Geoengineering

From Wikipedia, the free encyclopedia

An oceanic phytoplankton bloom in the South Atlantic Ocean, off the coast of Argentina. Encouraging such blooms with iron fertilization could lock up carbon on the seabed.

The modern concept of **geoengineering** (or **climate engineering**) proposes to deliberately manipulate a planet's climate, typically the Earth's, to counteract the effects of global warming from greenhouse gas emissions. Other uses of the word sometimes occur, meaning geotechnical engineering.

The National Academy of Sciences defined geoengineering as "options that would involve large-scale engineering of our environment in order to combat or counteract the effects of changes in atmospheric chemistry." [1] The Intergovernmental Panel on Climate Change concluded in 2007 that geoengineering options, such as ocean fertilization to remove CO_2 from the atmosphere, remained largely unproven.[2] It was judged that reliable cost estimates for geoengineering had not yet been published.

Geoengineering accompanies mitigation and adaptation to form a three-stranded 'MAG' approach to tackling global warming, notably advocated by the Institution of Mechanical Engineers.[3] Some geoengineering techniques are based on carbon sequestration. These techniques seek to reduce greenhouse gases in the atmosphere directly. These include direct methods (e.g. carbon dioxide air capture) and indirect methods (e.g. ocean iron fertilization). These techniques can be regarded as mitigation of global warming. Alternatively, solar radiation management techniques do not reduce greenhouse gas concentrations, and can only address the warming effects of carbon dioxide and other gases; they cannot address problems such as ocean acidification, which are expected as a result of rising carbon dioxide levels. Examples of proposed solar radiation management techniques include the production of stratospheric sulfur aerosols, which was suggested by Paul Crutzen,[4] space mirrors, and cloud reflectivity enhancement. Most techniques have at least some side effects.

To date, no large-scale geoengineering projects have been undertaken. Some limited tree planting[5] and cool roof[6] projects are already underway, and ocean iron fertilization is at an advanced stage of research, with small-scale research trials and global modelling having been completed.[7] Field research into sulfur aerosols has also started.[8] Some commentators have suggested that consideration of geoengineering presents a moral hazard because it threatens to reduce the political and popular pressure for emissions reduction.[9] Typically, the scientists and engineers proposing geoengineering strategies do not suggest that they are an alternative to emissions control, but rather an accompanying strategy.[10] Reviews of geoengineering techniques have emphasised that they are not substitutes for emission controls and have identified potentially stronger and weaker schemes.[11][12][13]

Contents

Definition

Geoengineering is the idea of applying planetary engineering to Earth. Geoengineering would involve the deliberate modification of Earth's environment on a large scale "to suit human needs and promote habitability".[14] Typically, the term is used to describe proposals to counter the effects of human-induced climate change. However, others define it more narrowly as nature-integrated engineering projects.[15] The term *geoengineering* is distinct from environmental damage and accidental anthropogenic climate change, which are side-effects of human activity, rather than an intended consequence. The global extraction of hydrocarbons from the subsurface using integrated geoscience and engineering technology has been termed 'petroleum geoengineering' as an activity with global impact.[16] Definitions of the term are not universally accepted.[17]

Background

The field is currently experiencing a surge of interest as it has now become broadly accepted that global warming is both real and dangerous. A degree of urgency in efforts to research and implement potential solutions is based on the historic failure to control emissions, and the possibility that tipping points in the Earth's climate system are close at hand.[18] In particular the Arctic shrinkage is causing accelerated regional warming. Rapid action with geoengineering may be necessary. Other tipping points might be avoided by reducing the impact of global warming in order to stifle positive feedback and prevent the resulting accelerated climate change.

The study of geoengineering is a complex discipline, as it requires the collation of knowledge in:

- scientific disciplines including atmospheric chemistry, ecology, meteorology, plant biology
- engineering disciplines including aeronautical engineering, naval architecture, ballistics
- management and control disciplines such as risk management, operational research, cost-benefit analysis

Several notable organisations have recently, or are soon to, investigate geoengineering with a view to evaluating its potential. Notably, NASA,[19] the Royal Society,[20] the Institute of Mechanical Engineers,[21][22] and the UK Parliament,[23] have all held inquiries or contests aimed at discovering and evaluating current knowledge of the subject. The Asilomar International Conference on Climate Intervention Technologies was convened to identify and develop risk reduction guidelines for climate intervention experimentation.[24]

The major environmental organisations such as Friends of the Earth[25] and Greenpeace[26] have typically been reluctant to endorse geoengineering. Some have argued that any public support for geoengineering may weaken the fragile political consensus to reduce greenhouse gas emissions.[27]

Proposed strategies

Several geoengineering strategies have been proposed. The documentaries *Five ways to save the world* and *La temperature grimpe*[28] describe many of the most notable projects. IPCC documents also detail several proposed projects.[29]

Solar radiation management

Main article: Solar radiation management

See also: Stratospheric sulfur aerosols (geoengineering) and Albedo

Solar radiation management[30] (SRM) projects seek to reduce the amount of sunlight hitting the Earth and thus counteract global warming. They do not reduce greenhouse gas concentrations in the atmosphere, and thus do not address problems such as ocean acidification caused by these gases. The phenomenon of global dimming as a side-effect of fossil fuel use is widely known, and is not necessarily a geoengineering technique, also occurring naturally as a result of volcanoes and major forest fires. However, its deliberate manipulation is a tool of the geoengineer.

Solar radiation management projects often have the advantage of speed. While greenhouse gas remediation offers a comprehensive possible solution to climate change, it does not give instant results; for that, solar radiation management is required.

Techniques that fall into this category include:

- Creating stratospheric sulfur aerosols
- Ocean foams[31]
- Cool roof—using pale-coloured roofing and paving materials
- Cloud reflectivity enhancement – using fine sea water spray to whiten clouds and increase cloud reflectivity.
- Space sunshade—obstructing solar radiation with space-based mirrors or other structures
- Cloud seeding of cirrus clouds, possibly using airliners.[32]

Greenhouse gas remediation

Main articles: Greenhouse gas remediation and Carbon sequestration

Greenhouse gas remediation projects seek to remove greenhouse gases from the atmosphere, and thus tackle the root cause of global warming. They either directly remove greenhouse gases, or alternatively seek to influence natural processes to remove greenhouse gases indirectly. These projects offer a comprehensive solution to the problem of excess greenhouse gases in the atmosphere, but they will take many years to work fully. Many projects overlap with carbon capture and storage and carbon sequestration projects, and may not be considered to be geoengineering by all commentators. Techniques in this category include:

- Ocean nourishment including Iron fertilisation of the oceans
- Creating biochar (anaerobic charcoal) and burying it to create terra preta
- Bio-energy with carbon capture and storage
- Carbon air capture to remove carbon dioxide from ambient air

Arctic geoengineering

Main article: Arctic geoengineering

Various hydrological geoengineering projects aim to change the climate without directly or indirectly removing greenhouse gases, or directly influencing solar radiation. These principally act by limiting Arctic sea ice loss. Keeping the Arctic ice is seen by many commentators as vital,[33] due to its role in the planet's albedo and in keeping methane, which is an important greenhouse gas, locked up in permafrost.[34]

Heat transport

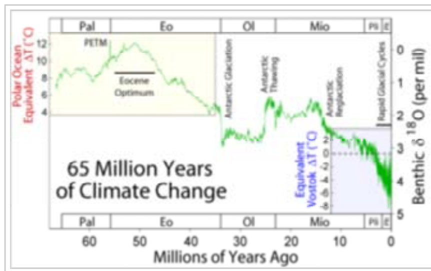
The use of vertical ocean pipes to mix cooler deep water and warmer surface water has been proposed. This technology has also been suggested for the disruption of hurricanes by Bill Gates and others in a recent patent application.[35][36] Modification of hurricanes may be considered weather modification rather than geoengineering, depending on the definition used.

Justification

The use of geoengineering to tackle climate change is advocated for several specific reasons:

Tipping points and positive feedback

It is argued that climate change has already, or is soon to have passed one or more tipping points [18] where aspects of the climate system may 'tip' from one stable state to another stable state, much like a glass tipping over. When the new stable state is reached, it may trigger or accelerate warming positive feedback effects,[37] such as the collapse of Arctic sea ice triggering the release of methane from permafrost in Siberia.[38][39] The "nightmare scenario" is that a domino effect will occur, with successive parts of the climate system tipping one after the other, with each change being caused by the previous one and causing the next one. Such a situation will lead to spiralling and potentially sudden climate change.



Climate change during the last 65 million years. The Paleocene–Eocene Thermal Maximum is labelled PETM.

The precise identity of such "tipping points" is not clear, with scientists taking differing views on whether specific systems are capable of "tipping" and the point at which this "tipping" will occur. [40] An example of a previous tipping point is that which preceded the rapid warming leading up to the Paleocene–Eocene Thermal Maximum. Once the tipping point is reached, cuts in greenhouse gas emissions will not be able to reverse the change. Depending on the precise nature of the individual system that "tips", positive feedbacks may occur, with warming causing more warming, which causes yet more warming—a runaway global warming event.[41] Therefore, some commentators suggest that more conservative use of resources is not enough to mitigate global warming. Even if all greenhouse emissions suddenly came to a complete halt, the world would continue to be affected for centuries,[42] and further warming may occur due to positive feedback. Conservation of resources and reduction of greenhouse emissions, used in conjunction with geoengineering, are therefore considered a viable option.[43][44][45] Geoengineering offers the hope of temporarily reversing some aspects of climate change and allowing the natural climate to be substantially preserved whilst greenhouse gas emissions are brought under control and removed from the atmosphere by natural or artificial processes.

Precautionary principle

Main article: Precautionary principle

Bearing in mind the threats from climate change, it can be argued that attempting geoengineering represents a lesser risk than not pursuing such strategies. While the understanding of geoengineering techniques is limited, the risks of global warming are at least partially understood, and are severe.[46]

Costs

Some geoengineering techniques, such as the use of pale-coloured materials for roofing and paving, can be achieved at little or no cost, and may even offer a financial payback.[47] IPCC (2007) concluded that reliable cost estimates for geoengineering options had not been published.[2] This finding was based on medium agreement in the literature and limited evidence.

Ethics and Responsibility

Climate engineering would represent a large-scale, intentional effort to modify the environment. It differs from inadvertent climate change through activities such as burning fossil fuels, cutting down forests and many others. Intentional climate change is viewed very differently from a moral standpoint as it would involve a planned and direct insertion of particles (for example sulphate aerosols) into the atmosphere.[48] This creates a moral hazard and raises questions of whether we as humans have the right to change the climate. Following on from this, is the question of what is the ‘right’ climate to live in. According to some scientists, regions such as Antarctica and northern parts of Canada would benefit from global warming as this would create opportunities for agriculture and other economical benefits.[49]

Geoengineering techniques to cool the planet for the time being have not been a popular and dynamic idea because of its inability to solve a multitude of other issues apart from lowering global temperatures.[50] This is the main reason that scientists have kept from publishing articles regarding this topic. The fear is that with the knowledge of the possible option of geoengineering, this reliance will reduce incentives for industries and even consumers to take measures to reduce emissions of greenhouse gases. It is argued that geoengineering could be used to ‘buy time’ before drastic climate change happens, allowing mitigation and adaptation measures more time to be implemented and work.[51] But the opposition points out that there are issues regarding the interference this causes with actual efforts for climate change, creating an unnecessary distraction.

Political viability

It has been argued that regardless of the economic, scientific and technical aspects, the difficulty of achieving concerted political action on climate change requires other approaches.[52] Those arguing political expediency say the difficulty of achieving meaningful emissions cuts [53] and the effective failure of the Kyoto Protocol demonstrate the practical difficulties of achieving carbon dioxide emissions reduction by the agreement of the international community.[54] However, others point to support for geoengineering proposals among think tanks with a history of climate change skepticism and opposition to emissions reductions as evidence that the prospect of geoengineering is itself already politicized and being promoted as part of an argument against the need for (and viability of) emissions reductions; that, rather than geoengineering being a solution to the difficulties of emissions reductions, the prospect of geoengineering is being used as part of an argument to stall emissions reductions in the first place.[55]

Geoenginering poses several challenges in the context of governance because of issues of power and jurisdiction.[56] Geoengineering as a climate change solution differs from other mitigation and adaptation strategies. Unlike a carbon trading system that would be focused on participation from multiple parties along with transparency, monitoring measures and compliance procedures; this is not necessarily required by geoengineering. Bengtsson[57] (2006) argues that “the artificial release of sulphate aerosols is a commitment of at least several hundred years”. This highlights the importance for a political framework that is sustainable enough to contain a multilateral commitment over such a long period and yet is flexible as the techniques innovate through time. There are many controversies surrounding this topic and hence, geoengineering has been made into a very political issue. Most discussions and debates are not about which geoengineering technique is better than the other, or which one is more economically and socially feasible. Discussions are broadly on who will have control over the deployment of geoengineering and under what governance regime the deployment can be monitored and supervised. This is especially important due to the regional variability of the effects of many geoengineering techniques, benefiting some countries while damaging others. The challenge posed by geoengineering is not how to get countries to do it. It is to address the fundamental question of who should decide whether and how geoengineering should be attempted – a problem of governance.[58]

Risks and criticisms

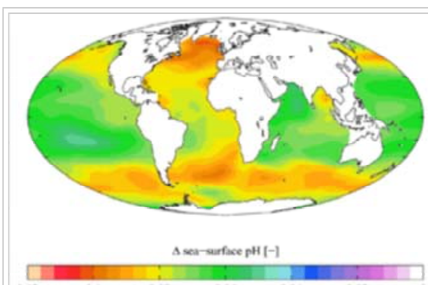
Various criticisms have been made of geoengineering.[59] However, the existence of criticism should not be taken to mean that those raising it are opposed to a particular technique, but rather that they are pointing out a potential disadvantage or downside which may need to be monitored or controlled, or may alternatively weigh against a particular technique. Some commentators appear fundamentally opposed, however. Individuals such as Raymond Pierrehumbert have called for a moratorium on geoengineering techniques.[60][61]

Ineffectiveness

The effectiveness of the schemes proposed may fall short of predictions. In ocean iron fertilization, for example, the amount of carbon dioxide removed from the atmosphere may be much lower than predicted, as carbon taken up by plankton may be released back into the atmosphere from dead plankton, rather than being carried to the bottom of the sea and sequestered.[62]

Incomplete solution to CO_2 emissions

Techniques that do not remove greenhouse gases from the atmosphere may control global warming, but do not reduce other effects from these gases, such as ocean acidification.[63] While not an argument against geoengineering *per se*, this is an argument against reliance on geoengineering to the exclusion of greenhouse gas reduction.



Change in sea surface pH caused by anthropogenic CO_2 between the 1700s and the 1990s. This ocean acidification will still be a major problem unless atmospheric CO_2 is reduced.

Control and predictability problems

The full effects of various geoengineering schemes are not well understood.[64] Matthews et al.[65] compared geoengineering to a number of previous environmental interventions and concluded that "Given our current level of understanding of the climate system, it is likely that the result of at least some geoengineering efforts would follow previous ecological examples where increased human intervention has led to an overall increase in negative environmental consequences."

Performance of the systems may become ineffective, unpredictable or unstable as a result of external events, such as volcanic eruptions, phytoplankton blooms, El Niño, solar flares, etc., potentially leading to profound and unpredictable disruption to the climate system.

It may be difficult to predict the effectiveness of projects,[66] with models of techniques giving widely varying results.[67] In the instances of systems which involve tipping points, this may result in irreversible effects. Climate modelling is far from an exact science even when applied to comparatively well-understood natural climate systems, and it is made more complex by the need to understand novel and unnatural processes which by definition lack relevant observation data.[68]

Side effects

The techniques themselves may cause significant foreseen or unforeseen harm. For example, the use of reflective balloons may result in significant litter,[69] which may be harmful to wildlife.

Ozone depletion is a risk of some geoengineering techniques, notably those involving sulfur delivery into the stratosphere.[70]

The active nature of geoengineering may in some cases create a clear division between winners and losers. Most of the proposed interventions are regional, such as albedo modification in the Arctic. Necessarily, such interventions compel those in the affected regions to tolerate the effects of geoengineering for the supposed benefit of the global climate.[71]

There may be unintended climatic consequences, such as changes to the hydrological cycle[72] including droughts[73] or floods, caused by the geoengineering techniques, but possibly not predicted by the models used to plan them.[74] Such effects may be cumulative or chaotic in nature, making prediction and control very difficult.[75]

Unreliable systems

The performance of the interventions may be inconsistent due to mechanical failure, non-availability of consumables or funding problems.

The geoengineering techniques would, in many instances, be vulnerable to being switched off or deliberately destroyed. As examples, cloud making ships could be switched off or sunk and space mirrors could be tilted to make them useless. Anyone capable of exerting such power may seek to abuse it for commercial gain, military advantage or simple terrorism.

Weaponisation

Geoengineering research began as a war tactic in the 1940s for the US and the Soviet Union during the Cold War.[49] During the Vietnam War, the US used geoengineering to flood certain areas. Then in 1976, 85 countries signed the U.N. Convention on the Prohibition of Military of Any Other Hostile Use of Environmental Modification Techniques.[56]

The Environmental Modification Convention generally prohibits weaponising geoengineering techniques. However, this does not eliminate the risk. Geoengineering techniques may serve as weapons of mass destruction, creating droughts or famines designed to destroy or disable an enemy.[76] They could also be used simply to make battlefield conditions more favourable to one side or the other in a war[77] (such as in Operation Popeye). For example, laser-guided weapons are confounded by clouds, and thus switching off cloud machines would favour forces using such weapons, and switching them on would favour ground forces defending against them.[78]

Whilst laws or treaties may prevent the manipulation of the climate as a weapon of war,[79] it could be argued that geoengineering is itself a manipulation, and thus destroying or disabling the geoengineering structures is not prohibited. A new legal framework may be necessary in the event that large-scale geoengineering becomes established.

Carnegie's Ken Caldeira said, "It will make it harder to achieve broad consensus on developing and governing these technologies if there is suspicion that gaining military advantage is an underlying motivation for its development..."[80]

Effect on sunlight, sky and clouds

Managing solar radiation using aerosols or cloud cover will change the ratio between direct and indirect solar radiation. This may affect plant life[81] and solar energy.[82] There will be a significant effect on the appearance of the sky from aerosol projects, notably a hazing of blue skies and a change in the appearance of sunsets.[83] Aerosols may affect the formation of clouds, especially cirrus clouds.[84]

Moral hazard

The existence of such techniques may reduce the political and social impetus to reduce carbon emissions.[85]

Other criticism comes from those who see geoengineering projects as reacting to the symptoms of global warming rather than addressing the real causes of climate change. Because geoengineering is a form of controlling the risks associated with global warming, it leads to a moral hazard problem. The problem is that knowledge that geoengineering is possible could lead to climate impacts seeming less fearsome, which could in turn lead to a weaker commitment to reducing greenhouse gas emissions.[86]

Lack of global control

Geoengineering opens up various political and economic issues. David Keith argues that the cost of geoengineering the Earth is within the realm of small countries, large corporations, or even very wealthy individuals.[87] Steve Rayner agrees that not all geoengineering possibilities are expensive, and that some, such as ocean iron fertilisation, are within the reach of very wealthy individuals, calling them a "Greenfinger" (after the fictional Goldfinger).[88][89] David Victor suggests that geoengineering is within the reach of any individual who has a small fraction of the bank account of Bill Gates, who takes it upon him or her self to be the "self-appointed protector of the planet".[90]

This effectively eliminates any control over who gets to decide when to cool the Earth and how often this should be done.[87] The resulting power would be enormous, and could not necessarily be readily controlled by legal, political or regulatory systems.[88] These legal and regulatory systems may themselves be far less powerful than the geoengineers controlling the climate become.

It is quite feasible for carbon offsetting firms to set up unregulated, unsupervised and dangerous geoengineering projects. This may be done in order to sell carbon credits to individuals and firms.

Geoengineering schemes have the potential to cause significant environmental damage, and may even end up releasing further greenhouse gases into the atmosphere.[91] Opposition to some early schemes has been intense, with respected environmental groups campaigning against them.[92]

Rapid warming if stopped

If solar radiation management were to abruptly stop, the climate would rapidly warm.[93] This would cause a sudden rise in global temperatures towards levels which would have existed without the use of the geoengineering technique. The rapid rise in temperature may lead to more severe consequences than a gradual rise of the same magnitude.[93]

Implementation issues

There is no general consensus that geoengineering is safe, appropriate or effective, for the reasons listed above. The issue of moral hazard means that many environmental groups and campaigners are reluctant to advocate geoengineering for fear of reducing the imperative to cut greenhouse gas emissions.[94] Other environmentalists see calls for geoengineering as part of an explicit strategy to delay emissions reductions on the part of those with connections to coal and oil industries.[95]

All proposed geoengineering techniques require implementation on a relatively large scale, in order to make a significant difference to the Earth's climate. The least costly schemes are budgeted at a cost of millions,[96] with many more complex schemes such as space sunshade costing far more.

Many techniques, again such as space sunshade, require a complex technical development process before they are ready to be implemented. There is no clear institutional mechanism for handling this research and development process. As a result, many promising techniques do not have the engineering development or experimental evidence to determine their feasibility or efficacy at present.

Once a technique has been developed and tested, its implementation is still likely to be difficult. Climate change is by nature a global problem, and therefore no one institution, company or government is responsible for it. The substantial costs of most geoengineering techniques therefore cannot currently be apportioned. Roll-out of such technologies is therefore likely to be delayed until these issues can be resolved. A notable exception is the use of small albedo manipulation projects, known as *cool roof*, in which the colour of roofing or paving surfaces can be manipulated to reflect solar radiation back into space. These can be, and are, implemented by individuals, companies and governments without controversy.[97]

Due to the radical changes caused by geoengineering interventions, legal issues are also an impediment to implementation. The changes resulting from geoengineering necessarily benefit some people and disadvantage others. There may therefore be legal challenges to the implementation of geoengineering techniques by those adversely affected by them.[98]

Evaluation of geoengineering

Few field experiments in geoengineering have been carried out. Most of what is known about the suggested techniques is based on small-scale trials and from simulations of global climate models and other computer modelling techniques. Some geoengineering schemes employ methods that have analogues in natural phenomena such as stratospheric sulfur aerosols and cloud condensation nuclei. As such, studies about the efficacy of these schemes can draw on information already available from other research, such as that following the 1991 eruption of Mount Pinatubo. However, comparative evaluation of the relative merits of each technology is complicated, especially given modelling uncertainties and the early stage of engineering development of many geoengineering schemes.[99]

In a 2009 review study, Lenton and Vaughan evaluated a range of geoengineering schemes from those that sequester CO_2 from the atmosphere and decrease longwave radiation trapping, to those that decrease the Earth's receipt of shortwave radiation.[11] In order to permit a comparison of disparate techniques, they used a common evaluation for each scheme based on its effect on net radiative forcing. As such, the review examined the scientific plausibility of schemes rather than the practical considerations such as engineering feasibility or economic cost. Lenton and Vaughan found that "[air] capture and storage shows the greatest potential, combined with afforestation, reforestation and bio-char production", and noted that "other suggestions that have received considerable media attention, in particular “ocean pipes” appear to be ineffective".[11] They concluded that "[climate] geoengineering is best considered as a potential complement to the mitigation of CO_2 emissions, rather than as an alternative to it".[11]

Reports into geoengineering have also been published in the United Kingdom by the Institution of Mechanical Engineers[12] and the Royal Society.[13] The IMechE report examined a small subset of proposed schemes (air capture, urban albedo and algal-based CO_2 capture schemes), and its main conclusions were that geoengineering should be researched and trialled at the small scale alongside a wider decarbonisation of the economy.[12]

The Royal Society review examined a wide range of geoengineering schemes and evaluated them in terms of effectiveness, affordability, timeliness and safety (assigning qualitative estimates in each assessment). Similarly to Lenton and Vaughan,[11] the report divided schemes into "carbon dioxide removal" (CDR) and "solar radiation management" (SRM) approaches that respectively address longwave and shortwave radiation. The key recommendations of the report were that "Parties to the UNFCCC should make increased efforts towards mitigating and adapting to climate change, and in particular to agreeing to global emissions reductions", and that "[nothing] now known about geoengineering options gives any reason to diminish these efforts".[13] Nonetheless, the report also recommended that "research and development of geoengineering options should be undertaken to investigate whether low risk methods can be made available if it becomes necessary to reduce the rate of warming this century".[13]

See also

- List of geoengineering topics
- List of proposed geoengineering projects
- Convention on Biological Diversity
- ETC Group
- Macro-engineering
- Megascale engineering
- Terraforming
- Virgin Earth Challenge
- Planetary Engineering
- Weather control
- Carbon sink
- Vertical farming

References

1. ^ Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base (http://books.nap.edu/openbook.php?record_id=1605&page=433) (1992), Committee on Science, Engineering, and Public Policy (COSEPUP)
2. ^ *a b* IPCC (2007). "C. Mitigation in the short and medium term (until 2030)." (http://www.ipcc.ch/publications_and_data/ar4/wg3/en/spmsspm-c.html) . In B. Metz *et al.*. *Summary for Policymakers.*. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Print version: Cambridge University Press, Cambridge, U.K., and New York, N.Y., U.S.A.. This version: IPCC website. ISBN 9780521880114. http://www.ipcc.ch/publications_and_data/ar4/wg3/en/spmsspm-c.html. Retrieved 2010-05-15.
3. ^ Fox, T (November 2009) (pdf). *Climate change have we lost the battle* (http://www.imeche.org/Libraries/Key_Themes/IMechE_MAG_Report.sflb.ashx) . Institution of Mechanical Engineers. http://www.imeche.org/Libraries/Key_Themes/IMechE_MAG_Report.sflb.ashx. Retrieved 2011-06-14.
4. ^ Crutzen, P. J. (2006). "Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?" (http://www.springerlink.com/content/t1vn75m458373h63/fulltext.pdf) . *Climatic Change* **77**: 211–220. doi:10.1007/s10584-006-9101-y (http://dx.doi.org/10.1007%2Fs10584-006-9101-y) . http://www.springerlink.com/content/t1vn75m458373h63/fulltext.pdf.
5. ^ Fearnside, P. (1999). "Forests and global warming mitigation in Brazil: opportunities in the Brazilian forest sector for responses to global warming under the “clean development mechanism”". *Biomass and Bioenergy* **16** (3): 171–189. doi:10.1016/S0961-9534(98)00071-3 (http://dx.doi.org/10.1016%2FS0961-9534%2898%2900071-3) .
6. ^ "Cool Roofs and Title 24" (http://www.energy.ca.gov/title24/coolroofs/) . The California Energy Commission. http://www.energy.ca.gov/title24/coolroofs/. Retrieved 2009-02-25.
7. ^ Boyd, P.W.; *et al.* (2007). "Mesoscale Iron Enrichment Experiments 1993–2005: Synthesis and Future Directions". *Science* **315** (5812): 612–617. doi:10.1126/science.1131669 (http://dx.doi.org/10.1126%2Fscience.1131669) . PMID 17272712 (http://www.ncbi.nlm.nih.gov/pubmed/17272712) .
8. ^ Izrael, Y. A.; Zakharov, V. M.; Petrov, N. N.; Ryaboshapko, A. G.; Ivanov, V. N.; Savchenko, A. V.; Andreev, Y. V.; Puzov, Y. A. et al. (2009). "Field experiment on studying solar radiation passing through aerosol layers". *Russian Meteorology and Hydrology* **34**: 265. doi:10.3103/S106837390905001X (http://dx.doi.org/10.3103%2FS106837390905001X) .
9. ^ "Geoengineering" (http://www.irgc.org/geoengineering) . International Risk Governance Council. 2009. http://www.irgc.org/geoengineering. Retrieved 2009-10-07.
10. ^ Wigley, T. M. L. (Oct 2006). "A combined mitigation/geoengineering approach to climate stabilization". *Science* **314** (5798): 452–454. Bibcode 2006Sci...314..452W (http://adsabs.harvard.edu/abs/2006Sci...314..452W) . doi:10.1126/science.1131728 (http://dx.doi.org/10.1126%2Fscience.1131728) . ISSN 0036-8075 (http://www.worldcat.org/issn/0036-8075) . PMID 16973840 (http://www.ncbi.nlm.nih.gov/pubmed/16973840) .
11. ^ *a b c d e* Lenton, T.M.; Vaughan, N.E. (2009). "The radiative forcing potential of different climate geoengineering options" (http://www.atmos-chem-phys.net/9/5539/2009/acp-9-5539-2009.html) . *Atmos. Chem. Phys.* **9** (15): 5539–5561. doi:10.5194/acp-9-5539-2009 (http://dx.doi.org/10.5194%2Facp-9-5539-2009) . http://www.atmos-chem-phys.net/9/5539/2009/acp-9-5539-2009.html.
12. ^ *a b c* "Geoengineering - Giving us time to act?" (http://www.imeche.org/Libraries/Key_Themes/IMechEGeoengineeringReport.sflb.ashx) . I Mech E. http://www.imeche.org/Libraries/Key_Themes/IMechEGeoengineeringReport.sflb.ashx. Retrieved 2011-03-12.
13. ^ *a b c d* "Geoengineering the climate" (http://royalsociety.org/WorkArea/DownloadAsset.aspx?id=10768) . The Royal Society. 2009. http://royalsociety.org/WorkArea/DownloadAsset.aspx?id=10768. Retrieved 2009-09-02.
14. ^ "a controversial field known as geoengineering, which means rearranging the Earth's environment on a large scale to suit human needs and promote habitability" How to Cool a Planet (Maybe) (http://www.nytimes.com/2006/06/27/science/earth/27cool.html?ex=1151985600&en=ca9e39a26d7e4ece&ei=5065&partner=MYWAY) New York Times - June 27, 2006
15. ^ "UC Berkeley Department of Civil and Environmental Engineering" (http://www.ce.berkeley.edu/geo/index.php) . http://www.ce.berkeley.edu/geo/index.php. Retrieved 2007-05-05.
16. ^ Corbett, P., 2009, Petroleum Geoengineering - Integration of Static and Dynamic models, Society of Exploration Geophysicists/European Association of Geoscientist and Engineers,100p, ISBN 978-1-56080-153-5
17. ^ Schelling, T. C. (1996). "The economic diplomacy of geoengineering". *Climatic Change* **33**: 303–307. doi:10.1007/BF00142578 (http://dx.doi.org/10.1007%2FBF00142578) .
18. ^ *a b* Lenton, T. M.; Held, H.; Kriegler, E.; Hall, J. W.; Lucht, W.; Rahmstorf, S.; Schellnhuber, H. J. (Feb 2008). "Tipping elements in the Earth's climate system" (http://www.pnas.org/cgi/pmidlookup?view=long&pmid=18258748) (Free full text). *Proceedings of the National Academy of Sciences* **105** (6): 1786–1793. Bibcode 2008PNAS..105.1786L (http://adsabs.harvard.edu/abs/2008PNAS..105.1786L) . doi:10.1073/pnas.0705414105 (http://dx.doi.org/10.1073%2Fpnas.0705414105) . PMC 2538841 (http://www.pubmedcentral.gov/articlerender.fcgi?tool=pmcentrez&artid=2538841) . PMID 18258748 (http://www.ncbi.nlm.nih.gov/pubmed/18258748) . http://www.pnas.org/cgi/pmidlookup?view=long&pmid=18258748.

19. ^ "Workshop on managing solar radiation" (http://event.arc.nasa.gov/main/home/reports/SolarRadiationCP.pdf) . NASA. April 2007. http://event.arc.nasa.gov/main/home/reports/SolarRadiationCP.pdf. Retrieved 2009-05-23.
20. ^ The Royal Society (28 August 2009). "Stop emitting CO2 or geoengineering could be our only hope" (http://royalsociety.org/Stop-emitting-CO2-or-geoengineering-could-be-our-only-hope/) . Press release. http://royalsociety.org/Stop-emitting-CO2-or-geoengineering-could-be-our-only-hope/. Retrieved 14 June 2011.
21. ^ "Hot ideas for cooling the planet" (http://www.imeche.org/about/keythemes/environment/Climate+Change/Cooling+the+Planet+competition/Hot+Ideas+for+Cooling+the+Planet.htm) . IMechE. http://www.imeche.org/about/keythemes/environment/Climate+Change/Cooling+the+Planet+competition/Hot+Ideas+for+Cooling+the+Planet.htm. Retrieved 2009-05-23.
22. ^ "Example geoengineering methods" (http://www.imeche.org/about/keythemes/environment/Climate+Change/Cooling+the+Planet+competition/Geo-engineering+methods.htm) . IMechE. http://www.imeche.org/about/keythemes/environment/Climate+Change/Cooling+the+Planet+competition/Geo-engineering+methods.htm. Retrieved 2009-05-23.
23. ^ "Geo-engineering research" (http://www.parliament.uk/documents/upload/postpn327.pdf) . *Postnote*. Parliamentary Office of Science and Technology. March 2009. http://www.parliament.uk/documents/upload/postpn327.pdf. Retrieved 2009-05-23.
24. ^ http://climateresponsefund.org/index.php?option=com_content&view=article&id=137&Itemid=81
25. ^ Adam, David (1 September 2008). "Extreme and risky action the only way to tackle global warming, say scientists" (http://www.guardian.co.uk/environment/2008/sep/01/climatechange.scienceofclimatechange2) . *Guardian Newspaper* (London). http://www.guardian.co.uk/environment/2008/sep/01/climatechange.scienceofclimatechange2. Retrieved 2009-05-23.
26. ^ Parr, Doug (1/9/8). "Geo-engineering is no solution to climate change" (http://www.guardian.co.uk/environment/2008/sep/01/climatechange.scienceofclimatechange1) . *Guardian Newspaper* (London). http://www.guardian.co.uk/environment/2008/sep/01/climatechange.scienceofclimatechange1. Retrieved 2009-05-23.
27. ^ http://www.21stcenturychallenges.org/focus/geo-engineering/
28. ^ La temperature grimpe-documentary (http://www.arte.tv/fr/histoire-societe/Rechauffement-climatique/A-l-antenne/1922676.html)
29. ^ http://www.grida.no/publications/other/ipcc_tar/?src=/CLIMATE/IPCC_TAR/wg3/176.htm
30. ^ http://thehardlook.typepad.com/thehardlook/files/schnare_supplemental_testimony_a_framework_for_geoengineering.pdf
31. ^ Evans, J.; Stride, E.; Edirisinghe, M.; Andrews, D.; Simons, R. (2010). "Can oceanic foams limit global warming?". *Climate Research* **42** (2): 155–160. doi:10.3354/cr00885 (http://dx.doi.org/10.3354%2Fcr00885) .
32. ^ Mitchell, D. L.; Finnegan, W. (2009). "Modification of cirrus clouds to reduce global warming". *Environmental Research Letters* **4** (4): 045102. Bibcode 2009ERL.....4d5102M (http://adsabs.harvard.edu/abs/2009ERL.....4d5102M) . doi:10.1088/1748-9326/4/4/045102 (http://dx.doi.org/10.1088%2F1748-9326%2F4%2F4%2F045102) .
33. ^ http://www.cleverclimate.org/climate/25/motivation/
34. ^ Zimov, S. A., et al. (2006), CLIMATE CHANGE: Permafrost and the Global Carbon Budget, Science, 312(5780), 1612-1613.
35. ^ US Patent Application No. 20090177569, titled: “Water alteration structure risk management or ecological alteration management systems and methods” US Patent Application No. 20090175685, titled: “Water alteration structure movement method and system” US Patent Application No. 20090173801, titled: “Water alteration structure and system having below surface valves or wave reflectors” US Patent Application No. 20090173404, titled: “Water alteration structure and system” US Patent Application No. 20090173386
36. ^ Vergano, Dan (2009-07-15). "Hurricane-calming technology? Bill Gates has a plan" (http://www.usatoday.com/weather/research/2009-07-15-gates-hurricanes_N.htm) . *USA Today*. http://www.usatoday.com/weather/research/2009-07-15-gates-hurricanes_N.htm. Retrieved 2009-07-23.
37. ^ http://www.energybulletin.net/node/10322
38. ^ Connor, Steve (2008-09-23). "The methane time bomb" (http://www.independent.co.uk/environment/climate-change/exclusive-the-methane-time-bomb-938932.html) . *The Independent* (London). http://www.independent.co.uk/environment/climate-change/exclusive-the-methane-time-bomb-938932.html. Retrieved 2010-03-30.
39. ^ Highfield, Roger (2007-03-16). "Arctic ice hits 'tipping point'" (http://www.telegraph.co.uk/scienceandtechnology/science/sciencenews/3352065/Arctic-ice-hits-'tipping-point'.html) . *The Daily Telegraph* (London). http://www.telegraph.co.uk/scienceandtechnology/science/sciencenews/3352065/Arctic-ice-hits-'tipping-point'.html. Retrieved 2010-03-30.
40. ^ http://researchpages.net/ESMG/people/tim-lenton/tipping-points/
41. ^ Jha, Alok (2006-09-04). "Energy review ignores climate change 'tipping point'" (http://www.guardian.co.uk/environment/2006/sep/04/greenpolitics.science) . *The Guardian* (London). http://www.guardian.co.uk/environment/2006/sep/04/greenpolitics.science. Retrieved 2010-03-30.
42. ^ http://cbs2.com/national/Global.Warming.Paris.2.279083.html
43. ^ Brown, Paul (2006-10-18). "How close is runaway climate change?" (http://www.guardian.co.uk/environment/2006/oct/18/bookextracts.books) . *The Guardian* (London). http://www.guardian.co.uk/environment/2006/oct/18/bookextracts.books. Retrieved 2010-03-30.
44. ^ http://ipsnews.net/news.asp?idnews=42662
45. ^ Arthur, Charles (2001-01-23). "Global warming now 'unstoppable', scientists warn" (http://www.independent.co.uk/news/science/global-warming-now-unstoppable-scientists-warn-702979.html) . *The Independent* (London). http://www.independent.co.uk/news/science/global-warming-now-unstoppable-scientists-warn-702979.html. Retrieved 2010-03-30.
46. ^ http://unfccc.int/resource/conv/conv_005.html
47. ^ http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm
48. ^ Bodansky, D. (1996) May we engineer the climate? Climatic Change 33: 309-321
49. ^ ***a b*** Victor, D. G., M. G. Morgan, J. Apt, J. Steinbruner, K. Ricke (2009) The Geoengineering Option: A last resort against global warming? Foreign Affairs March/April 2009
50. ^ Michaelson, J. (1998) ‘Geoengineering: a climate change Manhattan project’. Stanford Environmental Law Journal, Stanford CA, January 1998
51. ^ Gardiner, S. M. Is “Arming the Future” with geoengineering really the lesser evil? Some doubts about the ethics of intentionally manipulating the climate system in Gardiner, S., S. Caney, D. Jamieson & H. Shue (eds) Climate Ethics: Essential Readings. Oxford University Press, 2010, 284-314
52. ^ Appell, David (2008-12-12). "Let's get real on the environment" (http://www.guardian.co.uk/commentisfree/cifamerica/2008/dec/12/environment-climate-change-poznan) . *The Guardian* (London). http://www.guardian.co.uk/commentisfree/cifamerica/2008/dec/12/environment-climate-change-poznan. Retrieved 2010-03-30.
53. ^ Caldeira, Ken (2007-10-24). "How to Cool the Globe" (http://www.nytimes.com/2007/10/24/opinion/24caldiera.html?_r=2&ref=opinion&oref=slogin) . *The New York Times*. http://www.nytimes.com/2007/10/24/opinion/24caldiera.html?_r=2&ref=opinion&oref=slogin. Retrieved 2010-03-30.
54. ^ Adam, David (2008-09-01). "Extreme and risky action the only way to tackle global warming, say scientists" (http://www.guardian.co.uk/environment/2008/sep/01/climatechange.scienceofclimatechange2) . *The Guardian* (London). http://www.guardian.co.uk/environment/2008/sep/01/climatechange.scienceofclimatechange2. Retrieved 2010-03-30.
55. ^ http://www.worldchanging.com/archives/009784.html
56. ^ ***a b*** Robock, A., A. Marquardt, B. Kravitz, and G. Stenchikov (2009). Benefits, Risks, and costs of stratospheric geoengineering, Geophysical Research Letters, 36, D19703, doi:10.1029/2009GL039209
57. ^ Bengtsson, L. (2006) ‘Geo-engineering to confine climate change: is it at all feasible?’ Climatic Change 77: 229-234
58. ^ Barrett, S (2007) Why cooperate? The incentive to supply global public goods. Oxford University Press, Oxford

59. ^ "AMS Policy Statement on Geoengineering the Climate System" (http://www.ametsoc.org/policy/2009geoengineeringclimate_amsstatement.pdf) . American Meteorological Society. http://www.ametsoc.org/policy/2009geoengineeringclimate_amsstatement.pdf. Retrieved 2009-07-22.
60. ^ http://www.worldchanging.com/archives/008091.html
61. ^ http://features.csmonitor.com/environment/2008/07/16/can-we-engineer-a-cooler-earth/
62. ^ Seasonal rhythms of net primary production and particulate organic carbon flux to depth describe the efficiency of biological pump in the global ocean", Journal of Geophysical Research, vol. 112, C10011, doi:10.1029/2006JC003706
63. ^ http://infohost.nmt.edu/~chem/wingenter/Wingenter_PeECE_III_GRL_2007.pdf
64. ^ http://news.mongabay.com/2007/0627-planktos.html
65. ^ Matthews, H. D.; Turner, S. E. (2009). "Of mongooses and mitigation: ecological analogues to geoengineering". *Environmental Research Letters* **4** (4): 045105. Bibcode 2009ERL.....4d5105D (http://adsabs.harvard.edu/abs/2009ERL.....4d5105D) . doi:10.1088/1748-9326/4/4/045105 (http://dx.doi.org/10.1088%2F1748-9326%2F4%2F4%2F045105) .
66. ^ Keith Bower et al., 2006 Computational assessment of a proposed technique for global warming mitigation via albedo-enhancement of marine stratocumulus clouds. Atmos. Res., vol. 82, no. 1-2, 2006, pp. 328-336
67. ^ http://royalsociety.org/page.asp?tip=1&id=6232
68. ^ Bentley, Molly (2006-03-02). "Guns and sunshades to rescue climate" (http://news.bbc.co.uk/1/hi/sci/tech/4762720.stm) . *BBC News*. http://news.bbc.co.uk/1/hi/sci/tech/4762720.stm. Retrieved 2010-03-30.
69. ^ http://books.nap.edu/openbook.php?record_id=1605&page=824
70. ^ The Sensitivity of Polar Ozone Depletion to Proposed Geoengineering Schemes", Science, vol. 320, no. 5880, 30 May 2008, pp. 1201-1204, doi:10.1126/science.1153966
71. ^ http://www.newscientist.com/article/dn12397
72. ^ http://www.sciencedaily.com/releases/2008/05/080527155519.htm
73. ^ I. M. Held et al., "Simulation of Sahel drought in the 20th and 21st centuries", Proceedings of the National Academy of Sciences, vol. 102, no. 50, pp. 17891–17896, doi:10.1073/pnas.0509057102. Available online at: http://climate.envsci.rutgers.edu/pdf/2008JD010050small.pdf
74. ^ Keith Bower et al., 2006 Computational assessment of a proposed technique for global warming mitigation via albedo-enhancement of marine stratocumulus clouds. Atmos. Res., vol. 82, no. 1-2, 2006, pp. 328–336
75. ^ Robock, Alan (May / June 2008). "*20 reasons why geoengineering may be a bad idea* " (http://thebulletin.metapress.com/content/r567g4063g1h562l/?p=a537203c8e7b4be3b0cd5cd51fa30b61&pi=5) . *"Bulletin of the Atomic Scientists" (http://www.thebulletin.org)* . doi:10.2968/064002006 (http://dx.doi.org/10.2968%2F064002006) . http://thebulletin.metapress.com/content/r567g4063g1h562l/?p=a537203c8e7b4be3b0cd5cd51fa30b61&pi=5. Retrieved 2009-08-04.
76. ^ http://www.foreignpolicy.com/story/cms.php?story_id=4146
77. ^ http://www.fas.org/spp/military/docops/usaf/2025/v3c15/v3c15-1.htm
78. ^ http://www.fas.org/man/dod-101/sys/smart/lgb.htm
79. ^ http://www.state.gov/t/ac/trt/4783.htm
80. ^ Caldiera, Ken; Various (March 18, 2009). "DARPA and Geoengineering" (http://groups.google.com/group/climateintervention/browse_thread/thread/60f448608e209134?pli=1) . *Geoengineering Google group*. http://groups.google.com/group/climateintervention/browse_thread/thread/60f448608e209134?pli=1. Retrieved 2009-03-21.
81. ^ L. Gu et al., "Responses of Net Ecosystem Exchanges of Carbon Dioxide to Changes in Cloudiness: Results from Two North American Deciduous Forests", Journal of Geophysical Research, vol. 104, no. 31, pp. 421–31, 434 (1999); L. Gu et al., "Advantages of Diffuse Radiation for Terrestrial Ecosystem Productivity", Journal of Geophysical Research, vol. 107, (2002); L. Gu et al., "Response of a Deciduous Forest to the Mount Pinatubo Eruption: Enhanced Photosynthesis", Science, vol. 299, pp. 2,035–38 (2003)
82. ^ Balan Govindasamy and Ken Caldeira, "Geoengineering Earth's Radiation Balance to Mitigate CO2-Induced Climate Change", Geophysical Research Letters, vol. 27, pp. 2,141–44 (2000). For the response of solar power systems, see Michael C. MacCracken, "Geoengineering: Worthy of Cautious Evaluation?" Climatic Change, vol. 77, pp. 235–43 (2006)
83. ^ http://www.nasa.gov/centers/langley/news/researchernews/rn_robockfeature.html
84. ^ K. Sassen et al., ";The 5–6 December 1991 FIRE IFO II Jet Stream Cirrus Case Study: Possible Influences of Volcanic Aerosols", Journal of Atmospheric Science, vol. 52, pp. 97–123 (1993)
85. ^ David Adam, "Extreme and risky action the only way to tackle global warming, say scientists", Guardian, 1 September 2008. Available online at: http://www.guardian.co.uk/environment/ 2008/sep/01/climatechange.scienceofclimatechange2
86. ^ David Keith. "A surprising idea for solving climate change (lecture at TED conference)" (http://www.ted.com/index.php/talks/view/id/192) . http://www.ted.com/index.php/talks/view/id/192. Retrieved 2008-04-06.
87. ^ ***a b*** David Keith. "Engineering the Planet" (http://www.ucalgary.ca/~keith/papers/89.Keith.EngineeringThePlanet.p.pdf) (PDF). pp. "3–4,8". http://www.ucalgary.ca/~keith/papers/89.Keith.EngineeringThePlanet.p.pdf. Retrieved 2008-04-08.
88. ^ ***a b*** *BBC News*. http://news.bbc.co.uk/nol/shared/spl/hi/programmes/analysis/transcripts/31_07_08.txt. Retrieved 2010-03-30.
89. ^ James Randerson (2008-11-18). "Geoengineering 'no substitute' for climate targets, UK minister warns" (http://www.guardian.co.uk/environment/2008/nov/18/climatechange-greentech) . *The Guardian* (London: Guardian News and Media Limited). http://www.guardian.co.uk/environment/2008/nov/18/climatechange-greentech.
90. ^ David G. Victor (2008). "On the regulation of geoengineering". *Oxford Review of Economic Policy* (Oxford University Press) **24** (2): 322–336. doi:10.1093/oxrep/grn018 (http://dx.doi.org/10.1093%2Foxrep%2Fgrn018) .
91. ^ http://www.abc.net.au/science/articles/2007/11/09/2085584.htm
92. ^ http://www.worldwildlife.org/who/media/press/2007/WWFPresitem973.html
93. ^ ***a b*** Ross, A.; Damon Matthews, H. (2009). "Climate engineering and the risk of rapid climate change". *Environmental Research Letters* **4** (4): 045103. Bibcode 2009ERL.....4d5103R (http://adsabs.harvard.edu/abs/2009ERL.....4d5103R) . doi:10.1088/1748-9326/4/4/045103 (http://dx.doi.org/10.1088%2F1748-9326%2F4%2F4%2F045103) .
94. ^ "Geo-Engineering - a Moral Hazard" (http://www.celsias.com/article/geo-engineering-a-moral-hazard/) . celsias.com. 14 November 2007. http://www.celsias.com/article/geo-engineering-a-moral-hazard/. Retrieved 9 September 2010.
95. ^ http://www.worldchanging.com/archives//009753.html
96. ^ http://docs.google.com/gview?attid=0.1&thid=11e473ed2477ae05&a=v&pli=1
97. ^ http://www.consumerenergycenter.org/coolroof/
98. ^ http://ieet.org/index.php/IEET/more/2094/
99. ^ http://www.imeche.org/media/Public+Affairs/geoenginq.htm

Further reading

- Launder, Brian; Thompson, J. Michael T., eds (December 2009). *Geo-Engineering Climate Change: Environmental Necessity or Pandora's Box?*. Cambridge University Press. ISBN 978-0-521-198035.

- Eli Kintisch (2010). *Hack the Planet: Science's Best Hope, or Worst Nightmare, for Averting Climate Catastrophe*. ISBN 978-0470524268.
- Jeff Goodell (2010). *How to Cool the Planet: Geoengineering and the Audacious Quest to Fix Earth's Climate*. ISBN 978-0618990610.
- Morton, Oliver (May 10, 2007). "Climate change: Is this what it takes to save the world?". *Nature* **447** (7141): 132–136. doi:10.1038/447132a (http://dx.doi.org/10.1038%2F447132a) . PMID 17495899 (http://www.ncbi.nlm.nih.gov/pubmed/17495899) . -- Abstract only, full article requires payment.
- James Rodger Fleming (September 15, 2010). *Fixing the Sky: The Checkered History of Weather and Climate Control*. Columbia University Press. ISBN 978-0231144124.

External links

- What the UN ban on geoengineering really means (http://www.newscientist.com/article/dn19660-what-the-un-ban-on-geoengineering-really-means.html) November 1, 2010 by Fred Pearce of New Scientist
- Geoengineering sparks international ban, first-ever congressional report (http://www.washingtonpost.com/wp-dyn/content/article/2010/10/29/AR2010102906361.html) Juliet Eilperin Washington Post October 30, 2010
- Engineering the Climate : Research Needs and Strategies for International Coordination October 2010 report (http://www.washingtonpost.com/wp-srv/nation/pdfs/Geongineeringreport.pdf) from the U.S. House of Representatives
- Threat of global warming sparks U.S. interest in geoengineering (http://www.washingtonpost.com/wp-dyn/content/article/2010/10/03/AR2010100303437.html) by Juliet Eilperin of the Washington Post October 3, 2010
- Re-Engineering the Earth (http://www.theatlantic.com/magazine/archive/2009/07/re-engineering-the-earth/7552/) by Graeme Wood of The Atlantic , July 2009
- Geoengineering Retrospective (http://www.worldchanging.com/archives/008364.html) Overview of articles on geoengineering by Julia Levitt, Worldchanging, August 2008
- Geo-engineering website, describing current methods/proposals done to revert climate change by geo-engineering (http://geo-engineering.blogspot.com/) , by Sam Carana
- Geoengineering links (http://www.geocrisis.com/cpe_geoengineering_menu.htm) , annotated list, 2006?
- "The Geoengineering Gambit" (http://www.technologyreview.com/energy/24157/) , Technology Review, Jan. 2010
- 10 Ideas That Are Changing The World: 6.Geoengineering (http://www.time.com/time/specials/2007/article/0,28804,1720049_1720050_1721653,00.html) Time (magazine), March 2008
- Geo-engineering in the Southern Ocean (http://orgprints.org/15528/01/15528.pdf) , by John Paull, Australian National University, 2009
- 5 ways to save the earth (http://news.bbc.co.uk/1/hi/programmes/6298507.stm) , BBC documentary about geo-engineering, 20 February 2007
- Climate Engineering Is Doable, as Long as We Never Stop (http://www.wired.com/science/planetearth/news/2007/07/geoengineering) Wired (magazine), July 2007
- "Geoengineering: A Climate Change Manhattan Project" (http://www.metatronics.net/lit/geo2.html) by Jay Michaelson, Stanford Environmental Law Journal, 1998
- Terraforming Earth IV: The Question of Methane (http://www.openthefuture.com/wcarchive/2005/08/terraforming_earth_iv_the_ques.html) August 11, 2005
- "Futuristic fleet of 'cloudseeders'" (http://news.bbc.co.uk/2/hi/programmes/6354759.stm) John Latham BBC News. Feb. 15, 2007
- A Debate on Geoengineering: Vandana Shiva vs. Gwynne Dyer (http://www.democracynow.org/2010/7/8/a_debate_on_geoengineering_vandana_shiva) - video report by *Democracy Now!*
- Geoengineering: 'A Bad Idea Whose Time Has Come' (http://www.npr.org/templates/story/story.php?storyId=127245606) discussion on NPR
- We need birth control, not geoengineering (http://www.guardian.co.uk/environment/2010/apr/06/geoengineering-carbon-emissions) April 6, 2010
- Bill Gates' cloud-whitening trials 'a dangerous experiment' (http://www.guardian.co.uk/environment/2010/may/14/bill-gates-cloud-whitening-dangerous) May 14, 2010 regarding Bill Gates
- The powerful coalition that wants to engineer the world's climate: Businessmen, scientists and right-wing thinktanks are joining forces to promote 'geo-engineering' ideas to cool the planet's climate (http://www.guardian.co.uk/environment/2010/sep/13/geoengineering-coalition-world-climate) September 13, 2010 Clive Hamilton