AGU Climate Intervention Engagement: Leading the Development of an Ethical Framework

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I. Background

The 2016 Paris Agreement set an aspirational target to limit global warming to 1.5°C (2.7°F) above preindustrial levels. Meeting that goal will require global greenhouse gas emissions to be reduced by about 45% from 2010 levels by 2030, reaching net zero emissions by 2050. Those emissions targets and global temperature goals will require dramatic reductions in global carbon dioxide (CO_2) emissions combined with the active removal of CO_2 from the atmosphere.

Current technologies for active removal of carbon dioxide and other greenhouse gases from the atmosphere are not nearly at the scale needed to reach net zero emissions. Significant questions, both practical and ethical, remain as to the long-term storage of removed CO_2. As a result, other potential climate intervention technologies to mitigate warming are being researched and discussed in both the public and private sectors, including a variety of approaches known as "geoengineering." These methods are largely untested and pose significant risks if implemented at scale. They should not move forward for deployment without an international ethical governance structure to allow globally acceptable risk-controlled testing.

Issues around the ethics and governance of climate intervention research are complex. Many scientific reports call for dramatic intervention to avoid the risk of catastrophic climate tipping points, and research and small-scale tests are already in progress. However, the unintended consequences (or what engineers call revenge effects) of large-scale climate intervention are not fully understood. There is evidence that some large-scale climate interventions may have significant negative local and regional consequences. For instance, modeling studies of solar radiation management suggest such an approach could alter the South Asian monsoon season and reduce precipitation in India — affecting food security for more than a billion people. As a result, some have called for a total ban on such research and approaches.[1]

A listing of the primary climate intervention concepts that need ethical framework and governance is included in Appendix 1 of this report — some concepts are more controversial than others. Globally authoritative partners, public buy-in, inclusive representation and a strong-minded willingness to address potentially divisive topics will be needed for the development of this framework to be successful.

II. The Opportunity to Guide Solutions

The following passage from the Carnegie Council for Ethics in International Affairs summarizes both the need and opportunity to create an ethical framework for climate intervention:

[1] M. Bhowmick et al. (2021), Response of the Indian summer monsoon to global warming, solar geoengineering and its termination, *Sci. Rep.*, *11*, 9791, https://doi.org/10.1038/s41598-021-89249-6.

As the climate crisis deepens, policymakers and scientists are considering a range of emerging approaches to reduce risk. These include the large-scale removal of carbon dioxide from the atmosphere ('carbon dioxide removal' – which would address the primary human source of climate change), and the reflection of more sunlight back into space to cool the planet ('solar radiation modification' – which would address a symptom of climate change).

None of these approaches would reduce the need for other actions; they would all need to be part of a broad suite of responses, including reducing emissions to net zero and then net negative, plus adaptation.

But there are big questions about the significant risks and potential trade-offs some of these approaches would bring, and how these would be measured against the risks of a warming world. Policymakers do not know enough to take informed decisions, or how to balance the costs and benefits of various approaches. There isn't even agreement on what words should describe them. Some call these various technologies 'geoengineering', but different groups often use different terminology.

Awareness, knowledge, and discussions about these technologies are in their infancy. Their governance is essential, yet existing frameworks are insufficient to deal with the scale and speed with which some would need to be deployed. The governance of these climate-altering technologies also needs to be aligned with other sustainable development goals, such as biodiversity or human rights, so that one does not undermine the other.[2]

The AGU climate change and climate intervention position statement also points to the urgency of the situation and the need to consider all approaches, including intervention, but with guidance against risks, as stated in this excerpt:

> *Destructive consequences of global climate change can be moderated by taking prompt actions to use energy more efficiently, transition to energy sources and products and services that do not release greenhouse gases, implement existing and novel technologies and practices to remove and store CO_2 from the atmosphere, and adapt to unavoidable changes. These actions must involve individuals, communities, businesses, governments, acting at local, regional, national, and global scales. Done smartly, those actions can yield significant economic and social benefits, including better human health and well-being, employment opportunities, more sustainably used resources, and conserved biodiversity. Enhanced CO_2 removal from the atmosphere will be needed to achieve net-zero emissions. Other climate intervention approaches, such as solar radiation management, require cautious consideration of risks. Neither can substitute for deep cuts in emissions or the need for adaptation.*[3]

AGU has entered this discussion under the premise that more knowledge about climate intervention approaches and their consequences will help society make informed, just decisions about the deployment of climate intervention. AGU is not taking a position about specific climate interventions, but AGU is making the case that a robust body of scientific evidence about climate intervention and an ethical framework should be available as society weighs its options for managing and abating climate change.

[2]Carnegie Council for Ethics in International Affairs (2022), Introduction to Carnegie Climate Governance Initiative, www.c2g2.net/introduction/.
[3]AGU (2019), Position Statement on Climate Change, www.agu.org/Share-and-Advocate/Share/Policymakers/Position-Statements/Position_Climate.

We believe an ethical framework to help govern climate intervention research and potential deployment can be informed by the way the scientific community has approached research around genetic engineering and human participation in health, medical and social science research. Such a framework will lead to more robust, more just, evidence-based dialogue and decision-making about research, field experiments and any proposed deployment.

III. The Proposed Role for AGU

AGU is proposing to use its resources and expertise to convene key global stakeholders to develop an ethical framework around climate intervention research and experiments and any resulting potential deployment decisions. Our initial goal is to help shape the framework to a point of advanced global discussion by the Conference of Parties, COP27, in November 2022. This work will be done by partnering and co-leading with other respected authoritative organizations and global governing bodies to establish this governance framework. We also propose addressing guidance for ocean-based carbon dioxide removal research as a first step in this overall effort.

In a partnership arrangement with other authoritative voices, AGU also proposes building on its existing programs, such as the Thriving Earth Exchange, Ethics and Equity Center, AGU Science Policy and Government Relations, and AGU's scholarly publications, to educate and assure outreach to and engagement with local communities, government entities and scientific organizations globally. In addition, AGU will help leverage its scientific membership and scientific workforce development resources to assure attraction and development of early-career and next-generation scientists in this space to proactively address the climate change crisis across disciplines in both policy and ethical scientific practice strategies. AGU also will help provide scientific recognition and awards for such works and lend its expertise in seeking and managing external funding for needed global coalition initiatives.

IV. Why AGU?

We believe AGU is positioned to lead an effort to build this ethical framework because:

- AGU science and scientists represent a deep resource of knowledge necessary for proper climate intervention assessments.
- For more than 100 years, AGU has been a trusted and respected voice in science policy, scientific ethics and scientific publications. AGU also has unique global scientific convening expertise that can be used to forge partnerships and calls to action to proactively address and coordinate scientific attention and ethical climate actions.
- The AGU Strategic Plan makes an imperative call for AGU to (1) catalyze discovery and solutions to scientific challenges, (2) promote and exemplify an inclusive scientific culture, and (3) partner broadly with other organizations and sectors to address scientific and societal challenges. One of the most pressing science-related societal challenges needing action is global climate change.
- Building on existing programs, AGU is uniquely positioned to lead in bringing inclusive scientific outreach to local communities globally and to assure attraction and development of early-career and next-generation scientists in this space to proactively address the climate change crisis around the world in both policy and ethical practice strategies over the next 30 years.
- Because of the urgency of this growing crisis, bold and sustained action by AGU to help lead and address research about climate intervention strategies and implementation is both an ethical and moral organizational obligation.

AGU's Engagement Principles

We are committed to:

- Ensuring that research about climate intervention strategies is done in ways that are inclusive, representative and just.
- Ensuring that research about climate intervention strategies is done in ways that do not make deployment inevitable.
- Ensuring that research about climate intervention strategies does not undermine efforts to reduce carbon emissions.
- Assuring public participation and consultation in the development of ethical framework decision-making mechanisms and processes.

Below, AGU outlines its preliminary recommended actions and involvement over the next 5+ years to help assure that the effective and ethical local and governance structures for climate intervention research are properly vetted and executed with all key voices at the table.[4] A summary of the most prominent climate intervention technologies is provided in Appendix 1.

V. Ethical Issues to Be Addressed

AGU leadership and staff propose that any party pursuing climate mitigation strategies and engineered carbon removal or sequestration and storage technologies at all scales should abide by a recognized ethical process for climate intervention research or deployment and its governance. This ethical framework should include awareness, discussion and engagement by experts representing a full range of disciplines, national and international intergovernmental representatives, civil society, and the lay public. The framework would guide appropriate research and deployment protocols and standards across a wide range of potential scenarios and maturity stages. We propose that AGU invest the direct resources and organizational expertise necessary to partner and co-lead with other organizations and governing bodies to establish this governance framework.

Such an ethical governance framework must proactively address the following issues:

- Distributive justice (who benefits/who is harmed).
- Procedural justice (who decides/how will geoengineering decisions be made).
- Local right of refusal versus global impact of refusal.
- Capacity to conduct research not being equitably distributed.
- Measurements and reporting.
  a. Land use and ocean issues.
  b. Slippery slope and moral hazard hypotheses (and how to evaluate those hypotheses).
  c. Levels or maturity matrix for various phases of research and field experiments or deployment.

A preliminary ethical framework to address climate intervention research is proposed and attached in Table 1 (Appendix 3).

VI. Parallel Lessons from Governance of Other Technological Advancements

[4] We propose that AGU will use the term "climate intervention" rather than "geoengineering" to describe our actions and plans toward climate crisis mitigation. This term is consistent with findings and recommendations in a 2015 National Academy of Engineering report on technological options, summarized to state that "climate intervention" best describes the problem it is aimed at and expresses the uncertainty involved; that is, we're trying to influence a system, but we do not have a high degree of control, like we would in an engineering context.

Many lessons have been learned on the need, challenges and resulting successful models to apply ethical principles to governance of new and emerging technologies where there is/was huge potential human, global health or environmental risks and no prior research or application governance structures in place.

Table 2 (Appendix 4) summarizes areas where either voluntary or forced national and international governance structures have developed over the past two decades and some models that are still evolving. Partnership activities to develop ethical governance structures for climate intervention technologies should be informed by individuals and organizations who have led in establishing governance structures for these four relatively new emerging global technological activities and where potential technical application and research needs advanced more rapidly than ethical practices.

The four recent emerging technology challenges summarized in Table 2 are (1) human cloning, (2) development of genetically modified crops, (3) the advancement and application of nanotechnology, and (4) the emergence of CRISPR. Additional details are provided in the following links:

- "The Global Governance of Human Cloning: The Case of UNESCO": https://www.nature.com/articles/palcomms201719
- "Ethical Arguments Relevant to Use of Genetically Modified Crops": https://www.sciencedirect.com/science/article/pii/S1871678410005649?via%3Dihub
- "Nanotechnology Governance": https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1018707#:~:text=The%20nanotechnology%20governance%20proposal%20includes,substantial%20and%20diverse%20stakeholder%20involvement.
- "The Ethics of Nanotechnology": https://www.scu.edu/ethics/focus-areas/technology-ethics/resources/the-ethics-of-nanotechnology/
- "Governance Choices of Genome Editing Patents": https://www.frontiersin.org/articles/10.3389/fpos.2021.745898/full

Appendixes

1. Most Prominent Current Climate Intervention Technologies
2. Recent Relevant Reports
3. Table 1. A Proposed Ethical Framework for Responsible Climate Intervention Research
4. Table 2. Governance Models and Practices for Emerging Technologies

Appendix 1. Most Prominent Current Climate Intervention Technologies — Descriptions and Status Summaries

There are two significant categories of climate intervention technologies for which research is either proposed or currently in early stages of exploration. These are (1) solar radiation modification technologies and (2) carbon dioxide removal (CDR) and sequestration technologies.

1. Solar radiation modification (solar geoengineering)[5]
   i. Stratospheric aerosol injection
   ii. Solar reflection (space mirrors)
   iii. Marine cloud brightening
   iv. Cirrus cloud thinning

2. CDR and sequestration (carbon burial, ocean fertilization, biochar production and scrubbing towers)
   v. Ocean/marine based[6]
   vi. Land and nature based[7]

   This carbon climate intervention (both ocean and land based) seeks to remove carbon-based greenhouse gasses from the atmosphere and stratosphere. It goes beyond simple emissions reduction and enters the realm of negative emissions. Some carbon capture methods are relatively simple, such as reforestation, afforestation (introducing trees to a region where they did not previously grow), and forest restoration to capture carbon in the form of biomass[8]. Other carbon climate intervention methods involve removing carbon dioxide from ambient air and storing it in deep, pressurized porous rock formations.* Still other carbon research programs have studied the prospect of iron fertilization, wherein iron is scattered across the ocean to stimulate the growth of carbon-absorbing phytoplankton.

[5] A summary of solar radiation modification technologies is found in Simon Nicholson (2020), Solar radiation management, Wilson Center, www.wilsoncenter.org/article/solar-radiation-management#:~:text=Solar%20radiation%20management%20(SRM)%20has,be%20captured%20by%20greenhouse%20gases.

[6] See additional detailed information on ocean-based CDR from Ocean Visions, https://oceancdr.net/.

[7] Additional information on land-based CDR is given by T. M. Lenton (2010), The potential for land-based biological CO_2 removal to lower future atmospheric CO_2 concentration, *Carbon Manage.*, *1*(1), 145-160, https://doi.org/10.4155/cmt.10.12

[8] MasterClass staff (2020), Biomass energy explained: How bioenergy and biofuels work, https://www.masterclass.com/articles/biomass-energy-explained

* Edited 27 June 2022 to clarify description of carbon storage methods.

Appendix 2. Recent Relevant Reports

Recent reports related to the needs and opportunities associated with climate mitigation technologies and informing potential ethical framing are as follows:

- National Academies of Sciences, Engineering, and Medicine (2019), *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda*, Natl. Acad. Press, Washington, D.C., https://doi.org/10.17226/25259.
- Carnegie Council for Ethics in International Affairs (2022), Carnegie Climate Governance Initiative, https://www.c2g2.net/introduction/.
- National Academies of Sciences, Engineering, and Medicine (2022), A research strategy for ocean carbon dioxide removal and sequestration, https://www.nationalacademies.org/our-work/a-research-strategy-for-ocean-carbon-dioxide-removal-and-sequestration.
- A.-M. Hubert (2021), A code of conduct for responsible geoengineering research, *Global Policy*, *12*(S1), 82-96, https://doi.org/10.1111/1758-5899.12845.
- F. Biermann et al. (2022), Solar geoengineering: The case for an international non-use agreement, *WIREs Clim. Change*, https://wires.onlinelibrary.wiley.com/doi/10.1002/wcc.754.
- Project Drawdown (2020), The Drawdown Review: Climate Solutions for a New Decade, https://drawdown.org/publications/the-drawdown-review.
- National Research Council (2015), *Climate Intervention: Reflecting Sunlight to Cool Earth*, Natl. Acad. Press, Washington, D.C., https://doi.org/10.17226/18988.
- National Research Council (2015), *Climate Intervention: Carbon Dioxide Removal and Reliable Sequestration*, Natl. Acad. Press, Washington, D.C., https://doi.org/10.17226/18805.
- Aspen Institute (2021), Guidance for ocean-based carbon dioxide removal projects report, https://www.aspeninstitute.org/wp-content/uploads/files/content/docs/pubs/120721_Ocean-Based-CO2-Removal_E.pdf.
- D. R. Morrow et al. (2020), Principles for thinking about carbon dioxide removal in just climate policy, *One Earth*, *3*(2), 150-153, https://doi.org/10.1016/j.oneear.2020.07.015.
- WMO Commission for Climatology and Scientific Committee for the World Climate Research Programme (2014), Working together towards strengthened research and operations linkages for enhancing climate services, Joint CCL-WCRP Statement, https://www.wcrp-climate.org/about/Joint_CCl-WCRP_Statement_2014.pdf.
- S. Rayner et al. (2013), The Oxford Principles, *Clim. Change*, *121*, 499-512, https://doi.org/10.1007/s10584-012-0675-2.
- American Meteorological Society (2022), Climate intervention: A policy statement of the American Meteorological Society, https://www.ametsoc.org/index.cfm/ams/about-ams/ams-statements/statements-of-the-ams-in-force/climate-intervention/.
- Climate Response Fund (2009), Asilomar International Conference on Climate Intervention Technologies, March 2009, http://climateresponsefund.org/index.php?option=com_content&view=article&id=137&Itemid=90.

Appendix 3

Table 1. A Proposed Ethical Framework for Responsible Climate Intervention Research[9]		
Provision	**Content**	**Topic Addressed**
Article 1	Nature and scope[10]	• Designed to be a legally nonbinding (voluntary) instrument • Incorporates relevant legal principles and rules of international environmental law • Global in scope • Directs a range of state, intergovernmental and nonstate actors
Article 2	Objectives	• Promote the responsible conduct of climate intervention research, focusing on principles and procedures for outdoor experiments
Article 3	General principles	• The code of conduct should be interpreted and applied in light of relevant principles and rules of international environmental law and sustainable development
Article 4	Use of climate intervention	• No climate intervention activities should take place until there is an adequate scientific basis on which to justify such activities along with appropriate consideration of environmental and other effects • Exception for responsible scientific research conducted in accordance with all applicable laws and regulations and in compliance with the code of conduct • Climate intervention should not be communicated or used as a substitute for emission reduction efforts
Article 5	Cooperation on climate intervention research	Actors should cooperate to promote the responsible conduct of climate intervention research: • Through the establishment and implementation of governance for and harmonization of research • Through knowledge gathering and cooperation to assess efficacy, benefits and adverse effects • To promote knowledge sharing

[9] Based on Table I in A.-M. Hubert (2021), A code of conduct for responsible geoengineering research, *Global Policy*, *12*(S1), 82-96, https://doi.org/10.1111/1758-5899.12845.
[10] Ethical premise: The process of developing geoengineering research governance must involve awareness, discussion, and engagement on the part of different experts representing a full range of disciplines, government and intergovernmental representatives, civil society, and the lay public about geoengineering research and its governance.

		• To promote international equity through capacity building and other approaches
Article 6	Principles and practices for responsible climate intervention research	Actors should: • Conduct climate intervention research in a responsible manner • Exhibit due diligence to prevent and minimize environmental harm from outdoor experiments • Apply an incremental, proportional "step-by-step" approach to the design of outdoor experiments and conduct those experiments using the best scientific methods and means that are reasonably available • Avoid disruptions to other legitimate activities, including other research studies
Article 7	Assessment of outdoor experiments on climate intervention	All outdoor experiments on climate intervention should • Be assessed at an early stage in accordance with relevant laws and regulations and adhere to the code of conduct • Comply with further detailed guidance set out in in this section
Article 8	Public participation	• The public should be provided with timely information about climate intervention research, especially outdoor experiments, and should be given notice with the opportunity to comment
Article 9	Postproject monitoring of outdoor experiments on climate intervention	• Postproject monitoring of the outdoor experiment should be carried out, including monitoring for any adverse effects • Results of monitoring should inform future studies
Article 10	Access to information	Information on climate intervention research should: • Be accessible in a timely, complete and reliable manner • Comprise a nonexhaustive list developed for this section • Be provided through appropriate channels by those involved in the planning and execution of climate intervention research • Adhere to open science and open data principles[11]

[11] See AGU (2016), Position Statement on Free and Open Science, https://www.agu.org/Share-and-Advocate/Share/Policymakers/Position-Statements/Free-and-open-science.

		• Be peer reviewed
Article 11	Interpretation and application	• Sets out principles for how the code of conduct should be interpreted and applied, including taking a flexible and adaptive approach considering new information and by drawing upon the work of and involving existing institutional bodies, experts and civil society as appropriate

Appendix 4

Table 2. Governance Models and Practices for Emerging Technologies

Technology	Public Risk Issues	Ethical Governance Development Timeline	Resulting Governance Structure
Human reproductive cloning	Lack of rules or governance Health or psychological safety of the clone Exploitation of human reproduction technology for financial gain: who benefits? Potential positive health benefits for developing new organs Embryos harvested for stem cells rather than brought to term	1993-2016 (Dolly the sheep cloned in 1996)	• 1993 UNESCO (United Nations Education, Scientific and Cultural Organization) Bioethics Committee established • 1997 UNESCO *Universal Declaration on the Human Genome and Human Rights* • 1998 World Health Organization's resolutions on the implications of cloning for human health • 2005 United Nations adoption of Declaration on Human Cloning (nonbinding, ambiguously worded and ambivalent support from U.N. nation states) https://documents-dds-ny.un.org/doc/UNDOC/GEN/N05/249/40/PDF/N0524940.pdf?OpenElement • 2008 UNESCO Working Group to investigate the possibility of a legally binding convention to ban human reproductive cloning • 2016 UNESCO Universal Declaration on Bioethics and Human Rights, https://en.unesco.org/themes/ethics-science-and-technology/bioethics-and-human-rights
Genetically modified (GM) crops	Potential harm to human health Potential damage to the environment Negative impact on traditional farming practice Excessive corporate dominance The "unnaturalness" of the technology	1994–2016 (A GM tomato first introduced and available for sale in 1994 after regulatory review and approval in the United States)	National rather than international governance within each governing region In the United States: • The Department of Agriculture regulates field testing of GM crops for research • The Environmental Protection Agency (EPA) regulates plants with pest-resistant properties • The Food and Drug Administration (FDA) regulates any GM crops that are eaten by humans or animals At the international trade level: • Harmonization efforts are led by the Codex Alimentarius Commission, the Cartagena Protocol on Biosafety (CPB) and the World Trade Organization (WTO); although internationally harmonized guidelines for safety approval have been finalized at the Codex Alimentarius, there is no clear consensus on labeling regulations for GM food, some of which could be found inconsistent with the WTO, and there is an increasing risk of conflicts between the CPB and the WTO

Nanotechnology	Health risk due to small size, high surface area-to-mass ratio, and thus unique human toxicity concerns Risks at nanoscale cannot be derived from toxicity of similar materials at macroscale Nanoparticles are difficult to filter from the air and are thus an airborne risk Could become the next asbestos through potential absorption and bioaccumulation Potential environmental toxicity and harm to other species Limited capability to detect and measure in the environment	1986–current (In 1986, K. Eric Drexler published the first book on nanotechnology, *Engines of Creation: The Coming Era of Nanotechnology*)	• In the United States the 2007 National Nanotechnology Initiative (NNI) was designed to fund and coordinate nanotechnology research, including research on health, societal and environmental aspects of nanotechnology, but not to fund nanotechnology governance or regulation • The human health and environmental impacts of nanotechnology are thus governed by various agencies depending on the application involved and country of use; the primary U.S. regulating agencies are the EPA, the FDA, and the Occupational Safety and Health Administration
CRISPR	Improper application Designer babies The holy grail of molecular biology — cheap, easy to apply and universally successful in every species	2012-current	• Usage controlled and governed by patents and patent licenses • A relatively new area in which governance is still evolving by specific application