New electrochemical technology could de-acidify the oceans—and even remove carbon dioxide in the process

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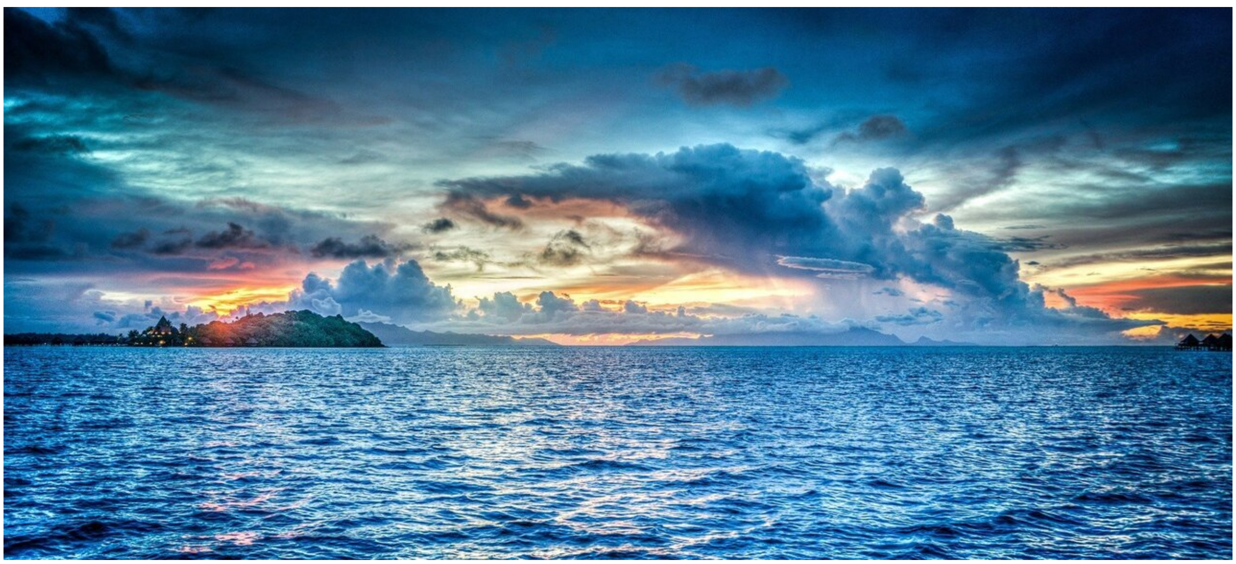

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In the effort to combat the catastrophic impacts of global warming, we must accelerate carbon emissions reduction efforts and rapidly scale strategies to remove carbon dioxide (CO_2) from the atmosphere and the oceans. The technologies for reducing our carbon emissions are mature; those for removing carbon from the environment are not, and need robust support from governments and the private sector.

Only 45 percent of carbon dioxide emissions remain in the atmosphere; the remainder is absorbed through two cycles: 1) the biological carbon cycle stores CO_2 in plant matter and soils, and 2) the aqueous carbon cycle absorbs CO_2 from the atmosphere into the oceans. Each of these cycles accounts for 25 percent and 30 percent of emitted CO_2, respectively.

CO_2 that dissolves in the oceans reacts to form chemicals that increase the acidity of the oceans. The dissolution of minerals from rocks along coastlines act to counterbalance this acidity, in a process called geological weathering, but the extreme increase in the rate and volume of CO_2 emissions, especially over the last 60 years, has far exceeded the rate of geological weathering, leading to a 30 percent increase in ocean acidity.

As the oceans acidify, millions of marine species and whole ecosystems—especially coral reefs—will be unable to adapt.

We are overwhelming the Earth's natural re-balancing systems and harming its ecosystems in the process. Our recent work at McMaster University and the University of Toronto, supported by the Carbon to Sea Initiative, has attempted to address these challenges.

The challenge ahead

The good news is it is possible to re-balance the pH of the oceans using a process called ocean alkalinity enhancement (OAE). What's more, this rebalancing will also encourage additional CO_2 to be absorbed from the atmosphere. By carefully and continually restoring the ocean's alkalinity, ocean acidification and excess atmospheric CO_2 concentrations can be tackled simultaneously.

The most obvious approach would be to add finely ground alkali minerals into the ocean to directly lower the acidity of the water. However, the massive scale at which these processes would have to be enacted is staggering.

For example, we estimate that the equivalent mass of roughly eight thousand Empire State buildings worth of alkaline substance would need to be added into the oceans each year starting by mid-century to meet IPCC emissions targets. Clearly, this technique cannot be the sole solution.

We believe an electrochemical approach operated on decarbonized energy is one of the best ways to combat ocean acidification. Using a process called bipolar membrane electrodialysis (BMED), the acidity of seawater is removed directly without the addition of other substances. This technology only requires seawater, electricity and specialized membranes.

The simplicity and modularity inherent to the BMED technology allows a flexible, scalable and potentially cost-effective method of carbon dioxide removal.

Building at scale

In 2015—with a team of researchers at the Palo Alto Research Center and X Development—we built and tested a small-scale BMED system. This system performed well and shows great promise when coupled with existing facilities such as desalination plants.

We identified its primary technological limitations, but in 2015–2017, carbon credits and incentives for climate change technologies were insufficient and the project was shelved. Now the economic and physical climate has changed.

On the economic front, both the tax credits provided by the Inflation Reduction Act (IRA) in the United States as well as the steadily rising revenue-neutral carbon tax in Canada are strengthening the economic viability of carbon dioxide reduction technologies.

Further, the recent extreme climatic events in the past year from massive wildfires in Canada, to the hottest months on record, to the warmest sea temperatures ever measured, are shocking people into the glaring realities of climate change and increasing the demand for real solutions. BMED technology is one of these solutions.

BMED technology is limited in part by the specialized membranes that are commercially available. What's more, these membranes account for a significant portion (around 30 percent) of the capital cost and have short lifetimes as they are susceptible to degradation.

Our work aims to develop scalable, ultra-thin membranes for use in a modified BMED process, while also identifying efficient operational conditions, optimal industrial couplings, and ideal global locations to cost-effectively implement this OAE technology around the world.

The ultra-thin membranes will extract acidity more efficiently than existing commercial membranes, while their manufacturing technique and optimal usage will dramatically decrease their production and operational costs.

Developing cost-effective BMED systems will open a pathway to economically viable OAE.

Cautious optimism

Recently, several start-ups have been formed—such as Ebb Carbon, SeaO2 and Vesta—that target ocean carbon dioxide removal through

OAE.

We encourage open communication about the progress and challenges facing OAE with the public, research institutions, governments and the private sector to accelerate solutions to OAE's challenges.

In particular, we must assess the impact of re-adjusting seawater alkalinity on marine ecosystems while, at the same time, also developing and implementing trusted systems to measure, report and verify the net amount of acidity and carbon removed.

Alongside this, we must also identify optimal large-scale deployment locations where OAE can be safely and effectively implemented.

These considerations are being researched by various groups, but much more support is needed to rapidly vet and scale this technology.

To overcome the technological challenges and environmental uncertainties, government, industrial, non-profit and venture capital support must be massively scaled and devoted to carefully and responsibly validating the large-scale implementation of OAE technologies around the world.

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