The Royal Academy of Engineering

Engineering Case Study – Geo-engineering

Response from The Royal Academy of Engineering to the Innovation, Universities, Science and Skills Committee

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Summary

- Geo-engineering is taken to be any activity designed to effect a change in the global climate.

- There are two general approaches: indirect carbon sequestration and reducing solar insolation (the amount of energy absorbed by an area of the earth from the sun).

- All the current proposals have inherent environmental, technical and social risks and none will solve all the problems associated with energy and climate change.

- Geo-engineering is multi-disciplinary in nature, with all of the relevant issues already taught in standard science and engineering courses.

- Current levels of academic research in the UK are low with a similarly low level of interest in UK industry.

- Failure by the international community to effectively tackle climate change has allowed geo-engineering onto the agenda despite the inherent risks.

1. Introduction

1.1. Climate change is one of the defining issues of our time and one that ultimately affects everyone on the planet. To date, the efforts of scientists, engineers and governments have been concentrated on three areas: understanding the climate and how human behaviour influences it; mitigation of global warming by reducing carbon emissions; and adapting to the effects of climate change. Increasingly, scientists are warning that concentrations of greenhouse gases in the atmosphere continue to rise are approaching dangerous tipping points beyond which serious and irreversible damage to the environment will occur. This has led some to propose a fourth strand in our fight against catastrophic climate change, namely geo-engineering.

1.2. "Geo-engineering" is a loosely defined term relating to any engineering that is concerned with large-scale alterations to the earth or its atmosphere. This could include geological alterations, but for the purposes of this response we shall take the term to mean any activity designed to effect a change in the global climate. Alternatives terms such as "geo-environment engineering", "planetary engineering" and "climate engineering" have been coined and it will take some time before the terms and definitions become more widely accepted.

2. Proposed geo-engineering schemes

2.1. Thus far, there are two general approaches to geo-engineering: indirect carbon sequestration and reducing solar insolation. The body of scientific evidence suggests that the climate is changing because of an increase in the levels of greenhouse gases in the atmosphere so the first approach, indirect carbon sequestration, attempts to reduce the levels of these greenhouse gases. The advantage these schemes have is that, in essence, they are simply reversing the problem man has created – namely taking the carbon out that we have put in. There are a number of ways of achieving this such as:

2.1.1. Air Capture: Scientists such as Klaus Lackner[1] and Frank Zeman[2] of Columbia University have put forward a variety of proposals that are designed to extract CO_2 out of the atmosphere by absorbing it in a chemical solvent[3]. Once captured the carbon would then be stored underground in geological depositories. This technology relates closely to the more mainstream carbon capture and storage (CCS) proposals that are being developed to capture CO_2 from coal fired power plants. Capturing it from the power plant where it is much more concentrated is more efficient but a large proportion of CO_2 emitted is from small scale or mobile sources of emissions where direct sequestration is not applicable.

2.1.2. Ocean Fertilisation: By fertilizing certain regions of the upper ocean it is possible to encourage the growth of phytoplankton blooms that absorb CO_2 from their surroundings as they grow. A proportion of this plankton is made up of carbonate skeletons which upon death, sink to the seabed, thus potentially sequestering large amounts of carbon[4]. Trials of this approach have been carried out with varying results. The potential risks of these schemes, however, are great, interfering as they inevitably do in a globally crucial ecosystem.

[1] http://www.seas.columbia.edu/earth/lacknerCV.html
[2] http://www.seas.columbia.edu/earth/faculty/zemanCV.html
[3] http://www.physorg.com/news96732819.html
[4] http://journals.royalsociety.org/content/t6x58746951336m1/

2.2. The second approach, reducing solar insolation, tackles the problem from a different angle. Greenhouse gases cause the global temperature to rise because they trap more of the sun's energy within the atmosphere. If, however, the amount of energy reaching the earth is reduced or more is reflected this could reduce the global temperature. Again there are a variety of methods such as:

2.2.1. Increasing the cloud albedo: By reflecting the sun's energy away from the earth certain types of cloud under certain conditions have the effect of cooling the planet. The effect can be produced by either increasing the amount of cloud, or their longevity, or their whiteness. For example, scientists such as John Latham[5] of the National Center for Atmospheric Research in Boulder Colorado have proposed releasing tiny droplets of sea water in maritime stratocumulus clouds in order to increase their reflectivity and provide a cooling effect.

2.2.2. Sulphate aerosols in the stratosphere: The eruption of certain volcanoes such as Mount Pinatubo in 1991 release large amounts of aerosols into the stratosphere. These have a shading effect leading to a cooling of the planet. Attempts to mimic this effect have been put forward by a number of scientists[6]. The appeal of this scheme is its potential to have an almost immediate effect on global temperatures although, again, the risks are potentially great and irreversible.

2.3. The examples given above represent only a few of the geo-engineering schemes currently proposed. They are not necessarily the only possible technologies and as research into this field continues, more possible methods will be developed. It should, however, be pointed out that, thus far, no geo-engineering technique has been tested to any significant degree and some of them would be best described as purely speculative.

2.4. It must also be remembered that none of these proposals will solve all of our energy and climate change issues. For instance, the schemes designed to reduce the amount of solar insolation would have no effect on the levels of greenhouse gases which are the root cause of the problem. They would not, therefore, stop the acidification of the oceans which may well prove to be as serious a problem as rising temperatures or sea-levels. Furthermore, none of the proposed schemes would have any effect on security of energy supply issues which are likely to become ever more serious as the population increases, countries develop and resources are strained.

3. The role of engineering

3.1. Engineering will clearly play an essential role in developing any of the potential technologies and, more importantly, assessing the risks and impacts associated with their deployment. In reality, the skills required to implement most of the technologies proposed are not unique and could be readily learned in standard engineering courses. Ultimately, engineers are extremely good at solving problems in a wide range of disciplines and the technical difficulties presented by most geo-engineering technologies would not present any particular problems requiring specific engineering based skills sets.

[5] http://www.mmm.ucar.edu/people/latham/
[6] http://journals.royalsociety.org/content/y98775q452737551/

3.2. The question is therefore not whether these technologies could be implemented but whether or not they should be. In order to answer this question a number of other issues must be addressed; issues such as cost, environmental impact, sustainability and risk as well as the broader social and moral considerations.

3.3. Engineering has much to add in these areas, both independently and in conjunction with other disciplines such as climate science and environmental policy. Risk in particular is paramount when considering any attempt to deliberately alter the earth's climate. The potential consequences could be disastrous and a great deal of research, modelling and testing would need to be carried out before moving forward with any geo-engineering scheme. A good understanding of how geo-engineering would affect the complex systems it would inevitably be a part of is also something that engineers have a wealth of experience in dealing with.

4. Education and research

4.1. In educational terms, geo-engineering is very multi disciplinary in nature. The skills needed cover a wide range of topics from the basic science of climate change to technical, economic and environmental issues. All these subjects are already part of standard university courses, and engineering courses in particular, and graduates coming out of these programmes will already be equipped to move into geo-engineering research should they so wish. Thus, at present, it is not deemed necessary for geo-engineering to be introduced into the curriculum as a topic in its own right.

4.2. On a related matter, it has been suggested that geo-engineering might be a good subject with which to engage with young people and encourage them into the engineering profession. As was noted earlier, climate change is a hugely important issue and one that garners a large amount of media attention. Young people appear particularly concerned about what mankind is doing to the planet and keen to work towards finding solutions. Highlighting the crucial role all engineering disciplines have in working out what those solutions might be and, more importantly, actually making them happen, is the key issue and should be more than enough to attract the younger generation. Focussing solely on geo-engineering would be a distraction for what would only ever be a narrow branch of engineering.

4.3. Currently, levels of research into geo-engineering are very low, even in global terms. The Academy itself does not fund any research in this field despite a strong interest in energy and climate change. That is not to say that we would not be open to the possibility of funding research into geo-engineering. Indeed, the Academy recently established a Research Chair in Emerging Technologies, aimed at research into technologies at a pre-competitive stage. This would have been eminently suitable for geo-engineering technologies and in fact, an application focusing on artificial photosynthesis was received, but in this instance it was not successful.

5. Industry and government

5.1. The next stage after education and research would be actual field testing. This could be carried out either by universities – perhaps with support from Government – or by industry. At present, geo-engineering is barely visible to industry in the UK. Given this low level of interest and the inherent high

financial risks involved it is likely that Government funding would be needed in the early stages of testing. However, depending on the particular technology chosen and the relative costs, it is possible that some forward thinking industries might take an interest, although this seems more likely to happen at this stage in the US where geo-engineering has a higher profile.

5.2. A major consideration for industry would be the potential for profit if the technology were to be successful, and indeed, how success could be measured. A globally recognised price for carbon might provide a financial incentive for some of the sequestration technologies and if this was sufficiently high or the technology sufficiently low cost the profits could be considerable. These technologies might also be eligible for the Virgin Earth Challenge prize of $25 million for "…a viable technology which will result in the net removal of anthropogenic, atmospheric greenhouse gases each year for at least ten years without countervailing harmful effects."[7] This prize, announced by Sir Richard Branson and Al Gore in February 2007, could also serve as a driver to industry although the terms and conditions do limit the number of potential winners.

5.3. Neither the price of carbon nor the Virgin Earth Challenge prize is applicable to the technologies designed to reflect solar energy away from the earth. Here, the only measurable effect would be change in temperature either locally or globally. It is possible that a local effect could be measured in a reasonably short time frame and hence provide the potential for a private company to charge for such a service. But, in terms of global changes in temperature, it would be almost impossible to attribute such changes to one specific technology and it is hard to see why any private company would consider such an option without the direct involvement of a government.

5.4. This does, however, highlight one of the main differences between geo-engineering and other methods of dealing with climate change. Mitigation and adaptation require coordinated global action and, as the Kyoto agreement has shown, this requires long and difficult negotiations between the world's governments. Progress is being made politically but it is slow and the effects of climate change are already with us. Mitigation and adaptation can also be expensive (although as the Stern Review pointed out the cost of action now is likely to be a great deal lower than doing nothing and having to pay later). Also, regardless of the efforts being made on reducing greenhouse gas emissions, the inertia of the earth's climate means that we are already tied into decades of warming. With geo-engineering, the effects could be much more immediate and low cost in comparison with current approaches.

5.5. Individual governments could see geo-engineering as an excuse to continue with a business-as-usual approach and would be able to act independently, thus bypassing the sometimes tortuous path to international agreement. A number of international treaties covering the oceans, atmosphere and space would, in theory, prevent such action. However, these are not always adhered to hence the risk, albeit small, of a state acting unilaterally cannot be ignored. It is therefore incumbent on the Government to stay well informed on this issue, particularly in its international relations on climate change and the environment.

[7] http://www.virginearth.com/

6. Conclusion

6.1. It might seem imprudent to even consider geo-engineering given the potentially enormous risks associated with it. However, despite stark warnings from climate scientists over the past decade or more about the dangers of greenhouse gas emissions and concerted government action to curb these emissions very little has actually been achieved. Atmospheric concentrations of carbon dioxide continue to rise and the predictions of climate scientists become ever more pessimistic. Geo-engineering should never been seen as an ultimate solution in any sense. Even if it could help to alleviate the effects of climate change it has nothing to add in terms of security or sustainability of energy supplies. Mitigation and adaptation are still the best long term policies but if time really is running out and geo-engineering was able to provide some breathing space it would be morally remiss of us not to at least consider this option.

6.2. Engineering would play a central role in developing any of these technologies and assessing their potential impact. It would also be crucial in addressing the enormous inherent risks. Even though geo-engineering is still very much in its infancy, a number of scientists and engineers around the globe are working seriously on such technologies and as such, it cannot be ignored. A great deal of research is required before any of the possible geo-engineering schemes should ever be contemplated on a global scale. And even then, they must not be seen as an excuse to continue on a business-as-usual path. That said, it is possible that any research carried out could help further our knowledge of the earth's climate and mankind’s effect on it. Taking on board all these points, geo-engineering is a subject the Government should stay well informed on and treat with caution, being mindful of potential consequences.

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