The Regulation of Geoengineering - Science and Technology Committee Contents

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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 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	Medium	Medium	Medium

alkalinity			
Chemical air capture and carbon sequestration	High	Low	Low
Ocean fertilisation	Low	Medium	High
Ocean N and P fertilisation	Medium	Medium	High

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]

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 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]

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]

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 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.

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27 HC (2008-09) 50-I, para 160 Back

28 HC (2008-09) 50-I, paras 163-82 Back

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

30 Q 8 [Dr Blackstock] Back

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

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

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

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

35 HC (2008-09) 50-I, para 174 Back

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

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

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

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

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

41 *As above Back*

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

43 HC (2008-09) 50-I, para 168 Back

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. Back

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

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

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. Back

48 Ev 45 Back

49 *As above Back*

50 Ev 2 [Dr Blackstock], para 10 Back

51 Ev 2 [Dr Blackstock], para 10 Back

52 Ev 50, para 4 Back

53 Ev 33, section 3 Back

54 *As above Back*

55 *As above Back*

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

57 Ev 34, section 3 Back

58 Ev 32, section 1 Back

59 Ev 32, section 2 Back

60 *As above Back*

61 Qq 16-17 Back

62 Q 16 Back

63 Ev 52 [Royal Society], para 4 Back

64 Ev 5, para 5 Back

65 Ev 2, para 10 Back

66 Ev 52, para 5 Back

67 Q 39 Back

68 Ev 21, para 6 Back

69 Q 18 Back

70 Ev 52, para 7 Back

71 Q 20 Back

72 Q 21 Back

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