COMMITTEE ON
SCIENCE, SPACE AND TECHNOLOGY
CHAIRMAN FRANK LUCAS

SUBCOMMITTEE ON ENVIRONMENT
AND
SUBCOMMITTEE ON ENERGY

HEARING CHARTER

"Navigating the Blue Frontier:
Evaluating the Potential of Marine Carbon Dioxide Removal Approaches"

Thursday, September 19, 2024
10:00 a.m.
2318 Rayburn House Office Building

Purpose

The purpose of this hearing is to explore the benefits and risks of marine carbon dioxide removal (mCDR) approaches as they relate to carbon capture and sequestration. In addition, this hearing will inform members on research and development of this technology and address scientific gaps and deficiencies facing researchers and scientists today.

Witnesses

- **Mr. Noah Deich,** Senior Advisor, Office of Fossil Energy and Carbon Management, U.S. Department of Energy
- **Dr. Sarah Kapnick,** Chief Scientist, National Oceanic and Atmospheric Administration, U.S. Department of Commerce
- **Mr. Ben Tarbell**, CEO and Co-Founder, Ebb Carbon
- **Dr. Scott Doney,** Joe D. and Helen J. Kington Professor in Environmental Change, The University of Virginia

Overarching Questions

- Where do mCDR techniques stand in terms of technology readiness levels (TRLs)? Are these techniques ready for large-scale, open-system deployment?
- What resources do scientists and researchers need from the Federal government to advance and scale up mCDR?
- What are the environmental benefits and risks of mCDR to the ocean system, marine life, and coastal communities?

- How should federal agencies, the private sector, and academia collaborate in order to most efficiently further research of mCDR? What are each agency's strengths and weaknesses in this field?

Background

The ocean is the Earth's largest carbon sink, holding 42 times the amount of carbon dioxide (CO_2) that is in the atmosphere and absorbing 25% of human-caused carbon dioxide emissions each year. Global atmospheric carbon reduction efforts have led scientists to try to enhance the ocean's natural sequestration abilities by developing mCDR techniques. Leveraging the ocean can help diversify the range of carbon dioxide removal approaches, reducing the pressure on land-based approaches.[1] Marine CDR can also have non-carbon environmental benefits, such as reducing ocean acidification, replenishing ecosystems, and providing jobs. However, most mCDR techniques have not been tested at scale, and a few are at the earliest stages of research. Dedicated resources, including streamlined permitting, to enable research will help clarify the uncertainties associated with mCDR.

Key Marine Carbon Dioxide Removal Techniques

Ocean Fertilization Methods

Ocean fertilization (OF) enhances phytoplankton production in the ocean to accelerate the natural process that moves carbon from the atmosphere to the deep sea. In this process, specific nutrients are added to the ocean's surface to promote phytoplankton growth that then removes atmospheric carbon dioxide through photosynthesis and converts it into biomass.[2]

Ocean Alkalinity Enhancement Methods

Ocean alkalinity enhancement (OAE) can be achieved in a variety of ways, including depositing fine alkaline minerals into seawater, spreading alkaline sand or gravel on beaches or coastal seabeds, and using specialized fuel cells to facilitate the reaction of sea water with alkaline minerals. Adding alkalinity to the ocean removes carbon dioxide from the atmosphere through a series of reactions that convert dissolved CO_2 into stable bicarbonate and carbonate molecules, which in turn causes the ocean to absorb more CO_2 from the air.[3]

Electrochemical Engineering Methods

Electricity can be used to remove carbon dioxide from seawater through chemical reactions that either release CO_2 from the seawater for capture and sequestration or alter seawater's chemical balances to enable it to store more CO_2 than it naturally would.[4] This combination of carbon sequestration and ocean alkalinization requires large quantities of reactants, seawater, and energy. Further, electrochemical engineering has been demonstrated only at the prototype scale due to the amount of energy required.

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[1] *Demystifying Ocean Carbon Dioxide Removal*, ENVIRONMENTAL AND ENERGY STUDY INSTITUTE (EESI) AND WORLD RESOURCES INSTITUTE (WRI), Congressional Briefing, Apr. 16, 2024.

[2] *Impacts of Ocean Fertilization*, DEEP-OCEAN STEWARDSHIP INITIATIVE (2021), https://www.dosi-project.org/wp-content/uploads/Ocean-Fertilization-Policy-Brief.pdf.

[3] *Ocean Alkalinization Carbon Removal Fact Sheet*, AMERICAN UNIVERSITY (2020), https://www.american.edu/sis/centers/carbon-removal/upload/icrlp_fact_sheet_ocean_alkalinization_2020_update.pdf.

[4] Taqieddin, A., Sarrouf, S., Ehsan, M.F., et al. *Electrochemical ocean iron fertilization and alkalinity enhancement approach toward CO2 sequestration*. NPJ OCEAN SUSTAIN (2024), https://doi.org/10.1038/s44183-024-00064-8.

Artificial Upwelling and Downwelling Methods

Upwelling involves the transport of cold, nutrient-rich seawater from the deep sea to the surface in order to stimulate phytoplankton activity and increase carbon intake.[5] The inverse process is downwelling, pushing surface water to deeper depths in order to increase the dissolved oxygen concentration in bottom waters and mitigate hypoxia. Since the 1950s, researchers have sought to artificially enhance these physical transport processes to geoengineer localized regions of the ocean.

Key Stakeholders Making Progress on Marine Carbon Dioxide Removal

National Oceanic Atmospheric Administration (NOAA)

The National Oceanic Atmospheric Administration (NOAA) is home to the Ocean Acidification Program (OAP), established to better understand impacts of ocean acidification and adaptation.[6] In May 2023, the program, in collaboration with the Pacific Marine Environmental Laboratory, published their paper *Strategy for NOAA Carbon Dioxide Removal Research: A White Paper documenting a potential NOAA CDR Science Strategy as an element of NOAA's Climate Interventions Portfolio*.[7] In September 2023, OAP announced $23.4 million in funding for public and private research in mCDR, with a focus on understanding uncertainties and filling knowledge gaps for different mCDR approaches.[8] These awards support 17 projects with partners from 47 institutions to further enhance efficiency of marine research and provide NOAA with funding and information sharing opportunities to advance mCDR development.

Of note, on June 5, 2024, NOAA signed a memorandum of agreement (MOA) with the Department of Energy, including the Office of Fossil Energy and Carbon Management, the Office of Science, and the Water Power Technologies Office, to further accelerate progress towards large-scale, efficient mCDR research and development.[9] The MOA also defines four primary mutual responsibilities, summarized below:

- Coordinate and collaborate on efforts relevant to multiple mission areas such as research efforts, technical plans, funding opportunities, and technical viability projects.
- Accelerate the development of research and development infrastructure to enable mCDR testing.
- Engage in the development of standard operating procedures for accountable (e.g., utilizing monitoring, measurement, reporting, and verification) and science-based mCDR to inform permitting and regulation, private investment, and carbon credit markets.
- Enter into additional agreements to implement the purposes of this MOA.

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[5] *Artificial Upwelling and Downwelling*, OCEANVISIONS.ORG, https://oceanvisions.org/artificial-downwelling/ (last visited Jul. 23, 2024).

[6] *NOAA Ocean Acidification Program*, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, https://oceanacidification.noaa.gov/ocean-acidification-research/ (last visited Jul. 23, 2024).

[7] Cross, J.N., Sweeney, C., Jewett, E.B., et.al. *Strategy for NOAA Carbon Dioxide Removal Research*, NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (May 2023), https://sciencecouncil.noaa.gov/wp-content/uploads/2023/06/mCDR-glossy-final.pdf.

[8] National Oceanic and Atmospheric Administration, *Announcing $24.3M Investment Advancing Marine Carbon Dioxide Removal Research*, NOAA.GOV (Sep. 7, 2023), https://oceanacidification.noaa.gov/fy23-nopp-mcdr-awards/.

[9] U.S. Department of Energy and National Oceanic and Atmospheric Administration, *Memorandum of Agreement Between Office of Fossil Energy Carbon Management, the Office of Science, the Water Power Technologies Office, and the National Oceanic and Atmospheric Administration*, NOAA.GOV (Jun. 5, 2024), https://www.noaa.gov/sites/default/files/2024-06/EXEC-2024-003330-Final_NOAA-DOE_MOA_05222024_GR_RS_Signed.pdf.

Department of Energy (DOE)

The Department of Energy (DOE) supports mCDR as a key technology development area. It is a central component of DOE's Carbon Negative Shot — calling for innovation in CDR pathways that can capture CO_2 and store it at gigaton scales for less than $100/net metric ton of CO_2-equivalent.[10]

In October 2023, DOE announced $36 million for 11 projects across 8 states, funneled through the Advanced Research Projects Agency-Energy's (ARPA-E) Sensing Exports of Anthropogenic Carbon through Ocean Observation (SEA-CO2) program, to accelerate the development of mCDR technologies.[11,12] The focus of the projects receiving these funds is to advance sensing and modeling techniques that more accurately measure the impacts of mCDR technologies. Supported projects include development of fiber optic sensor cables, micro-electronic seafloor probes, and ocean carbon flux monitoring. If successful, SEA-CO2 measurement, reporting, and verification technology innovations will ensure that the quantity and quality of emission removals are correctly valued.

Office of Science and Technology Policy (OSTP)

The Office of Science and Technology Policy (OSTP) is the federal government leader in interagency research collaboration, including research across the various disciplines associated with oceans. Recognizing the pivotal role the ocean must play in carbon reduction efforts, OSTP's National Science and Technology Council (NSTC) established a new Fast-Track Action Committee (FTAC) on Marine Carbon Dioxide Removal in September 2023.[13,14] The FTAC includes DOE and NOAA, along with other relevant federal agencies, and is focused on developing an implementation plan to advance mCDR and establish sufficient knowledge that can potentially guide research, development, and deployment decisions. The FTAC is set to sunset in November 2024, at which point a final report of the committee's findings and next steps will be published.

Businesses and Nonprofits

Private companies and nonprofits have been working diligently alongside federal agencies to promote and scale up different mCDR approaches. One of the witnesses at the hearing will represent Ebb Carbon which approaches mCDR with electrochemical OAE.[15] They have partnered with DOE's Pacific Northwest National Laboratory (PNNL) and opened their first site in 2023, which is now able to sequester 100 tons of CO_2 per year.

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[10] U.S. Department of Energy, *Carbon Negative Shot*, ENERGY.GOV, https://www.energy.gov/fecm/carbon-negative-shot (last visited Jul. 23, 2024).

[11] U.S. Department of Energy, *DOE Announces $36 Million to Advance Marine Carbon Dioxide Removal Techniques and Slash Harmful Greenhouse Gas Pollution*, ENERGY.GOV (Oct. 26, 2023), https://www.energy.gov/articles/doe-announces-36-million-advance-marine-carbon-dioxide-removal-techniques-and-slash.

[12] U.S. Department of Energy ARPA-E, *Sensing Exports of Anthropogenic Carbon through Ocean Observation (SEA-CO2)*, ENERGY.GOV, https://arpa-e.energy.gov/technologies/programs/sea-co2 (last visited Jul. 23, 2024).

[13] Scott Doney & Jane Lubchenco, *Marine Carbon Dioxide Removal: Potential Ways to Harness the Ocean to Mitigate Climate Change*, WHITE HOUSE OSTP BLOG (Oct. 6, 2023), www.whitehouse.gov/ostp/news-updates/2023/10/06/marine-carbon-dioxide-removal-potential-ways-to-harness-the-ocean-to-mitigate-climate-change/.

[14] U.S. National Science and Technology Council, *Charter of the Marine Carbon Dioxide Removal Fast Track Action Committee of the Subcommittee on Ocean Science and Technology*, NOAA.GOV (Sep. 15, 2023), https://www.noaa.gov/sites/default/files/2023-10/mCDR_FTAC_charter_2023_09_19_approved.pdf.

[15] Ebb Carbon, *Solution: Electrochemical Ocean Alkalinity Enhancement*, EBBCARBON.COM, https://www.ebbcarbon.com/solution (last visited Jul. 23, 2024).

While companies are engineering a variety of mCDR technologies, some nonprofits have focused their mission on looking deeper into the real-world context and viability of these technologies. One of the witnesses at the hearing will represent Carbon to Sea Initiative, a nonprofit that systematically assesses the conditions under which OAE can safely and permanently remove CO_2, as well as market intelligence to advance sector knowledge.[16]

[16] Carbon to Sea Initiative, *How We Work*, CARBONTOSEA.ORG, https://carbontosea.org/#how-we-work (last visited Jul. 23, 2024).