United Nations
Educational, Scientific and
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Division of Ecological and
Earth Sciences

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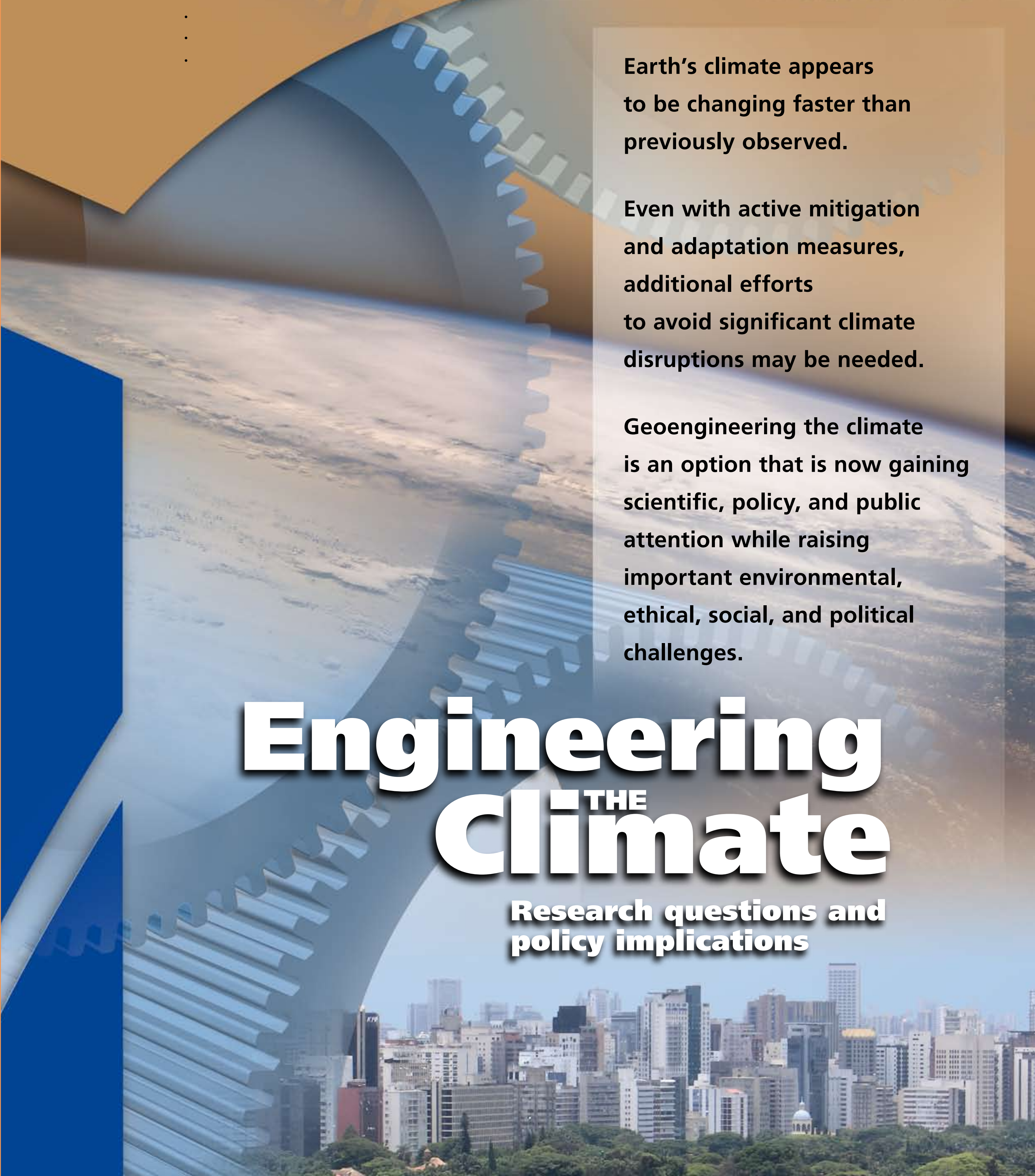
UNESCO - SCOPE - UNEP
Policy Briefs

November 2011 - No. 14



Earth's climate appears to be changing faster than previously observed.

Even with active mitigation and adaptation measures, additional efforts to avoid significant climate disruptions may be needed.

Geoengineering the climate is an option that is now gaining scientific, policy, and public attention while raising important environmental, ethical, social, and political challenges.

Engineering THE Climate

Research questions and policy implications

1 Why geoengineering?

Climate change is happening, and the consequences of inaction could be severe. Efforts to reduce emissions of greenhouse gases and prepare adaptation measures have begun, but do not yet reflect the measure of the task at hand.

Geoengineering, also known as **Climate Engineering,** proposes the deliberate large-scale manipulation of the Earth's climate in order to minimize the effects of climate change caused by increasing levels of greenhouse gases in the atmosphere.

The potential ability of some geoengineering techniques to limit at least the worst impacts of ongoing climate change has led prominent scientists and scientific institutions to propose significant research agendas. However, such geoengineering interventions involve considerable technical uncertainty and risk, including unforeseen consequences, and raise important international governance questions that need to be addressed.

2 Geoengineering interventions

To counteract changes in climate caused by increased concentrations of greenhouse gases in the atmosphere, two types of geoengineering techniques are being explored:

CARBON GEOENGINEERING

Also known as Carbon Dioxide (CO_2) Removal or **CDR**.

and

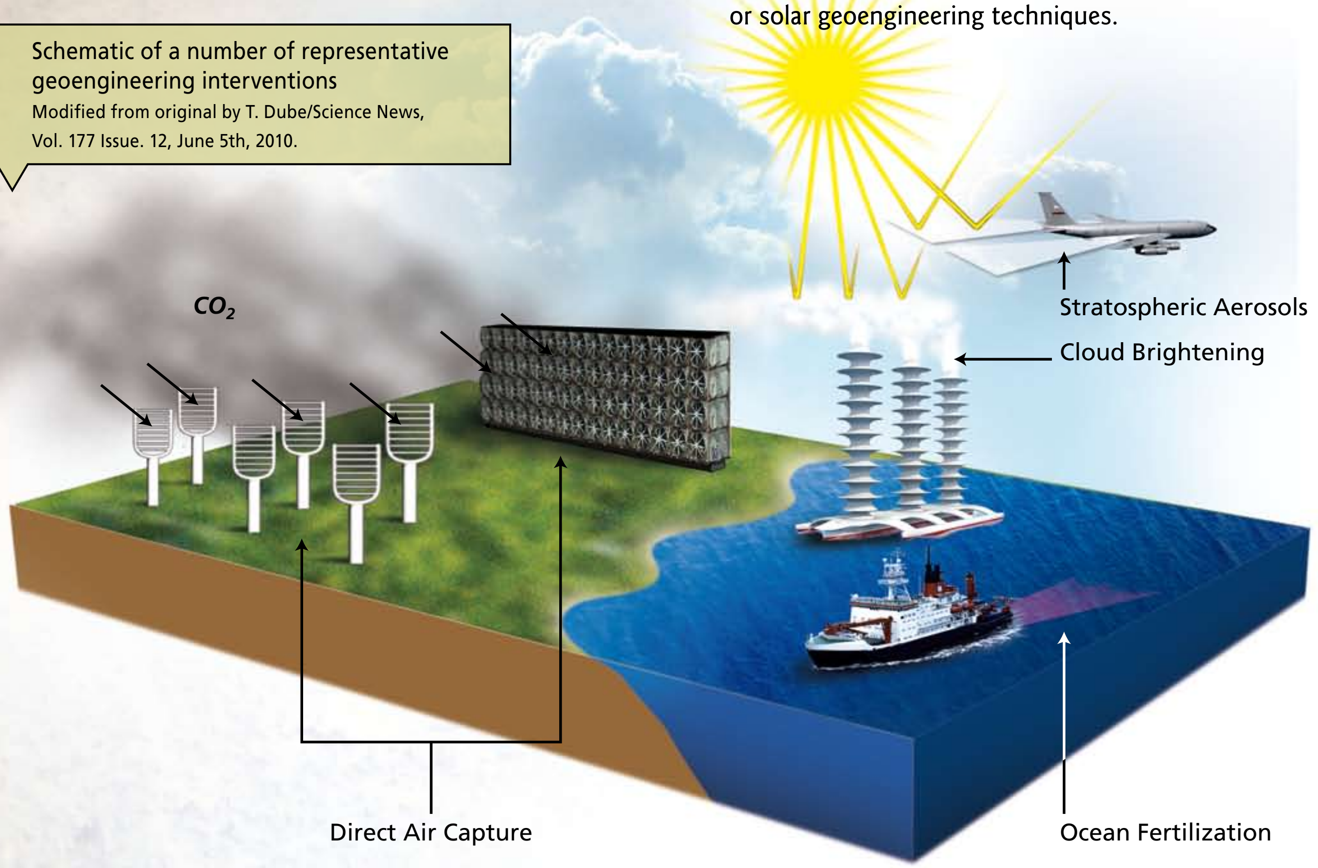
SOLAR GEOENGINEERING

Also known as Solar Radiation Management or **SRM**.

Naturally occurring phenomena such as CO_2 uptake by ecosystems or the impact of volcanic emissions on solar radiation, for example, were the inspiration for both types of intervention.

Geoengineering techniques have the potential to alter the environment at an unprecedented scale. These two types of interventions differ significantly in the way they impact the climate, as well as in the technical and financial capacity required for their implementation.

It is therefore necessary to address separately the policy and governance challenges for research and deployment of carbon or solar geoengineering techniques.



Schematic of a number of representative geoengineering interventions
Modified from original by T. Dube/Science News, Vol. 177 Issue. 12, June 5th, 2010.

3 Geoengineering techniques

CARBON GEOENGINEERING

would actively remove CO_2 from the atmosphere with the potential of directly reversing climate change.

These techniques would only have a notable impact on CO_2 concentration over decades, and are projected to incur equal or greater cost than mitigation.

Engineered techniques

would use chemical technologies to remove CO_2 directly from the air. These technologies are similar to those being implemented to capture and store CO_2 from the exhaust of power plants for a long period of time in what is known as Carbon Capture and Storage.

PROMINENT EXAMPLES

Ambient air capture

uses large-scale chemical processes to capture CO_2 directly from the air, for storage or use through various emerging methods.

Image above : Air contactor for atmospheric CO_2 capture as designed by Carbon Engineering Ltd.
©: Carbon Engineering Ltd.

NATURAL ANALOGUES

There are no direct examples from nature that have inspired the direct air capture of carbon dioxide with chemicals. Ambient air capture devices have been described by some as ‘artificial trees’, though they are only akin to trees in their ultimate function, not in the process by which they chemically remove carbon from the atmosphere.

Ecosystem techniques

would enhance the Earth’s natural carbon storage systems at very large scales such as in forests and oceans.

PROMINENT EXAMPLES

Ocean fertilization

is the addition of nutrients such as nitrogen or iron into the oceans in order to enhance algal blooms, and the resulting photosynthetic activity, with the intention of increasing storage of carbon from the atmosphere into the deep ocean.

NATURAL ANALOGUES

Algal blooms

Nutrients that restrict or limit algal growth are sometimes added to oceans in large amounts according to natural cycles. This results in large phytoplankton and algal blooms because these organisms are able to thrive after the addition of such limiting nutrients. The natural cycle of algae and other organisms fixes carbon from the atmosphere to grow, eventually to die and sink to the depths of the ocean. This effective sequestration of carbon is known as the ‘biological pump’, a well-understood natural phenomenon.

SOLAR GEOENGINEERING

would reduce the amount of solar radiation absorbed by the Earth’s climate system, resulting in a reduction of global average temperature.

Techniques that are based on the injection of reflective particles into the lower or upper atmospheres could have a notable climatic effect in less than a year, and are projected to be less costly compared to mitigation.

PROMINENT EXAMPLES

Stratospheric aerosols

would use the injection of sulphate or other light-scattering aerosols into the stratosphere (upper atmosphere) to mimic the cooling effect of volcanic eruptions.

Cloud brightening

would increase the extent and/or reflectance of clouds through the injection of tiny cloud-seeding particles such as sea salt into the atmosphere.

NATURAL ANALOGUES

Volcanic eruptions

Eruptions, like that of Mount Pinatubo in 1991, send sulphur particles high into the stratosphere where they reflect sunlight and can cause markedly cooler temperatures globally. The eruption of Mount Pinatubo resulted in the global average temperature dropping by roughly 0.5°C in 1992. This cooling effect disappeared within a couple of years.

4 Geoengineering research:

Different stages, different challenges

Considerable scientific and environmental uncertainty remains about the total climatic impact of geoengineering. Hence the development of responsible international regulation of geoengineering techniques requires scientific research to understand and evaluate their potential effects. Although controversial due to the potential environmental and social risks, major research into geoengineering techniques has been proposed by leading scientific institutions and researchers for two principal reasons:

1. To understand the utility and risks of geoengineering techniques before potential rapid onset of severe climate impact leads to public pressure for their deployment;

2. To be prepared to prevent or respond to simple, cheap, yet globally impactful geoengineering technologies being deployed unilaterally by individual states or actors.

Recent research has mostly involved climate modelling studies in North America and Europe. Proposals for broader involvement of other countries including technological development and field testing are now emerging.

Stage	Description	Challenges	Status
1. THEORY AND MODELLING	Publications and computational models studying the anticipated climatic impacts of geoengineering techniques	International cooperation, research funding, and development of more comprehensive models	Studies began more than 20 years ago and continue for both carbon and solar technologies
2. TECHNOLOGY DEVELOPMENT	Design and laboratory development of geoengineering deployment technologies	Emergence of governance issues when technologies are patented or classified. Who has access to and control over new technologies?	Many carbon geoengineering technologies are currently under development
3. SUB-SCALE FIELD TESTING	Feasibility testing of geoengineering deployment technologies at levels posing ‘demonstrably negligible’ environmental, and transboundary risks	Evaluating risks and modelling uncertainties related to the environmental impacts of field testing	Limited recent tests of atmospheric aerosol injection and ocean iron fertilization have taken place
4. LARGE-SCALE FIELD TESTING	Testing the climatic impacts of geoengineering deployment, nominally at scales below actual deployment, but with notable transboundary environmental impacts	Environmental and governance challenges of experiments spread unevenly at local, national, and regional levels	As yet, there are no significant calls for this kind of testing to begin soon

- Neither stages 1 nor 2 would directly impact the environment. By contrast, stage 3 experiments would be expected to affect the environment only near the testing site, while stage 4 would by design aim to have a global environmental and climatic impact.
- The thresholds between stages 3 and 4 can often be difficult to define. Due to the current uncertainties surrounding geoengineering science, demonstrating that a proposed field test of moderate scale poses ‘demonstrably negligible’ risk to humans and ecosystems can be very difficult. As a result, the limits below which a test would be considered ‘sub-scale’ could be politically contentious.

The eruption of Mount Pinatubo in the Philippines in 1991 injected 10 megatonnes of sulphur into the air. © Karin Jackson, USAF.

Algal bloom in the Barents Sea, Norway. Satellite image taken on by ESA's ENVISAT satellite with the MERIS intrument. © European Space Agency (ESA).

5 Potential for unintended consequences

If deployed at a large scale, geoengineering techniques would have substantial impacts on the Earth's climate. Although designed to ameliorate climate change impacts, their deployment may also generate unintended consequences. The potential side effects of geoengineering, such as the impacts of ocean fertilization on ocean ecosystems or changes to precipitation patterns caused by solar geoengineering, are presently not well understood. Exploration of possible side effects must be an important component of comprehensive research into any geoengineering technique, and should weigh significantly in any future policy decisions about any geoengineering deployment.

6 Ethical, social, and political challenges

The potential impacts of geoengineering also pose important political, social, and ethical challenges alongside environmental risks. Questions that need to be addressed by policy-makers include:

Who decides?

Decisions need to be taken at every stage of geoengineering research. Who should be involved in making decisions and through what processes are critically important issues for each decision.

When would geoengineering deployment be appropriate?

Geoengineering techniques have the potential to reduce some adverse impacts of climate change, but could also induce new types of environmental change, which may or may not be desirable. Any decision to use geoengineering techniques would differently affect a vast array of people and ecosystems, raising ethical and political questions about what criteria should be used to determine whether or not and/or how to deploy them.

How to ensure equity in the global commons?

The populations most vulnerable to – and least responsible for – climate change will also be the most vulnerable to any environmental change brought about by geoengineering. These populations stand to lose or gain significantly from geoengineering, and deserve particular attention and a voice in geoengineering decision-making.

Is there a moral hazard?

Geoengineering technology development could further reduce the motivation of nations and industries to reduce their carbon emissions by inaccurately appearing to provide a simpler and less expensive option to mitigation. Conversely, concerns over the prospect of geoengineering may trigger more thoughtful consideration of emission reduction measures.

How to deal with liability and compensation?

Geoenegineering techniques could bring unintended consequences that would be difficult to attribute conclusively to those techniques. There could be substantial uncertainty about liability in scenarios in which perceived 'losers' seek compensation.

Geoengineering
way forward

Weighing the risks

Decisions regarding geoengineering must weigh the risks of both action and inaction – of relying on existing mitigation and adaptation alone to cope with climate change, or attempting to use geoengineering methods to reduce the amount or rate of environmental change to which societies and ecosystems must adapt.

Engaging the global public

Achieving an equitable and effective governance framework for geoengineering research requires an informed global public. Providing information and fostering open dialogue with all relevant stakeholders is critical to build a common understanding of the geoengineering issue by the global community as a whole.

Establishing the rules

Meeting the political and ethical challenges of geoengineering requires gradually building towards an international governance framework to ensure that research into global climate modification is conducted responsibly and transparently, and that potential benefits and risks are equitably distributed.

This is an urgent issue for the international environmental policy community. The London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter and the Convention on Biological Diversity, for example, have begun to explore this issue. However, broader international discussion and engagement are needed before a detailed and robust regulatory framework can be established.

UNESCO-SCOPE-UNEP
Policy Briefs Series.
Engineering the climate.
Research questions
and policy implications
November 2011.
UNESCO-SCOPE-UNEP, Paris.

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Printed in November 2011
by ITC Grigny

Printed in France

ISSN 1998-0477

Cover: Earth. ©: NASA. São Paulo. ©: Wikimedia Commons - Indech

Further reading

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Useful links

United Nations Educational, Scientific and Cultural Organization (UNESCO): http://www.unesco.org/

Scientific Committee on Problems of the Environment (SCOPE): http://www.scopenvironment.org/

United Nations Environment Programme (UNEP): www.unep.org

Solar Radiation Management Governance Initiative (SRMGI): http://www.srmgi.org

UNESCO Expert Meeting on Geoengineering (12 November 2010): http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/single-view-earth/news/geoengineering_the_way_forward/

Centre for International Governance Innovation (CIGI): http://www.cigionline.org/

International Institute for Applied Systems Analysis (IIASA): http://www.iiasa.ac.at/

Stockholm Environment Institute (SEI): http://sei-international.org/

SEI STOCKHOLM ENVIRONMENT INSTITUTE

CIGI The Centre for International Governance Innovation
Centre pour l'innovation dans la gouvernance internationale

This policy brief is based on the UNESCO workshop on geoengineering organized by its Intergovernmental Oceanographic Commission, the Basic and Engineering Sciences and the Ecological and Earth Sciences Divisions (Paris, November 2010) It also draws on the on-going research collaboration between the Centre for International Governance Innovation (CIGI), the Stockholm Environment Institute (SEI), and the International Institute for Applied Systems Analysis (IIASA) on the science and governance of geoengineering.