Climate geoengineering options: practical, powerful, and to be avoided if possible

Report on the **2nd Permafrost Carbon Feedback Intervention Roadmap Dialogue**

To avoid catastrophic risk from climate change, we need to limit global warming to 1.5° Celsius. And given how close we are to that limit, even the most ambitious conventional decarbonization efforts will not be enough. Negative-emission technologies or other geoengineering methods will be necessary to compensate for emissions that push us beyond that manageable limit.

That statement, paraphrased from Leiden University researcher and guest presenter Oscar Rueda, probably best captures the consensus of a sometimes-fractious second dialogue (March 11, 2021) facilitated by the privately sponsored Permafrost Carbon Feedback Action Group – part of a four-session virtual symposia addressing the science, technology, economics, policy, social and ethical implications of permafrost thaw. The first dialogue (March 4, 2021) surveyed **Why Permafrost Carbon Matters** and garnered easy agreement: global permafrost is charged with twice as much carbon as that in all the earth's atmosphere and, as it thaws, natural processes trigger a dangerous release of that carbon in the form of the greenhouse gases CO_2 and methane, thereby reinforcing atmospheric warming.

The second dialogue, **Avoiding Permafrost Thaw: Managing Temperature**, considered whether we have the capacity to intervene to limit permafrost thaw – and whether we should. Even the first question provoked argument. The second, however, inspired a fiercer debate, among panelists and among more than 150 leading academics, government policy makers, technology investors, climate change activists and media who had tuned in online.

The dialogue featured three presenters and two responders or commentators, listed here in the order in which they spoke:

John Moore, Chief Scientists, College of Global Change and Earth System Science, Beijing Normal University

Douglas MacMartin, Senior Research Associate, Sibley School of Mechanical and Aerospace Engineering, Cornell University, New York

Oscar Rueda, Researcher, Department of Industrial Ecology, Institute of Environmental Sciences, Leiden University, Netherlands

Ted Parson, Faculty Director, Emmett Institute on Climate Change and the Environment, University of California Los Angeles, USA

Damon Matthews, Professor and Concordia Research Chair, Climate Science and Sustainability, Concordia University, Montreal, Canada

Ted Parson, appearing as a respondent, set the perfect context for the discussion, identifying some of the points that inspired the PCF Action Group to convene this dialogue series. Parson noted that the Arctic is warming faster than any other region on earth and is especially sensitive to the effects of that change. It is also the primary location of two of the most powerful positive (or climate change-reinforcing) feedbacks. First, the advancing melt of Arctic Ocean summer ice is diminishing the albedo effect, in which brighter surfaces reflect more radiant energy directly back into space, while darker surfaces – from open waters to high-latitude forests – absorb that energy and add to warming. Second, as mentioned, is the permafrost carbon feedback, in which warming promotes thaw, which increases emissions of GHGs, which accelerates warming.

But Parson suggested that this combination of vulnerability and reactivity could create what he dubbed an "Arctic Premium" – a dividend for regionally based climate interventions that could be less expensive, more effective and achieve faster results than if they were targeted over the whole earth.

One such intervention is the form of solar radiation management known as Stratospheric Aerosol Injection (SAI), which Douglas MacMartin described in his presentation, **Can we cool the Arctic?** Acknowledging immediately the controversial nature of geoengineering, MacMartin began by saying, "The short answer is yes." We *can* cool the Arctic. "But I phrased the question, 'can we?' rather than 'should we?' which is a much more complicated question."

Scientists know that aerosols in the stratosphere can block radiant energy because there have been huge natural experiments over the last 150 years, in which massive volcanic eruptions triggered global cooling for periods of months to years. So, MacMartin said, we could achieve a similar effect by flying airplanes into the stratosphere and spraying sulfur dioxide aerosols to reflect solar radiation back into space, cooling the earth below. This would be particularly powerful in the Arctic, where you could target sea ice or permafrost directly, lowering temperatures as well as preventing the feedback. SAI would also be easier in the Arctic because the tropopause – the boundary between the troposphere and the stratosphere – is lower in high latitudes, so you could use currently available aircraft to distribute the sulfur dioxide, rather than having to build custom vehicles to fly that much higher.

But if SAI offers a proven and immediately available technology to cool the earth, MacMartin said it should not be taken as an acceptable alternative to decarbonizing: "Obviously, the first thing we should do is cut our CO_2 emissions. I would liken this a little bit to: if you know you're going to hit the car in front of you, you should take your foot off the gas." SAI is also risky because it has negative effects on ultraviolet radiation and the SO_2 later comes down in the form of acid rain.

Another SRM option is Marine Cloud Brightening, in which "you spray salt water into the right kind of clouds over the ocean," and they reflect more solar energy, but MacMartin said this technology cannot be targeted in the north because the right kinds of clouds don't accumulate in the Arctic.

In his presentation, **Targeted Geoengineering: Conserving the Cryosphere**, John Moore, from Beijing Normal University concentrated on a more natural intervention: permafrost conservation through land-use modifications. Moore introduced the example of Pleistocene Park, a 20-square-kilometre area in Siberia, which the father-and-son team of Sergey and Nikita Zimov have been repopulating with large herbivores – horses, bison, musk-ox and deer. The Zimovs are working to recreate the conditions of the Pleistocene period, in which huge herds of herbivores fed on and fertilized grasslands, which are lighter in colour and therefore more reflective, even as they destroyed darker shrubs and trees that absorb more solar energy. Foraging animals also tamp down or clear winter snow, reducing its tendency to insulate the ground, so cold penetrates more effectively, better preserving the permafrost below.

The experiment appears to be working. Moore reported that Pleistocene Park is supporting the highest level of biodiversity in the last 12,000 years, and ground temperatures are cooler than in a neighboring control area. But Moore said this, too, should not be mistaken as a standalone climate solution: it's impractical to scale up – too costly to assemble enough land and impossible to quickly raise the huge herds of animals that would be necessary. But this kind of permafrost re-wilding could certainly be part of a portfolio of low-risk interventions, returning around 1% per annum on carbon storage investments if carbon prices are at as low as $5 per ton, or less depending on carbon tax mechanisms.

Picking up a thread from the first Dialogue in this series, Moore also stressed that the Arctic is not uninhabited, saying that the Northern people who use and depend upon the existing landscape need a strong voice in any discussion of what happens to the permafrost, both as it thaws under greenhouse gas forcing, and as it is adapted, for example, to prevent Arctic greening – a serious issue for herders as well as global climate. This has led to the CHARTER EU2020 program, which seeks to work with Arctic populations to find a sustainable way forward on land management.

Oscar Rueda's presentation, **Negative-Emissions technology portfolios to meet the 1.5°C target**, is also the title of a just-published *Global Environmental Change* paper on which Rueda was lead author. In the presentation and the paper, Rueda surveyed a selection of negative emission strategies, weighing their feasibility, effectiveness, and side impacts. These included:

- **Bioenergy with Carbon Capture and Storage (BECCS)**, in which you grow bioenergy crops that capture CO_2, burn the crops for energy, and then capture and sequester the CO_2 underground. This measure, which is used in most models that show global average temperatures staying within safe climate limits, is "simply not sustainable at the large scales usually considered," Rueda said. It requires so much agricultural land that it would threaten global biodiversity and food security.
- **Afforestation and reforestation** is regarded as a "no-regret" solution as forests improve biodiversity and ecosystem services even as they absorb carbon from the atmosphere, but it requires even more land than BECCS to capture the same amount of CO_2, and the forests sequester carbon only temporarily and are vulnerable to disturbance.
- **Soil carbon sequestration** is another no-regret solution. It uses agricultural practices, for example, adding secondary plantings among harvestable crops purely to capture and sequester CO_2. By improving productivity, it can even produce cost savings, but this option, too, has limited potential and needs ongoing maintenance.
- **Biochar** is a natural product created by burning plant material in a low-oxygen environment, so the carbon doesn't bond with oxygen to become CO_2. You then use the biochar as fertilizer. While technically feasible, this strategy has not been implemented at a large scale. It is also more expensive than soil carbon sequestration and afforestation and competes for biomass resources.
- **Enhanced weathering** refers to the acceleration of processes in which naturally eroded minerals consume CO_2 when they dissolve. This can be accelerated, for example, by pulverizing and distributing gigatons of minerals onto agricultural land. Rueda called it a promising alternative that can store carbon for thousands or millions of years, and an option worth exploring further.
- **Direct Air Capture** (DAC) describes technological processes that harvest CO_2 directly from the atmosphere and then separate out and sequester the carbon. It requires large amount of energy, but Rueda's research shows that DAC technologies, such as that being advanced by Canadian start-up, Carbon Engineering, will likely become cost effective under policies that would hold global temperatures to the 1.5°C maximum increase.

(A more detailed presentation and analysis is available in Rueda's *Global Environmental Change* paper. And a more comprehensive list and description of carbon dioxide removal options can be found in a March 2021 paper from the Carnegie Climate Governance Initiative paper, [Carbon Dioxide Removal and its Governance].)

Looking at all the options together, Rueda's research showed that natural solutions (afforestation biochar and soil carbon sequestration) are more affordable, but vulnerable to circumstances and difficult to measure. Whereas, the engineered solutions (BECCS, DAC and enhanced weathering) can have significant side impacts, are expensive and not yet technically feasible. In trying to clarify policy alternatives, Rueda's research showed the optimal negative-emission technology mix for different goals: for affordability – natural solutions, complemented by enhanced weathering; for effectiveness – engineered solutions; and, for sustainability – natural solutions, complemented by DAC. To balance feasibility and effectiveness, and to reduce side impacts, DAC would be the best option, followed by soil carbon sequestration and enhanced weathering.

But Rueda concluded, "if you wind up with a high need for negative emissions, there is nothing to choose: we need to deploy all negative emissions technologies to their maximum potential, which is very risky." He added that there are also large as-yet unrealized alternatives to such interventions. For example, eliminating animal products from the human diet would reduce GHG emissions by 8 billion tonnes of CO_2 per year in 2050 – "more than any of the negative-emissions technologies can remove."

That would stand among preferable alternatives for Damon Matthews, who questioned the whole prospect of geoengineering, saying, "I don't think we are going to solve the climate problem, which has emerged from fundamentally technological intervention in environmental systems, by designing new technological interventions. … Every additional intervention in a complex system carries consequences and risks. And I would argue that the total risks and impacts of climate change will increase, not decrease, if we chose to intervene in an already complex system." He added, "Rather than meddling further, we should prioritize energy solutions that do not reduce GHGs and do not cause climate change."

Matthews's intervention reflected a lively online debate among those tuned in to the dialogue. For example, Canadian Member of Parliament and former national Green Party Leader Elizabeth May said, "Mobilizing an emergency response to mitigation has not occurred on anything like the scale and pace and whole-of-government approach we have seen on COVID. And we really do NOT have until 2050. The window on 1.5°C closes well before 2030 without massive and accelerating effort."

Andrew Weaver, a University of Victoria Atmospheric and Oceanic Sciences Professor, former Intergovernmental Panel on Climate Change lead author, Member of the British Columbia Legislative Assembly and provincial Green Party Leader, agreed, recommending that everyone read Nancy and Eric Gurney's children's story, *The King, the Mice and the Cheese*, for a reminder about the impact of unintended consequences. (Weaver will be a presenter in the fourth Dialogue, March 25, 2021).

Rafe Pomerance, who was Deputy Assistant Secretary of State for Environment and Development in the Clinton Administration and who is now chair of Arctic 21, a network of organizations focused on communicating climate issues to policy-makers and the general public, commented in response that "Failure to deploy SAI also presents risks," a position Ted Parson endorsed, asking, "Can we (decarbonize) fast enough to prevent the already dangerous climate impacts from increasing to catastrophic levels? This is the reason we are considering geo-engineering at all."

That, again, seemed to sum up the consensus. Elizabeth May conceded: "No doors should be closed. We may well opt for some geoengineering, but we know what must be done and it can be done.

Slashing emissions and maximizing sequestration is do-able. Who would have imagined we would shut down the economy to save lives in a pandemic?"

Returning to the question of an Arctic premium, Ted Parson noted that, while there is merit in sounding the alarm about the risk of permafrost carbon feedback – and an imperative to do everything we can to accelerate emission cuts – there is further potential to identify potential responses and to prioritize those that could be more effective, cheaper, faster, and have more co-benefits by virtue of being targeted in the Arctic region.

Signing off with a call for consultation and a note of optimism, Parson also pointed to a different type of Arctic Premium. He said that northern people have a commonality of ecosystem and way of life, and even share some common institutions. It's possible that the governance problems that are so intractable at a global level might be more manageable with regionally targeted interventions. Given that Northern people are already seeing the effects of climate change, the North may be a place for a more pragmatic, constructive, and legitimate deliberative discussion on Arctic interventions.

Key Messages

1. Numerous natural and technological carbon dioxide removal (CDR) and other geoengineering methods offer a potential to mitigate or reverse the forces of global warming; although the most powerful technological methods also come with the highest risks.
2. Even those directly engaged in geoengineering research agreed that the world should look first to conventional decarbonization – i.e., reducing the burning of fossil fuels and mitigating other climate drivers – and that geoengineering if used at all, should be an addition, not an alternative, to conventional decarbonization.
3. Among those who oppose geoengineering, most acknowledge that the advance of climate change might leave us no choice but to accept some geoengineering interventions.
4. There is an Arctic premium. The Arctic is both highly vulnerable to warming and – with albedo and permafrost carbon feedbacks – highly reactive, which suggests that intervention directly in this confined region could be more affordable and achieve more dramatic and immediate results than if similar effort or investment was applied across the whole globe.
5. Northern peoples – essential leaders in any discussion of geoengineering interventions – have many common interests and institutions that could provide a unique governance advantage in addressing and countering dangerous anthropogenic climate effects.
6. At a time when we are not yet decidedly tackling climate change, there are still powerful alternatives to negative-emission technologies or other geoengineering solutions. For example, switching the world to a vegan diet (thereby reducing emissions by more than 8 billion tonnes of CO_2 equivalent/year) would dwarf the immediate effect of most negative-emission technologies.
7. We need more research to advance our understanding of geoengineering options and to accurately identify the point at which advancing climate change might trigger intervention. Natural negative-emissions solutions will require time to develop policies and incentives to align stakeholders and engage the public; and engineered negative-emissions solutions require further development to be ready, should they be needed.