ALL HANDS ON DECK FOR OCEAN-BASED CO_2 REMOVAL RESEARCH

Prof. Dr. Katja Fennel, Chair of the Department of Oceanography, Dalhousie University, Halifax, Nova Scotia, Canada, argues that we need all hands on deck for ocean-based CO_2 removal research

Mitigating global warming and other effects of anthropogenic greenhouse gas (GHG) emissions is the most pressing environmental challenge of our time. Yet pledges aimed at avoiding the worst consequences of climate change by keeping global average temperature at no more than 1.5°C or 2°C above the pre-industrial average, are increasingly tenuous.

Average global sea surface temperatures set jaw-dropping warming records in 2023 and 2024. Average global air temperature was 1.48°C above pre-industrial in 2023 and is expected to exceed 1.5°C in 2024. In other words, we have already overshot on our allowable emissions for the 1.5°C target.

At the same time, global CO_2 emissions (the most significant anthropogenic GHG) are at an all-time high of 57 giga tons (Gt) per year. Conversely, current national commitments for GHG emission reductions, if realized, will merely stabilize CO_2 emissions at current levels or lead to a modest reduction but fall well short of the emission reduction pathways needed to stay within the 2°C and 1.5°C by the year 2100.

Worse, the national commitments rely on implausible land-use changes through afforestation (e.g., converting two-thirds of global farmland into forests), and raise questions about the durability of carbon storage considering the increased risk of forest fires in a warmer world.

Ocean-based CO_2 removal research

In other words, we have now reached an all-hands-on-deck moment. Emission reductions alone will not be sufficient. Deliberate human intervention is highly likely needed to remove GHGs from the atmosphere to avoid the worst consequences of global warming. The Intergovernmental Panel on Climate Change (IPCC) estimates that 10 Gt of CO_2 per year will have to be actively removed from the atmosphere and durably stored by the middle of this century and 20 Gt of CO_2 per year by the end of this century. These are staggering amounts.

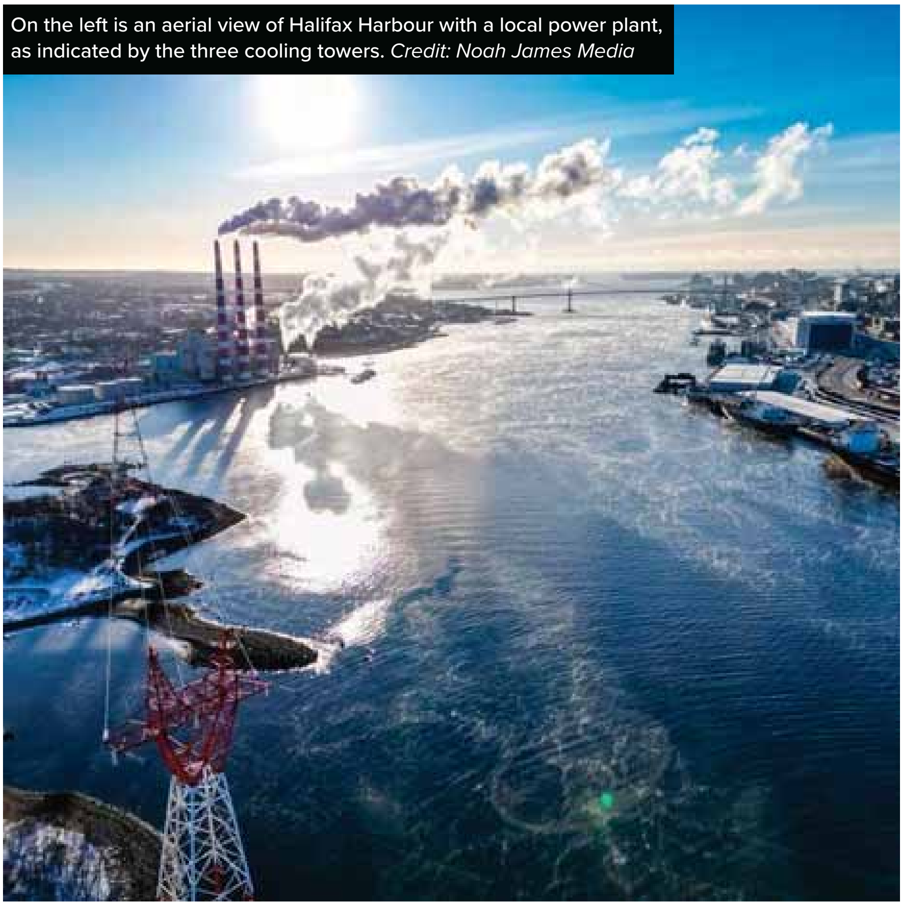
Possible technologies include the capture of CO_2 from air or seawater for storage in geological or other reservoirs, afforestation (noting the caveats mentioned above), enhancement of ocean alkalinity through the addition of alkaline minerals to soils, rivers, or the ocean directly, and fertilization of ocean primary producers by adding iron. The level of technological readiness, knowledge base, risk of undesirable effects, and feasibility of these technologies vary. Currently, none is proven to deliver carbon removal on climate-relevant scales of at least a few Gt of CO_2/yr.

As a scientist who has long been sceptical of deliberate geoengineering, I have come to realize about three years ago that time is up. The window for insisting on emission reductions as the only means of mitigating global warming has closed. In addition to drastic reductions in GHG emissions, research into carbon removal technologies is needed because the excess emissions that have already accumulated in Earth's atmosphere, and those that will continue to do so until we reach net-zero emissions, need to be removed and stored durably and safely.

Among the ocean-based technology ideas, alkalinity enhancement stands out for its large potential to deliver CO_2 removal (estimated at 3-30 Gt CO_2/yr), the durability of this particular carbon storage mechanism in the ocean, the potential environmental benefits from countering ocean acidification, and the fact that it relies on the well-understood, abiotic dissolution of CO_2 in the ocean without the need to manipulate ecosystem processes.

The Ocean Alk-align consortium

I lead an international group of researchers in an ambitious project on ocean alkalinity enhancement termed Ocean Alk-align that is funded by the philanthropic Carbon-to-Sea Initiative. The Ocean Alk-align consortium aims to


On the left is an aerial view of Halifax Harbour with a local power plant, as indicated by the three cooling towers. *Credit: Noah James Media*

determine: 1) the efficiency of alkalinity enhancement in removing and storing atmospheric CO_2, 2) the environmental risks and co-benefits for biological communities, and 3) how carbon removal can be reliably quantified and verified.

In coordination with the climate-tech company Planetary Technologies, the Ocean Alk-align researchers at Dalhousie University are conducting field trials in Halifax Harbour, Nova Scotia, Canada. Our industry partner began dosing alkaline feedstock through the cooling outfall of the local power plant in August of 2023. Our team of university researchers has mounted an intensive measurement campaign to observe changes in the inorganic carbon properties of the affected seawater.

The work is closely coordinated with other research teams, which observe related physical, chemical, and biological properties in seawater and some on the seafloor and potential impacts on biological communities. While our research is carried out in coordination and collaboration with our industry partner, we are independent. We are committed to transparency in our approaches and findings, open data sharing, and making every effort to engage with the public and municipal, provincial, and federal regulators, decision-makers, and stakeholders.

Partnership, regulatory frameworks and emission reductions

Pivotal for moving this research forward have been the close academic-industry partnership with clear ground rules about independence and transparency, and the significant support we have received from our philanthropic funders. Our initial results are encouraging. Despite this early success, investments in research and development and independent research efforts will have to be scaled up significantly over the next decade, if society is to implement carbon removal safely and verifiably.

Forward-looking regulatory frameworks will have to be developed to avoid hindering progress. Public engagement, transparency, and international collaboration will likely prove critical. Despite the can-do ethos that many of my partners, collaborators, and I share, we must remain open to the possibility that carbon removal technologies will ultimately fail to deliver the CO_2 removal targets necessary to meaningfully affect Earth's climate.

Emission reductions must remain the most urgent priority since even a temporary overshoot on allowable emissions, which is already well underway, will likely have irreversible and devastating effects.

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