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FORUM for CLIMATE ENGINEERING ASSESSMENT

Briefing Paper on Climate Engineering

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What is Climate Engineering (CE)?

Climate Engineering (also often referred to as Climate Geoengineering or simply Geoengineering) is defined as large-scale, deliberate intervention in the Earth system to counteract climate change. Two major sets of techniques are usually included: those that could remove significant amounts of carbon dioxide from the atmosphere (Carbon Dioxide Removal—CDR), and those that might offset the amount of incoming solar radiation in order to cool the planet (Solar Radiation Management—SRM).

CDR techniques are an enticing proposition because they would in some sense address the "cause" of climate change by drawing down carbon dioxide levels. There are, though, significant challenges associated with CDR proposals, not the least of which is that current proposals are extremely costly, would work only over very long time horizons, and would be extremely difficult to deploy at scale. Some proposed SRM techniques, on the other hand, could work quickly to bring down global temperatures. At the same time, there are a host of risks and challenges related to SRM that would need to be worked through before any deployment of SRM technologies could be reasonably and legitimately pursued.

Almost all climate engineering (CE) ideas that have received consideration are at the very earliest stages of consideration, and indeed most are still chalkboard concepts. There remains something of a taboo around investigation into SRM technologies, in particular. This could quickly change, however, especially in the wake of the Paris agreement, as policymakers and scientists wrestle with the fact that greenhouse gas emissions continue to rise despite growing levels of international ambition. CE technologies are a terrible thing to need to consider. Yet consider them we must, both for the potentially positive contribution they might make to international climate response efforts and for the devastating impacts that an unguided development and use of CE technologies could have on people and the planet.

A more detailed assessment of CE techniques and their implications can be found in the attached technical annex, which, if possible, should be read in conjunction with this note.

Why are we talking about and concerned with CE?

Recently there has been increasing discussion about the potential development and deployment of CE. Some experts have begun to openly state that the ambitious goals of the Paris Agreement, namely to keep global average temperature increases to well below 2°C above pre-industrial averages, and possibly to no more than 1.5°C, cannot be met without some combination of different techniques of CE. These kinds of claims are based on a reading of the Intergovernmental Panel on Climate Change's (IPCC) recent Fifth Assessment Report (AR5). AR5 included examination of 204 separate scenarios that, in the model runs, held atmospheric temperature increases to less than 2°C by 2100. Of those 204 scenarios, 184 incorporated large-scale deployment of one specific CDR option, Bioenergy with Carbon Capture and Storage, or BECCS.

Let's be clear about what this means, because it is a difficult thing to consider. What the model runs are saying is that it is still possible that the world can avoid 2°C of warming via energy system decarbonization, land-use change, and the other components of an aggressive mitigation agenda. However, the window for that kind of mitigation action to *alone* avoid 2°C, let alone 1.5°C, of warming is rapidly closing, as the global carbon budget continues to shrink.

Most of the models used in AR5 report were forced to incorporate a massive drawdown of carbon later this century in order to meet the internationally agreed temperature targets. "Negative emissions" have been mainstreamed, via Paris, into the international climate response conversation. At the moment, however, it is not clear whether any such technology or set of technologies could be developed and made to operate. Further, many of the CDR techniques being considered, and most notably BECCS, will have significant impacts on biodiversity and land use, and consequently on food prices and food security. Some experts have even said that the impacts on biodiversity and food systems of some CDR technologies needed to get to 1.5°C would be less acceptable than the impacts of allowing temperatures to rise to 2°C or more!

The world is being forced, then, into a set of "risk-risk" tradeoffs. Which is the more terrible proposition: development of CE technologies or the crossing of climate change-induced tipping points? Would CDR on top of aggressive mitigation be better than aggressive mitigation alone? Where might SRM fit in? Are there forms of SRM that could lessen the risks associated with climate change without imposing other, unacceptable risks on the world? There are, at this stage, with very little known about CE technologies, no clear answers.

Such decisions are being forced on the world, though, and may be closer than we care to think. There is a plausible scenario that in the coming years, perhaps because of bad news about global emissions that continue to rise or climate impacts that are getting considerably worse, a country, or a group of countries decide to move toward deployment—with or without agreement from the international community. The 2018 and especially the 2023 stocktaking events in the UNFCCC process could trigger such developments. In the nearer term, research will continue. It is clear that some private sector companies (in particular fossil fuel companies) are already engaged in research and development of certain CE technologies. Given potential security implications, the military and the security apparatus in different countries have also been active. A rogue state undertaking its own form of unsanctioned CE research in anticipation of rapid deployment is an unlikely proposition, but cannot be excluded.

The above scenarios are hardly desirable. However, they are plausible. Yet the reality is that we don't know enough about these CE techniques to be able to properly assess their viability, and the extent to which—if at all—they could be complimentary to other, more traditional methods of managing climate change.

What is the Status of CE today?

CE techniques are largely nascent, in that on the whole they have not been deployed or even much tested. This is particularly true with SRM, where all we know comes from models or from observation of natural analogues (e.g. volcanic eruptions depositing sulfate particles in the stratosphere). Many CDR methods are similar to mitigation methods—in fact there may be good reason to stop talking about at least some CDR methods as "geoengineering," since ideas like afforestation and soil management are already a part of the mitigation agenda. Still, while some specific CDR techniques have been tried in laboratories or small-scale deployment, most have not—especially not at the large scales one would require. There have also been some isolated incidents of unauthorized deployment (e.g., a case of ocean fertilization off the Canadian coast).

The CE agenda so far has largely evolved from the academic research community, with little or no oversight from public authorities. This is one significant and urgent gap in governance that needs to be filled, if further research is to proceed (and the required funding achieved).

What is the status of CE Governance?

There is no systematic, coherent set of governance frameworks in place to guide further research; to facilitate decision making about potential deployment; and to guide eventual deployment. There do exist a number of isolated, uncoordinated, and highly contentious elements of intergovernmental response, such as a *de facto* moratorium on CE in a decision of the Convention on Biological Diversity, or the decision to prohibit techniques like ocean fertilization by the London Dumping Convention. Yet the CBD decision and the actions taken under the London Dumping Convention were not discussed and considered in other fora, such as the UNFCCC, or the UN General Assembly, even though the potential positive and negative impacts (environmental, social, economic) go way beyond the biodiversity community.

Nor have national level or softer forms of governance received much attention. There are only very loose norms around scientific investigation in this space and little cross-country coordination. At the same time it is unclear whether existing regulations and institutions within particular countries and regions are sufficient to effectively shape or constrain development of CE technologies.

Key Governance Challenges

SRM and CDR methods are very different and so are their governance requirements and the challenges they pose. There are some aspects, however, which arise in both—and incidentally also with other technologies such as genetically modified organisms; synthetic biology; or nanotechnologies.

The governance issues arising out of SRM, and in particular of stratospheric injection of aerosols, pose particular challenges at the international level. To do stratospheric aerosol injection well would require one or more countries possessing the relevant aerospace technologies to undertake this on behalf of the international community—and possibly do this for decades, and depending on the intensity of parallel mitigation efforts, possibly over hundreds of years. Who will decide to start, and eventually to end? Who will control the "global thermostat"? How will decisions be made to balance the global need to reduce the average global temperature with environmental and social impacts that may not all be equally distributed across the globe? How will decisions be made to balance the costs and benefits of traditional mitigation methods versus CDR and SRM, and of adaptation efforts that are not covered should these methods be deployed? How will the required governance frameworks withstand potentially substantial geopolitical changes during the period on question?

The CE research community has begun to address these issues, but the global policy community has not.

The work of the Forum for Climate Engineering Assessment and the Carnegie Council

FCEA and the Carnegie Council both recognize that the highest priority at this time is for countries to pursue their activities to reduce emissions of greenhouse gases. At the same time a prudent assessment of plausible scenarios indicates that these efforts may not be enough to keep temperature increases below 1.5 degrees Celsius. Consequently, one also needs to consider a range of risk management scenarios, including the possibility that CE might also be used. With this in mind:

- FCEA has convened the Academic Working Group 0n International Governance of Climate Engineering (AWG). This process has engaged governance experts who are developing relevant analysis and recommendations to the policy community on the governance challenges of SRM, in particular. FCEA is also engaged in a range of other work streams focused on building robust, anticipatory forms of governance to guide and, where appropriate, to constrain development of CE technologies.

- The Carnegie Council, building on work done by different stakeholders (including the AWG mentioned above), will, over the next five years, aim to shift the debate on CE governance from academia to the intergovernmental policy community. It will do so by engaging with intergovernmental institutions, informally with government officials, as well as with a range of non-state actors, to further the dialogue on the subject, and to encourage and to contribute to the development of governance frameworks. The ultimate result of this project after five or more years would be intergovernmental action on governance of CE.

It is often stated that there is a "moral hazard" in engaging in such work, because by the mere fact of doing it, one brings the international community closer to eventual decisions to deploy. This may be so, but the converse—not discussing, not engaging on this issue—could be worse, especially given the factors outlined at the beginning of this note. Moreover, the moral hazard may actually go in the other direction. Ignorance about CE allows for what some have called "magical thinking" to creep into the policy conversation. It is too easy a thing to imagine that some magical technology rests just over the horizon, ready to save us all from the difficult choices and actions that climate change demands. We need to know more about what CE technologies really offer if the benefits and risks are to be adequately assessed.

As we learn more about the complexity of the governance and technical requirements of CE, we will learn if the development of CE technologies is simply untenable or something to carefully consider in a highly regulated manner. We need to know more about CE, if only to discover what is and is not possible, and we need to be careful that investigation in this space is not driven solely by the interests of a few unsupervised individual investors or scientists.

APPENDIX:

Technical Briefing Note on Climate Engineering

This briefing paper summarizes the research community's understanding of climate engineering, focusing on solar radiation management (SRM). It proceeds as follows:

1. What is SRM? What technologies could be used to implement it?
2. What role might SRM play in international climate policy?
3. How does SRM relate to negative emissions and carbon dioxide removal (CDR)?
4. What risks would SRM create? What risks could it reduce?
5. How might SRM evolve over the next decade or so?

1. What is SRM? What technologies could be used to implement it?

- **Solar radiation management (SRM)** is a proposed means of reducing climate risk by **reflecting a small fraction of incoming sunlight back into space before it can warm the planet**, thereby slowing or reducing global warming and associated climatic changes. SRM is therefore a form of **climate engineering**, which is defined as large-scale, deliberate intervention in the Earth system to counteract climate change.
    - **A high-CO_2 world cooled by SRM would have a different climate than a low-CO_2 world without SRM** because SRM compensates imperfectly for greenhouse gas-driven changes (e.g., to precipitation).
    - **SRM would not address the physical driver of anthropogenic climate change** because it would not directly affect atmospheric greenhouse gas levels, though it could indirectly affect them by protecting carbon sinks.
- The two **main proposals** for implementing SRM are:
    - **Stratospheric aerosol injection (SAI)**, which would involve injecting a few megatons of sulfates or other particles into the stratosphere each year using specialized planes, tethered balloons, or other technologies.
    - **Marine cloud brightening (MCB)**, which would involve using specialized ships to spray sea salt or other particles into the lower atmosphere, where it would brighten existing marine clouds, making them more reflective.
- **Other proposals** include:
    - **Cirrus cloud thinning (CCT)**, which would thin cirrus cloud coverage to allow more outgoing infrared radiation to escape into space. While not technically SRM, it shares many features with SRM. The idea of CCT is newer and less well studied than SAI and MCB.
    - Space mirrors and ground-based albedo modification (e.g., white roofs, more reflective crops, etc.) are often mentioned but the research community generally regards them as unaffordable and ineffective, respectively.

***2. What role might SRM play in international climate policy*?**

- **Emissions reductions must remain the top priority in climate policy.** The research community's consensus is that, for various reasons, SRM cannot replace mitigation. Most importantly, the risks from intense SRM, discussed in §4, would be too great to justify using it to offset enough warming in a business-as-usual scenario, and relying solely on SRM would allow ocean acidification to proceed more or less unchecked.

- The **main proposals** for using SRM to **complement mitigation** are:
  - **Rate-slowing.** Combined with aggressive mitigation, a multi-decadal, low- or moderate-intensity deployment of SRM could reduce the rate of warming, buying time to decarbonize the economy and for societies and ecosystems to adapt to unavoidable warming. SRM could be phased out as the rate of warming approaches zero.
  - **Peak-shaving**. In many IPCC scenarios, temperatures "overshoot" international targets and then decline as carbon emissions approach zero and become strongly negative. In this context, a multi-decadal, low- or moderate-intensity deployment of SRM could reduce the peak temperature during the overshoot period and then be phased out as atmospheric CO_2 declines.
- Researchers mostly reject some other proposed uses for SRM:
  - Some popular accounts suggest using SRM as a permanent replacement for mitigation. The research community rejects this proposal, as explained above.
  - Some researchers have, in the past, suggested that SRM could help address a **climate emergency**, such as the approach of a climate tipping point. Few do so now. By the time a looming tipping point was identified, SRM probably could not prevent it. Furthermore, there is potential for geopolitical conflict over declaring a climate emergency.

3. How does SRM relate to negative emissions and carbon dioxide removal?

- **Negative emissions technologies (NETs)** are proposed technologies for implementing **carbon dioxide removal (CDR)**, which involves removing CO_2 from the atmosphere and sequestering it in soils, the deep ocean, or geological reservoirs for decades, centuries, or millennia. CDR is usually considered a form of climate engineering, though the boundary between CDR and mitigation is fuzzy in certain cases (e.g., afforestation).
- **In theory, CDR could be used to achieve net negative carbon emissions**, which would reduce atmospheric CO_2 levels at rates of up to a few parts per million per year. Significant reductions would require very large-scale deployment over many decades. In practice, such large-scale deployment might be prohibitively expensive or difficult or create significant physical or social side effects (e.g., on food security; demand for energy, land, or water; or biodiversity).
- Prominent proposed NETs include afforestation, biochar, better soil carbon management, enhanced mineral weathering on land or sea, ocean fertilization, bioenergy with carbon capture and sequestration (BECCS), or direct air capture and sequestration. Each NET has different advantages, disadvantages, co-benefits, risks, and side effects.
- **CDR offers significant governance challenges because of the potential physical and social implications of NETs.**
- Because CDR and SRM affect the climate through very different mechanisms and require very different social and political mechanisms for governance and implementation, **the risks and benefits of CDR differ significantly from those of SRM**. Thus, claims about the potential, risks, or governance needs of one cannot automatically be assumed to apply to the other.

4. What risks could SRM reduce? What risks could it create?

- SRM could reduce almost all climate risks, but it would do so imperfectly and unevenly (e.g., because of regional differences in effects) and without addressing ocean acidification. Especially in a context of severe climate change, the global and regional benefits could be significant.
- The **risks created** by SRM can be divided into **physical risks and social risks**. It also raises **additional ethical concerns**.
- The **physical risks created by SRM** arise because SRM counteracts greenhouse warming imperfectly. They include:
  - **Changes in the hydrological cycle.** SRM will change precipitation patterns by reducing evaporation and precipitation. Since climate change will speed up the hydrological cycle, deploying SRM in the context of significant climate change may move (parts of) the world back toward pre-industrial patterns of precipitation. Some modeling studies suggest that high-intensity SRM (e.g., to fully offset global warming of 4ºC) might weaken Asian and other monsoons relative to pre-industrial averages, but this is disputed and is not expected with low- or moderate-intensity deployments.
  - **Changes in ocean and atmospheric circulation.** SRM may change circulation patterns in the oceans and atmosphere.
  - **Ozone depletion (SAI only).** Stratospheric aerosols might do some harm to the ozone layer, though costlier non-sulfate aerosols may avoid this.
  - **Termination shock.** If a moderate or high-intensity deployment of SRM were stopped abruptly and not resumed within a few years, then under certain conditions, global average temperature would rise sharply and rapidly. Global catastrophe could result, especially if CO_2 levels were very high at the time.
  - **Unknown climatological risks.** Unexpected climatological effects may develop, especially for more intense or longer deployments.
- The **social risks created by SRM** include:
  - **"Moral hazard."** Policymakers may unwisely use SRM (and/or CDR) as an excuse to avoid or reduce mitigation efforts. Doing so might lead to otherwise avoidable climatic changes that prompt SRM deployment.
  - **Geopolitical conflict over testing or deployment.** Disputes about how to "set the global thermostat" could lead to regional or global conflict. Furthermore, the difficulty of attributing floods, droughts, storms, etc. to SRM may generate conflicts over demands for compensation, changes to deployment plans, etc. While researchers now think that **unilateral deployment** or deployment by non-state actors is unlikely, many now see contested **"minilateral" deployment** as a serious possibility.
  - **Inadequate or inappropriate governance.** Because SRM would have global impacts, SRM should be subject to well-defined and ideally international governance, even at the research stage. Public engagement and deliberation are widely recognized as essential elements in that governance, but the mechanisms for achieving these ideals need further development. Without them, decisions about researching or deploying SRM may be deemed illegitimate or may lack adequate public oversight.

    - **Technological lock-in.** Investing heavily in a particular technology for implementing SRM could lead to reliance on suboptimal technologies.
- Other **ethical concerns raised by SRM** include:
    - **Distributive injustice.** Different ways of deploying SRM would have different distributional impacts, especially for the global poor.
    - **Hubris.** Many commentators see SRM as hubristic or incompatible with humanity's proper relationship with nature.

5. How might SRM evolve over the next decade or so?

- In our assessment, SRM is **highly unlikely to be deployed or tested at large scales in the next decade**. While it might be technically possible to do so, researchers expect that even a well-funded, well-run research program would take at least 20–30 years to learn whether and how one could deploy SRM intelligently. More rapid deployment is probably socially and politically infeasible because it would occur without adequate governance or scientific understanding.
- Some physical scientists and engineers are eager and ready to begin **small-scale outdoor experiments** to test, e.g., microphysics of aerosol dispersal or engineering designs for marine cloud brightening. We believe that some of these research groups will likely find funding for these projects in the next few years.
    - Most of the research community believes that outdoor research should not proceed without some governance regime, including mechanisms for public oversight, though they disagree about whether governance should precede research or co-evolve with it.
- **Analysis and development of legal frameworks** will likely continue, expanding beyond existing analyses of domestic and international law.
- Efforts to improve and expand **public engagement** will continue, hopefully with greater international reach, including efforts to develop **protocols and mechanisms for anticipatory governance** and other forms of **public deliberation**, drawing on mechanisms created for other emerging technologies.
- Official **research programs and formal and informal governance structures** are likely to begin taking shape at the national and international levels, broadening the existing discussion beyond the academic research community to include public institutions and the policy community.