Environment Canada | Environnement Canada

Terrasses de la Chaudière
10 Wellington Street, 27th Floor
Gatineau, Québec K1A 0H3

Your File Votre référence

Our File Notre référence
A-2013-01364 / CL3

MAR 1 3 2014

Mr. Bill Vander Zalm
3553 Arthur Drive
Ladner, British Columbia V4K 3N2

Dear Mr. Vander Zalm,

We have completed processing your request under the *Access to Information Act* for:

> "Clarification received December 20, 2013: To receive copies of the release packages for the following requests: A-2012-01542, A-2012-01267, A-2013-00527 and A-2013-00960."

Further to the partial release package sent to you on January 13, 2014, please find enclosed a final release package to this request.

Please be advised that you are entitled to file a complaint with the Information Commissioner concerning the processing of your request within sixty days of the receipt of this notice. In the event you decide to avail yourself of this right, your notice of complaint should be addressed to:

Information Commissioner of Canada
30 Victoria Street
Gatineau, Québec K1A 1H3

If you have any questions regarding this request, please do not hesitate to contact Colleen Leger at 819-953-9750.

Yours sincerely,

Nancy Hamzawi
Access to Information and Privacy Coordinator

Enclosures

This is Exhibit "A" referred to in the affidavit of William Vander Zalm sworn before me at Surrey, B.C. this 20th day of December, 2014.

A Commissioner for taking Affidavits Within British Columbia

MICHAEL KENDLER
Barrister & Solicitor
Suite 1500, 13450 - 102nd Ave.
Surrey, B.C. V3T 5X3
604-581-7001

Canada

BACKGROUND

Geoengineering involves intentional, large-scale intervention in Earth's environmental systems to prevent, control or counteract climate change.[1]

Given the challenges of reducing greenhouse gas (GHG) emissions, along with observations indicating that some areas (such as the Arctic) are experiencing rapid environmental change, there is increasing interest in geoengineering options.

In brief summary, EC's deck (Attachment 1) identifies two types of geoengineering: carbon dioxide (CO_2) removal; and solar radiation management.

Proposed methods of CO_2 removal include:

- large-scale afforestation;
- increased oceanic CO2 sequestration by adding iron to the oceans to enhance growth of CO_2-storing phytoplankton;
- direct injection of liquefied CO_2; and
- direct, large-scale extraction of CO_2 from the atmosphere.

Proposed methods of solar radiation management include:

- increasing the reflectivity of the atmosphere via sulphur injections;
- using satellite mirrors; and
- changing Earth's reflectivity via large reflective covers and light-coloured pavement.

EC notes that, although various geoengineering considerations are referenced in several international agreements, there is no overarching international governance mechanism.

CONSIDERATIONS

s.21(1)(a)
s.21(1)(b)

[redacted]

[1] Geoengineering does not include carbon capture and sequestration or fracking, and is not the same as geotechnical engineering, which deals with structural foundations.

Page 3

is withheld pursuant to sections

est retenue en vertu des articles

15(1), 21(1)(a), 21(1)(b)

of the Access to Information Act

de la Loi sur l'accès à l'information

CL > humboldt > all community > general community

reply x prohibited [?] Posted: 22 days ago

Stop the spraying, copy and send to your reps (Humboldt Chemtrails)

RESOLUTION TO REQUIRE PUBLIC CONSENT PRIOR TO ANY GEOENGINEERING (Climate Remediation), EXPERIMENT OR PROGRAM COMMENCING in, or having either an indireet, or a direct effeet in Eureka and the County of Humboldt .

GEOENGINEERING DESCRIBES ACTIVITIES SPECIFICALLY AND DELIBERATELY DESIGNED TO EFFECT A CHANGE IN THE GLOBAL CLIMATE WITH THE AIM OF MINIMIZING OR MASKING ANTHROPOGENIC CLIMATE CHANGE (GLOBAL WARMING). SCHEMES OR EXPERIMENTS INCLUDE ANY AND ALL ATTEMPTS TO ALTER, REMEDIATE, OR MASK CLIMATE CHANGE OR GLOBAL WARMING BY REMOVING CARBON DIOXIDE FROM THE ATMOSPHERE OR BY SOLAR RADIATION MANAGEMENT (SRM - - ALSO REFERRED TO AS MARINE CLOUD WHITENING), WHICH INJECTS AEROSOLS, PARTICLES, CHEMICALS, GASES, VAPORS, SULFUR, BARIUM, ALUMINUM OXIDE (ALUMINA), CHAFF, SALT OR OTHER COMPOUNDS INTO THE ATMOSPHERE TO REFLECT A PORTION OF THE SUN'S RADIATION BACK INTO SPACE, THEREBY REDUCING THE AMOUNT OF SOLAR RADIATION (DIRECT SUNLIGHT), REACHING THE EARTH. These schemes have the potential to change the weather, and if ongoing any period of time, change the climate.

WHEREAS, Geoengineering (Climate Remediation), would have an economic impact on Eureka and the County of Humboldt as defined by the Bipartisan Policy Task Force October 4, 2011 Report: ". . .as intentional actions taken to counter the climate effects of past greenhouse gas emissions on the atmosphere...(we mean past or future relative to the time that the action is taken). . ." and that Solar Radiation Management (SRM) Techniques or strategies aim to counteract or mask the effect of rising greenhouse gas concentrations in the atmosphere by increasing the amount of solar energy that is reflected back into space. . ."

WHEREAS, Geoengineering would have an economic, soil, and air quality impact on Eureka and the County of Humboldt under the Solar Radiation Management ". . .category of climate remediation options includes a range of ideas, but most current research is focused on two distinct concepts: 1) Introducing very fine particles or liquid droplets--known as aerosols--into the stratosphere to deflect incoming solar radiation, and 2) Altering the reflectivity of clouds by means such as spraying droplets of seawater into the atmosphere to make cloud droplets more numerous and smaller and to make the clouds more reflective (i.e., brighter). . ." Bipartisan Policy Task Force October 4, 2011 Report

WHEREAS, Geoengineering (Solar Radiation Management), would have an economic impact on Eureka and the County of Humboldt as ". . .SRM may be able to mask some impacts of greenhouse gases on the climate system, it would do nothing to deal with the chemical consequences of increased CO2 concentrations in the atmosphere, including ocean acidification--a phenomenon that poses significant risks, particularly for marine life. . ." Bipartisan Policy Task Force October 4, 2011 Report.

WHEREAS, Geoengineering (Solar Radiation Management), would have an economic impact on Eureka and the County of Humboldt as ". . .SRM may be able to mask some impacts of greenhouse gases on the climate system, it would do nothing to deal with the chemical consequences of increased CO2 concentrations in the atmosphere, including ocean acidification--a phenomenon that poses significant risks, particularly for marine life. . ." Bipartisan Policy Task Force October 4, 2011 Report. (Note California Air Resources Board White Paper: ". . .scattering of sunlight by acrosols masks as much as 50% of the present warming effect of greenhouse gases [Ramanathan et al., 2001].)

WHEREAS, Geoengineering (SRM), would have an economic impact on Eureka and the County of Humboldt because ". . .deployment of SRM could raise particularly difficult national security questions and could create challenges for international policy coordination because it could help some regions while harming others. . .and the burden of long-term management of SRM systems that cannot be stopped without creating harmful, sudden increases in global temperature. . .(and), it could result in decreased precipitation and evaporation, altered monsoon rains and winds, and perhaps delayed recovery of the ozone hole. . .In addition, to these anticipated risks, there may be further risks that scientists have not yet been able to identify. . ." Bipartisan Policy Task Force October 4, 2011 Report. (Clearly, synergistic and cumulative impacts of various types of Geoengineering Schemes have not been considered by those promoting many of these different schemes.)

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt (which includes weather modification and weather mitigation programs) by producing reductions in regional rainfall that could rival those of past major droughts, leading to winners and losers among the human population and possible conflicts over water according to Grant University and NOAA. Decreased rainfall would have a huge agricultural impact on Long Island 's farming community, trees, water supplies, and citizens.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt by large scale Geoengineering, weather modification, and climate remediation schemes may promote rain or snow in one area to the detriment of another, and the legal and liability issues pertaining to Geoengineering (Climate Remediation), with the potential adverse consequences on life, property, air quality and water resource availability resulting from these activities, must be considered in advance prior to implementation or rejection of these schemes.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt by reducing the total amount of direct sunlight reaching Earth's surface. All plants, agricultural crops, and trees require direct sunlight for photosynthesis. Scientists need to assess the impacts on crops and natural vegetation of reductions in total, diffuse, and direct solar radiation according to Bulletin of Atomic Scientists before proceeding with Solar Radiation Management (SRM) experiments.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt through injection of sulfur or aluminum oxide particles, water vapor (a greenhouse gas), other compounds or gases into the atmosphere leading to increased air, water pollution, and acid rains which will have a deleterious effect on the seafood industry. Acid rain damages fish populations by disrupting their reproductive cycle and leaching aluminum from soil into rivers, streams, and other water tributaries, according to the New York State Department of Environmental Conservation.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt due to increased acid rain (from sulfur, aluminum oxide particles, gases or other compounds), which causes adverse impacts on highly sensitive forest ecosystems. Acid rain damages forests by draining nutrients from the soil resulting in altered tree growth and dieback according to the New York State Department of Environmental Conservation. According to The Dying of the Trees by Charles Little, studies show that acid rain causes aluminum to be unnaturally released from the soil. Aluminum is then free to be absorbed by trees and plants through their root systems. Aluminum kills or damages the roots first which means that trees can no longer absorb and transport nutrients. Aluminum's effects are multiplied exponentially as acidification increases. Geoengineering (Climate Remediation) schemes would exacerbate acid rain problems and aluminum toxicity of the soil, resulting in the further decimation of forests, plants, agriculture farm land, and tourism.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt because sulfate, aluminum oxide particles (gases), or other compounds used in Geoengineering Schemes, would eventually fall from the stratosphere into the troposphere and "rain out" onto the land and ocean. This would contribute to ocean acidification and could negatively impact crop soils and built structures, according to the U.S. House Science & Technology Committee, February 2010.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt , Geoengineering (SRM, marine cloud whitening) also runs the risk of creating localized impacts on regional climates throughout their deployment. This decrease in sunlight over the oceans could affect precipitation patterns and regional ocean ecosystem function (seafood industry), according to U.S. House Committee on Science and Technology, February, 2010. Long Island is a tourist destination. Decreased sunlight, increased precipitation and increased cloud cover would have detrimental effects on local businesses, fishing and other industry.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt by decreasing effectiveness of alternative forms of energy such as solar panels due to reductions in direct sunlight or diffuse sunlight according to NOAA.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt by increasing atmospheric water vapor (a greenhouse gas), and cirrus clouds which are formed from aircraft engine exhaust and jet engine combustion often visible as persistent jet contrails. Cirrus clouds exert a warming influence on the surface by allowing most of the Sun's rays to pass through but then trapping some of the resulting heat emitted by the surface and lower atmosphere according to NASA. Aircraft (rockets have been used in the past), are considered the most economical way to disperse atmospheric aerosols (gases or particles). In 2009, the U.S. Navy and NASA disbursed an aluminum oxide dust cloud (2009), using a NASA Brandt Rocket, over the East Coast of the United States (U.S. Navy Charged Aerosol Release Experiment CARE). As aluminum oxide is highly toxic to humans, plant life and aquatic sea life, public consent should be mandatory prior to any experiments using rockets, balloons, pipes, tubes or any other methods or devices that disperse chemicals, particles, CHAFF, gases, vapors, salt, aerosols, or other such materials by any corporation, government agency, NASA, private corporations or private individuals. (We need to consider synergistic and cumulative impacts of multiple schemes deployed by the U.S. Military as they are engaged in atmospheric testing and chemical releases.)

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt by increasing the anthropogenic warming it is intended to offset. Aircraft emissions are responsible for 4-8% of surface global warming since surface air temperature records began in 1850--equivalent to a temperature increase of .03 - .06 Celsius overall. Aircraft vapor trails in the Arctic produced 15-20% of warming according to Stanford University studies. (Water vapor is a potent greenhouse gas-EPA.)

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt due to black carbon (soot) in the atmosphere. Geoengineering does not decrease carbon (CO2) in the atmosphere. Black carbon acts as an absorbing aerosol--a particle that absorbs the sun's heating rays. Black carbon also has varying effects on precipitation and weather events. In the lower layers, it increases precipitation and in the upper layers, it decreases precipitation. Black carbon also causes human health problems. Aircraft and rockets are a notable source of emissions, including soot and water vapor, into the atmosphere according to Carnegie Institution and the U.S. Environmental Protection Agency.

WHEREAS, Geoengineering (Climate Remediation), would have an economic and human health impact on Eureka and the County of Humboldt by negatively impacting the protective ozone layer and by decreasing sunlight which would cause Vitamin D deficiencies. Vitamin D deficiency (from increasing cloud cover - Center for Disease Control), is linked to rickets, asthma, allergies, increased cancer, hyperparathyroidism, osteoporosis, depression, diabetes, and other health problems, according to Mayo Clinic. These illnesses could overburden the State of California Health Care system through decreased worker productivity, increased sick days, pharmaceutical costs, etc.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt , ". . .ultraviolet radiation constitutes only about 5 percent of the total energy emitted from the sun, it is the major energy source for the stratosphere and mesosphere, playing a dominant role in both energy balance and chemical composition. Most ultraviolet radiation is blocked by Earth's atmosphere, but some solar ultraviolet penetrates and aids in plant photosynthesis and helps produce vitamin D in humans. Too much ultraviolet radiation can burn the skin, cause skin cancer and cataracts, and damage vegetation. (EPA) There have been no assessments made with regard to the impact of multiple Geoengineering Schemes on UV Radiation issues or their impacts on the stratosphere or mesosphere. (Note: Honey Bees also navigate by using ultraviolet light. Many pollinators and honey are in decline across the United States-we can't afford to further damage their ability to pollinate the majority of food we eat.)

WHEREAS, Geoengineering would have an economic and health impact on Eureka and the County of Humboldt , according to NASA, ". . .aerosols in

the troposphere, such as dust and smoke, not only scatter but absorb UV-B radiation. . .in some circumstances, aerosols can contribute to an increase in UV exposure at the surface. . ." If ice particles form (from persistent jet contrails as one example), ". . .The ice particles. . .allow complete chemical reactions to take place in a manner than can deplete stratospheric ozone. . ." thus, allowing high UV radiation readings at the Earth's surface. . ."

WHEREAS, Geoengineering would have an economic and health impact on Eureka and the County of Humboldt by negative health effects due to high concentrations of fine particulate sulfate and alumina (small and nano-size particulates), now being considered for use in several Geoengineering experiments including weather modification programs where nano-silver is being considered as part of these programs, that can enter the cardiovascular and respiratory systems, resulting in disease or even death according the New York State Department of Environmental Conservation.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt due to negative health effects. Aerosols could deplete the ozone layer and contribute to air pollution according to University Corporation for Atmospheric Research. Reductions in stratospheric ozone levels will lead to higher levels of UVB radiation reaching the Earth's surface. Laboratory and epidemiological studies demonstrate that UVB causes nonmelanoma skin cancer and plays a major role in malignant melanoma development, and cataracts according to the EPA.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt as aluminum oxide (alumina) dust is one of the light reflecting materials under serious consideration according to Unilateral Geoengineering Workshop at Council on Foreign Affairs and David Keith (2010 AAAS Meeting on Geoengineering). Aluminum oxide causes birth or developmental effects, brain and nervous system effects, and reproduction, and fertility problems as noted by Environmental Working Group.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt due to the fact that once begun, studies show that these schemes would have to be continued indefinitely or risk an abrupt warming with rates that are unprecedented for modern human societies and would likely cause sizeable economic disadvantages according to Penn State University.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt as the individuals and corporations that are researching and funding said programs stand to reap the profits of implementation of the program at unknown health, environmental, and monetary costs to citizens according to Bulletin of the Atomic Scientists. In addition, governments and private entities in Germany, India, Russia, and the United Kingdom are exploring or moving ahead with their own Geoengineering (climate remediation), research efforts. Controversies have already arisen in the international diplomatic arena according to Bipartisan Policy Center's Task Force on Climate Remediation research. As such, the public must be informed and consent must be mandatory to avoid governance or implementations of such programs by private corporations, wealthy individuals, foreign nations or proponents of these types of programs.

WHEREAS, Geoengineering would have an economic impact on Eureka and the County of Humboldt by Geoengineering (Climate Remediation or Solar Radiation Management), chemicals, particles, gases, vapors, and other compounds or contaminants used in said experiments or research would violate State of New York Laws: Article 1 - Title 3 - § 1-0303. General definitions: "19. "Pollution" shall mean the presence in the environment of conditions and or contaminants in quantities of characteristics which are or may be injurious to human, plant or animal life or to property or which unreasonably interfere with the comfortable enjoyment of life and property throughout such areas of the state as shall be affected thereby. . ."

THEREFORE, air quality must be monitored to ensure such programs are not implemented without public consent due to the secrecy surrounding this issue to date. Tests must be performed on a continuous basis to ascertain levels of proposed and known chemicals, particles, gases, metals, other compounds, and materials to ensure that these programs are not implemented without public consent. The public should be included in all proposed decisions to implement, restrict, or prevent SRM, Geoengineering, weather modification, and other schemes.

THEREFORE, since the general public is unaware of the risks associated with Geoengineering, climate remediation, weather modification programs and the numerous private, corporate, university, and government meetings held by the U.S. House Science & Technology Committee, agreements between the U.S. House and UK House of Commons on Global Geoengineering Governance, current research and schemes being conducted, and Global Geoengineering Governance Rules and Regulations being formulated to implement these programs, we, the people, due to the risks involved, require participation, review, and oversight over these rules and regulations along with Environmental Impact Statements for each proposed scheme, along with their cumulative and synergistic impacts.

THEREFORE, since there have been many meetings regarding Global Geoengineering Governance which will ensure that a few countries decide who controls and approves these programs and when they are implemented without the knowledge or acceptance of the public (Royal Society Geoengineering Report 2010 on Governance Rules), Public Government Hearings must be mandatory prior to any proposed testing to include Public Comment periods of at least 60-90 days. In addition, a Required Environmental Impact Report (EIS) must be completed prior to any testing or implementation of Geoengineering (Climate Remediation), schemes or weather modification programs and presented to the people of Eureka and the County of Humboldt

- do NOT contact me with unsolicited services or offers

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JUL 04 2012

MEMORANDUM TO THE ASSOCIATE DEPUTY MINISTER

c.c.: Stephen Lucas, ADM, SPI
Geoff Munro, ADM, IETS
Brian Gray, ADM, ESS

MEETING WITH DEPUTY MINISTERS REGARDING GEOENGINEERING

(Meeting on July 5, 2012)

SUMMARY

s.21(1)(a)

- You will attend a meeting convened by Environment Canada's (EC) Deputy Minister, Mr. Paul Boothe, on July 5, 2012. At the meeting, EC will present a summary of current interest, science and governance issues regarding geoengineering options to address climate change [redacted]
- The meeting will be held from 10:30 a.m. to 12:00 p.m. at the Large Boardroom, 27th Floor, les Terrasses de la Chaudière, 10 Wellington Street, Gatineau, with the following other invitees:
  - Ms. Claire Dansereau—Deputy Minister, Fisheries and Oceans;
  - Mr. Rob Fonberg—Deputy Minister, Defence;
  - Mr. Richard Fadden—Director, Canadian Security Intelligence Service;
  - Mr. Morris Rosenberg—Deputy Minister, Foreign Affairs and International Trade; and
  - Mr. Stephen Rigby—National Security Advisor to the Prime Minister, (Privy Council Office).
- [redacted]

Canada

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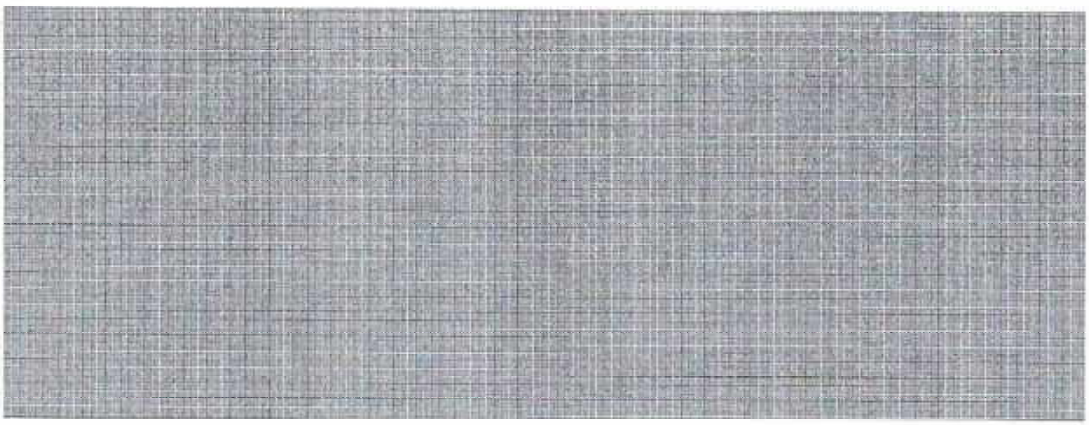
s.21(1)(a)
s.21(1)(b)



The Energy and Environment Policy Division, Energy Policy Branch, would be pleased to support you at the meeting and in coordinating further action on geoengineering issues.

Mark Corey

Attachment: (1)

Contacts: Joy Senack, 613-995-2821
David Henry, 613-996-6474
Energy Policy Branch, ES

Environment Canada
Environnement Canada

SECRET

Geoengineering: Science and Governance

Environment Canada

July 5, 2012

Purpose

- To outline the interest in research on geo-engineering
- To describe the current scientific understanding of geo-engineering
- To review potentially relevant international governance impacting this issue
- [redacted] s.21(1)(a) s.21(1)(b)

Geoengineering: the deliberate large-scale intervention in the Earth's climate system in order to moderate global warming

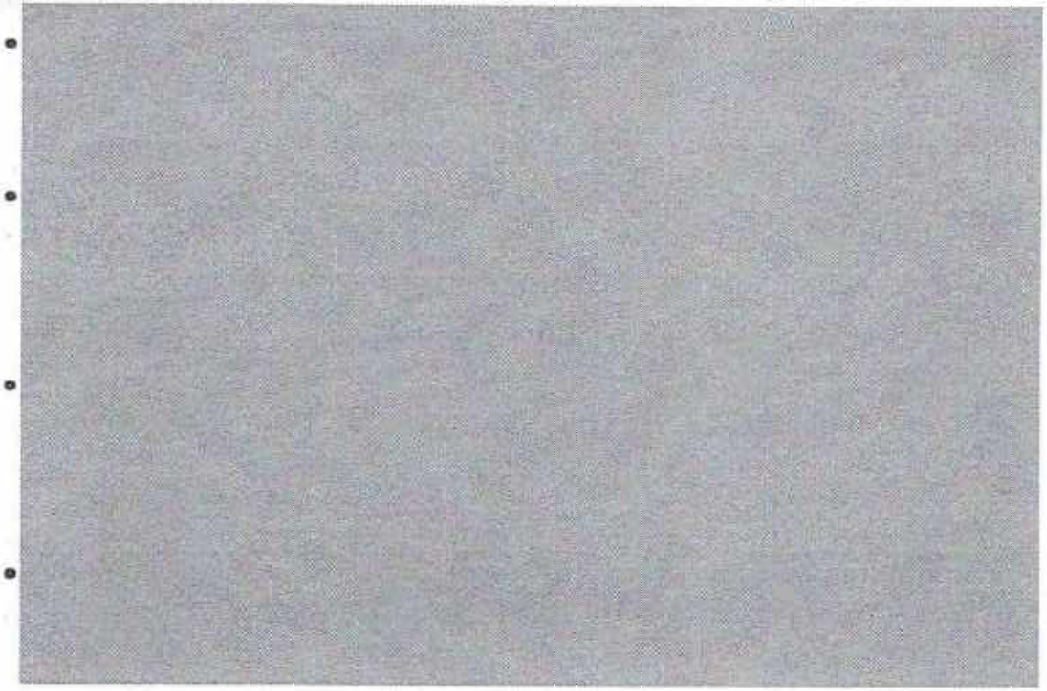
Outline

- Context
- Introduction: geoengineering approaches [redacted] s.21(1)(a)
- Description of two broad approaches:
  - CO_2 removal
  - Solar radiation management
- Governance of geoengineering
- Looking ahead

**Note: Carbon capture and storage at source is not geoengineering by this definition*

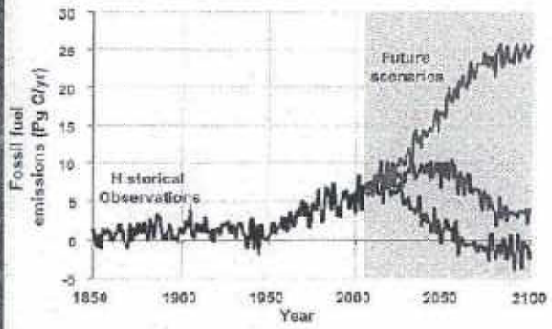
s.15(1)
s.21(1)(a)
s.21(1)(b)

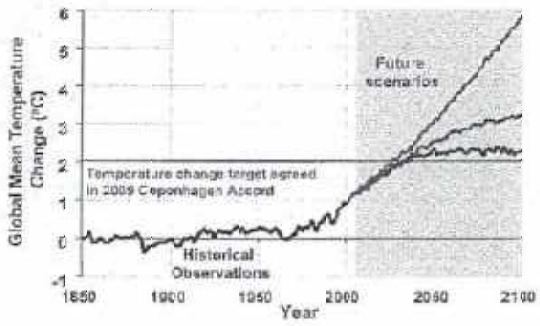
Context



Introduction

- The Earth's climate is warming in response to anthropogenic emissions of greenhouse gases, and even rapid implementation of emission reductions may not limit warming to the 2°C limit agreed in Copenhagen





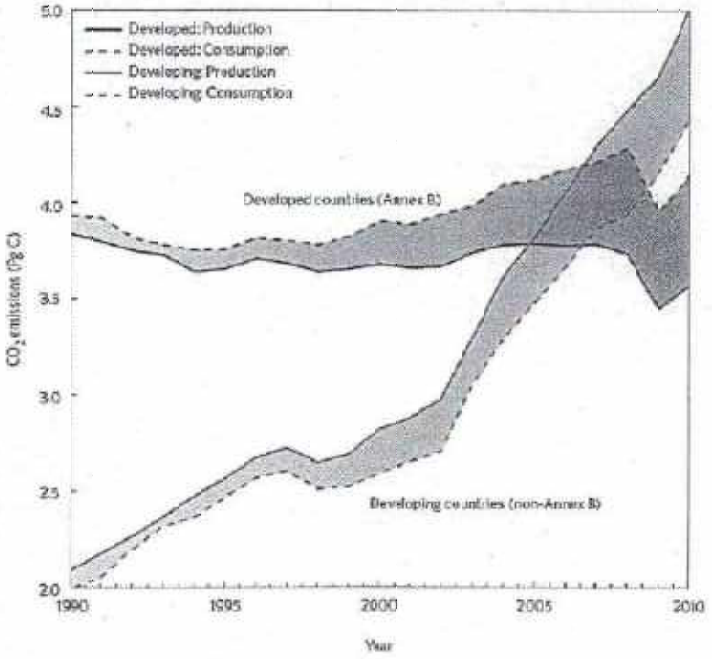
If greenhouse gas emissions continue unabated, models predict 2°C warming target, agreed to in Copenhagen, will be exceeded by mid century.

To avoid surpassing it, global CO_2 emissions must level off immediately, and decline to *negative* values before end of century (implying net CO_2 extraction from atmosphere), or other means of moderating warming would be needed.

Fig. Ref: Arora et al., Geophys. Res. Lett., 2011

Introduction (cont'd)

- Global fossil-fuel CO_2 emissions continue to rise, following the brief dip associated with the global financial crisis. No evidence that overall growth in global emissions is slowing, let alone beginning to decline.



- Global CO_2 emissions grew by 5.9% in 2010 (highest annual growth rate since 2003), and more than offset the 1.4% decrease in 2009
- Growth dominated by emissions from emerging economies

Ref: Peters et al., Nature Climate Change, Jan 2012, pp 2-4.

Introduction (cont'd)

- Potential implications of global average temperature increases:
  - Increase in extreme weather events (e.g., floods, droughts, heatwaves, fires and cyclones)
  - Impacts on costal cities due to sea level rise (due to melting glacier and ice caps)
  - Precipitation changes – decreased water availability, increased drought (mid-latitudes)
  - Impacts to agriculture – food security
  - Biodiversity loss

Introduction (cont'd)

- Geoengineering is increasingly discussed as a possible approach to reducing future warming
- Scientific questions relate to effectiveness, timescales, control and possible unintended consequences
- Most geoengineering approaches can be classified as either:
  - ***CDR*** – Carbon Dioxide Removal (from the atmosphere)
  - ***SRM*** – Solar Radiation Management
- There are many possible approaches within each of these categories

Carbon Dioxide Removal (CDR)

- When the global carbon cycle is at equilibrium, natural fluxes balance and atmospheric CO_2 concentration and temperature remain constant
- However, humans affect this balance through emissions from burning of fossil fuels and land-use change
- To achieve a stable climate, net emissions (sources minus sinks) must be zero
- ***CDR*** geoengineering methods involve removal of CO_2 from the atmosphere so as to move toward net zero emission
- Examples include: afforestation, ocean fertilization, and direct extraction of CO_2 from the atmosphere

Afforestation

- Involves global-scale planting of trees on cropland or other unforested land so as to enhance CO_2 removal from the atmosphere
- Recent research shows that even afforestation of 50% of global crop area (a rather extreme scenario), leads to a modest warming reduction of 0.24°C by end of century. "Realistic" afforestation would have an even smaller impact
- Like all CDR schemes, Afforestation takes a long time to become effective

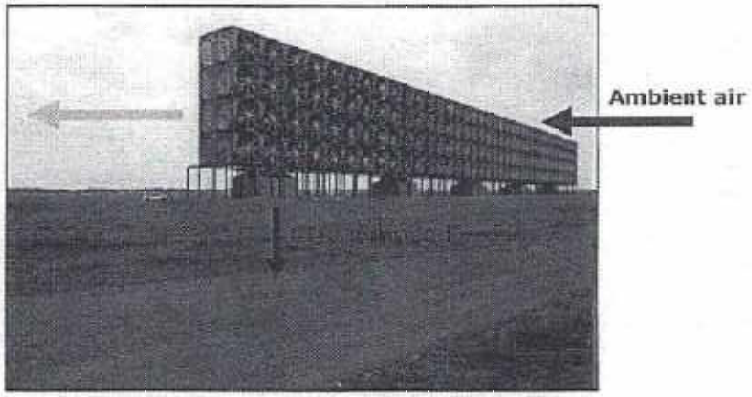
Ref: Arora and Montenegro, Nature Geoscience, 2011

Ocean Fertilization

- Phytoplankton are oceanic "plants" that take up CO_2 by photosynthesis
- A small fraction of the carbon taken up by phytoplankton is converted into inorganic carbon which is sequestered in the deep ocean
- Ocean productivity in many regions is limited by availability of micronutrients, mainly iron
- "Iron fertilization" offers the possibility of enhancing productivity and hence CO_2 uptake
- Field experiments show that iron fertilization does temporarily enhance chlorophyll, but the CO_2 taken up is quickly recycled back to the atmosphere, so not much net removal
- At present, consequences for ocean acidification remain unclear

Direct Carbon Capture

- Objective is to use technological approaches to remove CO_2 directly from the atmosphere and sequester it somewhere.



A difficulty is that CO_2 is a trace gas in the atmosphere (~390 parts per million = 0.039%) and so a lot of air has to be processed when employing such methods.

As a result, extracting CO_2 from ambient air can be energy intensive.

Image: http://keith.seas.harvard.edu/AirCapture.html

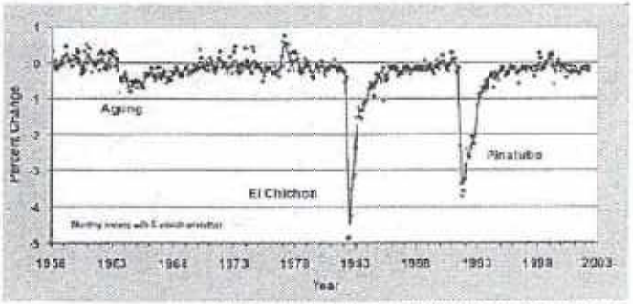
Solar Radiation Management (SRM)

- Methods aimed at reducing solar input – accomplished by increasing reflectivity
- One approach would be space-based orbiting mirrors

** Note that in SRM schemes, CO_2 continues to accumulate in the atmosphere and ocean, adding to ocean acidification.*

Stratospheric Sulfur Aerosols

- An SRM proposal that is better studied is injection of sulfur aerosols directly into the stratosphere (using airplanes, rockets, balloons, etc.) to mimic the effect of a volcano. From observations we know this has a cooling effect

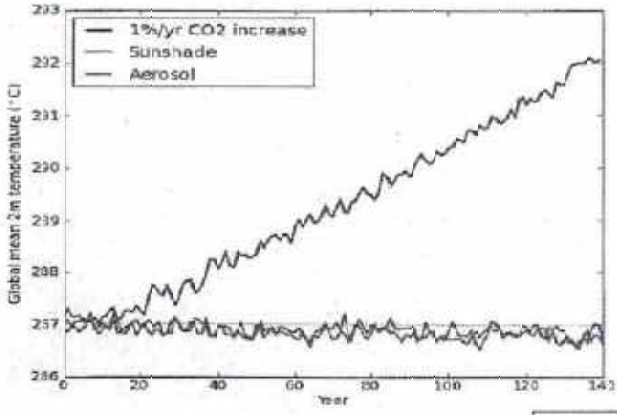


http://www.esrl.noaa.gov/gmc/about/climate.html

- Since aerosols remain in stratosphere for only 1-3 years, such injection would have to be continuous
- Alternate approaches involve injection of aerosols into lower atmosphere to enhance cloud formation, but these aerosols only remain aloft for a few days
- This approach would have to be used continuously to be effective on temperature but like all SRM it does not address the isssue of ocean acidification

GEOMIP – an internationally-coordinated climate modelling experiment

- Aimed at quantifying climatic effects of 'ideal' SRM implementation
- EC has undertaken two types of experiments, one in which incoming solar radiation is reduced so as to exactly offset CO_2 warming, and another in which aerosols are injected into the stratosphere
- Idealized climate model experiments allow one to look at the response of the climate system to such interventions



Ref: Fyfe et al., manuscript in prep., 2012

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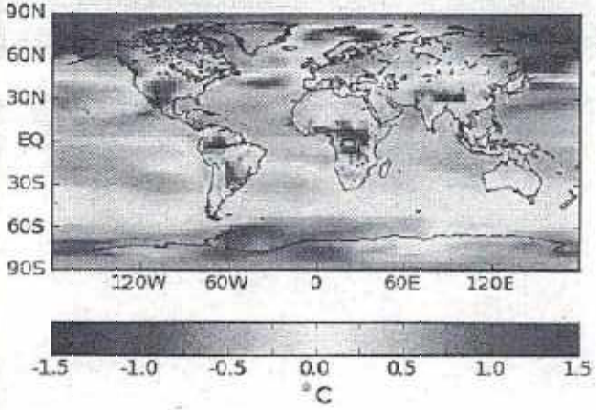
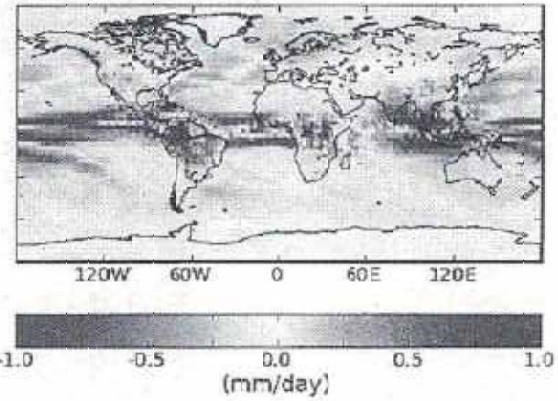
Temperature Change



Precipitation Change

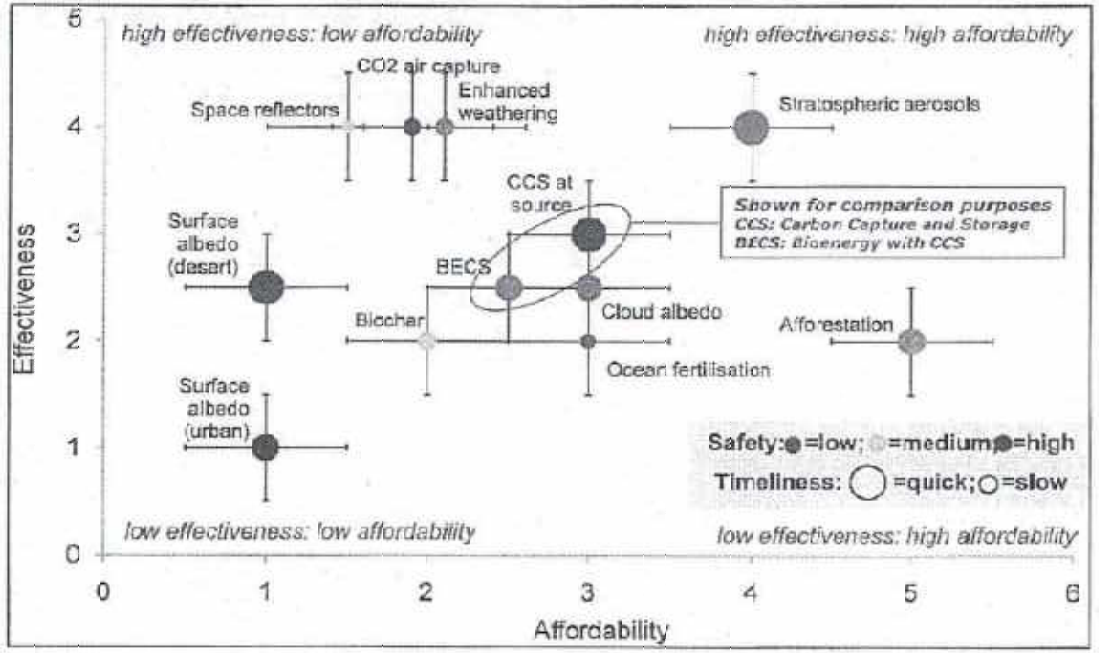


Although global mean warming can be averted, regional changes remain – some areas continue to warm, particularly high latitudes.

Precipitation change is not averted however, and models suggest substantial ongoing drying in Tropics.

Ref: Fyfe et al., manuscript in prep., 2012

Summary from Royal Society report on Geoengineering



Ref: Figure 5.1 Geoengineering the climate. UK Royal Society (2009).

Summary of Science related to Geoengineering

- Climate model results clearly indicate that all emission scenarios considered lead to warming of about 2ºC by 2050
- Emission reductions essentially determine the extent to which warming will stabilize around this value or surpass it
- This has motivated scientific research into geoengineering as a potential supplement to emission reductions
- Approaches generally involve either enhancing carbon dioxide removal from the atmosphere (*CDR*) or increasing the reflectivity of Earth (solar radiation management - *SRM*)
- Global Earth System models allow 'what if' experiments, aimed at improved understanding of effectiveness and some unintended consequences of possible geoengineering methods
- Many questions remain: effectiveness re temperature increase, impact on other implications of GHG emissions, unintended effects and control

Risks, uncertainties and need for governance

- Geoengineering entails both risk and uncertainty
- Legitimate scientific research involving geo-engineering must proceed carefully
- Geoengineering raises issues regarding "reversibility", "encapsulation", "commercial involvement" and "public engagement"
  - *Reversibility* is being able to cease the technology program and end the adverse effects
  - *Encapsulation* is the containment of the technology program and in the current context, whether there is control over the release of substances in the environment
- The "Oxford principle" (2012) states that geo-engineering should be regulated as a public good; there should be public participation in decision-making; research should be disclosed and results published openly; impacts should be assessed independently; and decisions to deploy the technologies should be made within a robust governance framework

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Geoengineering Governance

- Some treaties have made statements and resolutions to curtail geoengineering until the state of knowledge increases and global governance is put in place.

UN Convention on Biological Diversity (CBD) – In 2010, no geoengineering should take place that may affect biodiversity until there is an adequate scientific basis.

Environmental Modification Convention (ENMOD) (1978) – bans environmental modification for hostile purposes. Signed by all major countries with the exception of China and Israel.

Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention - LC) and the 1996 Protocol thereto (London Protocol – LP)

- Concern regarding marine pollution from large scale Ocean Fertilization (OF) proposals triggered the London Convention/London Protocol (LC/LP)
- 2008 resolution voluntarily interprets OF as prohibited except for legitimate scientific research
- 2010 resolution adopted an assessment framework to determine if projects are legitimate scientific research
- [redacted]

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Slide 5

The figure on the left shows GHG emissions – in red, green and blue are three different representative concentration pathways. On the right, are historical temperature and then in red, green and blue, predicted temperature given the GHG emissions.

Take home message is that limiting warming to 2C will be very difficult.

Emission reductions are slow to take effect because of long residence time of CO2 in atmosphere, and 'compatible' emissions in figure on right suggest immediate and very deep cuts needed.

Though the results presented here are from one particular model, Environment Canada's CanESM2, similar results are obtained by other models.

Slide 6

Emission data indicates that global emissions continue to rise, at an accelerating rate. No indication that emissions are close to levelling off or declining as would be necessary to halt warming.

This is what has motivated thinking about supplementary actions like geoengineering in the international community.

Figure caption from original paper:

Historic CO2 emissions from 1990 to 2010 of developed (Annex B) and developing (non-Annex B) countries with emissions allocated to production/territorial (as in the Kyoto Protocol) and the consumption of goods and services (production plus imports minus exports). The shaded areas are the trade balance (difference) between Annex B/non-Annex B production and consumption6,14. Bunker fuels are not included in this figure.

Slide 8

- Note that a comprehensive review is available in "Geoengineering the climate: science, governance and uncertainty", published by the Royal Society in 2009. In this report, many different CDR and SRM approaches are described and evaluated in terms of their effectiveness, affordability, safety and timeliness.
- In this presentation, only a few will described.

Slide 11

In many areas of the ocean, phytoplankton productivity is limited by a lack of some micronutrient – typically iron.

Iron fertilization involves the artificial introduction of iron into the upper ocean, thereby eliminating this micro-nutrient limit and allowing enhanced ocean productivity.

If this enhanced productivity leads to enhanced export of carbon to the deep ocean (where it can reside for years to centuries), this would result in a reduction of atmospheric CO2.

Slide 12

Note that Direct Carbon Capture from the atmosphere is distinct from Carbon Capture and Storage at source.

CCS captures carbon *before* it is released to the atmosphere

DCC 'scrubs' it out of the atmosphere

Slide 14

Large explosive volcanoes, particularly those in the Tropics, inject large volumes of sulphur dioxide into the stratosphere (the layer of the atmosphere between about 10 and 50km altitude). There it becomes sulphate aerosol which can reside in the stratosphere for 1-3 years, and is very effective at reflecting short-wave (solar) radiation. This reduces the solar radiation that reaches the surface as shown by the observed near surface solar radiation time series in the upper right – the effect of recent volcanoes is clearly visible.

With some careful statistical analysis, one can deduce the global surface temperature anomaly associated with volcanic eruptions, and this is shown in the time series on the middle right.

Take home message: volcanic aerosols do have a cooling effect on climate, but even a very large volcano has an effect of only a couple tenth's of a degree, and the effect disappears after a couple years as the aerosol is eventually transported or precipitated out of the stratosphere. Intentional injection of sulphate aerosol into the stratosphere would have a cooling effect, but it requires a lot of material to be injected, and it has to be done continuously to remain effective.

Also important to note that long-lived greenhouse gases are removed very slowly by natural processes, and so even if net GHG emissions were to reach zero at some time in the future, the GHG concentration at that time remains for centuries, and therefore so does their warming effect. This means that, if implemented, any offsetting by SRM geoengineering would have to continue even long after emission reductions have been achieved or else the GHG warming would be 'unmasked'.

Pinatubo injected ~15 million tons of sulphur dioxide into the atmosphere. (source: http://visibleearth.nasa.gov/view.php?id=56217)

Slide 15

The international scientific community has begun some coordinated climate model experiments to better understand the effectiveness and unintended consequences of SRM-type geoengineering approaches.

Figure shows simulated global mean surface temperature in a scenario of increasing CO2 (black curve), and two scenarios in which idealized SRM approaches are used: 'sunshade' (red curve) shows result of CO2 warming perfectly offset by reducing incoming solar radiation (e.g. by orbiting mirrors); 'aerosol' (green curve) shows result of CO2 warming perfectly offset by injection of stratospheric aerosols.

Take home message here is that, at least in computer simulations of the climate system, such approaches are viable in offsetting global warming. However, next slide shows that spatial patterns of warming and cooling remain, and precipitation changes are not abated.

Slide 16

Upper panels show temperature and precipitation change at the time of CO2 doubling in these idealized experiments (in which CO2 is the only greenhouse gas prescribed). Warming is evident everywhere, and global mean precipitation increases (although there are some regions where it decreases). The lower panels show the temperature change in one of the 'geoengineering experiments'. Although global mean temperature change is zero (by design), there are large areas of both warming and cooling. Some areas like central Africa, South America and the polar regions continue to warm, while other regions cool.

More importantly perhaps, SRM schemes do not control changes in precipitation. Under a warming climate, precipitation is projected to increase globally, though some regions are expected to see a reduction. Under the geoengineering scenarios, global mean precipitation decreases (i.e. less water availability), and this effect is particularly pronounced in Asia and South America (the red colors in the precipitation maps on the right indicate areas where precipitation decreases; green indicates increasing precipitation).

Take home message: while able to offset global warming, SRM schemes do not do so uniformly, and do not avert large reductions in precipitation, particularly in the Tropics. This drying is an unintended consequence of the geoengineering strategy and would limit water availability in many highly populated parts of the world.

Slide 17

This summary plot is from the Royal Society's comprehensive report on Geoengineering. It shows 'effectiveness' of various geoengineering schemes plotted against 'affordability'. Their assessment is that stratospheric aerosol injection provides the best combination of effectiveness and affordability. Afforestation is deemed more affordable but less effective, and ocean fertilization less effective and less affordable.

The size of the symbols indicates 'timeliness', with larger circles indicating quicker effect.

The color of the symbol indicates 'safety', with red being less safe and green being more safe.

Carbon Capture and Storage at source is shown in the centre of the plot for comparison puproses.

Other schemes not presented in this deck are also shown here – many of these were deemed by the Royal Society Assessment to be less affordable and/or less effective.

Slide 21

CDB decision applies only to geoengineering which may affect *biodiversity*

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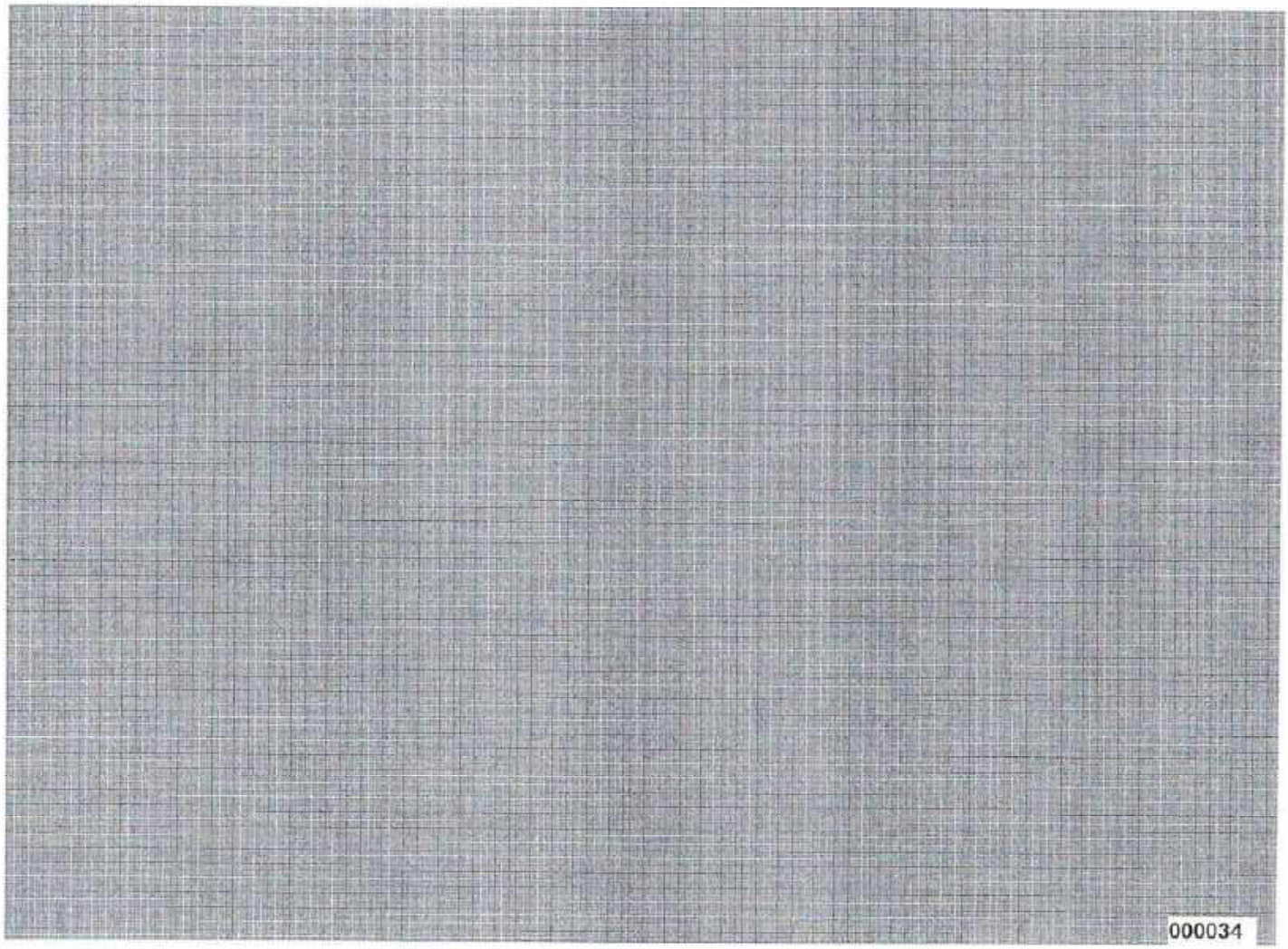

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DM-155778

MEMORANDUM TO DEPUTY MINISTER

CLIMATE GEO-ENGINEERING

For Information

PURPOSE

To provide you with information on climate geo-engineering, with a focus on scientific and international elements; and to provide you with responses to your questions specific to geo-engineering experiments and activities, risks and governance (see Annex I).

SUMMARY

- Geo-engineering refers to the intentional modification of the Earth System so as to moderate or mitigate climate change. The term captures a broad spectrum of activities.
- This approach is increasingly discussed in the scientific and policy communities because global greenhouse gas (GHG) emissions continue to grow while science is converging on the need to reduce such emissions immediately in order to limit global warming to 2°C above pre-industrial levels (i.e. Copenhagen Accord).
- Though geo-engineering may have the potential to ameliorate some of the consequences of rising GHG levels, none of the methods currently available offer an immediate solution nor address all concerns. Therefore, GHG emission reductions remain critical.

CURRENT STATUS

Geo-engineering methods are generally classified into two groups: Solar Radiation Management (SRM) and Carbon Dioxide Removal (CDR). Both methods aim to reduce global temperature, but they do so using different approaches. SRM aims to reduce the amount of solar radiation absorbed by the Earth, while CDR methods aim to increase the rate of removal of carbon dioxide (CO_2) from the atmosphere.

Most commonly, SRM refers to planetary scale modification of the Earth's albedo (reflectivity), by launching reflectors into space, enhancement of cloud coverage or reflectivity, or mimicking the effect of explosive volcanoes by injecting aerosols high into the atmosphere. CDR methods include methods that aim to enhance the uptake of CO_2 by either land or oceans, for example, by enhancing land carbon sinks through advanced biomass sequestration methods, or by fertilizing the ocean (also known as "ocean fertilization") with iron to stimulate uptake of CO_2 by phytoplankton. Another form of CDR involves technologies that aim to artificially capture CO_2 directly from the air. The CO_2 removed would then need to be either sequestered underground, or industrial uses of CO_2 would need to be developed and expanded on a scale to match what is needed to significantly lower atmospheric CO_2 levels. See also the Background section for further information about SRM and CDR approaches.

At present, there is a coordinated international climate modelling experiment underway: the Geo-Engineering Model Intercomparison Project (GEOMIP) which is aimed at improving our understanding of the efficacy and unintended consequences of SRM. Scientists at Environment

Canada's Canadian Centre for Climate Modelling and Analysis (CCCma) of the Climate Research Division are involved in this coordinated experiment. A research paper is also being prepared wherein initial results will be provided.

The two major categories of climate geo-engineering are distinguished by the timescales over which they take effect and the extent to which they can address the suite of concerns related to climate change and emissions of GHGs. CDR methods do address the primary source of the problem – rising levels of atmospheric CO_2; however, they take decades to begin to take effect and so do not offer immediate relief from global warming. SRM methods, on the other hand, can provide rapid cooling (within a few years of deployment) to offset warming from GHGs, but do nothing to address other impacts associated with elevated GHG levels, such as ocean acidification.

Several studies, using global climate models, have shown that stratospheric aerosols could offset greenhouse gas warming, if maintained (i.e. to exert a continual counter-forcing to that of rising GHG levels in the atmosphere); but this offsetting is not perfect. Some areas of the world will continue to warm whereas others will cool (even though globally the warming has been offset). More importantly, precipitation patterns are expected to be affected by the reduction in sunlight –introducing new risks to climate change mitigation. In addition, since SRM does nothing to address rising CO_2 concentrations, it will not help mitigate ocean acidification and associated ecosystem impacts, which are a direct consequence of increasing atmospheric CO_2. Modelling studies and in-situ experiments have shown that ocean fertilization is not a viable geo-engineering solution. Although such fertilization does lead to enhanced phytoplankton production (which removes CO_2 from the atmosphere through photosynthesis), the carbon typically remains in the upper ocean where it is fairly quickly recycled back to the atmosphere. While potentially effective for long-term removal of carbon from the atmosphere, ocean fertilization also alters ocean chemistry and thereby introduces potential new ecological risks.

CONSIDERATIONS

Geo-engineering is still subject to significant uncertainty and the science and understanding of geo-engineering continue to evolve. Moreover, techniques that involve modification to natural processes, whether on land or ocean, raise questions about potential consequences for other components of ecosystems, and the efficacy of such techniques requires further assessment including consideration of feedbacks on the climate system. SRM methods, considered relatively cheap and within the means of many countries to deploy, raise pressing questions about governance, including governance of in-situ (vs. modeling) experiments[1].

An important contribution to advancing understanding of geo-engineering will be the work of the Intergovernmental Panel on Climate Change (IPCC), which is currently assessing geo-engineering for its upcoming Fifth Assessment Report (AR5), though the results of this assessment will not be available for another two years. Specifically, Working Group I will assess geo-engineering in several chapters of its contribution to the AR5; improved scientific understanding of the impacts of geo-engineering proposals on human and natural systems will be assessed by WGII; and WGIII will review possible impacts and side effects and their

[1] See, for example, the discussion of reaction to a field trial in the U.K. for a technology that could be applied to climate geo-engineering. Nature News 17 November 2011, Vol 479 page 293.

implications for mitigation cost in order to define the role of geo-engineering within the portfolio of response options to anthropogenic climate change. WGIII will also evaluate options for appropriate governance mechanisms. A Joint IPCC Expert Meeting of WGI, WGII, and WGIII was held on Geo-engineering, in June 2011 in Lima, Peru. The report from this meeting was released on May 9, 2012.

Geo-engineering has not yet been addressed within the United Nations Framework Convention on Climate Change (UNFCCC). As the IPCC is the main provider of scientific and technical expertise to the UNFCCC negotiations, the publication of IPCC AR5 and its chapters on geo-engineering may precipitate a discussion of the issue with the UNFCCC.

Geo-engineering has already been addressed through the UN Convention on Biological Diversity (CBD), where at its 10th Conference of Parties in October 2010, the CBD adopted decisions stipulating that "*no climate-related geo-engineering activities 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...*". Most countries have ratified and thus are parties to the CBD. The only notable exception is the United States, which has not ratified the Convention.

Geo-engineering activities are also subject to the Environmental Modification Convention (ENMOD), an international treaty (which came into force in 1978) prohibiting the military or other hostile use of environmental modification techniques. ENMOD bans weather warfare, which is the use of weather modification techniques[2] for the purposes of inducing damage or destruction, but does not hinder the use of environmental modification techniques for peaceful purposes. Signatories to ENMOD include Canada, United States, Russia, most of Europe, India, Pakistan, Iran, and Democratic People's Republic of Korea. Notable non-signatories include China and Israel.

In 2010, Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention), adopted an Assessment Framework for Scientific Research Involving Ocean Fertilization, as required under a 2008 resolution, designed to assess whether proposals for ocean fertilization constitute legitimate scientific research. The 2008 resolution stated that ocean fertilization activities, other than legitimate scientific research, should not be allowed. The resolution followed previous discussions by Parties to the two treaties on planned operations for large-scale fertilization of the oceans using micro-nutrients – for example, iron – to sequester carbon dioxide (CO2).

Karen L. Dodds, PhD
ADM S&T

[2] Weather modification, which is different from climate geo-engineering, is the act of manipulating or altering certain aspects of the environment to produce desirable changes in weather, such as cloud modification for the enhancement of precipitation, hail suppression or dissipation of fog.

Cc:
Associate Deputy Minister, ADM McDougall, ADM Keenan, ADM Grimes, ADM Volk

Attachments:

- Annex 1 : Supplemental Questions and Answers
- CCI input (SECRET)
- Good Governance for Geoengineering article

BACKGROUND

Solar Radiation Management (SRM): The Earth's climate system is ultimately driven by energy received from the sun. This energy, primarily in the visible (short) wavelengths is absorbed at or near the surface and is largely balanced by outgoing infrared (longwave) radiation. Greenhouse gases, such as water vapour and carbon dioxide, absorb the longwave radiation and keep heat trapped near the surface.

SRM counters the longwave heat-trapping effect of increasing greenhouse gases by reducing incoming solar radiation, thereby providing a cooling effect. Possible approaches could include: activities to brighten surfaces on Earth, for example, by painting structures white, or placing reflective material over large areas of ground; direct 'shading' of the planet by launching reflectors of some sort into Earth's orbit; or enhancing cloud coverage. Another approach, deemed more feasible in the near term, is to mimic the effect of large explosive volcanoes which are observed to cause detectable climate cooling for a year or two after eruption. This cooling is caused by aerosols (microscopic particles) injected into the stratosphere where, due to the lack of 'rain out' and limited mixing with the lower atmosphere, they can remain for a year or more. Sulphate aerosols (a byproduct of combustion of sulphur-bearing fuels) are known to exert a significant cooling effect in the lower atmosphere, but they remain airborne for only a few days since they are quickly washed out by precipitation (leading to 'acid rain'). Various schemes have been suggested to mimic the effect of explosive volcanoes by injecting sulphate aerosols into the stratosphere (10-50km above the surface): this could be accomplished by aircraft, rocket or balloon-borne injectors.

Carbon Dioxide Removal – Ocean Fertilization: The ocean presently takes up roughly 30% of the carbon emitted by human activities (about 25% is taken up by terrestrial vegetation and soil, and the balance remains in the atmosphere, increasing CO_2 concentration). The ocean takes up carbon directly through dissolution of carbon dioxide into water (increasing ocean acidity), and through the photosynthetic uptake by ocean plants (phytoplankton). In the latter case, a portion of the carbon taken up by phytoplankton is eventually converted to dissolved inorganic carbon and sequestered in the deep ocean. In both cases, the dissolved carbon is transported by ocean currents and mixing from the surface into the deep ocean where it can reside for centuries.

The important observation is that there are areas of the ocean which nitrogen (the primary nutrient for phytoplankton) is abundant, but phytoplankton is not. In these so-called 'high nitrogen, low chlorophyll' (HNLC) regions, productivity is limited by the availability of micro-nutrients, particularly iron. Iron is normally provided to the ocean from river runoff and dust deposition, and so ocean areas remote from such sources can be limited in this way. The geo-engineering suggestion therefore is to 'fertilize' the ocean with iron in a suitable form, thereby promoting phytoplankton growth and associated (enhanced) uptake of carbon from the atmosphere.

ANNEX I

SUPPLEMENTAL QUESTIONS AND ANSWERS

Geo-engineering Experiments/Activities

Q1: In addition to GEOMIP, please provide detail on who (countries, groups) is planning/conducting experiments. Who are the lead government departments on climate geo-engineering in the U.S. government, major EU countries, Japan etc?

A1: The only major coordinated research (experiments) on geo-engineering that we are aware of at this time is the international climate modeling experiment Geo-Engineering Model Intercomparison Project (GEOMIP), which is a community coordinated modeling project, endorsed by the Working Group on Coupled Modeling of the World Climate Research Programme (WCRP).

The 2009 report by the U.K. Royal Society on Geoengineering (*Geoengineering the Climate: science, governance and uncertainty*, available at: http://royalsociety.org/policy/publications/2009/geoengineering-climate/) noted that in general, little research has been done on most geo-engineering methods and that there had been (up until publication of the report in 2009), no major directed programs of research on the subject -- [David Keith, Adjunct Professor at the University of Calgary (and currently Professor at Harvard), was an author of this report]. Indeed, one of the recommendations of this report was that international scientific organizations should coordinate international programs of research (as GEOMIP is doing) and that international collaboration in the development of appropriate governance mechanisms might be needed for some such research. The same report identified relevant UK departments as the Dept. of Energy and Climate Change (DECC) and the Dept. for Environment, Food and Rural Affairs (DEFRA) along with U.K. Research Councils. We expect the situation is similar among other major countries, with shared responsibility among a number of federal departments and research councils in recognition of the breadth of activities captured by the term "geo-engineering." In the U.S., some analyses identify the Office of Science and Technology Policy as a potential lead agency working with relevant federal agencies.

In 2010, a scientific assessment of ocean fertilization was published by the International Oceanographic Commission (IOC) (*Ocean Fertilization: A Scientific Summary*, available here: http://www.unesco.org/ulis/cgi-bin/ulis.pl?catno=190674&set=4FA98F8B_2_122&gp=1&lin=1&ll=1). Ken Denman of Fisheries and Oceans Canada (DFO) was an author of the report. At time of publication, 13 small scale ocean fertilization experiments had been conducted, all by independent researchers; results of these were assessed in the IOC report. Since 2008, there has been an effective ban on ocean fertilization experiments under the London Convention/London Protocol while Parties discuss development of a regulatory framework for research on ocean fertilization.

Q2: For GEOMIP, who are our Environment Canada experts? Are we leaders in this SRM research area? What is going on (in EC) in terms of experiments/research on the CDR side?

A2: Within EC, expertise in GEOMIP resides at the Canadian Centre for Climate Modeling and Analysis (CCCma), a section of the Climate Research Division within the Atmospheric Science and Technology Directorate. We would not be considered 'leaders' in SRM research, but we are actively participating in the internationally-coordinated GEOMIP experiment. Our results are available through the CCCma data server for use by the science community. In addition, CCCma has undertaken additional model simulations to further explore the climatic effects of idealized SRM approaches, mainly with an aim to explore the effects of SRM on other aspects of the climate system, particularly the water cycle and the carbon cycle. This work will help answer questions about how, in a future climate in which global mean temperature has been perfectly stabilized, other aspects of the climate system continue to change. How do precipitation patterns evolve? How does the terrestrial biosphere respond? These experiments go beyond the basic GEOMIP experiment and will be the first to consider the role of the biosphere in altering (indeed amplifying) the ongoing precipitation changes that take place in spite of stabilized global mean temperature. A paper describing these results is in preparation and will be submitted to a scientific journal within the next few weeks. CCCma is not involved in any other sort of CDR experimentation -- only the climate model simulations described above.

Q3: Are other Canadian government departments at the Federal level involved in climate geo-engineering research/experiments? Other Canadian research institutions/academics?

A3. Geo-engineering is a broad term that captures a range of activities. Enhancement of GHG sinks, and the use of biomass for carbon sequestration or as a fuel, for the purpose of climate change mitigation, can be considered forms of geo-engineering. Research in these areas by a number of federal departments and by a diverse community of university scientists would be relevant. However, in terms of emerging CDR technologies such as direct air capture of CO_2, and various methods of SRM, we do not know of any research being done by other federal departments. Consultation would be required to provide a more definitive answer.

Within Canadian universities, David Keith is the most well-known researcher of methods of direct air capture of CO_2. Jason Blackstock, Adjunct Professor of the University of Waterloo and currently a Visiting Fellow at the Institute for Science, Innovation and Society at the University of Oxford, U.K., has written about the scientific, political and global governance dimensions of geo-engineering. In terms of climate modeling research, there is related work on climate stabilization underway in some Canadian universities (for example, a University of Victoria graduate student, co-supervised by a CCCma

research scientist, is doing some analysis of the GEOMIP experiments, as is a University of Victoria research associate). On the marine side, DFO has scientists working on ocean fertilization, though in general, this work is not directly linked with an intent or potential application for geo-engineering.

Q4: Do we have access to the inputs for IPCC AR5 for WGI and II? Are any of the inputs/work led or informed by Canadian researchers?

A4: EC currently has access to the First-Order-Draft of the AR5 WGI report. This draft underwent Expert Review in late December and at that time a copy of the draft report was provided to all Governments for information (not for comment). The First-Order-Drafts of WGII and WGIII are currently being prepared by the authors and the Expert Reviews of these reports are expected to commence in June; EC will gain access to the draft reports of WGII and WGIII at that time.

In the First-Order-Draft of the WGI report, geo-engineering is covered in two chapters. Chapter 6 (Carbon and Biogeochemical cycles) has a section entitled "Effects of Carbon Dioxide Removal Methods and Solar Radiation Management on the Carbon Cycle", and Chapter 7 (Clouds and Aerosols) has a section entitled "Solar Radiation Management and Related Techniques". From a review of the authors contributing to these chapters and their known areas of expertise, there do not appear to be any Canadians 'leading' any of these contributions. However, this work will undoubtedly be informed by Canadian research in this area, particularly the GEOMIP work summarized above.

Risks associated with geo-engineering

Q5: What type of events could happen as a result of climate geoengineering efforts/experiments (i.e. those that did not go "as intended")? What would be the possible implications for the environment, human health/safety? Please provide more detail about the experiment referred to in the Nature article in footnote 1.

A5: There are, of course, many potential 'unintended consequences' of various geo-engineering approaches, by which we mean adverse effects that might accompany the 'intended' consequence of stabilizing global temperature. Many of these are discussed in the U.K. Royal Society report cited above. As an example, injection of sulphate into the stratosphere will be accompanied by precipitation that is more acidic ('acid rain') with harmful effects on natural ecosystems. At CCCma, the focus is on unintended climate consequences, particularly changes in precipitation patterns (and hence local water availability) that could be a byproduct of a climate whose temperature is stabilized by some SRM approach. A few papers have already been published on this subject. Water availability is central to many aspects of human health and food security, particularly in developing countries.

Similar concerns arise with ocean fertilization as this also involves manipulation of a natural system by release of a substance (e.g. iron) into that system. In addition to the intended consequence of stimulating the growth of phytoplankton and enhancing CO_2

uptake, unintended changes in ocean chemistry will also occur which will, in turn, affect biological communities. The IOC assessment report on ocean fertilization referred to above concluded that the biological and chemical responses to nutrient fertilization were variable and difficult to predict based on the limited work to date, but cautioned that sustained ocean fertilization for the purposes of climate change mitigation can be expected to have far-field and long term unintended consequences for the ocean.

The footnote refers to an experiment planned in the UK to explore the 'engineering' aspects of a particular method proposed to deliver aerosols (like sulphate) into the upper atmosphere. The proposed scheme was to elevate a long pipe by means of a large balloon, and pump liquid up this pipe to be 'sprayed' into the upper atmosphere. The test was to have been done with water and would have had no discernable climatic or environmental effect; it was merely aimed at testing the balloon-borne system. The test did not take place because it did not satisfy certain review criteria, mainly related to how the experiment and its purpose was communicated. Article attached.

Q6: Are there reports of any "rogue" geo-engineering activities by countries/groups/individuals?

A6:

s.16(1)(c)

[redacted] (contact: Linda Porebski, ESB).

<u>Global governance of geo-engineering</u>

Q7: What is the department's view on global governance of geo-engineering? Are the current international mechanisms in place (the CBD, the Convention on the Prevention of Marine Pollution, and EMOD) effective?

A7: ** See attached SECRET document titled: DM-155778 – Additional Input from IAB for Q7

Q8: Provide more details on IPCC AR5 WGIII on governance. Can we summarize initial input/findings if we have access (one paragraph)? What is Canada's role in WGIII if any? Is anyone involved from the federal government or Canadian

academic communities? What were the issues/outcomes of the June, 2011 Lima conference (one paragraph)?

A8: Based on the approved outline of the WGIII report, it is expected that geo-engineering options will be assessed in the WGIII report from a technical perspective. From a governance perspective, the WGIII report is expected to assess policies, institutions and financing for climate change mitigation as a whole, which may include consideration of geo-engineering. We will be able to check this when the First-Order-Draft of the WGIII report is circulated for Expert Review in June.

There are a total of six Canadians involved as lead authors on the WGIII report (1 from DFO, 4 from universities and 1 from a consulting firm). In particular, David Keith is a lead author on the chapter of the WGIII report that will assess geo-engineering options from a technical perspective. Two of the Canadians are involved in chapters relating to assessment of policies, institutions and financing for climate change mitigation, but, to our knowledge, their contributions to the report do not relate to geo-engineering.

The report of the June 2011 IPCC Expert Meeting on Geo-engineering (Lima) was just released May 9th. Much of the time at the meeting was focused on bringing consistency to the treatment of geo-engineering in the upcoming IPCC AR5. The need for consistency applied to both issues of terminology (in particular, which CDR methods should be considered geo-engineering vs. mitigation) and criteria for assessment. A list of criteria is proposed for consideration by AR5 authors during the assessment process that extended across the physical, economic and social sciences. In terms of terminology, two key characteristics were identified that differentiated geo-engineering from other mitigation methods. These were scale of deployment and scale of impact, although boundaries remain blurred and even particular methods can fall on either side of the boundary. The reality of a very limited knowledge base for many aspects of geo-engineering was identified as a significant challenge for the IPCC assessment process.

Attachment: Nature Comment, 17th November, 2011, Vol 479, Nature p293.

Drafting Officer's Name: Climate Research Division, with input from Climate Change International (IAB), Science Policy Division (STB), Environmental Assessment and Marine Programs Division (ESB), and Strategic Policy (SPB).
Directorate/ Branch: Atmospheric Science and Technology Directorate, S&T Branch
Phone No: 416-739-4249
Date Drafted: March 30, 2012; Updated: May 11, 2012

CCI Input to MtDM on Geoengineering

IAB has been requested to provide input for a MtDM on Geoengineering which is being led by S&TB. Following a recent meeting with David Keith, an academic from University of Calgary with expertise in the field, the DM is seeking a departmental assessment of geoengineering science elements, international discussions (e.g. IPCC, national-level) and activities (e.g. trial experiments), governance and policy considerations. IAB was asked specifically to frame the issue in an international context, focusing on international conventions and governance.

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Canada recognizes that geoengineering is still subject to significant uncertainty and that the science and understanding of geoengineering continue to evolve. An important contribution in this regard will be the work of the Intergovernmental Panel on Climate Change (IPCC), which is currently assessing geoengineering for its upcoming Fifth Assessment Report (AR5), though the results of this assessment will not be available for nearly two years. The IPCC is the definitive body for policy-neutral assessments of science for climate change issues.

It is Canada's view that the international community's future approach to geoengineering should be framed by the latest definitive science and assessments, as provided by the IPCC and other respected sources.

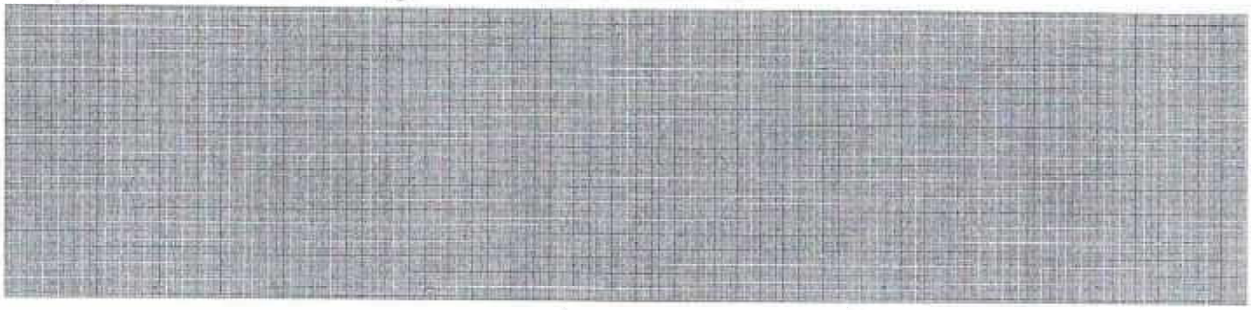
Though geoengineering may have the potential to contribute to addressing the global issue of climate change, geoengineering is not a substitute for reducing greenhouse gas emissions, the only long-term definitive solution to the issue of climate change.

Due to the uncertainties surrounding geoengineering, it is important to reach international consensus on the need for and application of it. Geoengineering has not yet been addressed within the UNFCCC. As the IPCC is the main provider of scientific and technical expertise to the UNFCCC negotiations, the 2014 publication of IPCC AR5 and its chapters on geoengineering may precipitate a discussion of the issue with the UNFCCC.

Geoengineering has already been addressed through the UN Convention on Biological Diversity (CBD), where at its 10th Conference of Parties, the CBD adopted decisions stipulating that "*no climate-related geo-engineering activities 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*".

Geoengineering activities are also subject to the Environmental Modification Convention (ENMOD), an international treaty prohibiting the military or other hostile use of environmental modification techniques. ENMOD bans weather warfare, which is the use of weather modification techniques for the purposes of inducing damage or destruction, but does not hinder the use of environmental modification techniques for peaceful purposes. Signatories to ENMOD include Canada, US, Russia, most of Europe, India, Pakistan, Iran, and DPRK. Notable non-signatories include China and Israel.

s.21(1)(b)



BACKGROUND

IPCC

- The IPCC will assess the science of geoengineering for the first time in its upcoming Fifth Assessment Report (AR5). While the understanding of the physical science basis of geoengineering is still limited, Working Group I will assess this in several chapters of its contribution to AR5, while improved scientific understanding of the impacts of geoengineering proposals on human and natural systems will be assessed by WGII, and WGIII will take into account the possible impacts and side effects and their implications for mitigation cost in order to define the role of geoengineering within the portfolio of response options to anthropogenic climate change. WGIII will also evaluate options for appropriate governance mechanisms.
- A Joint IPCC Expert Meeting of WGI, WGII, and WGIII was held on Geoengineering, in June 2011 in Lima, Peru.

CBD

- The tenth meeting of the Conference of the Parties to the Convention on Biological Diversity (CBD) adopted decision X/33 which includes, in paragraph 8 (w) and (x) (see below), a section on climate-related geo-engineering and its impacts on the achievement of the objectives of the CBD.

  8. *Invites* Parties and other Governments, according to national circumstances 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 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;
  >
  > (x) Make sure that ocean fertilization activities are addressed in accordance with decision IX/16 C, acknowledging the work of the London Convention/London Protocol;

  In addition to the above, the Conference of the Parties, in decision X/33 paragraph 9(l) and (m), requests the Executive Secretary to:

  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

- 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.

Good governance for geoengineering

Phil Macnaghten and Richard Owen describe the first attempt to govern a climate-engineering research project.

Climate-engineering research must have strong governance if it is to proceed safely, openly and responsibly [1,2]. But what this means in practice is not clear. The Stratospheric Particle Injection for Climate Engineering (SPICE) study demonstrates the difficult judgements involved. As chairman of the panel that supported decisions by the UK Engineering and Physical Sciences Research Council (EPSRC) as to whether and how this project should proceed (P.M.), and the architect of the project's governance process (R.O.), we draw lessons from these challenges.

In mid-September 2011, SPICE announced the go-ahead for the United Kingdom's first field trial of climate-engineering technology. SPICE aims to assess whether the injection of sulphur particles into the stratosphere would mimic the cooling effects of volcanic eruptions and provide a possible means to mitigate global warming. An equipment test — spraying water at a height of 1 kilometre — was proposed (see 'SPICE field trial'). No climate engineering would result from the test, but response to the announcement was dramatic, and the project was soon at the centre of a storm of criticism.

CAREFUL REVIEW

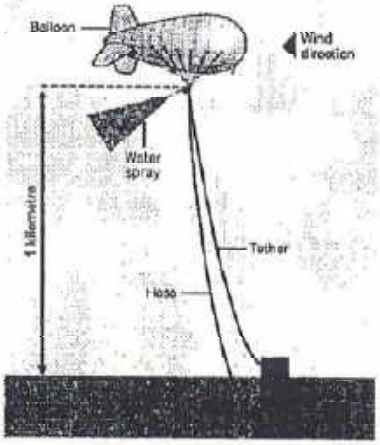
On 26 September 2011, the EPSRC, one of the study's main funders, postponed the trial after a review. Later the same day, the council received a letter and open petition [3], also sent to UK energy and climate-change secretary Chris Huhne and signed by more than 50 non-governmental organizations (NGOs) and civil-society organizations, demanding that the project be cancelled. The signatories saw the research as a first, unacceptable step towards a fix that would deflect political and scientific action away from reducing greenhouse-gas emissions. Others, by contrast, saw the research as urgently needed to find possible ways of coping with climate change [4]. The question at the heart of this debate was: should work in this controversial field proceed at all, and if so, under what conditions?

The strong feelings about the first test of SPICE's equipment show how important it is to have robust governance, and for scientists and funders to ensure that the public and other parties are consulted at the earliest opportunity. This is an unfamiliar and difficult process, but it is crucial for the evaluation of climate-engineering approaches.

SPICE was conceived in March 2010 at an EPSRC interdisciplinary workshop, at which researchers were invited to develop innovative geoengineering proposals. The project's funding incorporated field testing, but release of money was conditional upon it passing a 'stage-gate' review — a governance process in which funding for each phase of research and development is preceded by a decision point. To pass the review, SPICE scientists were required to reflect on the wider risks, uncertainties and impacts surrounding the test and the geoengineering technique to which it could lead — solar-radiation management.

On 15 June 2011, the stage-gate panel (including atmospheric scientists, engineers and social scientists, as well as an adviser to an environmental NGO) evaluated the SPICE team's response to five criteria for responsible innovation. These were that: the test-bed deployment was safe and principal risks had been identified, managed and deemed acceptable; the test-bed deployment was compliant with relevant regulations; the nature and purpose of SPICE would be clearly communicated to all relevant parties to inform and promote balanced discussion; future applications and impacts had been described, and mechanisms put in place to review these in the light of new information; and mechanisms had been identified to understand public and stakeholder views regarding the predicted applications and impacts.

SPICE FIELD TRIAL
Water sprayed through a 1-kilometre high hose will test equipment with potential for climate engineering.



Recognizing the efforts of the SPICE team, the panel concluded that although the first two criteria had been met, more was required on the remaining three. It asked the team to develop a revised communications plan to inform further public debate, a review of the risks and uncertainties of solar-radiation management — including social, ethical, legal and political dimensions — and a thorough process of engagement with stakeholders.

The test bed was delayed by EPSRC in September to allow the team to undertake these outstanding actions. When the panel reconvenes, it will independently assess a revised response; until then, the project remains under review.

LESSONS LEARNED

Aspects of SPICE's governance could have been improved. The framework should have been in place before the project's conception; the test date should not have been announced until the stage-gate criteria had been met; and the structures and resources to support the social research should have been in place earlier. Even now, the decision on whether to proceed will not be easy. There are few right or wrong answers to the many questions about climate engineering. But it is vital that we make space to listen to and discuss these questions, and that the debate transparently influences the decisions that are taken.

For geoengineering technology to progress, its developers must be mindful of wider impacts from the outset; and it must proceed under robust governance mechanisms. The SPICE responsible-innovation framework is one evolving approach to achieving it. ■

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