RACHEL CARSON COUNCIL

Fact Sheet

Marine Carbon Dioxide Removal

BACKGROUND

Carbon dioxide plays an important role on our planet. The carbon cycle—the natural and human movement of carbon—ensures that life on Earth continues.[1] However, humans are putting more carbon dioxide into the atmosphere than it can recycle, and the consequences are far-reaching. Right now, carbon dioxide pollution acts as the largest driver of human caused climate change.[2]

One solution to carbon dioxide pollution is supplementing the natural removal of carbon dioxide by carbon sinks (natural systems that store carbon dioxide) with anthropogenic removal; also called 'Carbon Dioxide Removal'.[3] The International Governmental Panel on Climate Change (IPCC) has reported that **carbon dioxide removal is a necessary component to preventing global warming by 1.5 to 2 degrees celsius.**[4] Importantly, the oceans, through various biologic and physical processes, have the potential to absorb a large amount of the excess carbon dioxide in our atmosphere. In fact, **oceans store 20 times as much carbon as land does and a quarter of all anthropogenic CO2 emissions**.[5] As a result, scientists are beginning to view Marine Carbon Dioxide Removal as an important part of mitigating carbon dioxide pollution.

WHAT IS MARINE CARBON DIOXIDE REMOVAL?

Marine Carbon Dioxide Removal (MCDR) encompasses a range of Abiotic to Biotic approaches; in other words, those related to **non-living chemical processes** versus those related to **living organisms and plants**.[6]

Abiotic MCDR harnesses the **physical** or **geochemical** processes that the ocean currently uses to store carbon.

Ocean Alkalinity Enhancement

Naturally, various shells and rocks in the ocean dissolve into minerals in saltwater that help the ocean absorb more CO2. In this manner, the ocean stores trillions of tons of carbon, but very slowly over thousands of years. If scientists can accelerate this process by safely adding reactive minerals into the ocean, or using electrothermal reactors, marine carbon absorption could increase and ocean acidity (as a byproduct) would decrease.

Ocean Thermochemical Approaches

In this approach, seawater is pumped into an electrothermal reactor that alters the chemistry of the water in order to increase carbon dioxide absorption. This altered water is then pumped back out into the ocean.

Direct Ocean Removal (DOR)

DOR pumps ocean water into a facility that directly removes carbon dioxide and then repumps it into the ocean. The extracted carbon is either stored underground or used; in synthetic fuels, the formation of industrial products like plastics, or even to make carbonated beverages.[7] DOR is found to be more efficient and less expensive than its atmospheric counterpart; Direct Air Removal.[8]

Biotic MCDRs leverage the ocean's biological processes, like photosynthesis, to absorb carbon. There are four main methods of biotic marine carbon dioxide removal:

Seaweed Cultivation

Sometimes called 'ocean afforestation', this method involves cultivating seaweed or kelp in large farms in order to increase the ocean's carbon dioxide removal via photosynthesis, and then sinking the biomass into the deep ocean to store the absorbed carbon.

Ocean Iron Fertilization (OIE)

While named after iron, this method can also use nitrogen or phosphorus. Across the global oceans, phytoplankton and other unicellular photosynthesizing organisms absorb carbon dioxide and emit around 40-50% of the world's oxygen.[9] By supplementing the nutrients these organisms use in photosynthesis (such as iron), their populations can increase, along with their rates of photosynthesis. Iron is particularly attractive because only a small amount is needed to yield a large increase in phytoplankton biomass.

Artificial Upwelling

This is a theoretical, but emerging, method where colder, more nutrient-dense, water that has "sunk" is pumped up to create phytoplankton blooms. While OIE artificially adds nutrients, this method redistributes nutrients already available in the ocean through long vertical pipes and/or pumps in order to increase phytoplankton biomass.

Blue Carbon Ecosystems

The final biotic MCDR method is restoring or cultivating coastal vegetated ecosystems. Mangroves, salt marshes and seagrass beds are coastal ecosystems proven to capture and store carbon dioxide. By conserving and cultivating these habitats along coastlines, we can encourage the storage of carbon dioxide and production of oxygen.

WHY ARE MCDRs VALUABLE?

Marine Carbon Dioxide Removal is gaining attention from economists and public health officials alike. As the voluntary carbon market grows, many firms see marine carbon dioxide removal as the future for net zero carbon promises.[10] NOAA projects Marine Carbon Dioxide Removal to become a trillion-dollar market in 2050.[11] Countries in the E.U, China, Singapore, and Canada - as well as many private industries - are moving forward with research and investments into this space.

Public health officials are similarly interested in the potential to remove a greenhouse gas from the atmosphere for improved air quality and climate change hazard mitigation. In addition, implementing these methods in marine ecosystems could be beneficial to the **food security** of both the coastal and terrestrial communities who rely on them.

However, there are still many unknowns associated with Marine Carbon Dioxide Removal.[12] Carbon storage through photosynthesis and the success of various abiotic methods is novel and largely understudied. In order for MCDR to continue scaling into a viable market solution, **additional research is needed**.

ENDNOTES

1. https://education.nationalgeographic.org/resource/carbon-sources-and-sinks/
2. https://oceanacidification.noaa.gov/carbon-dioxide-removal/
3. https://education.nationalgeographic.org/resource/carbon-sources-and-sinks/
4. https://www.ipcc.ch/report/ar6/wg3/downloads/outreach/IPCC_AR6_WGIII_Factsheet_CDR.pdf
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8. https://www.weforum.org/stories/2024/10/direct-ocean-capture-carbon-removal-technology/
9. https://pubmed.ncbi.nlm.nih.gov/24311124/
10. https://www.carbontosea.org/2025/11/26/canada-mcdr-opportunity-report/
11. https://oceanacidification.noaa.gov/carbon-dioxide-removal/
12. https://www.frontiersin.org/journals/climate/articles/10.3389/fclim.2024.1506181/full

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