacts including, for example, eVects on health, crops and economic well-being. This research will help inform judgements about impact and whether geographical areas or social groups merit compensation.

12. Geoengineering development involves several stages and regulatory frameworks must be flexible enough to cover the full cycle (eg from research through implementation through monitoring to evaluation). While knowledge of geoengineering techniques and the development of relevant technologies remain limited, interest is growing. It is therefore important at this stage that appropriate mechanisms for the regulation of research (as well as implementation) are established. Field-based research (such as method testing and small-scale trials) would for instance be expected to have much more limited impact than full-scale geoengineering interventions. Nevertheless, even small-scale actions could generate negative environmental, social and economic consequences if undertaken without appropriate controls in place or a suYcient level of expertise. For example, a field trial involving atmospheric SRM manipulations might temporally—but perhaps coincidentally—be linked to extreme weather events resulting in high economic consequences. Some highly controversial techniques could be applied at relatively low cost and with relative ease, opening up geoengineering as a feasible unilateral activity to a wide range of actors with diVerent knowledge, skills and motivations. Such actions may be linked to political as well as, or even instead of, environmental concerns. This suggests regulation might be best monitored at the level of supra-national governance structures such as the UN.

13. An example highlighting the potential issues arising from the regulation of research on geoengineering is provided by ocean fertilization. Large-scale ocean fertilization is not currently allowed under the Convention on Biological Diversity (CBD). Research is also restricted by the CBD, until a regulatory framework has been developed; this is in progress, via the London Convention and London Protocol (LC/LP). During 2009, the scientific basis for a framework to allow further research (via large-scale experiments outside territorial waters) was agreed, through discussions that involved a wide range of stakeholder interests. However, whilst representatives of the international scientific community were able to reach consensus relatively rapidly, eight diVerent legal options were developed, covering the range from "light touch" to much more complex and demanding approval arrangements. DiVerent legal options were favoured by diVerent countries; overall agreement is needed for LC/LP decisions; and there is no early prospect for resolution of this issue to be reached. Thus it could be some time before a regulatory outcome is obtained and, once produced, it will apply only to research, not geoengineering per se.

14. In terms of research and the implementation of geoengineering techniques, the development of new national and international regulation mechanisms, and the feasibility of doing so, is highly dependent on the technique under consideration. This is shown in Table 1, Annex 1, grouping the need for new regulation as high, medium or low for 13 techniques considered by the recent Royal Society report.[3] This broadly shows that SRM techniques currently lack regulatory control, in comparison to techniques involving CDR. However, a more fundamental grouping relates to the diVerent environments—space, atmosphere, ocean and land—in which the techniques are deployed, a function of the diVerent jurisdictions applicable to diVerent resource ownership arrangements.

15. The situation is most straightforward for land-based activities, since although there is potential for regional eVects any adverse impacts are more likely to be experienced by the country carrying out the action. For the lower atmosphere above nationally-owned land and for territorial waters, any adverse impacts of geoengineering may be predominantly local and "self-inflicted"; for the upper atmosphere and open ocean,

[3] Royal Society (2009) Geoengineering the climate: science, governance and uncertainty. RS Policy Document 10/09;

much larger adverse impacts are possible, potentially on a global scale (indeed, for geoengineering global-scale impacts are the intended outcome). The ocean has, however, been recognised by most countries as a global good requiring international stewardship, with three legal instruments for potential regulation of geoengineering in non-territorial waters: the UN Convention on Law of the Sea (UNCLOS), LC/LP; and the CBD.

16. In the future, assuming geoengineering occurs, its implementation and monitoring are also likely to require a verification-based form of regulation. These stages are also potentially problematic. Assuming that geoengineering techniques are formally recognised as contributing to climate change mitigation (ie as part of national commitments to international climate change agreements), such techniques will need linking to emission trading schemes or other mechanisms that may evolve. Such regulation is essentially international standard-setting, to verify that the amount of carbon dioxide (or other greenhouse gas) removed from the atmosphere, or cooling achieved by other means, is as claimed. This also raises the broader point that the development of geoengineering techniques should only be considered as complementary to other methods of climate change mitigation and adaptation, and that the regulation of geoengineering should therefore ensure that the aims of such methods are not compromised.

17. As noted above, it is essential that mechanisms for the regulation of geoengineering are imbued with a high level of flexibility. This will be necessary for a variety of reasons. First, regulatory controls will need to adapt to the evolution of environmental, scientific, technological, geo-political, economic and social risks. Major uncertainties remain about geoengineering and it is impossible to foresee how technologies will develop, their public confidence, and the measures that will be needed to shape and respond to such developments. In addition, environmental, geo-political, economic and social factors that will influence the development of geoengineering are also in a constant state of flux and must therefore be accounted for through flexible regulatory arrangements. For example, the low likelihood of being able to create and maintain the decadal-to-century political stability that will be required to manage some geoengineering projects on a global scale would need to be guarded against through suYcient flexibility of regulatory mechanisms. Research is required to both establish the extent to which such instability has been successfully incorporated into other regulatory frameworks and the degree of instability that might reasonably be expected to occur in the geoengineering domain.

18. The potential eVects of geoengineering activity are transboundary in nature. Mechanisms must be flexible enough to regulate activity carried out in a wide range of locations and by a variety of people operating under diVerent legislative, social and cultural environments. As a channel through which to trade in the carbon market, the private sector may become an important force in the development of geoengineering in some regions. It will therefore be vital that businesses are subject to the same stringent controls that are applied to other bodies.

19. It will be paramount that regulatory measures are able to respond rapidly, if necessary, following the application of geoengineering techniques. A key criterion for geoengineering to be taken forward is the ability for applications to be withdrawn quickly in case of negative consequences (where this action in itself does not entail further negative impact). Rapid agreement on such decisions will be challenging for many international bodies. A mechanism by which consensus could quickly be reached, and action taken without unilateral counter-action in response, would need to be incorporated into regulatory measures. Research can help inform policy makers about the sort of mechanisms and regulatory frameworks that have been able to successfully respond in such rapid ways.

How should international regulations be developed collaboratively?

20. The international mechanisms currently most applicable to the regulation of geoengineering activity have not been developed for this purpose. However, through modification and expansion, existing international governance mechanisms should be used as much as possible, subject to rigorous evaluation of their fit for purpose. IPCC could, for example, provide a framework to establish whether there is suYcient scientific justification for research on diVerent techniques and, if so, where eVort ought to be focussed. The international global change programmes, co-sponsored by International Council for Science (ICSU), (International Geosphere-Biosphere Programme (IGBP); World Climate Research Programme (WCRP); International Human Dimensions Programme on Global Environmental Change (IHDP) and Diversitas; grouped under the Earth System Science Partnership, (ESSP)) also have a role in coordinating relevant research and providing independent international assessments which could be adapted for the purposes of geoengineering research.

21. At the later stages of development, implementation and monitoring, it is unclear whether the regulatory measures and controls needed for geoengineering may be adequately incorporated into existing international, regional, and national regulatory structures and bodies. The Environmental Modification Convention (passed by the UN in 1977) banned the use of weather modification for hostile use and, on a broad conceptual level, therefore oVers one channel through which new regulatory mechanisms may be enforced. Given the fundamental aim of geoengineering, the United Nations Framework Convention on Climate Change (UNFCCC) would also need to inform its development. Research of how these legislative frameworks should be amended would be valuable.

22. More specifically, the regulation of particular geoengineering techniques may logically fit into the remits of other international treaties and bodies. Ocean fertilisation for instance has direct relevance to the UNCLOS while the implementation of "space mirrors" may be monitored through the United Nations Outer Space Treaty. It has been suggested that the only major geoengineering technique being discussed that could not be managed within existing regulatory structures is the application of stratospheric aerosols.

23. Polar regions are likely to be at the forefront of future geoengineering debate, because of climatic feedback risks (relating to albedo change and methane emissions) and socio-economic risks (sea level rise due to ice-sheet loss). If SRM geoengineering could (mostly) be confined to these regions, its negative impacts with regard to crop production, natural productivity, economic development and social well being would be minimised. The Antarctic is, however, strongly protected through the Antarctic Treaty System, including the Protocol on Environmental Protection to the Antarctic Treaty (Antarctic-Environment Protocol), whilst any geoengineering activities in the Arctic would be highly politically-sensitive, particularly in the context of recent new claims to undersea resources and the claims of indigenous peoples.

24. The cost, eVectiveness, timeliness and risk of putative geoengineering approaches vary substantially. It is therefore important that international collaboration is sought at an early stage. An international geoengineering advisory group may well be an appropriate body to help address these challenges. With representation from the scientific, policy, commercial, regulatory and non-governmental communities, such a group would provide independent oversight of evolving regulatory issues concerning geoengineering. It would be tasked with the coordination of existing research, and the identification of a new research agenda, as well as the development of an eVective and objective assessment framework to inform the regulation of geoengineering. This would involve making informed judgements about the weight of diVerent environmental, social and economic costs and benefits and striking an appropriate balance between short-term and long-term eVects.

What UK regulatory mechanisms apply to geoengineering and geoengineering research and what changes will need to be made for the purpose of regulating geoengineering?

25. UK-based terrestrial and atmospheric geoengineering and geoengineering research could be covered by existing national and regional planning and pollution control regulation, and, in part, by research institutes, funders and professional bodies, as well as civil society more generally. However, it is recommended that an early stage testing of these assumptions is undertaken by independent experts with a brief to address public engagement. Marine activities within the UK Exclusive Economic Zone should be covered by the newly-formed Marine Management Organisation (created under the 2009 Marine Act) and the equivalent body for Scotland Marine activities outside UK waters are primarily covered by LC/LP, with Defra as the national regulatory department.

Annex 1

Table 1. Preliminary assessment of the need for geoengineering regulation for specific techniques, based on those identified in 2009 Royal Society report. Convention on Biological Diversity (CBD); Carbon Capture and Storage (CCS); Carbon Dioxide Removal (CDR); London Convention/London Protocol (LC/LP); Solar Radiation Management (SRM); UN Convention to Combat Desertification (UNCCD); UN Convention on Law of the Sea (UNCLOS); UN Framework Convention on Climate Change (UNFCCC).

Technique	Environment	CDR or SRM	Existing regulatory framework, if any	Comment
1. HIGH need for international regulation				
1. 1 Cloud albedo enhancement (via ocean spray)	Lower atmosphere, upper ocean	SRM	?	Potential eVects on regional weather, ocean dynamics, marine productivity, food production, economic and social well being
1.2 Stratospheric aerosols	Upper atmosphere	SRM	Long-range Transboundary Air Pollution Convention? Antarctic-Environment Protocol?	Global scale eVects—but not direct reversal of CO_2 warming. Reduced insolation, crop and plant productivity, economic, social and cultural well being
1.3 Space-based methods	Space	SRM	Outer Space Treaty?	Global scale eVects—but not direct reversal of CO_2 warming. Reduced insolation, crop and plant productivity, economic, social and cultural well being

Technique	Environment	CDR or SRM	Existing regulatory framework, if any	Comment
2. MEDIUM need for international regulation				
2.1 Biomass burial in deep ocean	Land and ocean	CDR	LC/LP (potentially); UNCLOS; carbon trading	Land-grown crops/timber would be ballasted and sunk to deep ocean, could locally aVect food availability and price
2.2 Enhanced weathering—ocean	Land and ocean	CDR	LC/LP (potentially); UNCLOS; carbon trading	Land-mined silicate rocks added to ocean, or carbonates used instead —to derive $Ca(OH)_2$
2.3 Ocean fertilization	Ocean	CDR	LC/LP: regulation in prep for research (with CBD); also UNCLOS	Could be based on adding iron, other nutrients or enhanced mixing
2.4 Surface albedo—deserts	Land	SRM	UNCCD?	Might aVect regional weather, crop production, economic, social and cultural well being
3. LOW need for international regulation				
3.1 Land use management, aVorestation, reforestation & deforestation avoidance	Land	CDR	Carbon trading under UNFCCC	Not necessarily regarded as geoengineering
3.2 Bio-energy with carbon sequestration (BECS)	Land (ocean?)	CDR	Carbon trading; CCS regulation	Not necessarily regarded as geoengineering. (Ocean?) relates both to potential use of algae and sub seafloor CCS reservoirs
3.3 Biochar and terrestrial biomass burial	Land	CDR	Carbon trading	
3.4 Enhanced weathering—terrestrial	Land	CDR	Carbon trading	Land-mined silicate rocks added to soil
3.5 Carbon dioxide capture from ambient air	Land , lower atmosphere (ocean)	CDR	Carbon trading; CCS regulation	(Ocean) relates to CCS components
3.6 Surface albedo—human settlement	Land	SRM		Limited eVectiveness on global scale

Whilst climate system modelling provides a "safe" means of investigating the eVectiveness of diVerent engineering approaches, it does not necessarily include all interactions and eVects that will occur in the real world. Further investment in modelling techniques will enhance the accuracy of the models; however, large-scale field testing will be an inevitable intermediate step for any geoengineering techniques considered worthy of serious attention. Because of natural variability in weather/climate and biogeochemical processes, multiple studies are likely to be needed for adequate replication to achieve unambiguous eVects. For some methods, large-scale field testing is likely to be an extremely fraught and controversial step; research on the potential social, economic and cultural eVects, as well as how to mitigate these in advance of implementation, is essential.

December 2009

Witnesses: Joan Ruddock MP, Minister of State, Department of Energy and Climate Change, Professor David MacKay, Chief Scientific Adviser to the Department of Energy and Climate Change, and professor of natural philosophy in the department of Physics at the University of Cambridge, and Professor Nick Pidgeon, on behalf of RCUK, gave evidence.

Chairman: We welcome our third panel in what has been a pretty hectic morning, looking at geoengineering and the regulation of. We warmly welcome Joan Ruddock MP, the Minister of State for the Department of Energy and Climate Change. We seem to be seeing a lot of each other at the moment, Joan, we are both working on the Energy Bill. A warm welcome to Professor David MacKay, the Chief Scientific Adviser at the Department for Energy and Climate Change, we have not met you formally before, but you are very welcome to our Committee, Professor MacKay. And last but by no means least, representing RCUK, Research Councils UK, Professor Nick Pidgeon. Welcome to you all. We are very tight for time, we are finishing at 11.25, so if we could keep our answers really quite tight, we would be very grateful.

Q51 Graham Stringer: What sort of urgency does the Government give to research into geoengineering? I suppose, so that we are all talking about the same thing, it might be useful to have the Government's definition of what they understand to be geoengineering.
Joan Ruddock: Thank you for the question. Can I first of all apologise to the Committee for the fact that I understand for some completely unknown reason, you failed to receive, and it is undoubtedly our fault, we did not succeed in delivering to you our written evidence. I understand you now have it, but obviously you would have appreciated it much sooner, and I apologise for that. I will answer your question on urgency, and then I will ask David if he would like to define the geoengineering which he knows that we understand, just in case I fail to be precise in the technical terms. Is there an urgency in this matter? Our view is there is not. We do not think that at the moment, it is a priority for Government. The techniques that are involved are ones which are far from being developed to the point of viability at the moment. That is quite diVerent from saying one should not keep a watching brief, but we do not think there is an urgency in terms of this particular dimension to addressing climate change. What we do believe is utterly urgent is to continue on the route which this Government has followed so keenly of reducing greenhouse gas emissions in this country, of legislating to that eVect, and of participating in the international discussions about trying to arrive at a global deal, which goes beyond the Copenhagen accord that we have just struck, so that we can ensure that the world eVort is designed to keep us within no more than a two degree Celsius temperature rise. That is the priority of these times, and that is where the Government is on that matter.

Q52 Chairman: That is clear. Definition?
Professor MacKay: I think in DECC, we recognise the same categories that the Royal Society use in their report, we recognise the important distinction between carbon dioxide removal and solar radiation management. I think we would include in geoengineering some forms of activity that I think would be viewed as innocuous and legal, such as someone growing trees and putting them into a disused coalmine, that activity would be essentially the reverse of our current coalmining activity, and I think we would include that as an example of small scale geoengineering activity. We would also include, I think, the growing of biomass for co-firing in a power station that has carbon capture in storage, we would include that as another example of a geoengineering option that again I think would not be viewed as politically unacceptable.

Q53 Graham Stringer: Let me be clear, so that I understand you are both saying the same thing, I understand what Joan is saying, that you want to concentrate on reducing carbon dioxide, but does not the Government's energy policy and the security of supply depend on developing carbon capture technology, as Ed Miliband said? If I understand what you are saying, Professor MacKay, carbon capture is understood to be geoengineering but it is not getting urgent treatment?
Professor MacKay: Yes, I am sorry to have—

Q54 Graham Stringer: That is what I really want to understand.
Professor MacKay: I am sorry to have complicated things. Clearly we do have a policy of developing coal power stations with carbon capture and storage. If those power stations were used to co-fire biomass, then that would cause carbon dioxide reduction, so I was just wanting to give a complete answer. There are some forms of geoengineering that clearly are possible and also are perhaps not controversial—

Q55 Graham Stringer: So what you are really talking about that you are not putting research into is solar radiation management; is that too simplistic an understanding?
Professor MacKay: I think the Minister's answer was yes, the more controversial forms of geoengineering, especially the forms of geoengineering that would have cross-boundary impacts, are not a research priority. We do think they are important concepts that we would like to understand better, and we are happy to see the EPSRC, for example, investing in research into these options, but it is not an urgent priority to have research into these boundary crossing methods, which would include solar radiation management, and also some other forms of geoengineering that do carbon dioxide removal, for example, using the oceans; again, those would have cross-boundary impacts. We view these, as Professor King said earlier, as interesting options to keep on the table, but they are very much options of last resort, and they are not an urgent research priority right now.
Joan Ruddock: Can I just for the record, Mr Willis, make it very, very clear that whereas, and perhaps I was foolish to ask our Chief Scientific Adviser to give the definition, because in its broadest sense, it does include things that are already part of the

Government programme. So in its broadest sense, yes, carbon capture and storage, where it is considered to be geoengineering, is part of the programme, and is a matter of considerable urgency, and we are applying ourselves to that, not least in the Energy Bill, which is currently going through Parliament. So there is a distinction which I think we need to be very clear about. The areas that we are not pursuing except in a small way, which I am happy to explain to you if you want that detail, are those of carbon dioxide removal of the kind that is—

Q56 Graham Stringer: I just wanted to be clear we were talking about the same things really. Just going back to your original answer, Joan, which I understand, are you not open to the charge of being complacent? Copenhagen, to put it mildly, was not a success, there is no guarantee that the international community will reduce the amount of carbon dioxide in the atmosphere. Do you not think we should be doing research for a Plan B, if the international community fails, as it patently did in Copenhagen?
Joan Ruddock: First of all, I do not agree the international community failed in Copenhagen. We did not succeed in getting certain things, we did not get as great reductions as we sought to get, and we did not get a timetable to move towards a legally binding treaty. But we have got, for the first time ever, agreement between developed and developing countries that they will make changes in their emission reductions; those are to be codified, they are going to be delivered by the end of this month, and we have got the agreement that we need the world community to stay within the two degree centigrade rise that all our activities in reduction should be aimed to keep us within that framework, and to avoid dangerous climate change. So I do not agree it was a failure, it is a good start, in my view, and it has got to be built upon, and I think the danger of adopting a Plan B, if that were even feasible, which I would question, but the danger in adopting a Plan B is that you do not apply yourself to Plan A, and the point of Plan A is it is all entirely do-able. We know how to do these things. Every country in the world knows how to reduce greenhouse gas emissions. With a financing mechanism, it is possible to help the developing countries that cannot otherwise aVord it. If the argument is that we failed to make an international agreement of the best substance on this occasion, then how much more diYcult might it be to create a regulatory framework for geoengineering which has greater implications for the whole world, in terms of possible risks and environmental damage and concern? So if one is diYcult, then I would suggest the other might be more diYcult, and that is why the priority must be to enhance and move further beyond what we have with the Copenhagen accord.

Q57 Graham Stringer: I understand the priority, and I understand the arguments. I do not agree with you about Copenhagen, I think it was a fiasco and a failure, but we can disagree about that. Is not the danger with the policy that it is all the Government's eggs or all our eggs in one basket, and if that does fail, then there is not a Plan B? Should not the Government be at least considering in a theoretical sense what choices it would make within the sort of range of geoengineering possibilities, that if things go wrong, and there has to be a diVerent approach, should not the Government be considering that?
Joan Ruddock: Well, it is not to say that the Government should not consider, it is a question of urgency, which is the question I was asked.

Q58 Graham Stringer: Well, if it has considered, has it made a choice then?
Joan Ruddock: I said it is clearly not in our view a matter of urgency, it is clear that we have other and much greater priorities which we need to apply ourselves to very vigorously, and we will. So what I am suggesting is that we look to more of a watching brief, and that we do things at a de minimis level. I think that very much accords, as I understand it, with what the Royal Society is suggesting, and I think they are a very good barometer in these matters. So, for example, we do have some small expenditure on modelling techniques, for example, and if the Committee has time, Mr Willis, I can just say what research is being undertaken with Government money.

Q59 Chairman: I think that is in your note to us, is it not?
Joan Ruddock: It is.
Chairman: No, we will leave that on the record.

Q60 Graham Stringer: Just within that spectrum, have the Government made any choices? Does it have any priorities of which way it would want to go if Plan B was necessary?
Joan Ruddock: I think it would be entirely premature, because we are dealing with techniques here which are not proven techniques, which have great risks, which do not have a regulatory framework, and frankly, at the moment, it would be, I think, quite ridiculous for Government to be making any choices. But in terms of the major areas where there is interest, injecting sulphate aerosols into the stratosphere, for example, there is some current work which has Government funding; there has been work on low level cloud development, which again has some Government funding; and there has been another study on the impact of oceanic iron fertilisation on cloud formation. So on some of these areas, which are the ones that are particularly being put forward by those who advocate these kind of solutions as a Plan B, there is what I would call a watching brief taking place, and some small amount of Government funding, and as you continue to question, I can indicate further what the Government is interested in doing.

Q61 Chairman: I think just before we leave this particular angle, you have made it clear that you do not want to spend a great deal of money in terms of putting money into research.
Joan Ruddock: Correct.
Chairman: We will come on to RCUK in a second to look at some of the work that is going on there, but surely, Minister, you have an interest in supporting

international regulation, because if somebody in the United States or China or Indonesia actually goes heavily into geoengineering in terms of large scale experiments, that may well aVect not only neighbouring countries but, of course, work in the oceans, for instance, could significantly impact ultimately on our ecosystem as well. So what are we doing in terms of that global regulation?

Q62 Dr Iddon: Could I just add a rider to that, Chairman? Sir David King in the previous panel actually suggested that we ban temporarily solar radiation management techniques, because once you put trillions of mirrors in the sky, for example, they are irretrievable. Do you have an opinion on that as well, Joan?
Joan Ruddock: I do indeed. I mean, I think first of all we need to look at what might be being done within any particular research group, and the extent to which we seek to put any legal constraints on that. When it is a case of theoretical work, when it is modelling work, obviously Government does not seek to put any restraint on that. I think the Royal Society has suggested there should be a code of conduct; for research at a certain level, a code of conduct is probably entirely appropriate, and we would very much support that. But as you have just indicated, Mr Willis, and I did not hear Sir David King, but I can imagine why he would have said what he said, there are very, very clear implications for every country in the world, if any individual country were to start on a course of interfering with our atmosphere to that sort of degree. So it is absolutely the case that we need to develop an international regulation that comes before any deployment. Now there is an in between stage, which would be infield experimentation, and we may need to be thinking about that, and what implications that might have—

Q63 Chairman: I think my question is: have you done anything in terms of discussions with international partners about the possible regulation of geoengineering? I am not talking about domestic geoengineering, which from this Committee's point of view would not be regarded as geoengineering, but have you had any discussions, I mean, yes or no?
Joan Ruddock: There are continuing discussions obviously between people in the department and people who are engaged in this work. What we have been considering is setting up within the department a working group that would actually study this issue. Now we are considering that positively, but we are also very aware of the position of the Royal Society, and we will, I think, need to work closely with them, because they are also setting up a series of working groups, and so (a) we do not want to duplicate, (b) there is undoubtedly more expertise, not to embarrass our Chief Scientific Adviser, but more expertise in the whole of the Royal Society than we could possibly have within DECC itself. So we are considering this matter, we are aware that this is work that needs to be done, but we want to proceed in the most useful way, and that is why we are continuing to have discussions with the Royal Society. I do not know if David might want to add something to that?
Chairman: Can I just bring in Tim Boswell?

Q64 Mr Boswell: I am grateful, Minister, not least because I fear I have to go in a moment, but may I just pick you up on what you have said? I understand why in a sense you are devolving the scientific burden to the Royal Society, but in terms of, as it were, the ministerial clout, you need to be introducing some of your counterpart ministers, either in the EU or climate change fora or whatever, to the importance of this. Is this something that you are doing as a department as well as, as it were, the professional scientific network?
Joan Ruddock: I personally cannot recall any ministerial involvement in discussions, and I do not believe our Secretary of State either has been holding such discussions. So I think at this stage, it is unlikely that we have had any ministerial discussions on regulation, but we are aware, our oYcials are alive to the issue, and it is something that we know needs to be done. Of course, the IPCC is going to be reporting itself, and we have taken a lot of our leads from reports from the IPCC. It is clear that if there is to be regulation, it is going to have to be in some international body, whether a scientific body, or whether the UN itself, but clearly, this is something that will have to be developed over time.
Chairman: You have made that clear. You have mentioned the Royal Society, and I know Ian Cawsey wishes to pick that up.

Q65 Mr Cawsey: It is quite interesting that an awful lot of what has been said so far is about the Government almost holding a watching brief on this, and waiting to see what the developments are. I just wonder to what extent that is enough, certainly in terms of public opinion, because it strikes me that if you look at quite recent things, GM crops being one, even climate change really, there is quite a significant dislocation between where public opinion is and where scientific opinion is. I can see geoengineering ever so easily fitting into that category yet again. The Royal Society did say in their recent report on it that the acceptability of geoengineering will be determined as much by social, legal and political issues as by scientific and technical factors. Do you agree with that assessment, and if you do, what will the Government do to encourage debate on the social acceptability of geoengineering?
Joan Ruddock: Well, I do not think it is for the Government to encourage a debate on the social acceptability of geoengineering, because that presumes that the Government has taken a view that geoengineering is a good thing, and that we should actually deploy. We have not taken that view. I think that it is important to involve the public in discussions as these things develop. It is important not to allow the public to get into a position where the public has been alarmed or is ignorant, so it is very important that the dialogue includes public communication. It is one of the considerations that we make about setting up a working group; should

we do so, then indeed we would want to see that it contained a wide spectrum of people, including social scientists, ethicists, as well as scientists and administrators. So we are alive to the fact that there would need to be public engagement, and we know that NERC have a public dialogue programme that they are about to launch. So it is important to talk with the public and to avoid ignorance and prejudice, but at the same time, it is not for the Government to persuade the public of the need for this.
Professor Pidgeon: From the RCUK perspective, I will just make one comment about research: obviously, as you know, a small amount of money following the Royal Society report will be going into fundamental research on top of the research that is currently being done, and also the public dialogue has been initiated. The latter will be a first, really, anywhere in the world. For the UK to do that, that is fine, but we might also want to think more widely about public dialogue, because this is an international question, so the poor and people in other countries will have an interest in the outcome of geoengineering research. But the point about research I would like to make is that although it is not urgent, the science and the social and ethical research should come together at an early stage. Very often, those of us who study public acceptance of technology, nuclear power is a good example of this, social scientists were only asked 20 years after nuclear had become extremely unpopular to actually look at why this might have occurred. I think we have learnt that lesson, so RCUK and ESRC in particular are very keen that as research progresses on the science, research on the ethical, legal, economic and public acceptability issues also takes place as well.

Q66 Mr Cawsey: In the first session we had this morning, where we had people from diVerent countries via videolink participating, I think they all came to the conclusion that whilst the NERC was going oV and doing this consultation here, it was actually much more important that there were international talks going on and protocols and things being established there, so what is the Government doing to try and encourage that to happen? If we do continue with this public consultation through the NERC, how can we diminish criticism that actually, this is what we always do, we always consult the public, and then actually it has no eVect on the policies at the end of the day anyway?
Joan Ruddock: I think if I may say so, Mr Cawsey, your questioning is still in my view premature, we are not at that point. The Committee clearly may like to comment on this, but our first decision is as to whether we set up a separate working group within Government to look at all of these issues, or whether we work with the Royal Society to look at all of these issues. We are going to do something, it is not that we are doing nothing, we just want to see the lie of the land, and make our decisions as to how we progress, but whatever progression is undertaken, as Professor Pidgeon has said, it will quite rightly engage social scientists and others alongside scientists.

Q67 Mr Cawsey: I can understand why the Government would take that view, and I do not necessarily disagree with it, for what it is worth, but it is not necessarily premature to take a decision that this would be better dealt with internationally rather than nationally, is it?
Joan Ruddock: I think it is going to be for the working group to—whether with us or jointly, or however it is done, we need a basis on which people have the opportunity to do some work, to do some thinking, and to come up with some proposals, because it is not possible for a government to just leap into an international negotiation. We have to develop our own thinking, we have to decide what it is we think is appropriate to put forward in an international forum, and we have to decide which international forum it would be appropriate to attempt to engage with. So at the moment, none of these things have been worked through, and that is why I cannot say to you, we are just going to rush oV to the UN or wherever and say, let us all start this debate. Clearly, the initiative might come from others, but we have to get our own framework sorted out as to what we think is appropriate, and that is work that has not yet been done.

Q68 Chairman: Can I bring in Professor Pidgeon here? I am really quite confused about RCUK's position, and certainly the evidence that you have given us. There is an international convention on biological diversity, which deals with issues surrounding the oceans, and yet in your evidence to us, you are suggesting that any sort of regulatory framework is premature, and yet there is a regulatory framework in existence, which presumably the UK participates in developing.
Professor Pidgeon: I should add, I am not a lawyer myself, so I cannot comment in detail on the law.

Q69 Chairman: I am not either, so we are on common ground.
Professor Pidgeon: My reading of the evidence, which I had some input to, but obviously not all of it, is that RCUK are saying, as many have said today, that we have a heterogeneous field here that we call geoengineering, so many, many techniques, and it is likely that some techniques and deployments, if they were to come about, will fall under existing regulation, and others will fall between aspects of regulation. For others, there may be nothing at all. Again, that is why we need the analytic work now, to look at what regulation applies. To take another example, with nanotechnology five years ago, we were in a very similar situation, and DEFRA sponsored a gaps analysis to look at what areas of regulation would apply to certain nanomaterials, and that has been very valuable for them, to look at where the gaps are, so I think that is—

Q70 Chairman: Sorry, is RCUK doing that?
Professor Pidgeon: Not at this point in time.

Q71 Chairman: Because the Government is not doing it, the Minister has just said the Government is not, and you are not as the Chief Scientist.
Professor Pidgeon: But we are at what could be said an upstream moment, that is the way it is described, in the emergence of a new technology.

Q72 Chairman: What does an upstream moment mean?
Professor Pidgeon: So early that the uncertainties are wide. Compare it to nuclear energy, which is a mature technology, we know what it is, people have views on it. In the upstream moment, we do not even know how it will develop, and what public responses there will be. There is very low public knowledge, which is a big challenge for public engagement, and great uncertainties. So we are in a phase which is very uncertain and diYcult to give definitive answers on the technology, governance frameworks and public attitudes. It is not that people are not trying to give answers, it is just very, very early.

Q73 Chairman: I will leave the last word with you, Minister, because we are about to close: I think what we are trying to get is that the UK is arguably, well, I would say definitely the world's second scientific nation, second to the United States. We have a position of real leadership in here. We are a nation surrounded by oceans, and we have given, I think with respect to our Government, a real lead in terms of climate science, and yet here is an area where clearly it is a long way oV, we are not even prepared to seriously lead the debate in terms of a regulatory framework. Do you not find that disappointing?
Joan Ruddock: No, because as I have indicated at the outset of this evidence session, we have real priorities which we are working on. We have within every part of Government people all of whom are engaged in moving us to a low carbon economy, and making the emissions cuts that we have committed to in law. Now that is a way forward to deal with climate change. It is a proven way forward, and we need to do as much of that as we can, and we need to work as intensively as we can in the international community to ensure that as much of that as possible happens. So there is no question about the leadership continuing in this Government and in this country, and you are absolutely right about the climate science. But what I have made clear is not that we are unaware, and totally neglectful of this area of endeavour, it is that we have not prioritised it, and it is that we are on the point of making some decisions about how we as a government should move forward. So we are aware of what is required, it will be undoubtedly some international regulation, that we need to have that in place before there is any question of deployment, but we think deployment is rather a long way oV, and therefore, we do have time, and we should not be panicked into this, we know what we are doing, we understand the issues, we will look to international regulation in due course, we will play our part in that, and as I indicated to this Committee, and the Committee may like to comment on it, we either set up a working group within Government, or we work with those who have clearly led this field to date, and that is the Royal Society. That is the point at which we are at, and we will be active.
Chairman: Minister, thank you very, very much indeed for your presence this morning. Thank you, Professor David MacKay and Professor Nick Pidgeon.

Supplementary memorandum submitted by the Department of Energy and Climate Change (DECC) (GEO 13A)

(Letter to the Science and Technology Committee)

Thank you for giving me the opportunity to examine the transcript of the oral evidence session of your enquiry onto the regulation of geo-engineering last month at which Professor David MacKay and I gave evidence. We have no corrections to make to the transcript but I hope you will permit me to provide some clarification on a couple of points raised during the session.

We were asked for the Government definition of geo-engineering. The Royal Society broadly defines geo-engineering as the "deliberate large-scale intervention in the climate system" and I would like to make clear that the Government agrees with this, recognising that this encompasses both carbon dioxide removal and solar radiation management techniques and the distinction made between the two categories.

With regard to the question of carbon capture and Government priorities, we do not consider conventional carbon capture and storage (CCS) coupled to coal-fired plants to be a form of geo-engineering as the carbon dioxide is captured at source and does not enter the climate system. CCS when coupled with bio-energy plants, however, is included in our broad definition of geo-engineering. In this case, carbon dioxide is removed directly from the atmosphere by biomass which is then harvested for use as fuel. Use of coal CCS technology is a Government priority in our transition to a low carbon economy.

I hope this clarifies our position and I await the outcome of your enquiry with interest.

Joan Ruddock

February 2010

Memorandum submitted by Dr James Lee (GEO 01)

1. Summary of Main Points

Cloud seeding is a geo-engineering tool that is widely used by more than 30 countries. With climate change, fresh water resources will be in decline in many parts of the world, particularly around the equator. One result may be an increase in the use of cloud seeding. As cloud seeding becomes more eVective and widely disseminated, it may be a factor in conflict situations or a reason to precipitate conflict. Disputes over cloud seeding could fall under the Environmental Modification Treaty.

2. Brief Introduction about Me

I currently hold administrative and faculty positions at American University. Prior to that, I have worked at the U.S. Trade Representative and U.S. Environmental Protection Agency.

3. Factual Information

Most recently, I am the author of Climate Change and Armed Conflict (Routledge, 2009), "Global Warming Is Just the Tip of the Iceberg", Washington Post, 4 January 2009, and "A Brief History of Climate Change and Conflict", Bulletin of the Atomic Scientists, 14 August 2009. I also run the website, Inventory of Conflict and Environment. http://www1.american.edu/ted/ICE/index.html

4. Recommendations

There needs to be a better understanding of the modes for cloud seeding and its impacts. A beginning point would be a multilateral registry of cloud seeding events with information and data collection on key characteristics.

1. Climate Change and Cloud Seeding

Countries will take measures to counteract and adapt to climate change, namely trends of declining precipitation and increasing temperature. There will be a great temptation and need to use cloud seeding, the oldest and most common form of environmental modification (a type of geo-engineering). Cloud seeding is an issue regarding fresh water resources, rights, and obligations. As with other water issues, cloud seeding can be a source of dispute. Climate change will cause diVering regional impacts and thus a variety of motivations for cloud seeding.

It is important to distinguish between climate change and weather, since cloud seeding is more likely to aVect the latter. Weather is a state of the atmosphere over the short-term and more likely at specific points and places. Climate is a long-term phenomenon expressed as average weather patterns over a long period. Cloud seeding could aVect climate when carried out over a long period. Key measures of weather and climate are precipitation and temperature.

The line between hostile and peaceful uses of cloud seeding (and environmental modification in general) is extremely thin and at times ambiguous. One country in the midst of a severe humanitarian emergency may perceive cloud seeding as a benevolent act. A neighbour country, encountering the same drought and humanitarian crisis, may perceive their lack of rain as being "stolen" by their neighbour. The key word here is "hostile", which of course is in the eye of the beholder.

2. The Environmental Modification (ENMOD) Treaty

During the Cold War, the United States and the Soviet Union explored diVering Weapons of Mass Destruction (WMD) that included the use of nuclear, biological, and chemical devices. In 1945, the mathematician John von Neumann met with other U.S. scientists to discuss the possibility of deliberately modifying weather (a new WMD) as a tool of war (von Neumann, 1955). Weather modification was one way to destroy Soviet agricultural harvests, cause mass starvation, harm their economy, and incite internal dissension. The goal was to make the Cold War very cold.

There was widespread use of geo-engineering during the Vietnam War. Between 1967 and 1972, the United States ran Operation Popeye, a cloud seeding operation to disrupt transport of military supplies along the Ho Chi Minh trail and aimed at parts of South and North Vietnam, Laos and Cambodia. The operation occurred during the dry season when it was ordinarily easiest for the North Vietnamese to move men and materials south. While the program was successful in causing heavy rains out of season, it was not successful in stopping the flow of men and materials southward. Heavy rains attributed to the cloud seeding program led to catastrophic floods in 1971 that caused a poor harvest in North Vietnam.

The disclosure of Operation Popeye led many to realize that such a tactic took the idea of "all-out war" to a new level, and one that was disturbing. As a result, in 1977 countries agreed to the "Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques" (ENMOD). The treaty forbids the use of environment in hostile circumstances and supports the use of weather modification for peaceful purposes. Climate change is but one of a number of environmental phenomena covered by this treaty.

Earthquakes, tsunamis; an upset in the ecological balance of a region; changes in weather patterns (clouds, precipitation, cyclones of various types and tornadic storms); changes in climate patterns; changes in ocean currents; changes in the state of the ozone layer; and changes in the state of the ionosphere.

(Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques 1978)

A re-confirmation of the ENMOD principles occurred at the Framework Convention on Climate Change (UNFCCC) and the 1992 Earth Summit in Rio de Janeiro. The statement suggests far-reaching implications in the jurisdiction of a nation's sovereign area.

> "States have… in accordance with the Charter of the United Nations and the principles of international law, the (…) responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction." (UNFCC, 1992)

Most techniques covered by the ENMOD treaty are quite speculative. Causing earthquakes or tsunamis is far beyond the capacity of current technology. Cloud seeding, on the other hand, is a technology that is often used.

No country has invoked ENMOD, but cases have been possible candidates. During the 1991 Gulf War Iraqi forces burned oil wells on a large scale, placing huge amounts of particulates in the air that may have aVected weather patterns in neighbor countries. Iraq also polluted the Persian Gulf with oil that did cause environmental damage to other states, upset the ecological balance in a region, and led the mass sea life destruction.

3. A Brief History of Cloud Seeding

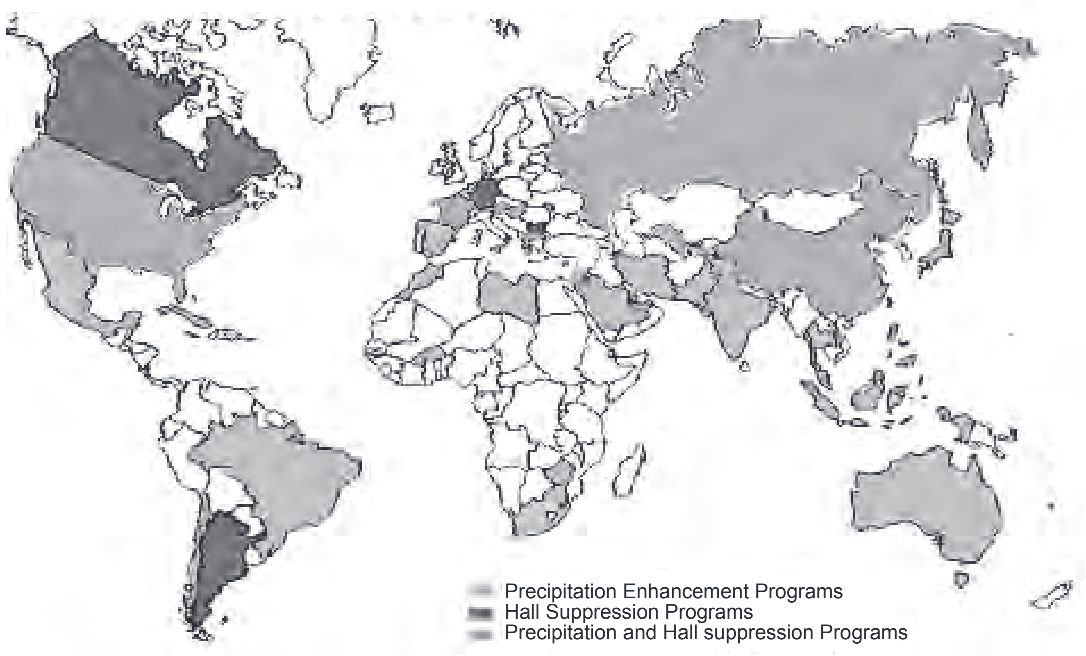
Cloud seeding is one of several rainmaking techniques. The first scientific demonstration of cloud seeding occurred in 1946 in the United States. The use of cloud seeding has substantially grown over the last half century.

There is nonetheless controversy over the eYcacy of cloud seeding. While many countries report successes, the U.S. National Academy of Science, National Research Council, published a study in 2003 that questioned the utility of cloud seeding and the extent of impacts outside of local areas. The report called for greater research into practices for understanding and improving cloud seeding eVectiveness. The reality is that many countries practice cloud seeding and believe it works. Regardless of the scientific debate, the perception of the viability of cloud seeding can lead to dispute.

Cloud seeding causes precipitation by introducing substances into cumulus clouds that cause condensation. Most seeding uses silver iodide, but dry ice (solid carbon dioxide), propane, and salt are also used. At least 30 countries have identified programs and some, like China and the United States, have extensive programs (See Figure 1). Most countries that practice cloud seeding are parties to the ENMOD treaty, but China is not.

Figure 1

Weather Modification Around the World

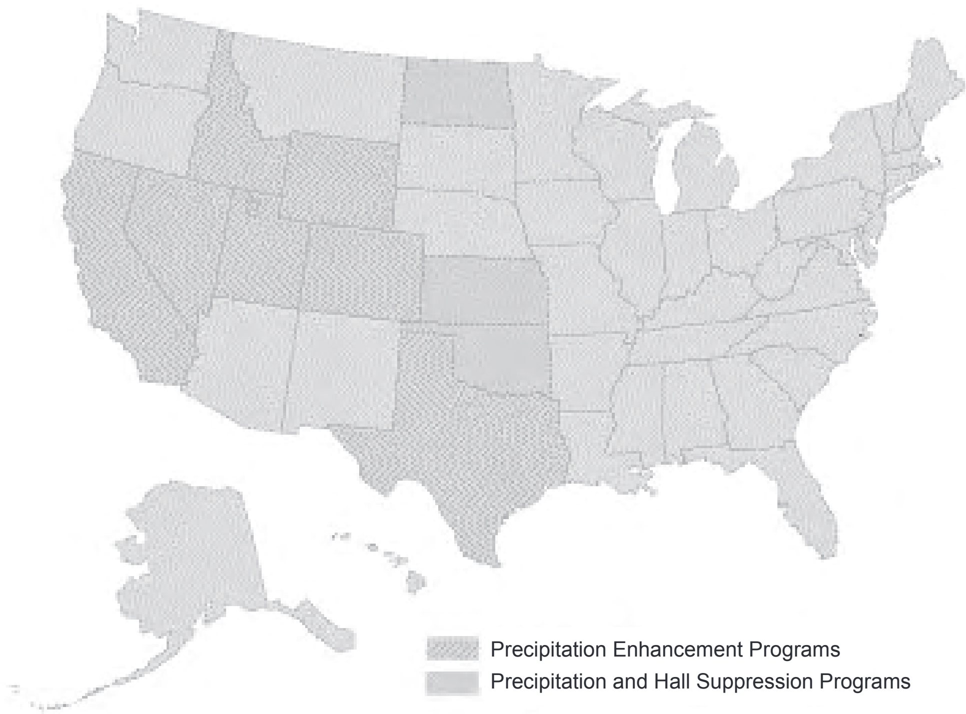


(“Overview of Weather Modification Programs Around the World”, National Center for Atmospheric Research)

There has been extensive use of cloud seeding in the United States (see Figure 2), largely in the southern states near the Mexican border. Programs concentrate on two geographical areas. First, there are several south central states, such as Texas, prone to dry conditions in the summer or during spring planting. Hail suppression is a concern in Kansas and Oklahoma. The other major nexus of use is the states in the Colorado River Basin, including Colorado, Wyoming, Utah, Nevada, and California, who use it to increase winter snowpack. North Dakota seeds clouds for hail suppression and Idaho for increasing fresh water resources.

Figure 2

Weather Modification in the United States



(“Overview of Weather Modification Programs Around the World”, National Center for Atmospheric Research)

The year that the Katrina and Rita hurricanes devastated the U.S. Gulf Coast, Senator Kay Bailey Hutchinson of Texas introduced S. 517 [109th Congress] the “Weather Modification Research and Development Policy Authorization Act of 2005”. It calls for greater research and development into cloud seeding (Section 5, “Duties of the Board”) with two key goals. (The measure has never become law.)

(1) improved forecast and decision-making technologies for weather modification operations, including tailored computer workstations and software and new observation systems with remote sensors; and

(2) assessments and evaluations of the eYcacy of weather modification, both purposeful (including cloud-seeding operations) and inadvertent (including downwind eVects and anthropogenic eVects).

The United States began technical assistance on clouding seeding to the Mexican state of Coahuila in 1996. Canada uses cloud seeding for hail suppression while Brazil, Argentina and Cuba use it for precipitation enhancement. In November 2009, Venezuela began cloud seeding operations after El Nino conditions led to droughts and water rationing in Caracas. Cuba provided technical assistance to Venezuela in carrying out the program.

China’s cloud seeding program is the largest in the world, using it to make rain, prevent hailstorms, contribute to firefighting, and to counteract dust storms. On New Year’s Day in 1997, cloud seeding made snow in Beijing, for probably no other reason than popular enjoyment. During the 2008 Olympics, China extensively used cloud seeding to improve air quality. China sees cloud seeding as part of a larger strategy to lower summer temperatures and save energy.

The Soviet Union and later Russia use cloud seeding to assure good weather during political events, such as a rain-free May Day parade. To save money, the mayor of Moscow proposes use to lessen winter snowfall in the city.

Employing cloud seeding in emergencies illustrates how perceptions of impact may diVer. Soviet air force pilots seeded clouds over Belarus after the Chernobyl nuclear disaster of 1986 to prevent radioactive clouds from reaching Moscow and other major populated areas. (Grey, "How we made the Chernobyl rain", 2007). While Moscow saw benefit, Belarus surely did not.

Many Middle Eastern countries are natural candidates for cloud seeding. France conducted tests in Algeria as early as 1952. Libya began testing in 1971, Jordan in 1986, Iraq under Saddam Hussein in 1989, and Syria in 1991. Israel has a long-standing cloud seeding program. Saudi Arabia has experimented with cloud seeding, beginning in 1990 and is increasing its programs, particularly in the southwest portion of the country near the Yemen border.

Iran has long experience with cloud seeding, especially around Yazd, the driest major city in Iran. "Statistical evaluation of the eVectiveness of regular cold-cloud seeding operation, carried out over the project territory in the Central part of Iran during the period of operation, shows that from 0.7 to 1.9 km^3 of additional water was obtained about 22–40% of the natural seasonal precipitation annual." (Khalili, "Results of Cloud Seeding Operations", 2008)

4. Hostile and Peaceful Uses of ENMOD

Article I of the ENMOD treaty requires members "not to engage in military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe eVects as the means of destruction, damage or injury to any other State Party". The general intent of the treaty is to limit the use of ecology in a military context. It distinguishes between weather related actions (short-term) from those that are climate related (long-term). The key word of course is "or", meaning any one of the three is suYcient to cause a treaty violation. The "Understanding Relating to Article I" provides the three indicators of environmental modification covered by the treaty and de minimus levels of impact.

(a) widespread: encompassing an area on the scale of several hundred square kilometers;

(b) long-lasting: an act whose duration lasts months, or approximately a season; and

(c) severe: involving serious or significant disruption or harm to human life, natural and economic resources, or other assets.

The treaty is clear on what it forbids: widespread, long-lasting, or severe environmental modification. It is thus quite revealing to consider what the treaty allows. It does permit cloud seeding (or other actions) that may adversely aVect a neighbour so long it is undertaken without a military or hostile intent. Further, military personnel could carry out a non-hostile action as long as it was without military intent. The treaty permits weather modification by the military even with a hostile intent when it is localized, short-term, and produces positive outcomes. These exceptions obviously can lead to ambiguity in real situations.

First, widespread refers to the geographic scope covered by the treaty. Treaty violations occur when impacts exceed 300 square kilometers (or 186.4 miles), so a square of roughly 17.3 kilometers (or 10.7 miles) in length and width. Washington, DC (a partial square city) is 177 square kilometers in comparison, so these are not extremely large areas but they could be home to millions of people.

The second concept is long-lasting, denoting time duration. One season corresponds to about three months. The chosen months however would produce diVering impacts. If cloud seeding occurred during a planting season, it would mean the loss of an entire year of production. If cloud seeding occurred in the winter, to build snow pack for example, the impact may be benign or even positive.

The third premise focuses on a severe disruption to the environment and may be the most diYcult concept to pinpoint. Specific indictors might use socio-economic indicators (such as income) or human health markers (such as infant mortality). A violation might significantly reduce ecological, economic or health indicators. A full understanding of impacts may not occur until long after the act occurred.

The treaty references assisting other countries in transferring technology related to the development of harmful or hostile ENMOD techniques. This implies the trade of materials, equipment, technology, or expertise. Export technology treaties cover materials that may have military application as dual-use technologies. The ENMOD Treaty suggests that exports of cloud seeding technologies may as well fall into such categories.

5. Building a Multilateral Registry of Cloud Seeding Events

ENMOD Article III, 2. The States Parties to this Convention undertake to facilitate, and have the right to participate in, the fullest possible exchange of scientific and technological information on the use of environmental modification techniques for peaceful purposes.

Little scientific exchange seems to have resulted from the ENMOD Treaty. Exchanging information is of course a first step in a confidence building process in the development of a treaty and its understandings. In cases of environmental modification, collecting information on activities is a necessary beginning point, starting with cloud seeding. A multilateral cloud-seeding registry, that is voluntary, can begin to reduce possible future ambiguities over weather modification by compiling and releasing reports of country activity.

Registry information could include detail on the clouding seeding event, starting with the scope, intensity, and particular economic impacts on human health and economy. Countries might also report the type of chemical used to induce rain and the subsequent precipitation amounts in target and adjacent areas. The data collected might also include specific indicators of widespread, long-lasting, and severe impacts. The registry could be open to non-signatories. Countries that have not joined ENMOD Treaty include China, France, Nigeria, Indonesia, Spain, Mexico, South Africa, and Saudi Arabia.

As climate change and technology proceed, the desire and the ability to claim fresh water will extend into the atmosphere and far underground. The registry may be a means to oVer transparency to uses of cloud seeding and avoid ambiguities that may be the basis for dispute.

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Washington, DC

December 2009

Memorandum submitted by the British Geophysical Association (GEO 02)

1. Our recommendation is that, before any proposed geoengineering project proceeds, evidence-based geophysical modelling of its eVects should be carried out and must demonstrate that, with appropriate hazard mitigation measures, relevant risks are low and proportionate to the benefits that will be obtained.

2. Geophysics is the application of physics to the study of the Earth and planetary systems. It includes the understanding of atmospheric dynamics and atmosphere-Earth-Sun interactions crucial to the prediction of climate and weather, and the rock-fluid-gas interactions crucial to secure carbon dioxide (CO_2) sequestration. Much of this understanding has come from computer modelling; with the sophistication of these models increasing as computing power has increased. Where such modelling is isolated from real evidence, there is a danger that it can become unrealistic. By evidence-based modelling we mean that the computer models used to test the eVects of a geoengineering intervention in the Earth's system have themselves been proved against observations. Such observations depend on steady funding and in some cases, a legal obligation to deposit them with a government agency and hence are endangered by legal or financial neglect.

3. A variety of observations can be used to test Earth system models. Laboratory experiments on real or artificial rocks under pressure and permeated with fluid or gas, and downhole and remotely-sensed (eg seismic) observations of gas flow through rocks, have been used for many years by the oil industry in enhancing production of subterranean oil and gas. The storage and curation of records from these experiments is needed to ensure that they are available for future proving of geoengineering-related models. The British Geological Survey, for instance, has recently announced plans to integrate its “library” of borehole cores and logging records from onshore and oVshore UK into a single modern facility within the National Geoscience Data Centre. The evidence against which to gauge weather and climate models includes centuries-long unbroken weather records. Continuing to add to and preserve records such as these incurs a regular cost that is prone to be cut when short-sighted cost savings are made, because the economic benefit is not immediate. Further back than the purposeful records, historical, archaeological, palaeontological and geological evidence can all be gained by research. Such research is expensive, painstaking and frequently unglamorous, as exemplified, for instance, by the drilling of many boreholes in the seafloor and careful identification and counting of microfossils in the borehole cores by experienced palaeontologists. The Integrated Ocean Drilling Program, to which the UK subscribes through NERC and the EC, carries out such work. A commitment to continuous support of this programme is essential to secure the evidence of past climates and climate change that is necessary to predict the likely eVects of geoengineering.

4. Key to both the modelling and the testing against evidence is the education of the next generation of geoscientists. A strong maths and science background at school is required for a geophysics degree. A 2006 report on university geophysics education in the UK, commissioned by the BGA, found that a poor appreciation of subjects such as geophysics and of their societal impact leads many students to make ill-advised choices at entry to Key Stage 4 that leave them unable to begin such a degree. The Institute of Physics and especially the School Seismology Project (based at the British Geological Survey) runs teacher professional development courses that try to address this ignorance, but teachers are finding it diYcult to get time oV work to attend such courses. This contributes to a global deficit of geophysicists, already noted by the oil industry. Unless addressed through improved science and technology education at secondary school level, the lack of good geoscience graduates will sap our national capability to evaluate geoengineering projects rigorously.

The BGA represents UK geophysicists, particularly in the fields of solid Earth and geomagnetic studies, and is a joint association of the Royal Astronomical Society and the Geological Society. Geophysics, the application of physics to the study of the Earth and planetary bodies and their surroundings, is crucial to the prediction of the eVects of geoengineering.

We recommend that as well as incorporating the attached submission into your final report you seek oral evidence from leading geophysicists in the fields of Earth systems observation and modelling.

Sheila Peacock
Secretary, British Geophysical Association

December 2009

Memorandum submitted by Alan Gadian (GEO 03)

Declaration of Interest:

I am a scientist, who has specialised in the “Cloud Whitening Scheme” Geoengineering Scheme. The intention is to investigate a scheme that may provide a window of opportunity of x 50 years in which a longer term solution can be found to the rapidly warming Planet Earth.

Background

1. The HoC S&T committee requested input in response to three specific questions. (Appendix 1 contains the remit specification). The “Carbon Dioxide Removal” (CDR) methods are not discussed, in this submission, as being of design to return the atmosphere to the status quo.

2. The comments below specifically refer to the geoengineering “Solar Radiation Management” (SRM) schemes, as referred to in the Royal Society Report, but could also be applied to other compensatory schemes. Three “Solar Radiation Management” (SRM) schemes referred to below are “Cloud Whitening”, (Planet Earth, www.planetearth.nerc.ac.uk, 2009-winter, p 9–11, issn 1475–2605) and “Stratospheric Sulphur” and “Mirrors in Space” schemes (National Geographica, 2009, August, p24). All schemes are briefly discussed in the Institute of Physics Publication: “Geoengineering: Challenges and Impacts”, October 2009, “Report on seminar in the House of Commons, 15 July 2009”. This response only refers to the scientific content in my area of expertise. Two pdfs relating to the cloud whitening scheme for the “Planet Earth” and the IOP case.

General comment:

3. There is a need to make a good scientific assessment of all the schemes being studied. The Royal Society Report (published 1/9/09) recommended £10 million a year for the next 10 years to assess the science behind the scheme. £3.5 million over three years has been suggested by EPSRC for a sandpit, but has not yet been arranged. Data from Arctic ice reductions, and methane releases suggests that we might have only x 10 years before it could be necessary to use geoengineering schemes to prevent serious climate catastrophe. Thus the funding of research activity is urgent.

> Recommendation 1 is that there should be urgent action to research into the science issues as well as discussion of governance issues, which currently seem to be taking precedence. There needs to be a significant programme of research immediately. Scientists who are involved with the research, and not just heads of Research Councils should be consulted about what is required: it can be argued the prolonged procedures of a peer review system is unsuitable for rapidly generation of new ideas.

Is there a need for international regulation of geoengineering and geoengineering research and if so, what international regulatory mechanisms need to be developed?

4. There is a need to define what is meant and referred to as geoengineering. In the context of this submission, I refer to it a "man made environmental change". As in recommendation 1, there is an urgent need to complete geoengineering research. Only if the results of the research are positive, should positive action geoengineering schemes be considered. Thus the current applicable question for research is: Is there a need for international regulation of geoengineering research? Submissions to the committee will say that some schemes are more dangerous than others. This needs to be determined. In the Royal Society Report, the figure of costs and dangers has been disputed by many scientists, and this needs further scientific work. The Cloud Whitening has been classified as "semi-dangerous" and this is itself incorrect, as very recent peer reviewed literature has demonstrated. Further, I do not believe that field trials or experiments in "Cloud Whitening" do not have a "HIGH need for international regulation".

> Recommendation 2 is that specific geoengineering schemes need to be in analysed, discussed and researched, before an informed analysis and context of the need for regulation can be applied for the assessment of each specific scheme.

5. For geoengineering research regulation, the scale of the "geoengineering" needs to be considered. Ship tracks caused by a ship moving across the sea, produce cloud streaks which reflect solar radiation, and therefore could be considered as a "SRM" Cloud Whitening experiment. The fact that thousands of ship tracks are produced daily, does not constitute research, or a significant issue. Thus geoengineering research activity has to be considered in relation to what is currently happening in everyday life. A further example of an experiment, could be sulphur aerosols being dropped from a helicopter, and measurements made of the increased reflectance of the sun (as measured by other aircraft), and as carried out in Russia. These releases of sulphur aerosols are far smaller than would be emitted by a small coal power station, and therefore represent a much smaller intervention than normal activity.

6. Taking the specific cases of "Cloud Whitening" and "Atmospheric Sulphur Aerosol" schemes, if they have only a local impact over an area of x 100km by x 100km, eVects can be shown to be undetectable outside this region, have no impact on other nations or groups, and any perturbation experiment has a lifetime of less than one month, then little regulation is required. In such cases, international participation should be encouraged, and no commercial funding, other than charitable donations, should be permitted. Calibrated data should be made freely available as soon as possible after the experiment.

> Recommendation 3 is that where the nature of the geoengineering research is in a locality, of size and duration such that it is significantly smaller than other human emissions, is not the subject of any commercial or private gain, and has no impact on other regions outside the test zone, then there should be a registry and full open documentation and no international regulation is required.

7. For geoengineering research which occurs on larger scales (eg. Sulphurs aerosols in the stratosphere, with large residence times, large scale ocean fertilisation experiments) then international regulation is required.

Recommendation 4 is that where the geoengineering research is on a regional scale, there needs to be regulation.

8. International bodies, the UN, (eg groups which developed the United Nations Outer Space Treaty, Environmental Modification Convention, the United Nations Framework Convention on Climate Change, United Nations Outer Space Treaty, United Nations Arctic and Antarctic Environmental treaty), the London Convention, the World Climate Research Programme, the WMO etc. should all be consulted for the development of regulatory framework for dealing with geoengineering.

> Recommendation 5 is that all relevant international bodies be consulted.

9. However, social acceptability should be examined as part of geoengineering . Recent applications to research councils for funding to examine this should be encouraged, not vetoed as has happened in the past.

How should international regulations be developed collaboratively?

10. As a scientist, I would prefer that international agencies should be paramount. I would express caution that some organisations, such as IPCC, should take a major role. Having been in conversation with scientists from smaller and less well developed countries, there is concern that the IPCC is influenced by the major "western" nations, and therefore more countries should be involved, as is the case in the UN. This is an international problem.

What UK regulatory mechanisms apply to geoengineering and geoengineering research and what changes will need to be made for purpose of regulating geoengineering?

11. As a scientist, I have no input here, other than that DEFRA, DECC, maritime agencies are the best ones to determine these.

Alan Gadian
NCAS, Environment, University of Leeds

December 2009

Memorandum submitted by John Gorman (GEO 04)

1. Obviously geoengineering must be regulated at a global level by the one global organisation that exists for something this important, the United Nations.

2. It might seem obvious that geoenginering should be included in the remit of the body already set up by the UN to coordinate the world's response to climate change, the Intergovernmental Panel For Climate Change, the IPCC.

3. It is very important that the climate academic community is not given control of geoengineering. It is very important that this does not happen for the following reasons.

4. Unfortunately the IPCC has shown itself to be remarkably inaccurate or complacent in predicting the seriousness of climate change. The 2007 prediction for sea level rise was 40 centimetres by 2100. It is now universally accepted that the figure will be one to two metres. This was fairly obvious to anyone with scientific commonsense at the time as demonstrated by the coverage in the new scientist in March 2007.

> "How and why did explicit warnings disappear from the latest IPCC report?
>
> The final edit also removed references to growing fears that global warming is accelerating the discharge of ice from major ice sheets such as the Greenland sheet."(Leader and article 10 march 2007)

5. At the same time the IPCC has been naive in their demands and estimates for immediate emissions reductions. "Delusional" is the word used in a recent publication from the UK energy industry. It seems likely that the challenging but realistic agreement that will come from the climate talks in Copenhagen this week will confirm a doubling of worldwide emissions by 2020.

6. This leaves a massive and obvious gap between what is needed and what can be done. However the only action that can possibly fill that gap, geoenginering, was dismissed in the IPCC 2007 report with 18 words in some 20,000 pages.

7. Even if one were to take seriously the rate of emissions reduction proposed by the IPCC, this still assumes that the world can live with ("adaptation" is the word used) a global temperature rise of 2)C. I don't think the world at large would agree if it were given the facts. The current global average temperature rise is about 0.7) C. Because of the 9:1 ratio from equator to pole the present rise is about five times greater in the Arctic and Antarctic at 3 to 4) C.(British Antarctic Survey Position Statement)

8. With the well-publicised eVect that this is having in Greenland, the Arctic and the Antarctic Peninsula it is very diYcult to see how anyone can look upon three times this rise (10 to 12) C.) as something that the world can adapt to.

9. At present the world climate academic community (which is what the IPCC is) has shown a lack of practicality and a very strong anti-geoenginering prejudice.

10. Oliver Morton, who is now the environment editor of the Economist, was previously a general science editor for Nature—not specifically on climate. In 2006–07 he studied geoenginering to write a six-page feature and quickly understood the politics of the situation and wrote "Much of the climate community still views the idea (of geoengineering) with deep suspicion or outright hostility".

11. This hostility extends to suppression of geoenginering ideas. Even the Nobel laureate Paul Crutzen had diYculty in getting his seminal paper on stratospheric aerosols published in 2006 and only did so eventually with the help of Ralph Cicerone, the president of the American Academy of Sciences who wrote "many in the climate academic community have opposed the publication of Crutzen's paper for reasons that are not wholly scientific".

12. Oliver Morton also wrote "In the past year, climate scientists have shown new willingness to study (geoengineering) although many will do so—simply to show—that all such paths are dead-end streets".

13. At the most local level there is evidence of this happening. The Engineering and Physical Sciences Research Council has recently allocated £3 million to research into geoenginering. This is possibly as a result of the hearings last year by this committee and the comments by the chairman on the government's negative attitude:

> The select committee's chair, the liberal democrat MP Phil Willis, said he was disappointed with the government's position of adopting only a "watching brief" over the emerging field. "That seems to me a very very negative way of actually facing up to the challenge of the future," he said. "It's a very pessimistic view of emerging science and Britain's place within that emerging science community." He said government should support many diVerent avenues to tackling climate change. "There have to be plethora of solutions. Some of which we do not know whether they will work, but that is the whole purpose of science." (quote from Guardian report)

14. To allocate this money there was a "workshop" in November in London. Among the attendees were three people with simple practical research proposals. (There may have been others.) After the workshop none of the three believed that they were likely to succeed. Their comments were:

(1) It was dominated by geophysicysts wanting to study the problem more than solving the problem.

(2) The workshop was of little importance, The problem, I fear is not realised.

(2) The main problem is that no oYcial wants to be associated with anything that can sink, catch fire, explode or just not work. Careers are much safer with paper as the only deliverable.

15. In raising these concerns about the scientific objectivity of the IPCC, the recent controversy about the content of e-mail communications from the University of East Anglia is obviously relevant. The situation cannot be expressed better than the leader in this week's "The Week" by Jeremy O'Grady.

> Just as the appalling behaviour of the Catholic Archbishops in Ireland has no direct bearing on the truth of Catholic doctrine, so the skulduggery of scientists of climate change in East Anglia does not constitute refutation of the theory of man made global warming. What it does do, however, is to shake the laity's faith in the integrity of their scientific high priests. And should that lead to those priests to question their immaculate view themselves, it will probably be no bad thing.
>
> The view of themselves as prelapsarian truth seekers unaVected by the psychological frailties which aZict the rest of us finds its clearest expression, you will recall, in Karl Popper's classic, "The Logic of Scientific Discovery". To Popper, the method of framing testable theories and then discarding them if the facts fail to fit was the distinctive way scientists not only should, but do, proceed. But in real life argued Thomas Kuhn in "The Structure of Scientific Revolutions", scientists engage in "group think". You have been taught in a certain "school" of theory; the imminent scientists who oversee your career have built reputations in the school: why let mere facts get you in psychological and career diYculties? If Kuhn is right, this suggests that the scientists' boast that their work has been peer-reviewed often means little more than that it has been exposed to group think. "If the facts change, I change my mind. What do you do?" asked Keynes with studied naiveté. The answer, at least where the East Anglian scientists are concerned, is that you massage the facts.

16. In conclusion: the The climate academic community/IPCC "group think" has three parts:

(A) Failure to recognise the seriousness of the situation—maybe because scientists require "proof". ("But we don't know that those things are going to happen" Met oYce head of climate change in group discussion after geoenginering hearing at this committee.)

(B) Grossly unrealistic "ivory tower" mentality on how quickly an idea (eg for clean energy generation) can be developed into a mature fully implemented technology.

(C) Grossly unrealistic "ivory tower" mentality on how the world can adapt to change such as one to two metres of sea level rise.

17. It is vital that the decisions on how the world reacts to the major worldwide problem of climate change are made by those in government who can apply common sense and not get lost in the detail. As EF Schumacher said 40 years ago in "Small Is Beautiful."

> "Maybe it was useful to employ a computer for obtaining results which any intelligent person can reach with the help of a few calculations on the back of an envelope because the modern world believes in computers and masses of facts and it abhors simplicity" and "the endless multiplication of mechanical aids in fields that require judgement more than anything else is one of the chief dynamic forces behind Parkinson's Law".

December 2009

Memorandum submitted by Dr Adam Corner (GEO 06)

DR ADAM CORNER AND PROFESSOR NICK PIDGEON, UNDERSTANDING RISK RESEARCH GROUP,[4] CARDIFF UNIVERSITY

1. In their recent report on geoengineering the Royal Society commented that "the acceptability of geoengineering will be determined as much by social, legal and political issues as by scientific and technical factors".[5] We agree fully with this statement and have recently completed a paper which will be published in the journal Environment in January 2010 outlining some of the social and ethical implications of pursuing research into geoengineering techniques.[6] A key consideration will be the public acceptability of both specific geoengineering proposals themselves and the governance arrangements set in place. Research in the UK and elsewhere on the public acceptance of the risks of new technologies (such as nuclear power or biotechnology) shows clearly that people raise a range of generic concerns about new technologies. These include concerns over: long-term uncertainties; who will benefit; arrangements for control and governance; and who to trust to regulate any risks.[7] Geoengineering is unlikely to be any diVerent in this regard.

2. We agree that work on the technical feasibility of geoengineering should not begin prior to a thorough evaluation of governance arrangements for research. Our most fundamental concern is that a programme of public engagement should be an important component feeding into governance and research priorities. Thus, the first challenge for geoengineering governance is to pursue an international programme of upstream public engagement. This programme of social research needs to meaningfully engage as broad a range of aVected publics and stakeholders as possible. While conducting upstream public engagement is a significant challenge, there are now precedents for this type of work in the field of nanotechnology.[8] Recent attempts to engage with public opinion towards climate change governance in advance of the UNFCCC negotiations in Copenhagen have also suggested that large-scale, international engagement is possible.[9]

3. Particular proposals to geoengineer the climate may well encounter objections from groups and individuals in society on social or ethical grounds, and it would be unwise to commence a technical research programme (or commit significant resources) without fully considering these objections. Equally a programme of public engagement may reveal support for limited and controlled research into geoengineering. The critical issue is that such views play a meaningful and legitimate role in the initial decisions made about research into any technical programme. The Natural Environment Research Council, together with Sciencewise, has recently announced a geoengineering public engagement initiative for the UK, and this is to be welcomed. A legitimate criticism of much public engagement conducted in the UK in the past however is lack of a route to influence policy. Accordingly, we urge that the results of the NERC/ Sciencewise engagement process should be considered seriously by policy makers.

4. In the remainder of the memorandum, we outline some of the key social and ethical questions that geoengineering will raise (as we see it) and their relevance for governance.

5. It is clear that humans have the capacity to geoengineer and have done so on many previous occasions. But the intentional manipulation of the climate has not previously been attempted, and the intentionality of geoengineering proposals might demarcate them from previous anthropogenic interference in the global climate. This asymmetry between intended and unintended acts is clearly observed in law, medical ethics and military conduct.[10] Any governance arrangements should seek to reflect this distinction.

6. Some proposals for geoengineering, such as release of atmospheric particulates, have clear international implications. Other proposals, such as localised carbon reduction eVorts, are less problematic in this regard. Any governance arrangements will need to reflect this heterogeneity amongst the technical options.

7. The UK and the US have a long history of international cooperation, but how will the perspectives of people in the poorest countries be taken into account? While the current collaboration with the US Congressional Committee on geoengineering governance might form the first step in a process of more widespread international cooperation, it is important that the debate over (and governance of) geoengineering is not confined to nations that are industrialised, wealthy and politically influential. People in the poorest nations are often the ones most at risk from climate change, and may also bear a

[4] The Understanding Risk Research Group is based at CardiV University and studies public attitudes, engagement with, and governance of a range of risk issues including climate change, nuclear power, biotechnology and nanotechnologies. See: www.understanding-risk.org

[5] The Royal Society. Geoengineering the climate: Science, governance and uncertainty. (Science Policy Centre Report 10/09, 2009, pp ix).

[6] Corner, A & Pidgeon, N (in press). Geoengineering the climate: The ethical and social implications. Environment

[7] See eg Risk—Analysis, Perception and Management: Report of a Royal Society Study Group, London, The Royal Society, pp 89–134; also BickerstaV et al (2008) Constructing responsibility for risk(s). Environment and Planning A, 40, 1312–1330.

[8] Pidgeon, N F, et al (2009) Deliberating the risks of nanotechnology for energy and health applications in the US and UK. Nature Nanotechnology, Vol 4, Feb 2009, 95–98; Engineering and Physical Sciences Research Council, Nanotechnologies for the Targeted Delivery of Therapeutic Agents & Nanotechnologies for Diagnostics: Summary of Public Consultation Findings (Swindon: EPSRC, 2008).

[9] World Wide Views on Global Warming, http://www.wwviews.org/files/images/WWViews_info_sheet-v80-27_September%2009.pdf (accessed 2 October 2009).

[10] D Jamieson. "Ethics and Intentional Climate Change." Climatic Change 33 (1999): 323–336.

disproportionate burden of hazard if unanticipated consequences of geoengineering deployments do emerge. Hence every eVort must be made to develop a broad international consensus on geoengineering governance.

8. Contemporary research on geoengineering has its roots in military strategies developed for weather modification. While geoengineering's military history does not preclude benevolent uses, it is clear that climate modification schemes come with a potential for global conflict that should be taken seriously. Conflict might arise due to the unilateral pursuance of a climate modification programme by a nation perceived to be placing its own interests above those of other nations. It is even conceivable that a wealthy individual or private company might develop geoengineering technologies. Picking apart the climatic eVects that could be attributed to a rival nation's geoengineering from those which would have occurred naturally would be extremely diYcult. The scope for conflict—even in the absence of intentional provocation—would be significant. This underscores the importance of developing a broad and inclusive international consensus—and being willing to accept the possibility that the consensus might not be favourable towards some forms of geoengineering research.

9. Geoengineering might be considered a "dangerous distraction" from the urgent task of mitigation through more traditional methods of emissions reductions. The Royal Society refer to this as a "moral hazard" argument—the phenomenon whereby people who feel "insured" against a risk may take greater risks (ie mitigate less) than they would otherwise be prepared to. Whether geoengineering will suppress individual and group incentives for action on climate change (or alternatively galvanise some sections of society) is something which can only be resolved through careful empirical work. This emphasises the need for detailed social research on geoengineering's impact on attitudes to climate change, as well as behavioural intentions and responses. The Social and Economic Research Council would be the best placed to lead any sponsorship of such social research.

10. We conclude that the first and most urgent task of governance is to initiate a large-scale and international programme of upstream engagement with as broad a range of aVected publics as possible. The outcomes of this public engagement programme should form part of the evidence-base for determining whether a large-scale technical research programme begins at all.

December 2009

Memorandum submitted by Tim Kruger (GEO 07)

Draft principles for the conduct of geoengineering research.

Summary

1. In this memorandum, we present a set of draft principles for the conduct of geoengineering research, which we suggest as a framework to act as a starting point for the collaborative development of international regulation.

2. We lay out five key principles by which we believe geoengineering research should be guided:

— Geoengineering to be regulated as a public good.

— Public participation in geoengineering decision-making.

— Disclosure of geoengineering research and open publication of results.

— Independent assessment of impacts.

— Governance before deployment.

3. We believe that geoengineering needs to be regulated and that there is a need to engage more widely internationally to ensure that any such regulation has broad legitimacy.

About the Authors

4.

— Steve Rayner is Professor of Science and Civilisation and Director of the Institute of Science, Innovation and Society at the Said Business School, University of Oxford. His expertise is in the relationship between science and society and he was a member of the Royal Society's working group on geoengineering.

— Catherine Redgwell is Professor of International Law at University College London. Her expertise is in the fields of international energy law and international environmental law and she was also a member of the Royal Society's working group on geoengineering.

— Julian Savulescu is Professor of Practical Ethics and Director of the Uehiro Centre, University of Oxford. His expertise is in the fields of genetic ethics and medical ethics.

— Nick Pidgeon is Professor of Psychology at CardiV University. His expertise is in the field of risk—its perception, communication and management—and public engagement with science and technology.

— Tim Kruger is Director of the Oxford Geoengineering Institute. His expertise is in the technical aspects of geoengineering, specifically a process that involves reducing atmospheric carbon dioxide by enhancing the capacity of the ocean to act as a carbon sink.

Background

5. If the international community fails to reduce greenhouse gas emissions suYciently to prevent catastrophic climate change it may become necessary to resort to techniques involving deliberate large-scale intervention in the Earth's climate system—geoengineering. Geoengineering techniques may be divided into two categories: Carbon Dioxide Removal techniques which remove CO_2 from the atmosphere; and Solar Radiation Management techniques which reflect a small percentage of the sun's light and heat back into space. There are major diVerences between these two categories in terms of their objectives, impacts, and timescale. Such techniques must be seen not as an alternative to conventional mitigation techniques, but rather as an additional option to which recourse may be had in the event mitigation alone does not avert climate change on a catastrophic scale.

6. Increasingly it is apparent that some geoengineering techniques may be technically possible, though with major uncertainties regarding their eVectiveness, cost and socio-economic and environmental impacts. It is imperative that governance structures are in place to guide research in the short term and to ensure that any decisions taken ultimately with respect to deployment occur within an appropriate governance framework. Transparency in decision-making, public participation, and open publication of research results are key elements of such a framework, designed to ensure maximum public engagement with and confidence in the regulation of geoengineering research. Alone or in combination, many of these principles are already applied in the regulation of hazardous substances and activities such as the transboundary movement of hazardous wastes and pesticides, radioactive substances and GMOs.

7. Accordingly, the following principles are suggested as a framework to guide research into geoengineering techniques.

Draft Principles for the Conduct of Geoengineering Research

Preamble

8. Recognising the fundamental importance of mitigation and adaptation in combating climate change and its adverse eVects;

9. Acknowledging nonetheless that if, in the near future, the international community has failed to reduce greenhouse gas emissions and urgent action is needed to prevent catastrophic climate change then it may be necessary to resort to techniques involving deliberate large-scale intervention in the Earth's climate system ("geoengineering");

10. Ensuring that, in the event such resort is necessary, potential geoengineering techniques have been thoroughly investigated to determine, which, if any, techniques will be eVective in addressing the issue of climate change without producing unacceptable environmental and socio-economic impacts;

11. Recognising that there are a variety of proposed geoengineering techniques which diVer both in what they are trying to achieve (Solar Radiation Management or Carbon Dioxide Removal) and how they are trying to achieve it (engineered solutions or interventions in ecosystems) so that each must be assessed on its own terms, rather than applying a one-size fits all governance approach;

12. Noting that there is no empirical evidence to suggest researching geoengineering techniques will undermine climate change mitigation eVorts;

13. Emphasizing the importance of proceeding cautiously with responsible research so as to assess the potential advantages and disadvantages of proposed geoengineering techniques, recognizing that failure to do so will not reduce the probability that such techniques may be resorted to, but will mean that such resort will take place in the absence of a suYcient evidence base on which to determine which techniques carry the least risk;

14. Stressing that research into geoengineering techniques does not lead inevitably to deployment, and that principles to govern research may need to be adapted to guide decisions regarding deployment, if any;

15. Recognising that the regulation of geoengineering research by existing national, regional and international laws and regulations may be suYcient, but that governance gaps may emerge requiring the creation of new rules and institutions;

16. Propose the following principles to guide research into geoengineering techniques:

17. Principle 1: Geoengineering to be regulated as a public good.

While the involvement of the private sector in the delivery of a geoengineering technique should not be prohibited, and may indeed be encouraged to ensure that deployment of a suitable technique can be eVected in a timely and eYcient manner, regulation of such techniques should be undertaken in the public interest by the appropriate bodies at the state and/or international levels.

18. Principle 2: Public participation in geoengineering decision-making

Wherever possible, those conducting geoengineering research should be required to notify, consult, and ideally obtain the prior informed consent of, those aVected by the research activities. The identity of aVected parties will be dependent on the specific technique which is being researched—for example, a technique which captures carbon dioxide from the air and geologically sequesters it within the territory of a single state will likely require consultation and agreement only at the national or local level, while a technique which involves changing the albedo of the planet by injecting aerosols into the stratosphere will likely require global agreement.

19. Principle 3: Disclosure of geoengineering research and open publication of results

There should be complete disclosure of research plans and open publication of results in order to facilitate better understanding of the risks and to reassure the public as to the integrity of the process. It is essential that the results of all research, including negative results, be made publicly available.

20. Principle 4: Independent assessment of impacts

An assessment of the impacts of geoengineering research should be conducted by a body independent of those undertaking the research; where techniques are likely to have transboundary impact, such assessment should be carried out through the appropriate regional and/or international bodies. Assessments should address both the environmental and socio-economic impacts of research, including mitigating the risks of lock-in to particular technologies or vested interests.

21. Principle 5: Governance before deployment

Any decisions with respect to deployment should only be taken with robust governance structures already in place, using existing rules and institutions wherever possible.

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December 2009

Memorandum submitted by Tim Kruger et al (GEO 07a)

1. In this memorandum, we respond to some of the oral evidence given to the Select Committee, with regard to the role of the private sector in geoengineering.

2. During the oral evidence, a number of the witnesses were asked their thoughts about the set of principles laid out in our previous memorandum. This memorandum is in response to some comments with regard to the role of the private sector in geoengineering. Some witnesses interpreted the principle that geoengineering should be regulated as a public good as a wholesale rejection of the involvement of the private sector. This is not our position. In this memorandum we lay out how it is important to consider carefully the role of the private sector.

3. We would like to make a comment on the role of the private sector in geoengineering research and deployment. As we state in our submission:

> "While the involvement of the private sector in the delivery of a geoengineering technique should not be prohibited, and may indeed be encouraged to ensure that deployment of a suitable technique can be eVected in a timely and eYcient manner, regulation of such techniques should be undertaken in the public interest by the appropriate bodies at the state and/or international levels".

4. We would like to draw attention to the particular issue of patents and other intellectual property rights in this area. The granting of patents in this area could have serious negative impacts:

5. The ability to obtain patents on geoengineering technique could create a culture of secrecy and may lead to the concealment of negative results.This has been observed in the pharmaceutical industry, where negative research results are deliberately concealed. This is doubly damaging—firstly, the negative consequences of a geoengineering technique could be far more wide-ranging than from a drug trial, and secondly, the concealment of negative results could lead to a public backlash against all geoengineering research and research scientists. With respect to the latter, the highly regarded House of Lords Science and Technology Committee "Science and Society Report" of 2000 concluded that openness and transparency are a fundamental precondition for maintaining public trust and confidence in areas which may raise controversial ethical or risk issues.

6. Patents could lead to the creation of powerful vested interests in the field of geoengineering. Lobbying by these vested interests could lead to undesirable technological lock-in.

7. The field could become blocked by a thicket of patents which some patent-holders may use to extort a rent on technologies which could be used to tackle climate change, resulting in delays and needless expense. Such blocking patents could be described as "socially useless".

8. The benefit of allowing the granting of patents is that it may encourage investment in research and development. But these benefits need to be weighed against the potential downsides.

9. An example of a field where there has been considerable investment from both the public and private sectors despite tight restrictions on patent rights is in the Human Genome Project. It was recognised that it would not be in the public good for a small group of organisations to own large parts of our genetic code and a decision was taken that the genome sequence could not be patented. Despite these restrictions investment in the field remains high.

10. It should be noted that geoengineering is a widely heterogeneous field and it is likely that the operation of normal patent regulations in some areas (such as, for example, biochar) may stimulate investment without leading to countervailing problems. Nevertheless we would encourage regulators to explicitly reserve the right to intervene in this area to encourage transparency and to stymie the creation of powerful vested interests that may operate against the public interest.

11. We have attached a copy of the recently published Manchester Manifesto, which was written by, amongst many others, Professor Sir John Sulston (Nobel Laureate 2002—Physiology or Medicine). It considers the question "Who owns science?" and concludes that ownership rights pose a real danger to scientific progress for the public good.

12. There is an opportunity as we start to research and regulate geoengineering to ensure that we structure it in such a way as to spare our successors from having to grapple with powerful vested interests in the future. The question should be asked: if geoengineering research does not qualify as a public good, what on Earth does?

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February 2010

Memorandum submitted by the Sustainability Council of New Zealand (GEO 08)

Cutting Emissions is Not Enough

Although governments have a duty under the UN Framework Convention on Climate Change (FCCC) to avoid "dangerous" climate change, the treaty does not specify what concentration of greenhouse gases would constitute a safe level. In absence of this, international negotiations have operated on the basis that limiting the average rise in global temperatures to 2)C will be suYcient. It has also been widely assumed that if the concentration can be stabilised at 450 parts per million equivalent (ppme),[11] this would provide a 50% chance of holding the temperature rise below that 2)C limit.

[11] This is a measure of the concentration of all greenhouse gases, expressed on a carbon dioxide equivalent basis, in "ppme". Concentrations of CO_2 alone are expressed as "ppm of CO_2".

A 50% chance of avoiding dangerous outcomes is a very low level of protection for an intergenerational endowment. Yet international negotiations to date have implicitly targeted concentrations of 450 ppme and above. Further, the modelling behind these estimates excludes what are termed “slow” feedback eVects—changes to ice sheets and vegetation.

If climate models are required to deliver an appropriately high chance of keeping within the 2)C target, and also to account for slow feedback eVects, the world’s “carbon” budget is already overspent. Citing a changed understanding of the timescale for slow feedback eVects, James Hansen of NASA last year revised down his estimate of a “safe” concentration for CO_2 alone to 350 ppm—meaning less than 400 ppme for all gases. This is below today’s level and would require that a significant volume of greenhouse gases be extracted from the atmosphere.

In contrast, the plan to confront global warming that is the current focus of international negotiations is based simply on cutting emissions. It assumes that the atmosphere can absorb suYcient additional carbon to allow a prompt but unhurried transition to a low carbon economy. However, a truly low risk and precautionary plan would require not just cutting emissions but also reducing the existing concentration by extracting CO_2 from the atmosphere.

Can Sequestration Bridge the Gap?

Avoiding dangerous climate change will require a new plan that makes use of a mixture of options. There is a clear hierarchy of preferred measures:

1. Abatement: reducing greenhouse gas emissions;
2. Sequestration: removing greenhouse gases from the atmosphere; and
3. Reflection: limiting warming by reflecting or blocking sunlight.

Immediate options for large-scale sequestration are biologically based and dominated by aVorestation, while the capture of CO_2 from the air by chemical reaction is seen as the key emerging technology.

If all the sequestration capacity estimated to be available were used together with responsible rates of abatement, this would be almost enough to absorb both new and historic emissions at a rate suYcient to deliver a 380 ppme concentration by 2050. While new techniques may well raise future estimates of the available capacity, it remains uncertain what proportion of the technical potential could be accessed in practice and the extent to which financial constraints would limit uptake.

Further, if the concentration is already above a safe level and it will take many years to reduce this significantly under any plan, there is the risk that significant feedback eVects could be triggered in the meantime—such as the release of additional greenhouse gases from thawing permafrost. A precautionary plan would therefore also need to investigate reflection options.

Such a plan would place emphasis on managing risk, especially feedback eVects. These are triggered by what might be termed the Apparent Concentration—the warming eVect felt today as compared to that which can ultimately be expected. In particular, half the warming eVect of the greenhouse gases added to the atmosphere since the industrial revolution is suppressed by aerosol pollutants and other agents that reflect sunlight. It will be important to separately manage the net eVect of these two, the Apparent Concentration, while maintaining a long-term focus on reducing the greenhouse gas concentration.

Facing the Mirror

Reflection options receiving serious attention include injecting aerosols into the stratosphere and enhancing the reflectivity of clouds. If these techniques can be proven, each is estimated to have the capacity to neutralise the warming expected from the current concentration of greenhouse gases. They are both estimated to be low cost compared to sequestration and would lower average temperatures relatively rapidly.

The fundamental diVerence between sequestration and reflection, however, is that sequestration addresses the root issue (the concentration) while reflection merely treats the symptom (warming). Problems arising from this include:

— Reflection does not address the acidification of oceans that results from excess CO_2 in the atmosphere being absorbed by the sea;

— Schemes that inject particles into the atmosphere are likely to alter the distribution of rainfall and also cause some reduction in the global quantity of rainfall (as reflecting sunlight is not that same as reducing the CO_2 concentration); and

— Many reflection techniques will need to be replenished constantly over their lifetime and, if this is not kept up, extremely rapid warming could ensue.

Even if the physical eVects were considered an acceptable near-term trade-oV, the haunting concern lying behind reflection is that its use could severely undermine incentives for both sequestration and abatement such that fair and aVordable action on these would not be undertaken in the near term. Reflection schemes may be low cost but if the concentration needs to be lowered from its present level, someone will ultimately have to pay for this. Deferring abatement and sequestration passes debt and risk to future generations.

Recognition of the degree of climate change risk currently being run carries profound implications. Not least is that stopping all emissions now would not be enough to prevent dangerous levels of warming if 350 ppm of CO_2 turns out to be as important a threshold as Hansen believes: the gases already released would cause this. Restoration of the atmosphere to a safe set of conditions will in any case require very significant and sustained investment in sequestration, whatever shape the new plan eventually takes.

The societies that spawned the activities producing greenhouse gas emissions have spectacularly failed to manage the risks arising from them to date. A current abatement-only plan that leaves so much to chance, and the absence of an adequately researched alternative plan, is inconsistent with the FCCC requirement for precaution. It is important to acknowledge there has been serious systemic failure and that continuing in some form of denial would be dangerous.

The atmosphere is a life-sustaining system and it is crucial that any new plan is developed and implemented under the intent of stewardship and not as a geoengineered response. Stewardship would have a primary focus on protecting and restoring the atmosphere by reducing concentrations.

Sequestration and Storage

Restoration focuses on identifying the volumes of carbon that need to be extracted from the atmosphere and allocating the costs of achieving this. A crucial step in this process is determining a concentration governments are willing to deem acceptable—an Accepted Concentration. This would define a total volume of greenhouse gases above pre-industrial levels that was considered reasonable for the atmosphere to carry on a long-term basis. Allocating each nation a fair share of this Available Capacity would logically be based on some metric of cumulative emissions and population.

That process would also quantify what volume of greenhouse gases is in excess at present and allocate responsibilities for sequestering it among nations. If governments set the Accepted Concentration such that CO_2 levels would be 350 ppm, that would require about 35 ppm of CO_2 to be sequestered and would result in a bill for historic excess emissions of about US$10 trillion if aVorestation was used. The United States' share of this would be similar to the US$3 trillion in banking losses currently being absorbed, and Europe's bill would be much the same.

Looking forward, if the atmosphere no longer has the capacity to safely accept additional emissions on a long-term basis, then it follows that further rights to utilise atmospheric capacity can only be temporary in nature. Permits for temporary storage can provide a means of reconciling protection of the atmosphere with the time required for economies to "decarbonise", if they are otherwise appropriately constrained. Temporary Storage Permits would authorise additional emissions on condition that the emitter pays to bring that carbon back down if later required. These would be in place of Kyoto-style permits and limitations on the storage period would be the critical discipline.

Developed countries have a financial incentive to delay determining an Accepted Concentration and so requirements for sequestration spending. An important countermeasure would be for nations to agree to pay fees for temporary storage. Total fees for new emissions (per tonne of carbon) would rise to the cost of sequestration during a transition period.

As the cumulative emissions of developing countries are low by any measure, they would pay no storage fees during the transition period. All storage fees would be used to fund sequestration projects, with proposals scored on multiple counts to maximise available co-benefits, such as enhanced biodiversity.

Two factors make storage possible. One is the lag between emissions being produced and higher temperatures being felt. The other is the cooling eVect provided by aerosols and other reflective agents. However, storage capacity is limited and a considerable proportion is already being used. The further the system is pushed, the greater the risk of triggering feedback eVects.

An Atmosphere Regulatory Commission

Avoiding dangerous climate change will require integrated planning across two distinct timeframes. The long-term focus on cutting emissions and sequestering carbon involves extended negotiations among governments and could be the enhanced role of the FCCC.

In the meantime, a focus is needed on ways to keep temperatures below levels that are dangerous or might trigger significant feedback eVects. If an Atmosphere Regulatory Commission (the Commission) were also established, it could have the hands-on role of managing the Apparent Concentration so as to present the least risk at any time, consistent with an overarching goal of restoring the atmosphere. It would also determine how much temporary storage is to be made available, and for how long.

The Commission would focus on three climate response measures: sequestration and two forms of reflection—traditional aerosol emissions and reflection projects. In this context, reflection would provide a continuum of options ranging from more active management of aerosols already being produced, through to emergency measures involving large-scale intentional reflection projects. It would assess climate change risk and response options, and then weigh whether the risks and costs of proceeding with a particular plan or intervention would lower climate change risk overall.

The Commission would first take account of the eVorts made by governments to abate and sequester. It would also directly contract for sequestration projects itself, using the funds derived from storage fees that would pass to it. If abatement and sequestration eVorts proved insuYcient to hold the Apparent Concentration within acceptable bounds, the Commission would need to consider whether any reflection option would lower the overall risk.

While the Commission need not undertake technology research or build infrastructure, it would be the sole potential purchaser of any reflection services. Private developers would be excluded from operating reflection services and no tradeable credits of any form would be recognised for reflection projects. As a check against the Commission's monopsony power, it would be subject to the highest degree of disclosure at all times.

Where precisely to locate the Commission is an important question. Placing it outside the FCCC could raise expectations that reflection options will be used, and so reduce the incentives for sequestration. However, separation of the Commission from the FCCC would appear to oVer a considerable advantage overall. By providing greater transparency and accountability, it would help deter governments from favouring reflection options simply to avoid higher cost abatement and sequestration. It would also separate out functions that will need to operate at a faster pace and under a diVerent culture to that the FCCC has worked to.

Constituting the Commission will likely require a new international treaty. The Law of the Sea provides a precedent for more detailed regulation, whether under a UN treaty or alternative arrangements. Reflection activities would initially be regulated by way of two interlocking moratoria. The first would restrain all field trials until minimum conditions necessary for these were established and a second would cover all projects over and above this level. Parties gaining from a reflection project relative to other parties would compensate those that suVer losses, and project sponsors would be liable for harm arising from any scheme.

Shades of Darkness

While a number of factors make it realistic to plan for the cooperative governance of reflection, it is important to confront the potential for unilateral deployment and conflict arising from its use. A clear driver for unilateral action would be if one region were significantly aVected by climate change and felt the international community was responding too slowly. Developing nations will in general suVer soonest from the more serious eVects of climate change. The prospect that a small group of developing countries could deploy reflection schemes shifts the balance of power such that the pace of climate change responses in general will tend to better align with their preferences.

In another scenario, financial factors could drive a group of developed countries to act independently as a way to sideline negotiations with developing countries and simply impose a new order. Large-scale reflection also has the potential to be a "dual use" technology, capable of modifying the weather of a particular region to suit one group of countries at the expense of others. A worst-case scenario for environmental risk would be if a number of competing weather modification projects were to be launched in parallel, each operated independently, with uncoordinated objectives and synergistic eVects managed on the hoof.

There is also the disturbing potential for new arrangements to be cooperative, but at the expense of future generations. This would not result from the reflection deployment itself, but the absence of a linked commitment to sequester excess emissions. Under such a scenario, developing countries would be oVered a much greater volume of enduring emission permits so long as developed countries were excused from having to sequester their excess emissions in the medium term.

A Restoration Trust

Even if a Commission were established in a timely manner and in full form, non-governmental organisation would play a vital role monitoring and checking the regulator. A foundation for successful advocacy would be the capability to monitor the atmosphere as a whole, set thresholds for sustainability, account for performance against these, and devise restoration plans. It is proposed that the production of an integrated set of information be the focus of a new entity that might be called the Atmosphere Restoration Trust (the Trust). Its tasks would include the following:

- State of the Atmosphere Reports: would establish and then regularly update a comprehensive set of records on the atmosphere;
- An Atmosphere Restoration Plan: is required to chart the path to an Accepted Concentration and show how the Apparent Concentration will be managed during the transition; and
- Financial and Economic Analysis: would include contributions to the ongoing design of permits for temporary storage, and to defending the interests of future generations from being discounted in value.

Both the Commission and entities such as the Trust are just interim measures. Sustainable governance will require enforcement provisions and the establishment of a supranational regulator. This will involve the construction of a new set of international understandings, entailing compacts in respect of international justice, international trade, and military intervention. The place of those negotiations needs to be considered alongside demands arising from the overlapping issues of water, food and fuel security, and humanitarian concerns generally.

This submission is based on the Council's publication, Restoring the Atmosphere, August 2009.

Thank you for the opportunity to submit and we would welcome the opportunity to provide oral evidence by teleconference.

Key Terms

Actual Concentration: The total concentration of all long-lived greenhouse gases resident in the atmosphere at a particular time.

Apparent Concentration: The concentration that corresponds to the radiative force acting on the Earth due to human intervention, at a particular time.

Long Term Concentration: The total projected concentration after sequestration of all long-lived greenhouse gases resident in the atmosphere at a specified date at least 100 years in the future.

Accepted Concentration: A concentration governments collectively deem to be an acceptable Long Term Concentration.

Available Capacity: The diVerence between the pre-industrial concentration and the Accepted Concentration.

Excess Emissions: The quantity of emissions resident in the atmosphere that is in excess of the Accepted Concentration.

Enduring Emission Unit: A permit to emit a tonne of CO_2 equivalent gases.

Temporary Storage Unit: A permit to emit a tonne of CO_2 equivalent gases and the obligation to sequester a tonne of CO_2 equivalent gases at a later date—pre-specified or subject to notification.

Temporary Sequestration Unit: A credit recognising the temporary sequestration of a tonne of CO_2 equivalent gases. It expires on a pre-specified date unless proof of continued storage can be demonstrated.

Enduring Sequestration Unit: A credit recognising the semi-permanent sequestration of a tonne of CO_2 equivalent gases.

Storage Fee: At the time a Temporary Storage Unit is utilised (though the release of emissions under it), a storage fee is payable on each tonne of long-lived greenhouse gases, according to the rate set for it by the Commission.

December 2009

Memorandum submitted by ETC Group (GEO 09)

1. The Action Group on Erosion, Technology and Concentration (ETC Group) is an international civil society organization headquartered in Canada with oYces in the United States, Mexico and the Philippines. ETC Group dedicated to the conservation and sustainable advancement of cultural and ecological diversity and human rights. To this end, ETC Group monitors the societal impacts of emerging technologies, supports socially responsible developments of technologies useful to the poor and marginalized and we address issues related to international governance and the concentration of corporate power.

2. ETC Group has been actively monitoring developments in geoengineering for several years, publishing reports, arranging seminars and undertaking international advocacy work regarding geoengineering technologies. All of our publications and news releases on geoengineering are available for download at http://www.etcgroup.org/en/issues/geoengineering.Our publications on this topic to date include:

— 1 Feb 2007—"Gambling With Gaia"—A civil society introduction to Geoengineering.

— January 2009—"The better world we seek is not Geo-engineered! A Civil Society Statement against Ocean Fertilization".

— April 2009—"ETC Group Submission to Royal Society Working Group on Geo-Engineering".

— Sept 2009—"The Emperor's New Climate: Geoengineering as 21st century fairytale".

— Dec 2009—"Retooling the Planet? Climate Chaos and the Copenhagen Process in the Geoengineering Age".

3. ETC Group welcomes the news of the committee's inquiry into geoengineering governance. We hope that the inquiry will mark the beginning of a vigorous public and international policy debate on this important topic. We would welcome the chance to provide an oral submission to the committee.

4. ETC Group defines geoengineering to include not only solar radiation management and sequestration of atmospheric greenhouse gases (including methane, nitrous oxide and carbon dioxide) but also weather modification techniques such as hurricane suppression and cloud seeding. We encourage the committee to also consider weather modification in this inquiry.

5. At the time that we are submitting this evidence delegates at the UN Framework Convention on Climate Change are negotiating in Copenhagen in an eVort to make progress on an agreement to bring about significant reductions in global greenhouse gas emissions. The world's leading climate scientists agree that a reduction in greenhouse gas emissions is the world's best hope for averting a climate catastrophe.[12] Geoengineering must not distract from that goal.

6. Geoengineering could be seen by governments and industry as a "time-buying" strategy and as an alternative to reducing greenhouse gas emissions.[13] We encourage the committee to reflect on the meaning of the strong advocacy for geoengineering now coming from think tanks and industry-funded groups who formerly denied the existence or significance of anthropogenic global warming. ETC believes the prospect of geoengineering is being deliberately used by some of these groups as an attempt at distraction from tough action on greenhouse gas emissions reductions.

7. ETC Group believes that geoengineering is the wrong response to climate change and that inadequate knowledge of the earth's systems makes geoengineering, or even real-world geoengineering experiments, too risky. We do not know if geoengineering is going to be inexpensive for society, as proponents insist—especially if geoengineering technologies don't work as intended, forestall constructive alternatives or cause adverse eVects. We do not know how to recall a planet-altering technology once it has been released.

8. In addition to unintended consequences, geoengineering techniques could have unequal impacts around the world (sometimes referred to as "spatial heterogeneity").[14] As much as the Industrial Revolution's "inadvertant geoengineering" (ie, human-induced climate change) has disproportionately harmed people living in tropical and subtropical areas of the world, purposeful geoengineering experiments could well do the same. It is critical that those states and populations on the front lines in the fight against climate change, particularly the most vulnerable developing countries, be involved in a broad-based and international debate.

9. It should be recognized that states—or even corporations—with the technical and economic means to "adjust the global thermostat" may be tempted to do so. Geoengineering technologies warrant robust regulatory oversight. In the absence of a multilateral framework and a global consensus, any financial or political support for geoengineering technologies would be irresponsible and would reinforce the lack of accountability of industrialized countries for climate change and for the worsening negative consequences in the global South.

10. ETC Group draws a "line in the sand" at the lab door. We do not believe that it is warranted to move geoengineering out of the laboratory and the most urgent questions of governance concern keeping that lab door closed against the pressures from industrial players to move to open air geoengineering research and deployment.

11. We are extremely concerned by recent proposals that a research programme on geoengineering be established which might include real world experimentation of geoengineering techniques. While modelling studies or other lab-based approaches may be carried out safely it is irresponsible to move geoengineering research out of doors—most especially before global agreements on governing such research have been agreed.

12. Committee members should distinguish between very small scale experimentation for other purposes (eg biochar for soil fertility research or ocean fertilisation to investigate ocean biological processes) and experiments designed to develop geoengineering technologies. We encourage the committee to consider for example the proposal by Strong et al. in the journal Nature that ocean fertilisation in particular should no longer be pursued as a subject of geoengineering research.[15]

13. Climate systems are already unpredictable and contain much "noise". For any research activities on geoengineering techniques to have a noticeable impact on the climate, they will have to be deployed on a massive scale, and thus any unintended consequences are also likely to be massive. We don't know how to recall a planetary-scale technology.

[12] See for example, IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B Metz, O R Davidson, P R Bosch, R Dave, L A Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[13] See, for example, "Geo-Engineering: Giving us the Time to Act," Institute of Mechanical Engineers (UK), August 2009, available at http://www.imeche.org/

[14] UK Royal Society, Geoengineering the climate: science, governance and uncertainty, 1 September 2009, p. 62; available on the Internet: http://royalsociety.org/document.asp?tip%0&id%8729

[15] See Strong, Aaron; Chisholm, Sallie; Miller, Charles; Cullen, John "Ocean fertilization: time to move on" Nature, Volume 461, Issue 7262, pp. 347—348 (2009).

14. The experience of ocean fertilization shows that any acceptance of small scale experimention will inevitably slide to pressure for larger-scale experiments even if the results are poor. Despite at least 13 smaller-scale ocean fertilization experiments which failed to demonstrate the eYcacy or safety of the technique, there remains commercial and academic pressure for larger tests. This pressure should be resisted and the wider lesson applied to other geoengineering research.

15. OECD governments—which have historically denied climate change or prevaricated for decades (and are responsible for 90% of historic greenhouse gas emissions)—are the ones with the budgets and the capacity to execute geoengineering projects. Will they have the rights and well-being of more vulnerable states or peoples in mind?

16. It is possible—though far from certain—that some geoengineering techniques will be relatively inexpensive to deploy. The technical capacity to attempt large-scale climate interventions could be in some hands (of individuals, corporations, states) within the next ten years. It is urgent to develop a multilateral mechanism to govern geoengineering, including establishing a ban on unilateral attempts at climate modification.

17. Geoengineering interventions could lead to unintended consequences due to mechanical failure, human error, inadequate understanding of the earth's climate systems, eVects from future natural phenomena (eg, storms, volcanic eruptions), irreversibility or funding lapses.

18. Many geoengineering techniques are "dual use" (ie, have military applications). Any deployment of geoengineering by a single state could be a threat to neighboring countries and, very likely, the entire international community. As such, deployment could violate the UN Environmental Modification Treaty—ratified by the United States—which prohibits the hostile use of environmental modification.

19. Patent oYces are already being inundated with applications on geoengineering techniques. Monopoly control of any deployed global geoengineering scheme would be unacceptable. Nor do the issuance of patents make sense if indeed geoengineering is being developed as an emergency response measure.

20. Commercial interests should not be allowed to influence the research, development or deployment of geoengineering technologies. If, as advocates insist, geoengineering is actually a "Plan B" to be used only in a climate emergency, then it should not be a profit-making endeavor. Further, it should not be employed to meet emissions reduction targets.

21. The de-facto moratorium on ocean fertilization agreed by 191 governments at the Convention on Biological Diversity in May 2008 is the first truly global agreement on geoengineering governance and we encourage the committee the aYrm the line agreed by the UK Government at the CBD that ocean fertilization is not scientifically justified and should not proceed to larger scale or commercial activities outside of national jurisdictions.

22. We would suggest that the Convention on Biological Diversity might be an appropriate body for convening global governance discussions on geoengineering under the auspices of the UN since that treaty integrates biodiversity concerns with impacts of such activities on livelihoods, justice and rights of marginalized groups. We would caution against global governance initiatives being handed to smaller bodies that are closed to southern, indigenous and civil society participitation such as the OECD, G8, G22 or The London Convention and London Protocol on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.

December 2009

Memorandum submitted by The Royal Society (GEO 11)

1. The Royal Society welcomes the opportunity to respond to the Select Committee inquiry into the regulation of geoengineering. We also welcome the collaboration with the US Congressional Science and Technology Committee to which Professor John Shepherd FRS gave evidence on 5 November 2009. This submission has been prepared based on the Society's report "Geoengineering the Climate: Science, governance and uncertainty" and ongoing streams of work. A copy of the report has been enclosed with this submission.

2. The Royal Society decided to undertake a review of the feasibility and uncertainties of the various proposed geoengineering technologies due to the increased public awareness of, and interest in geoengineering. Under the chairmanship of Professor John Shepherd FRS of Southampton University, we assembled a group of 12 experts, drawn from environmental science, oceanography, engineering, economics, law and social science. The review took one year and the report was published in September 2009. Here we emphasise three main points:

— First, the report emphasises the geoengineering is not an alternative to greenhouse gas emission reductions. Geoengineering may hold longer-term potential and merits more research, but it oVers no quick and easy solutions that should distract policy-makers from working toward a reduction of at least 50% in global carbon dioxide (CO_2) emissions by 2050.

— Second, the report brings greater clarity to the debate by defining and comparing the two basic classes of geoengineering methods: Carbon Dioxide Removal (CDR) techniques that remove CO_2 from the atmosphere and Solar Radiation Management (SRM) techniques that reflect a small percentage of the sun's light and heat back into space.

— Third, the report looks beyond the science to highlight a broader set of issues that need to be considered before geoengineering could proceed. The mix of factors is complex, and it is desirable that both geoengineering research, and any plans for implementation, be pursued within robust frameworks of governance, accountability and public engagement.

3. The Royal Society is now planning to develop a partnership with other science academies and governance institutions to address the governance of geoengineering. The early stages of such a process are already underway, and further details are given in paragraph 23.

Is there a need for international regulation of geoengineering and geoengineering research and if so, what international regulatory mechanisms need to be developed?

(a) Fundamental issues

4. It is important to distinguish between the need for regulation of research and the need for international regulation of deployment. We are of the opinion that some geoengineering techniques will likely require international regulation of some forms of research, and most (but possibly not all) techniques are likely to require international regulation of deployment. There is a very wide range of geoengineering methods, with diverse characteristics, methods of action and potential side eVects; consideration of governance requirements is therefore best done with reference to specific techniques. We do not consider that a blanket requirement for regulation of research is necessary or desirable. Geoengineering techniques can be broadly split into two categories ie Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM) methods, with diVerent features requiring a diVerentiated approach.

5. Carbon Dioxide Removal (CDR) techniques treat the cause of climate change by removing CO_2 from the atmosphere. This can potentially be achieved through a number of diVerent technologies, eg air capture ("artificial trees"), ocean fertilisation, biochar/BECS, and enhanced weathering. Some of these technologies are likely to have a low risk of unintended consequences, but they will all only have a significant impact on global temperatures if applied for many decades. The ecosystem based methods, such as ocean fertilisation, have much greater potential for negative and trans-boundary side eVects. Research on many of these techniques (such as air capture and biochar/BECS) could however be adequately managed by national legislation as their eVects are not trans-boundary, other than via the removal of greenhouse gases (GHGs) from the atmosphere. The same also applies to deployment of these techniques, at least until the levels of GHGs in the atmosphere have been stabilised. Thereafter, international agreement on the levels to which they should be reduced will be required, but this requirement is not imminent.

6. Solar Radiation Management (SRM) techniques are those which reduce the net incoming short-wave solar radiation received by deflecting sunlight, or by increasing the reflectivity of the atmosphere, clouds or Earth's surface. These technologies do not treat the root cause of climate change and would not help to solve associated problems such as ocean acidification. If these techniques were deployed they would need to be sustained for a very long time (several centuries) unless and until atmospheric concentrations of greenhouse gases were reduced. SRM technologies would include space mirrors, aerosols (eg sulphates) in the stratosphere and cloud brightening. The eVects of most SRM techniques (other than "white roofs") would occur on regional to global scales and so would require international regulation.

7. We suggest that the fundamental criteria in relation to governance are whether (and to what extent) the techniques involve;

— trans-boundary eVects (other than the removal of GHGs from the atmosphere);

— dispersal of potentially hazardous materials in the environment; and

— direct intervention in (or major direct side-eVects on) ecosystems.[16]

8. In designing regulatory frameworks the potential for technical and structural reversibility of the technologies should also be considered.

(b) Institutional issues

13. CDR technologies could mostly be adequately controlled by existing national and international institutions and legislation. Many of the technologies are closely related to familiar existing technologies. Air capture technologies are very similar to those of carbon capture and storage; and this is likely to be one of the most environmentally benign technologies. Ocean fertilisation techniques are currently being managed by the London Convention on ocean dumping, under the London Protocol. The Convention of

[16] All methods will of course involve indirect side-eVects on ecosystems via their eVects on climate change.

Biological Diversity has also adopted a decision on ocean fertilisation which is mostly consistent with that of the London Convention. Biochar and BECS face similar regulatory issues to that of biofuels including life cycle analysis, and land use management. Ecosystem impacts of enhanced terrestrial weathering would be contained within national boundaries. Methods of enhanced weathering involving oceanic dispersion of the products would have trans-boundary eVects, but may also be able to be managed under the London Convention.

14. For SRM technologies there are fewer existing institutions that could manage research and development. Land surface albedo modification could be managed under national regulatory frameworks as there are unlikely to be major trans-boundary issues. The oceanic cloud brightening technologies would not fall under national jurisdiction and no existing international institutions have a clear mandate, so modifications and extensions of existing treaties (eg ENMOD) and institutions would be required. Existing treaties governing the atmosphere and space (CLRTAP & OST) would similarly not be adequate to regulate stratospheric aerosols and space mirrors. There is a risk that these methods could be applied by an individual nation or corporation which highlights the need for international regulation for deployment (and in some cases research).

(c) Mechanisms

15. Governance mechanisms should be decided, and where necessary, constructed for technologies that require them, before they are needed in practice.

16. Our report proposed that the Royal Society, along with other scientific institutions, should initially develop a voluntary code of practice to govern scientific research for both SRM and CDR technologies. We are now looking to take forward this work with a number of other science academies and governance institutions (see paragraph 23).

17. Governance mechanisms will be required for some research. Theoretical (modelling) studies and small scale experiments undertaken in the laboratory would not require regulation but we would encourage maximum transparency and international collaboration on such activities. Field tests that are below a level that could have discernable negative consequences should be permitted, but further consideration and international agreement is required to determine how these de minimis levels should be set. International co-operation and public engagement will also be needed to maintain trust in the process. For research where eVects on the environment could potentially have discernable negative consequences, it would be necessary to have governance mechanisms in place to ensure they are undertaken responsibly.

18. An important characteristic of any international mechanisms is that they should be flexible enough to deal with new proposals, and to adapt as our understanding improves of the technologies and their implications.

19. Eventual deployment of any geoengineering technologies will necessarily require involvement of and coordination within the UNFCCC.

How should international regulations be developed collaboratively?

20. Our report proposed that the Royal Society along with other scientific institutions should initially develop a voluntary code of practice to govern scientific research for both SRM and CDR technologies, as necessary. We are now looking to take forward this work with a number of other science academies and governance institutions. We are also continuing to actively engage other organisations in process to include governance specialists, NGOs and participants from a range of geographic locations.

21. We also suggested that a suitable international body (possibly the UN Commission for Sustainable Development) should commission a review of existing international and regional mechanisms to:

- Consider the relevant roles of the following bodies (and any others that we may have overlooked): UNCLOS, LC/LP, CBD, CLRTAP, Montreal Protocol, Outer Space Treaty, Moon Treaty, UNFCCC/KP, ENMOD.
- Identify existing mechanisms that could be used to regulate geoengineering research and deployment activities (if suitably extended as necessary).
- Identify where regulatory gaps exist in relation to geoengineering methods proposed to date, and establish a process for the development of mechanisms to address these gaps.

22. It will be important that the development of any regulatory framework be as open, transparent and inclusive as possible.

Ongoing Royal Society work on geoengineering

23. Following on from our report we are now seeking to facilitate a process of international research and discussion to address the governance of geoengineering in partnership with other prominent scientific and policymaking organisations. The early stages of such a process are already underway, the Royal Society and

the Centre for International Governance Innovation (CIGI) jointly hosted a series of three side events on "The Science, Research and International Governance of Geoengineering" at the COP15 in Copenhagen. These events disseminated the key messages and findings of the Royal Society report, and began engaging a broader audience of international policy-makers and stakeholders in discussions of geoengineering governance. SRM techniques present the greatest potential for near-term political, social and ethical challenges; therefore the envisioned process will focus predominantly on the governance of these techniques.

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