An Overview of
Geo-engineering and Bio-geo-engineering

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"Never doubt that a small group of thoughtful,
committed citizens can change the world.
Indeed, it is the only thing that ever has."

Margaret Mead.

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Extreme changes in climate are not new to planet Earth. The last Ice Age occurred from around 110,000 to 12,000 years ago and a geological period of warmer global average temperature followed which persists today.

What is new is the size of the human population[1] and the speed at which climate changes are currently occurring. A temperature analysis by NASA scientists shows that Earth's average global temperature has increased by about 0.8°Celsius since 1880. Two-thirds of the warming has occurred since 1975, at a rate of roughly 0.15-0.20°C per decade.[2]

Scientists suggest that a rise of up to 1.5^0C is safe, while 2^0C has the potential to severely disrupt and damage ecological stability worldwide with concomitant economic consequences and the risk of endangering millions of lives. A rise of 3^0C will be catastrophic.

Even this early in the twenty-first century news headlines regularly tell of climate related catastrophes. In 2003, a 'heat wave' led to the deaths of some 30,000 people across Europe.[3] The high temperatures melted glaciers in the Switzerland Alps, causing avalanches and flash floods. Arctic sea ice melt has resulted from a rise in temperature and has altered atmospheric circulation in a way that led to extreme snow and ice in the Northern Hemisphere.[4] The 2013–14 North American 'cold wave' extended from December 2013 to April 2014 with impacts as far south as Mexico: heavy snow and ice; aircraft grounded; electricity supply failures.

Environmentally induced population movements or displacement is and will be one of the consequences of extreme weather conditions and rising sea levels. Migration may be the only viable strategy for many communities. 'Environmental refugees' describes people who have been forced to leave their traditional habitat, temporarily or permanently, because of a marked environmental disruption, be it natural and/or triggered by people, that threatens their existence and/or seriously affects their quality of life.

During 2012, approximately 32.4 million people were displaced by environmental disasters; 98% caused by climate- and weather-related events, especially flooding.[5] Half of Bangladesh's population live less than five metres above sea level. Scientists predict the country will lose 17 percent of its land by 2050 due to encroachment by rising sea levels, and create up to 20 million environmental refugees.[6] Kiribati and other low-lying islands of the Pacific also battle rising sea levels.

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[1] As of 26 March 2014, the US Census Bureau estimated the world population at 7.16 billion. The UN projects it to reach 8.3 to 10.9 billion by 2050.
[2] http://earthobservatory.nasa.gov/Features/WorldOfChange/decadaltemp.php
[3] http://www.atmos.washington.edu/2009Q1/111/ATMS111%20Presentations/Folder%201/CampbellS.pdf
[4] "Is Shrinking Sea Ice Behind Chilly Spring?". National Geographic. 31 March 2013
[5] http://www.globalization101.org/environmental-refugees/
[6] http://education.nationalgeographic.com/education/encyclopedia/climate-refugee/?ar_a=1

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Worldwide, desertification currently affects between 100 and 200 million people.[5] In China, the Gobi desert is expanding over 10,000 square kilometres annually and can now be seen from the capital, Beijing.[7] Droughts in sub-Saharan Africa and other parts of that continent have lead to the deaths of domestic and wild animals and crops, resulting in famine.[8] [9] Droughts have also hit countries traditionally well provided for by weather systems. In 2013, most of New Zealand suffered drought.[10]

If Earth experienced a two-degree rise in temperatures by the end of this century, which many predict could happen, at a minimum we would see more of the foregoing: water stress, for crops and drinking, increasingly worse floods, snowfalls and heat waves, coastal erosion, and the potential elimination of up to 30 percent of animal and plant species.[11]

The international community has agreed to limit temperature rise to 2^0C above pre-industrial levels. Achieving this limit would not prevent, but may limit some adverse effects. The Intergovernmental Panel on Climate Change (IPCC)[12] concludes that avoiding a two degrees rise means reducing emissions by at least two fifths by 2050, and dramatically increasing the energy generated from low-carbon energy sources by the same date. In April 2014, it released the last of three reports which assessed the physical evidence of climate change, the expected impacts over the course of the 21st century, and what is needed to curb the rise in levels of greenhouse gases. It says to combat climate change may mean using new, untested technologies to reduce the level of CO_2 in the atmosphere. The magnitude and gravity of the problems demand immediate attention. Science is asking how can Earth's climate be manipulated on a global scale to lower temperatures?

This is where **geo-engineering** and **bio-geo-engineering**[13] propose remedial actions. As with all new technologies, science has to evaluate the ideas and their practical implementation which revolves around technical feasibility and cost, and more importantly around issues of ethics: governance, justice, morality and the very role humanity should, could and will play on Earth.

These emerging technologies must run parallel to and complement emission controls and communities living more sustainably, not as a replacement for these. So far, most research on geo-engineering and bio-geo-engineering has consisted of computer modelling or laboratory testing only with few actual applications. The focus is on two general areas:

- **Reducing the levels of carbon dioxide** (CO_2) from Earth's atmosphere to address a root cause of global warming. CO_2 is one of the main offending greenhouse gases (GHGs).

[7] http://en.reset.org/knowledge/environmental-refugees-%E2%80%93-how-climate-change-affects-peoples-lives
[8] http://pi.library.yorku.ca/ojs/index.php/refuge/article/viewFile/21640/20313
[9] http://www.refugeesinternational.org/who-we-are/our-issues/climate-displacement
[10] http://www.stuff.co.nz/business/farming/8405004/North-Island-drought-worst-in-history
http://www.nzherald.co.nz/droughts/news/article.cfm?c_id=180&objectid=10903236
[11] http://www.irinnews.org/report/96815/climate-change-a-four-degree-warmer-world
[12] The Intergovernmental Panel on Climate Change (IPCC) is an international body established in 1998 by the United Nations Environment Programme (UNEP) to assess climate change and provide a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. Thousands of scientists from all over the world contribute on a voluntary basis.
http://www.ipcc.ch/organization/organization.shtml
[13] Also referred to as climate engineering, climate remediation, and/or climate intervention

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- **Managing solar radiation** with the aim of offsetting the effects of GHGs by causing Earth to absorb less solar radiation and thereby become cooler.

Key proposals for CO_2 removal include:

- **Terrestrial based techniques** such as land use and afforestation, use of biomass with CO_2 sequestration, enhanced weathering on land and chemical air capture/carbon sequestration, as well as marine techniques such as ocean fertilization, alkalinity enhancement, and overturning circulation.

- **Solar radiation management** (SRM) techniques which revolve around changing cloud or surface albedo – through roof whitening, or through various grassland, crop or desert surface albedo changes. Other proposed SRM techniques are space-based. They may involve injection of aerosols into the stratosphere, or using mirrors and the like in Earth's orbit or between the sun and Earth.

NB In this overview, the term *geo-engineering* will be used for all applications except where the proposal involves organisms content where *bio-geo-engineering* will be used, *bio'* meaning life.

Geo-engineering describes a process of deliberate and large-scale intervention in Earth's climate system

Can proposed geo-engineering techniques work?

The US Government Accounting Office, in a September 2011 study on the technical status - maturity, potential effectiveness, cost factors, and potential consequences - of proposed geo-engineering technologies concluded that none of the proposed techniques were ready to address global climate change. (See Table 1 on page 7 and Table 2 on page 8 for an adapted summary of their findings.)

None of the carbon dioxide removal (CDR) based geo-engineering proposals are ready for use and do not seem to offer acceptable effectiveness. Most come with serious environmental downsides.

While expensive and currently largely at the idea stage, SRM techniques do offer the possibility of working, albeit with potentially serious or even disastrous environmental, economic and human health side effects. Furthermore, once deployed these technologies must be maintained to continue their effect on Earth's temperatures. Abrupt cessation may result in unpredictable temperature rises.

The Solar Radiation Management Governance Initiative (SRMGI) - formed by the UK Royal Society, the Environmental Defence Fund (EDF) and The World Academy of Sciences (TWAS) - concurs that limited computer modelling so far indicates global temperatures could be reduced within a few months of deployment, but with potentially serious regional consequences, climatically and socio-politically. They also make it clear SRM is not a substitute for atmospheric GHG reduction.[14]

[14] SRMG (2011). Solar Radiation Management: governance issues. Available at: http://www.srmgi.org/files/2012/01/DES2391_SRMGI-report_web_11112.pdf

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Currently, it is unclear if and how the safety of any of these technologies can realistically be assessed. Probably the safest laboratory technique, climate modelling, has numerous limitations, including lack of accuracy and precision and lack of computer power.

Conventional risk assessment - with its premise that risk events can be averaged out over time and space and that the probabilities can be estimated to determine the likelihood of an event occurring - is unlikely to be applicable in the case of geo-engineering. Similarly, the definition of risk itself, conventionally defined as hazard multiplied by exposure, appears to have little application in the case of geo-engineering technology.

Implicit in this paradigm of risk assessment is the assumption that uncertainties can be known or estimated. Geo-engineering proponents are proposing to use untested techniques on what are complex systems. Unpredictability is especially pronounced in complex systems and geo-engineering techniques are designed to interfere with these complex systems to change their behaviour. Precisely because it is hard to understand complex systems in their many interacting levels, using geo-engineering techniques may cause novel and unprecedented effects that are virtually impossible to mitigate. We may not be able to predict how the system will behave, until we have interfered with it.

The following are examples of proposed or actual geo-engineering applications:

'Cool' surfaces

Over 95% of cars and small trucks in California are equipped with air conditioners. A 'cool' cars project there has aimed at reducing air conditioning usage of cars by lowering in-car air temperatures.

Dark cars reflect only 10% of sunlight while 'cool' light-coloured cars can reflect 60%. Light-colours reduce the amount of heat transmitted into the interior of a car, decrease the need for air conditioning, save on fuel consumption, and decrease the emission of GHGs and urban air pollutants.[15]

'Cool' roofs and other 'cool' surfaces give similar results. A dark roof reflects 20% of sunlight, a 'cool' roof 80%. A dark pavement reflects 10%, a 'cool' pavement 40%.[16] However, on a global scale these techniques are insignificant. (See Table 2 on page 8.)

Ocean iron fertilization

Ocean iron fertilization is the intentional introduction of micro- or nano-iron particles in the upper ocean layer to stimulate a phytoplankton bloom. Iron is a necessary trace element for photosynthesis and such fertilization occurs naturally when:

- nutrient-rich deep-water wells up to the surface;
- wind-blown dust travels far over the ocean; and
- iron-rich minerals are deposited in the ocean by glaciers, rivers and icebergs.

[15] The Heat Island Group at Lawrence Berkeley National Laboratory, http://heatisland.lbl.gov/
[16] See http://heatisland.lbl.gov/ for illustration.

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Relatively small amounts of iron can trigger large phytoplankton blooms. Plankton generate calcium or silica carbonate skeletons which sink when they die. Most of the sinking skeletons dissolve, are re-mineralized well above the seafloor and eventually re-released into the atmosphere. The CO_2 in the skeletons reaching the ocean floor is sequestered for eons.[17]

Proponents of geo-engineering propose artificially inducing phytoplankton bloom.

For ocean studies that have examined the fertilization effects of iron particulates see http://en.wikipedia.org/wiki/Iron_fertilization.

View the ocean division zones and depths on http://en.wikipedia.org/wiki/Ocean.

Stratospheric sulphate aerosols

Proponents claim that releasing sulphate in the stratosphere will increase global 'dimming', that the presence of the particulates will reduce the amount of direct irradiance at Earth's surface. Global dimming can occur by natural means and have a cooling effect. It may be due to particulates in the atmosphere created by human activity or to particulates ejected by erupting volcanoes. In June 1991, the eruption of Mount Pinatubo discharged sulphur dioxide (SO_2) into the stratosphere which immediately began converting into sulphuric acid (H_2SO_4) aerosols.[18]
The H_2SO_4 aerosol-cloud spread around the planet in three weeks and caused a decrease in the net radiation reaching Earth's surface. The lower stratosphere also warmed immediately following the eruption and subsequently cooled to the lowest temperatures recorded causing changes in atmospheric circulation. Other effects included surface cooling in 1992 and 1993. The Pinatubo 'climate forcing' was stronger than the opposite, warming affects of either the El Niño[19] event or anthropogenic GHGs[20] in the period 1991 to 1993.

Proponents of stratospheric aerosols propose seeding the atmosphere with precursor sulphide gases: for example, dimethyl sulphide (CH_3SCH_3), carbonyl sulphide (COS), sulphuric acid (H_2SO_4), hydrogen sulphide (H_2S) or sulphur dioxide (SO_2). These precursor gases would gradually oxidize, through both gaseous and aqueous reactions, to end products involving the sulphate anion (SO_4^{2-}) in combination with various other cations.[21]

The potential effects may well be tragic and may include disruption of Asian and African summer monsoons with accompanying reduction in precipitation (rainfall), as well as delayed ozone layer recovery in the southern hemisphere and about a 30-year delay in recovery of the Antarctic ozone hole.

See BBC - Global Dimming
http://www.bbc.co.uk/sn/tvradio/programmes/horizon/dimming_prog_summary.shtml.

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[17] http://www.climatechangesask.com/html/learn_more/Solutions/Geo-engineering/Ocean_Iron_Fertilization_/index.cfm
[18] 'The Atmospheric Impact of the 1991 Mount Pinatubo Eruption', Self S, et al http://pubs.usgs.gov/pinatubo/self/
[19] El Niño is a band of anomalously warm ocean water temperatures that periodically develops off the western coast of South America and can cause climatic changes across the Pacific Ocean.
[20] Anthropogenic specifies an effect resulting from human activity. For example, pollution emissions produced as a result of human activities (CO_2 from combustion of carbon-based fuels like wood, coal, oil, and natural gas). The primary GHGs in Earth's atmosphere are water vapour, carbon dioxide, methane, nitrous oxide, and ozone.
[21] An ion or group of ions having a positive charge, characteristically moving toward the negative electrode in electrolysis.

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See more examples of proposed or actual geo-engineering applications in the following tables.

Table 1: maturity, potential effectiveness, cost factors, and potential consequences of CDR technologies

CDR Technology	Maturity	Effectiveness	Cost	Potential Consequences
Direct air capture of CO^2 with geologic sequestration	low	Uncertainty around scalability, but theoretically very high Impractical on a large scale?	Estimates vary from $27 to $630 or more per ton of CO^2 removed (excluding other costs)	Contamination through process materials or chemicals May have sequestration risks such as potential for CO^2 to escape from underground storage in the event of reservoir fracture or fissure from built-up pressure
Bioenergy with CO^2capture and sequestration	Low	Low to medium: Impractical on a large scale?	Cost of potentially large land area for growing and harvesting biomass Estimates vary from $150–$500 per ton of CO^2 removed (excluding other costs)	Aspects associated with handling process materials or chemicals May have sequestration risks
Biochar and biomass methods	Low	Low Impractical on a large scale?	Estimates vary from $2–$62 per ton of CO2 removed	Potential land-use trade-offs Long-term effects on soil uncertain, potentially detrimental Health and safety of pyrolysis and biochar handling
Land-use management (reforestation, afforestation, or reductions in deforestation)	Low	Low to medium Impractical on a large scale?	Value of land in other uses Potentially large land area for growing or preserving forests Type of flora planted or preserved Cheap?	Potential land-use trade-offs Possible co-benefits such as reduced water runoff
Enhanced weathering	Low	Unclear Impractical on a large scale?	Estimates of $4–$100 per ton of CO^2 removed	Potentially undesirable environmental and other consequences from large-scale mining and transportation
Ocean fertilization	Low	Low Impractical on a large scale?	$8–$80 per ton of CO2 removed	Ecological effect on ocean not well understood, but potential to be very detrimental Risk of algal blooms causing anoxic zones in the ocean Risk to livelihood of fisher people

Note: Based on GAO report), but expanded and/or shortened in parts. By courtesy of Dr Rye Senjen, NTN Australia 2012.

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Table 2: **maturity, potential effectiveness, cost factors, and potential consequences of SMR technologies**

Technology	Maturity	Effectiveness	Cost	Potential Consequences
Stratospheric aerosols	low	Potentially fully effective:	Literature-based estimates vary significantly: $35 billion to $65 billion in the first year; $13 billion to $25 billion in operating cost each year thereafter	Disruption of Asian and African summer monsoons with accompanying reduction in precipitation Delayed ozone layer recovery in southern hemisphere and about a 30-year delay in recovery of Antarctic ozone hole
Marine cloud brightening	Low	Potentially fully effective:	Estimates vary significantly at $42 million for development, $47 million for production tooling, $2.3 billion to $4.7 billion for 1,500-vessel fleet acquisition	Small changes in global average temperature, regional temperatures, and global precipitation Large regional changes in precipitation, evaporation, and runoff; both precipitation and runoff increase, and the net result might not “dry out” the continents
Scatterers or reflectors in space either in Earth orbit or deep space	Low	Potentially fully effective: Spacecraft’s limited lifetime	Estimates in the scientific literature vary significantly: an estimate of $1.3 trillion and an estimate of less than $5 trillion	Near earth technologies: A cool band in the tropics with unknown effects on ocean currents, temperature, precipitation, and wind Deep-space technologies: Annual average tropical temperatures a little cooler Annual average higher latitude temperatures a little warmer
Terrestrial reflectivity **Deserts** **Flora** **Urban or settled areas**	Low	Potential effectiveness of 0.21 (urban areas) to more than 57 percent (deserts)	Estimates in the scientific literature vary greatly from $78 billion (urban areas) to $3 trillion per year (deserts)	Cool deserts might change large-scale patterns of atmospheric circulation Reflective crops would probably not significantly affect global average temperature but might reduce regional summer temperatures Reflective urban areas would probably not affect global average temperature but might reduce air-conditioning costs

Note: Based on GAO report, but expanded and/or shortened in parts.
By courtesy of Dr Rye Senjen, NTN Australia 2012.

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Bio-geo-engineering aims to use or engineer living organisms in order to modify Earth's climate.

Bios means life.

The following are examples of proposed or actual bio-geo-engineering applications:

Using biomass

Biomass is a collective term for organic matter. A 2011 report by the IPCC says: "Combining biomass conversion with developing carbon capture and storage (CCS) could lead to long-term substantial removal of GHGs from the atmosphere..."

In a 2009 report on geo-engineering, Britain's Royal Society concluded that "afforestation, BECCS and biochar all scored high on safety – though not on effectiveness, timeliness and (except for 'afforestation') affordability."

BECCS (Bio-energy with carbon capture and storage)

The BECCS concept for removal of carbon comes from the integration of trees and crops that extract CO_2 from the atmosphere, the use of this biomass in processing industries or power plants, and the application of carbon capture and storage. The Fourth Assessment Report by the IPCC in 2007 suggested BECCS as a key technology for reaching low CO_2 atmospheric concentration targets. [22] [23] However, Azar et al (2013) found a critical factor in using BECCS is "that producing large amounts of bio-energy may have significant impacts on global food prices, biodiversity, water availability, etc. A back-of-envelope estimate of global land requirements suggests that 200 EJ yr−1 of bio-energy may require around 500 Mha of land, or one third of global crop land."[24] [25]

Biochar - CO_2 sequestration in soil using biomass

Terra preta is dark, fertile soil found in some areas of the Amazon Basin that comprises high concentrations of low-temperature charcoal, and organic matter such as plant residues. In its natural state, it creates a terrestrial carbon reef at a microscopic level with nano-scale structures providing for microbes and fungi that facilitate fertile soil creation. If left undisturbed, it will sequester CO_2 for thousands of years.[26] Biochar-terra preta has been proposed as a way of sequestering CO_2.

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[22] IPCC (2007) ISBN 978-0-521-88011-4. http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4_wg3_full_report.pdf
[23] http://en.wikipedia.org/wiki/Bio-energy_with_carbon_capture_and_storage
[24] 'Meeting global temperature targets - the role of bio-energy with carbon capture and storage', Azar et al, 2013 Environ. Res. Lett. 8 034004 doi:10.1088/1748-9326/8/3/034004 http://iopscience.iop.org/1748-9326/8/3/034004/article
[25] Henrik Karlsson MSc discusses 16 BECCS projects on http://www.youtube.com/watch?feature=player_embedded&v=gIHZ3HGMT48
[26] http://biochar.info/biochar.terra-preta.cfml

Proponents aim to plough a biochar-terra preta mixture into soils to create carbon sinks.[27] To achieve this on a large scale would require huge tracts of land to grow sufficient biomass to make this method effective. Any potential effectiveness has to be balanced against the environmental costs of degraded soils and nutrient loss, the emissions resulting from transporting the biomass to facilities for burning, and the environmental cost of that burning. Currently, there is little evidence that biochar-terra preta can be recreated on a large scale by applying industrial charcoal to large tracts of land.[28]
Biochar is essentially industrial charcoal - a waste product of biomass combustion (pyrolysis). Most plant material can be used, and animal manure, sewage and paper sludge. Industry has proposed incorporating up to 50% coal waste as a way to rehabilitate and upgrade marginal land, especially degraded coalmining land.

The research gaps relating to the use and production of industrial charcoal are enormous and worrying. Will the addition of biochar enhance nutrient use as claimed, or will it be detrimental? What will happen to soils' water-holding capacity and what effects will there be on soil stability?
Other poorly understood aspects of biochar-terra preta include erosion, transport through the environment, and its ultimate fate in the environment.

Planting of trees to offset carbon emissions - afforestation and reforestation

Through photosynthesis, trees absorb CO_2 from the atmosphere and convert it to sugars. The sugars provide energy and storage material to build cellulose and lignin, the main constituents of wood. The CO_2 is stored until the wood dies, decays or is burnt and the CO_2 released back into the atmosphere.

Removing CO_2 from the atmosphere is sequestration. Natural reservoirs, such as forests, accumulate and store CO_2. Afforestation[29] and reforestation would have to be on a huge scale globally, overseen by sustainable, long-term management, to make significant changes in CO_2 reduction.

As an example, Ireland's forest cover is just 10%. To encourage the planting of more forested areas, the country's Afforestation Grant and Premium Scheme is compensating forest owners towards the costs of forestry establishment and for the income foregone during the maturation of the timber crop.[30] The National Afforestation Project is to finance afforestation, research and planting material development activities and institutional strengthening in 15 provinces in China.[31] [32]

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[27] A carbon 'sink' is a forest, ocean, or other natural environment viewed in terms of its ability to absorb carbon dioxide from the atmosphere.
[28] Biochar, another dangerous technofix, Dr Rye Senjen, 2009 http://www.foe.org.au/sites/default/files/CR106.pdf, See also www.biofuelwatch.org.uk
[29] Afforestation – an area where there is no forestation. Re-forestation – the renewal or increase in forested areas.
[30] Department of Agriculture, Food and the Marine, Forest Service February 2012 http://www.agriculture.gov.ie/media/migration/forestry/grantandpremiumschemes/2012/AfforestationSchemeFeb12.pdf
[31] http://www.worldbank.org/projects/P003463/national-afforestation-project?lang=en
[32] Oxford Geo-engineering Programme afforestation www.geo-engineering.ox.ac.uk/geolibrary/index/reference/?tag_1=+Afforestation.

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Reclaiming deserts

Desertification is a significant global ecological and environmental problem. Deserts can be reclaimed as productive using relatively inexpensive practices[33] which will also foster economic activity. One proposal is planting fast-growing trees such as eucalypts, watered by seawater treated in coastal desalination plants and channelled through an irrigation network.[34] Tree cover would develop its own weather system and rainfall at the same time as soaking up CO_2. Researchers calculate forested deserts could draw down around eight billion tonnes of carbon annually, which is roughly equivalent to the CO_2 emitted from fossil fuels and deforestation.[35]

What trees are planted would affect results. For example, forestation in sub-tropical areas would soak up less sunlight than the darker, northern forest trees. Ecosystems may be adversely affected. The Sahara is acknowledged as a relatively stable, functioning ecosystem. Planting forests could destroy its stability, local agriculture and economies, and a way of life for millions of people. Subsistence farmers live in an harmonious, symbiotic relationship where land and humans benefit.

The Eden Foundation website says:

"A United Nations Environmental Programme (UNEP) study shows that 6.1 billion hectares are dryland of which 1 billion hectares are naturally hyper-arid desert. The rest of the dryland has either become desert or is being threatened by desertification. One quarter of the world's population inhabit the drylands and depend on this area for their livelihood."

The Foundation[35] promotes a local, constructive solution to desertification, for farmers to stabilise their environment themselves by intercropping edible perennials in their fields. Perennials act as anchors that stabilise the soil against wind and water erosion and also improve fertility.[36]

Ironically, increased CO_2 levels have helped encourage green foliage in desert regions over the past three decades through a process called CO_2 fertilisation. This effect occurs where elevated CO_2 enables a leaf, during photosynthesis, to extract more carbon from the air or lose less water to the air, or both. Where elevated CO_2 causes the water use of individual leaves to drop, desert plants respond by increasing the numbers of leaves. Such changes are detectable by satellite.[37] [38]

By using the Ningxia Desertification Control and Ecological Protection Project[39] and the Shandong Ecological Afforestation Project[40] China aims to control areas of desertification and degradation, and protect key farmland and infrastructure.

33 http://www.nature.com/nature/journal/v442/n7103/full/442624a.html; "Stop emitting CO2 or geo-engineering could be our only hope" (Press release). The Royal Society. 28 August 2009

34 http://dirt.asla.org/2009/11/20/new-geo-engineering-idea-turning-deserts-into-forests/

35 The Eden Foundation is a pioneering not-for-profit social enterprise whose purpose is to catalyse human potential, promote social and sustainable innovation, and create real transformative change. http://www.eden-foundation.org/.

36 http://www.eden-foundation.org/project/desertif.html

37 http://www.csiro.au/Portals/Media/Deserts-greening-from-rising-CO2.aspx

38 See 'Greening the Desert with Geoff Lawton', founder of the Permaculture Design Institute:
1. http://www.youtube.com/watch?v=xzTHjlueqFI; 2. http://www.youtube.com/watch?v=xzTHjl...; 3. http://www.youtube.com/watch?v=wTZ0Lb...; 4. http://www.youtube.com/watch?v=-Ps1Tp...

39 http://www.worldbank.org/projects/P121289/ningxia-desertification-control-ecological-protection-project?lang=en

40 http://www.worldbank.org/projects/P112759/shandong-ecological-afforestation?lang=en&tab=overview

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Biogenic aerosols

The IPCC suggests biogenic aerosols deserve more scientific study.

It is proposed biogenic aerosols be grown to replace the beneficial aerosols lost through the reduction in Earth's forests. Primary biogenic aerosols consist of plant debris, light-absorbing humic matter (an organic residue of decaying organic matter) and microbial particles like bacteria, fungi, viruses, algae, pollen, spores, etc.[41]

Scott et al (2013) found biogenic secondary organic aerosol (SOA) may “exert a negative radiative effect in the present day climate” and “the magnitude of these effects is highly sensitive to our understanding of SOA yield and aerosol microphysical processes”. The study reinforced the need to fully understand the influences of natural components on Earth’s system in order to accurately determine the radiative effects of human activities.[42]

Solutions without geo-engineering

One perspective of countering climate change is that nature can help. Proposals include identifying the role of land areas as natural, cost-effective solutions to climate change, and initiating a better understanding of their mitigation and adaptation potential. Natural systems can cushion the worst impacts of climate change. For example, they can provide space for floodwaters to disperse, stabilize soil against landslides, and block storm surges.

The World Wildlife Fund (WWF) estimates US coastal wetlands provide US$23.2 billion a year in protection against flooding caused by hurricanes. Protected areas help by their resilience, ecosystem services and the species that support them. Climate-friendly land use can comprise healthy, sustainable production and land management practices to reduce GHG emissions. Carbon can be sequestered and stored in nature’s sinks: forests and other vegetation, pastures and soils, and coastal and marine ecosystems such as mangroves, sea grasses and salt marshes.

Of important note is that 33 of the world’s 100 largest cities derive their drinking water from forest-protected catchment areas.

WWF provides the following figures:[43]

- Fifteen percent of the world’s terrestrial carbon stock - 312 gigatonnes - is stored in protected areas around the world.
- Over 4000 million tonnes of CO_2 is sequestered in Canada’s 39 national parks, estimated to be worth $39-87 billion in carbon credits.

[41] Schnell, R. C., Gabor Vali, 1976: Biogenic Ice Nuclei: Part I. Terrestrial and Marine Sources. J. Atmos. Sci., 33, 1554–1564. doi: http://dx.doi.org/10.1175/1520-0469(1976)033<1554:BINPIT>2.0.CO;2

[42] ‘The direct and indirect radiative effects of biogenic secondary organic aerosol, Scott et al, pub 26 June 2013, by Copernicus Publications on behalf of the European Geosciences Union. http://www.atmos-chem-phys-discuss.net/13/16961/2013/acpd-13-16961-2013.pdf

[43]‘Natural Solutions: protected areas helping people cope with climate change’, 2009, http://wwf.panda.org/what_we_do/how_we_work/conservation/forests/publications/?uNewsID=183021&utm_source=feedburner&utm_medium=feed&utm_campaign=Feed%3A+wwf%2Fforests%2Fpublications+%28WWF+-+Forest+Publications%29&utm_content=Google+International

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- Protected lands in the Brazilian Amazon are expected to prevent 670,000 km² of deforestation by 2050, representing eight billion tonnes of avoided CO_2 emissions. WWF suggests developing countries be given financial incentives to encourage economic growth without deforestation.

A new study claims soil production and weathering rate measurements in Earth's uplifting mountains may help "determine whether weathering rates increase or decline in response to rapid erosion. Concentrations in soils from the western Southern Alps, New Zealand, demonstrate that soil is produced from bedrock more rapidly than previously recognized, at rates up to 2.5 mm per year. Weathering intensity data further indicate that soil chemical denudation rates increase proportionally with erosion rates. These high weathering rates support the view that mountains play a key role in global-scale chemical weathering and thus have potentially important implications for the global carbon cycle."[44 45]

New Zealand and geo-engineering

In March 2011, Dr Philip Boyd, principal scientist at Otago University and NIWA Centre of Chemical and Physical Oceanography[46], organised a gathering of scientists and policymakers to talk about the implications of geo-engineering schemes for New Zealand. The participants were to consider how New Zealand should deal with proposed projects and their regional effects.[47] Dr Boyd warned that although geo-engineering was being promoted "as the next dotcom", not enough research had been done into possible side effects for large-scale projects to be launched. "If we start one of these things, we need to know how to stop it."

For the last 12 years, Professor Keith Hunter, pro-vice chancellor of sciences at the University of
Otago, has been researching the effects on the ocean and marine life of increased levels of CO_2 in the atmosphere, taking samples from beyond the continental shelf lying off the Otago coast.[48] The work of his research team confirms oceans are becoming more acidic as the more concentrated levels of CO_2 in the atmosphere mix with the waters below.

Professor Hunter says Earth's oceans are finely balanced in terms of the solubility of calcium carbonate, a critical compound for creatures at the bottom of the food chain. "Lowering the pH (acidification) of the water below a threshold creates conditions in which calcium carbonate, which makes up the exoskeleton of many marine organisms, would naturally dissolve." Measurements suggest an average pH drop of 0.02 since 2000. "A change in pH of 0.3 represents a doubling or halving of hydrogen ions. So 0.3 is 100% change."

A critical falling point is when calcium carbonate becomes soluble. This is to be expected first in the coldest ocean water, as CO_2 is more soluble in cold water. "We think that one of the earliest regions where this will become manifest will be in the Southern Ocean around

[44] 'Rapid Soil Production and Weathering in the Western Alps, New Zealand', I J Larsen et al, *Science,* 2014, http://www.sciencemag.org/content/early/2014/01/15/science.1244908
[45] Papers on natural solutions to climate change can be found on: http://cmsdata.iucn.org/downloads/brief_1___climate_change.pdf. See 'Putting Natural Solutions to Work: Mainstreaming Protected Areas in Climate Change Responses' 2012 http://www.bfn.de/fileadmin/MDB/documents/service/BfN-Skript-321.pdf
Protected Areas and Climate Change – links to useful documents http://protectedareasandclimatechange.groupsite.com/main/summary
[46] NIWA (National Institute of Water and Atmospheric Research; a crown-owned research and consultancy company, with a global reputation as experts in water and atmospheric research; http://www.niwa.co.nz/
[47] 'The implications of geo-engineering schemes for NZ', 4 March 2011, The Royal Society of New Zealand, http://www.scoop.co.nz/stories/SC1103/S00017/the-implications-of-geo-engineering-schemes-for-new-zealand.htm.
[48] http://www.odt.co.nz/lifestyle/magazine/269957/oceans-concern

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Antarctica, and we think that those waters will become corrosive to a group of small organisms called pteropods," says Professor Hunter. Pteropods are a kind of snail a few millimetres in size and have an important role in the food chain. "They will experience trouble around 2035."

The combined effect of these changes in New Zealand's seas is likely to have an impact on marine biodiversity. Professor Hunter points to the most important effects on the larval stage of marine animals. If there were a mass die-off of a type of larvae, adult numbers would be threatened.

Similar themes are explored in the new Report 'New Zealand's changing climate and oceans: The impact of human activity and implications for the future' published in July 2013 by the Office of the Prime Minister's Science Advisory Committee.[49]

Iron fertilization as a solution to counter the pH-lowering effect of CO_2 has been proposed. Iron particulates would absorb CO_2. However, the above Report does say, "such geo-engineering solutions only offer short-term solutions and may have unintended consequences at a system level."

In 2013, the Royal Society of New Zealand ran the New Zealand Climate Change Conference, focussed on scientific, technological and geopolitical aspects of geo-engineering schemes; and the implications for New Zealand.

The document, 'New Zealand's Sixth National Communication under the United Nations Framework Convention on Climate Change and the Kyoto Protocol, Ministry for the Environment 2013'[50] says climate change "is a truly global issue, requiring global engagement and a global solution." New Zealand is "engaging internationally in pursuit of binding agreements, through applying our skills in science and innovation to reduce agricultural emissions." The terms bio-geo-engineering and geo-engineering are not mentioned.

What must be heeded is the fact that what solutions are attempted locally, by whatever means, can potentially affect other areas of the world, just as solutions achieved elsewhere can potentially affect New Zealand.

Governance

A study published in Nature Communications in February 2014, suggests technological "fixes" designed to combat the negative effects of climate change, even if applied on a huge scale, will be ineffective in the face of increasing greenhouse gas emissions.[51] German researchers found no more than an 8% reduction in warming could result from four of the proposed geo-engineering techniques: ocean fertilisation, ocean alkalinisation, artificial ocean upwelling, and desert irrigation and reforestation. A fifth technique, reflecting solar radiation back to space, could potentially reduce warming more, but involved serious side effects and could not be safely stopped once begun.

[49] http://www.pmcsa.org.nz/wp-content/uploads/New-Zealands-Changing-Climate-and-Oceans-report.pdf
[50] http://www.mfe.govt.nz/publications/climate/nz-sixth-national-communication/sixth-national-communication.pdf.
[51] http://www.sciencemediacentre.co.nz/2014/02/26/exploring-the-side-effects-of-geoengineering-experts-respond/

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The findings reinforce the fact that there is no easy solution and no one methodology or technology will provide a silver bullet. The full effects of few geo-engineering proposals are well understood and most proposals have the potential to cause significant environmental damage. The end results may be ineffective, unpredictable or unstable due, for example, to external events such as volcanic eruptions, phytoplankton blooms, El Niño effects or solar flares, or to simple miscalculations.

There may also be unintended climatic consequences, such as changes to the hydrological cycle, including droughts or floods. Effects may be cumulative or chaotic in nature, making prediction and control difficult, and could potentially lead to profound and unpredictable disruption to the climate system.

While potentially providing jobs, many could disrupt communities, and destroy livelihoods and traditional ways of life. In the case of reclaiming desert land it could be argued that this should be the work of farmers themselves, particularly subsistence farmers, providing for the least disruption, but still gaining in results.

Many questions arise. Who will be accountable for negative results, disasters even? Will geo-engineering projects address the real causes of climate change? Will there be any control over who decides when to cool Earth and how often this should be done? Will vested interest set up unregulated, unsupervised and dangerous geo-engineering projects?

Matthews and Turner (2009) looked at a number of previous environmental interventions and concluded: "Given our current level of understanding of the climate system, it is likely that the result of at least some geo-engineering efforts would follow previous ecological examples where increased human intervention has led to an overall increase in negative environmental consequences."[52]

The key issue - apart from whether any of the proposed geo-engineering techniques would actually serve their intended purposes - is whether they can be safe, equitable and transparent. To illustrate the issues surrounding governance we may ask:

- What if a state or collection of states unilaterally decides to conduct large-scale trials or employ one of these techniques?
- What are the dangers of unregulated, unilateral, or self-interested uses?
- Who decides what should be researched and deployed, a limited number of 'capable' states or is global consent required?
- How can we limit vested commercial interests?
- What would the effect of geo-engineering techniques be on international/national efforts to reduce carbon emissions?
- Could geo-engineering lead to political destabilisation?
- Would its use lead to a decreased concern and hence decreased effort expanded toward dealing with climate change (termed 'moral hazard')?
- Who would ultimately be liable if things go wrong, even at the research stage? The government, the research institution, insurers? Across national boundaries?

[52] 'Of mongooses and mitigation: ecological analogues to geoengineering'. Environ. Res. Lett. Vol 4 No 4 (October-December 2009) 045105, doi:10.1088/1748-9326/4/4/0451052009, http://iopscience.iop.org/1748-9326/4/4/045105/fulltext/

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- How could liability be proven? How could a causal connection be established between a geo-engineering experiment and extreme weather conditions shortly thereafter?

The key governance challenge is who should decide where and when any experiments should be permitted and who will be held responsible and in what form if things go wrong. Is it possible to not only apply precautionary principles in the evaluation of these proposed technologies, but also ensure that the process of evaluation and decision-making is participative?

> *"Precaution – and common sense – demands the careful assessment of technologies before, not after, governments and inter-governmental bodies start funding their development and aiding their deployment around the globe. National and international public consultations, with the participation of the people who are directly affected, are critical. This is not a simple technical assessment conducted exclusively by experts: people must have the ability to decide which technologies they want and to reject technologies that are neither environmentally sound nor socially equitable".* [53]

Technology assessment must also include:

- Social and cultural contexts and the effects on community livelihoods;
- Help protect existing ecosystems and all life forms within them;
- Strictly adhere to the Precautionary Principle;
- Employ a full life-cycle analysis, reducing the use of non-renewable resources and minimizing waste;
- Minimize obstacles to access for the communities the technologies are intended to serve, including payments;
- Respect international human rights norms, including social, economic and cultural rights, the rights of Indigenous peoples, and the right to self-determination.

There are currently no real international mechanisms to govern these issues. A de facto moratorium on the use of geo-engineering, apart from small-scale research in controlled settings, was adopted under the Convention for Biodiversity Decision X/33 in November 2011.[54]

No existing organisation has sufficient funding or gravitas to carry out the task of international governance, yet for geo-engineering to be at all permissible such an organisation is essential.

Fiscal costs

Some geo-engineering techniques may cost relatively little and may even offer a financial benefit and thence production when used on a small scale by subsistence farmers. One example is reclaiming desert areas. Once established, such schemes could be self-financing or involve minimal annual upkeep costs. However, some proposed schemes would cost in

[53] ETC Group (2011). Can the new technology mechanism work for new technologies. www.etcgroup.org/upload/DurbanBriefing_28Nov2011.pdf
[54] CBD Notification, "Draft study on Impacts of Climate-Related Geo-engineering on Biological Diversity," 11 November 2011: http://www.cbd.int/doc/notifications/2011/ntf-2011-215-climate-en.pdf

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the millions, if not billions of dollars annually on an on-going basis. Proponents of the techniques argue these costs are still lower per annum than the costs to achieve comprehensive reductions in CO_2 emissions. How to finance these has not been given much publicity.

Are existing treaty structures relevant?

Because no existing treaties were specifically implemented to govern geo-engineering none provide full coverage to deal with it. Additionally, in their current form they may provide little practical guidance or regulation. That said some international treaties are or can be put to work.

- The London Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter and the London Protocol are being utilised to some extent to manage attempts to experiment with ocean fertilisation.
- The United Nations Convention on the Law of the Sea (UNCLOS) could be applied to regulate/control ocean fertilisation.
- The Convention on Biological Diversity (CBD) could potentially be applied to some land-based CDR activities, ocean fertilisation, as well as SRM activities. However, its enforcement provisions are weak.
- Other International treaties include the Convention on the Prohibition of Military or Other Hostile Use of Environmental Modification Techniques (questionable applicability), the Convention on Long-Range Transboundary Air Pollution; and the Vienna Convention and its Montreal Protocol for the Protection of the Ozone Layer.

As the Antarctic and oceans outside territorial waters are recognised as global commons, both the UNCLOS and the Antarctic Treaty provide for international stewardship of these. However, as experience has shown, even with supplementary fisheries treaty structures in place, the continued over exploitation of fisheries and marine mammals has not been stopped.

Clearly there is no single overarching treaty relevant to geo-engineering and furthermore it is unlikely that such a treaty could exist or even be negotiated. In the end, nation states are interested in protecting their own interests, which may or may not coincide with that of their world citizens.

Stewardship of Earth

Earth stewardship involves collaboration between earth system science and ecological science. Governance must ensure geo-engineering applications explore technologies that address climate stresses and bring social-ecological-economic benefits to communities. Projects will require multi-national effort. Governance, regulation and management must be clear and supported at all levels. There must be provision for consultation and disclosure of information, and integrated assessments of social-ecological-economic impacts. There must be a global consensus on such things as the fundamental questions of who should decide whether, how and by what means geo-engineering should be attempted, on the economics of who pays, on independent multi-national oversight of projects, on ethics, governance, and jurisdiction, on target temperatures, and much more.

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The Kyoto Protocol to the United Nations Framework Convention on Climate Change, established in 1998[55], has shown the practical difficulties of achieving CO_2 emissions reduction by international agreement. The goal of this international treaty is of preventing "dangerous" anthropogenic, i.e. human-induced, interference of the climate system. As part of the Kyoto Protocol, many developed countries have agreed to legally binding limitations and reductions in their emissions of GHGs in two commitments periods: 2008-2012 and 2013-2020. The first period has not been claimed a success.

The Oxford Martin School at Oxford University evaluated geo-engineering governance. The result is the Oxford Principles[56], endorsed by the UK House of Commons Science and Technology Select Committee on The Regulation of Geo-engineering:[57]

Principle 1: Geo-engineering to be regulated as a public good
Principle 2: Public participation in geo-engineering decision-making
Principle 3: Disclosure of geo-engineering research and open publication of results
Principle 4: Independent assessment of impacts
Principle 5: Governance before deployment

In 2010, the Asilomar Conference[58] was replicated to deal with geo-engineering governance, and reports into geo-engineering published by the UK Institution of Mechanical Engineers (IMechE) [59] and Britain's Royal Society[60]. The main conclusions of the IMechE report were that geo-engineering should be researched and trialled at the small scale alongside a wider decarbonisation of the economy.

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, also known as the London Dumping Convention, covers the deliberate disposal at sea of wastes or other matter. It entered into force in 1975 and as of 2013 there were 87 Parties to the Convention.[61] This addresses some aspects of law in relation to biomass ocean storage and ocean fertilization. (See Addendum 1.)

The Third United Nations Convention on the Law of the Sea (UNCLOS III), commonly referred to as The Law of the Sea Treaty, was adopted in 1982. Its purpose was to establish a comprehensive set of rules governing the oceans.[62] Under the UN Convention on the Law of the Sea Agreement relating to the implementation of Part XI of the Convention, it was agreed that there must be "a just and equitable international economic order which takes into account the interests and needs of mankind as a whole and, in particular, the special interests and needs of developing countries, whether coastal or land-locked."

It also said, "The area of the seabed and ocean floor and the subsoil thereof, beyond the limits of national jurisdiction, as well as its resources, are the common heritage of mankind, the exploration and exploitation of which shall be carried out for the benefit of mankind as a whole, irrespective of the geographical location of States." It affirmed that, "matters not

[55] http://unfccc.int/resource/docs/convkp/kpeng.pdf 1998
[56] http://www.geo-engineering.ox.ac.uk/oxford-principles/principles/
[57]http://www.publications.parliament.uk/pa/cm200910/cmselect/cmsctech/221/221.pdf printed 2010
[58] Asilomar International Conference on Climate Intervention Technologies 2010 http://www.whoi.edu/fileserver.do?id=62483&pt=10&p=39472
[59] Fox, T (November 2009). Climate change have we lost the battle (PDF). Institution of Mechanical Engineers
[60] Royal Society (September 2009), 'Geo-engineering the Climate: Science, Governance and Uncertainty (Report). p.1. ISBN 978-0-85403-773-5,
[61] http://www.unep.ch/regionalseas/main/legal/llondon.html
[62] http://www.unlawoftheseatreaty.org/

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regulated by this Convention continue to be governed by the rules and principles of general international law."[63]

In 2008, the 193-member United Nations Convention on Biological Diversity (CBD) initiated a moratorium on ocean fertilization which stopped public and private experiments to sequester atmospheric CO_2 in the oceans' depths by spreading nutrients on the sea surface.[29] In December 2010, it decided on a de facto moratorium on geo-engineering projects and experiments. The agreement asks governments to ensure that no geo-engineering activities take place until risks to the environmental and biodiversity, and associated social, cultural and economic impacts risks, have been appropriately considered as well as the socio-economic impacts.[64]

In 2009, the UK government recommended activities initially be regulated by moratoria.[65] It agreed geo-engineering technologies and techniques vary so much that any regulatory framework cannot be uniform, but starting work on that would provide the opportunity to explore fully the technological, environmental, political and regulatory issues. It gave three reasons why regulation is needed:

- "First, in the future some geo-engineering techniques may allow a single country unilaterally to affect the climate;
- Second, some — albeit very small scale — geo-engineering testing is already underway;
- Third, we may need geo-engineering as a 'Plan B' if, in the event of the failure of 'Plan A' — the reduction of greenhouse gases — we are faced with highly disruptive climate change."

It also stated that, "groundwork regulatory arrangements should consider such factors as trans-boundary effect, the dispersal of potentially hazardous materials in the environment and the direct effect on ecosystems."

In conclusion

A recent study[66] suggests technological "fixes" designed to combat the negative effects of climate change, even if applied on a huge scale, will be ineffective in the face of increasing GHG emissions. No more than an eight percent reduction in warming could result from four of the proposed geo-engineering techniques: ocean fertilisation, ocean alkalinisation, artificial ocean upwelling, and desert irrigation and reforestation. A fifth technique, reflecting solar radiation back to space, could potentially reduce warming more, but would involve serious side effects and could not be safely stopped once begun. These findings reinforce the fact that there is no easy solution.

On a global scale, it is certain that efforts to date to rein in GHGs emissions have not been successful. Atmospheric levels of CO_2 keep rising and, without a reduction, can geo-

[63] http://www.un.org/depts/los/convention_agreements/texts/unclos/closindx.htm
[64] http://www.cbd.int/decision/cop/?id=11659; 6 December 2010, by ETC Group. Nagoya, Japan; http://www.etcgroup.org/sites/www.etcgroup.org/files/publication/pdf_file/ETCNRCBDmoratorium101029.pdf.
[65] http://www.publications.parliament.uk/pa/cm200910/cmselect/cmsctech/221/221.pdf
[66] 'Potential climate engineering effectiveness and side effects during a high carbon dioxide-emission scenario', Keller et al, February 2014 Nature Communications 5, 3304 doi:10.1038/ncomms430, http://www.nature.com/ncomms/2014/140225/ncomms4304/full/ncomms4304.html

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engineering slow or even prevent climate-change? While there are responsible moves being made there is no substantive international consensus on geo-engineering that it is safe, appropriate or effective, no protocols or legislation, nor any universally agreed framework for the regulation of either projects or research.

In 'Geo-engineering, Governance, and Social-Ecological Systems: Critical Issues and Joint Research Needs'[67] Dr Victor Galaz concluded technological changes are pushing humanity beyond the age in which human activity has been the dominant influence on climate and the environment. Coming into play are geo- and bio-geo-engineering, biotechnology, nanotechnology, synthetic biology, and more, bringing potential and risks and to where technologies can produce unexpected re-combinations of existing technologies. Any may have important ecosystem impacts, beneficial or devastating.

Galaz raises these questions: Can we geo-engineer Earth in ways that allow humanity to stay within critical planetary boundaries? What are the best ways to acknowledge the fundamental role played by Earth stewards in current international attempts to govern geo-engineering proposals and technologies? And how do we stay ahead of novel re-combinations of technologies that could help us steer away from devastating nonlinear environmental change, but that could also create novel, large-scale ecological risks? He says these are all questions that emerge as the result of an increasingly intense debate about the opportunities and risks involved with geo-engineering, large-scale technological interventions in the climate system."

Whether geo-engineering can successfully answer Earth's climate problems remains to be seen. One thing is certain we cannot carry on with a "business as usual" attitude. We can all make changes. Reduce emissions through simple actions like switching off lights, using less water, and recycling. The US Environmental Protection Agency site http://epa.gov/climatechange/wycd/ has guidelines; 25 easy steps you can take at Home, School, the Office, and On the Road to protect the climate, reduce air pollution, and save money. Check out http://www.wwf.org.nz/what_we_do/climate_change_new/solutions_to_climate_change/what_you_can_do_about_climate_change/. Small steps do add up.

Compiled by

Physicians and Scientists for Global Responsibility New Zealand Charitable Trust May 2014

Reviewed by Dr Rye Senjen, Lecturer and researcher, known internationally for her work on many issues. Research interests include technology assessment and governance with a particular emphasis on a sustainable future, and moral and ethical issues associated with technology development and the environment.

Further suggested reference material

Several Conference presentations on the implications of geo-engineering schemes for New Zealand. (here)

[67] Ecology and Society, Vol. 17, No. 1, Art. 24, 2012, http://www.ecologyandsociety.org/vol17/iss1/art24/

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‘The Geo-engineering Debate’, NIWA (here)

International Law for the Governance of Marine Geo-engineering (here)

Philosophical Perspectives, Legal Issues, and Governance Frameworks (here)

The United Nations position on geo-engineering (here)

The NZ Government’s commitment to playing its part in the global response to climate change: (here)

NZ Climate Science Coalition (here)

Geo-engineering watch (here)

World Watch Institute (here)

Reports from the ETC Group (here)

The Sustainability Council of New Zealand (here)

Transition Towns NZ Aotearoa – geo-engineering (here)

Chemtrails connected to UN 2013 Report? 7 March 2013, http://www.youtube.com/watch?v=fCohucT7FmQ&list=PL6ECBAD13C9A077D1&index=12

Air Force Whistleblower Lifts The Lid (here)

weatherwars.info by Scott Stevens (here)

Project Earth On Line (here)

UK Natural Environment Research Council (NERC) for numerous reports (here)

Experiment Earth? Findings from a Public Dialogue on Geo-engineering (here)

The Spice Project – The Stratospheric Particle Injection for Climate Engineering http://www2.eng.cam.ac.uk/~hemh/SPICE/SPICE.htm More… http://www2.eng.cam.ac.uk/~hemh/climate/Geo-engineering_RoySoc.htm

BBC World Service Discovery Channel – Geo-engineering 19 January 2014 http://www.bbc.co.uk/programmes/p01p2pf4 and http://www.bbc.co.uk/search/?q=geo-engineering

Geo-engineeringWatch (here)

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Addendum 1 - The full texts of the relevant decisions on geo-engineering

Under Climate Change and Biodiversity (UNEP/CBD/COP/10/L.36)

8. Invites Parties and other Governments, according to national circumstance and priorities, as well as relevant organizations and processes, to consider the guidance below on ways to conserve, sustainably use and restore biodiversity and ecosystem services while contributing to climate-change mitigation and adaptation:

….

(w) Ensure, in line and consistent with decision IX/16 C, on ocean fertilization and biodiversity and climate change, in the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering, and in accordance with the precautionary approach and Article 14 of the Convention, that no climate-related geo-engineering activities[1] that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies that would be conducted in a controlled setting in accordance with Article 3 of the Convention, and only if they are justified by the need to gather specific scientific data and are subject to a thorough prior assessment of the potential impacts on the environment;

[1] Without prejudice to future deliberations on the definition of geo-engineering activities, understanding that any technologies that deliberately reduce solar insolation or increase carbon sequestration from the atmosphere on a large scale that may affect biodiversity (excluding carbon capture and storage from fossil fuels when it captures carbon dioxide before it is released into the atmosphere) should be considered as forms of geo-engineering which are relevant to the Convention on Biological Diversity until a more precise definition can be developed. Noting that solar insolation is defined as a measure of solar radiation energy received on a given surface area in a given hour and that carbon sequestration is defined as the process of increasing the carbon content of a reservoir/pool other than the atmosphere.

AND

9 9. Requests the Executive Secretary to:

….

(o) Compile and synthesize available scientific information, and views and experiences of indigenous and local communities and other stakeholders, on the possible impacts of geo-engineering techniques on biodiversity and associated social, economic and cultural considerations, and options on definitions and understandings of climate-related geo-engineering relevant to the Convention on Biological Diversity and make it available for consideration at a meeting of the Subsidiary Body on Scientific, Technical and Technological Advice prior to the eleventh meeting of the Conference of the Parties;

(p) Taking into account the possible need for science based global, transparent and effective control and regulatory mechanisms, subject to the availability of financial resources, undertake a study on gaps in such existing mechanisms for climate-related geo-engineering relevant to the Convention on Biological Diversity, bearing in mind that such mechanisms may not be best placed under the Convention on Biological Diversity, for consideration by the Subsidiary Body on Scientific Technical and Technological Advice prior to a future

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meeting of the Conference of the Parties and to communicate the results to relevant organizations;

Under New and Emerging Issues UNEP/CBD/COP/10/L.2:

4. Invites Parties, other Governments and relevant organizations to submit information on synthetic biology and geo-engineering, for the consideration by the Subsidiary Body on Scientific, Technical and Technological Advice, in accordance with the procedures of decision IX/29, while applying the precautionary approach to the field release of synthetic life, cell or genome into the environment;

Under Marine and Coastal Biodiversity UNEP/CBD/COP/10/L.42

13. Reaffirming that the programme of work still corresponds to the global priorities, has been further strengthened through decisions VIII/21, VIII/22, VIII/24, and IX/20, but is not fully implemented, and therefore encourages Parties to continue to implement these programme elements, and endorses the following guidance, where applicable and in accordance with national capacity and circumstances, for enhanced implementation:

(e) Ensuring that no ocean fertilization takes place unless in accordance with decision IX/16 C and taking note of the report (UNEP/CBD/SBSTTA/14/INF/7) and development noted para. 57 – 62;

Impacts of ocean fertilization on marine and coastal biodiversity

57. Welcomes the report on compilation and synthesis of available scientific information on potential impacts of direct human-induced ocean fertilization on marine biodiversity (UNEP/CBD/SBSTTA/14/INF/7), which was prepared in collaboration with United Nations Environment Programme-World Conservation Monitoring Centre (UNEP-WCMC) and the International Maritime Organization in pursuance of paragraph 3 of decision IX/20;

58. Recalling the important decision IX/16 C on ocean fertilization, reaffirming the precautionary approach, recognizes that given the scientific uncertainty that exists, significant concern surrounds the potential intended and unintended impacts of large-scale ocean fertilization on marine ecosystem structure and function, including the sensitivity of species and habitats and the physiological changes induced by micro-nutrient and macro-nutrient additions to surface waters as well as the possibility of persistent alteration of an ecosystem, and requests Parties to implement decision IX/16 C;

59. Notes that the governing bodies under the London Convention and Protocol adopted in 2008 resolution LC-LP.1 (2008) on the regulation of ocean fertilization, in which Contracting Parties declared, inter alia, that given the present state of knowledge, ocean fertilization activities other than legitimate scientific research should not be allowed;

60. Recognizes the work under way within the context of the London Convention and London Protocol to contribute to the development of a regulatory mechanism referred to in decision IX/16 C, and invites Parties and other Governments to act in accordance with the Resolution LC-LP.2(2010) of the London Convention and Protocol ;

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61. Notes that in order to provide reliable predictions on the potential adverse impacts on marine biodiversity of activities involving ocean fertilization, further work to enhance our knowledge and modelling of ocean biogeochemical processes is required, in accordance with decision IX/16 (c) and taking into account decision IX/20 and LC-LP.2 (2010);

62. Notes also that there is a pressing need for research to advance our understanding of marine ecosystem dynamics and the role of the ocean in the global carbon cycle;

CONFERENCE OF THE PARTIES TO THE CONVENTION ON BIOLOGICAL DIVERSITY
Tenth meeting, Nagoya, Japan, 18-29 October 2010, Agenda item 5.2, MARINE AND COASTAL BIODIVERSITY
(http://cmsdata.iucn.org/downloads/cbd_cop_10_position_paper_marine.pdf.)

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