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# Demystifying Ocean Carbon Dioxide Removal

Tuesday, April 16, 2024

# About EESI



## **Non-partisan Educational Resources for Policymakers**

A bipartisan Congressional caucus founded EESI in 1984 to provide non-partisan information on environmental, energy, and climate policies



## **Direct Assistance for Equitable and Inclusive Financing Program**

In addition to a full portfolio of federal policy work, EESI provides direct assistance to utilities to develop “on-bill financing” programs



## **Commitment to Diversity, Equity, Inclusion, and Justice**

We recognize that systemic barriers impede fair environmental, energy, and climate policies and limit the full participation of Black, Indigenous, people of color, and legacy and frontline communities in decision-making



## **Sustainable Solutions**

*Our mission is to advance science-based solutions for climate change, energy, and environmental challenges in order to achieve our vision of a sustainable, resilient, and equitable world.*

# Polycymaker Education

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Live, in-person and online public briefings, archived webcasts, and written summaries

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## Fact Sheets and Issue Briefs



Timely, objective coverage of environmental, clean energy, and climate change topics

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Tuesday, April 16, 2024



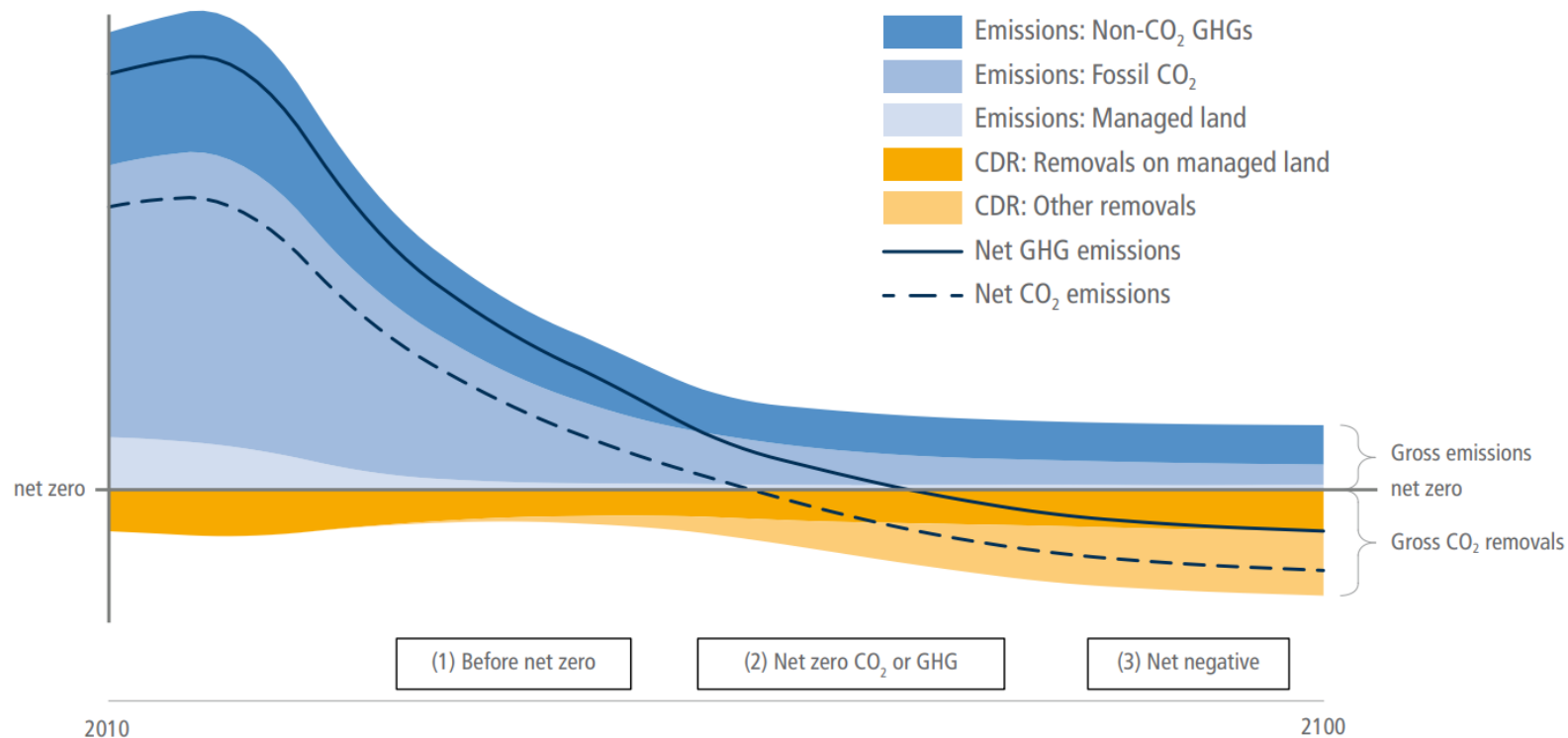
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# OCEAN CARBON DIOXIDE REMOVAL

*Introduction and Landscape*

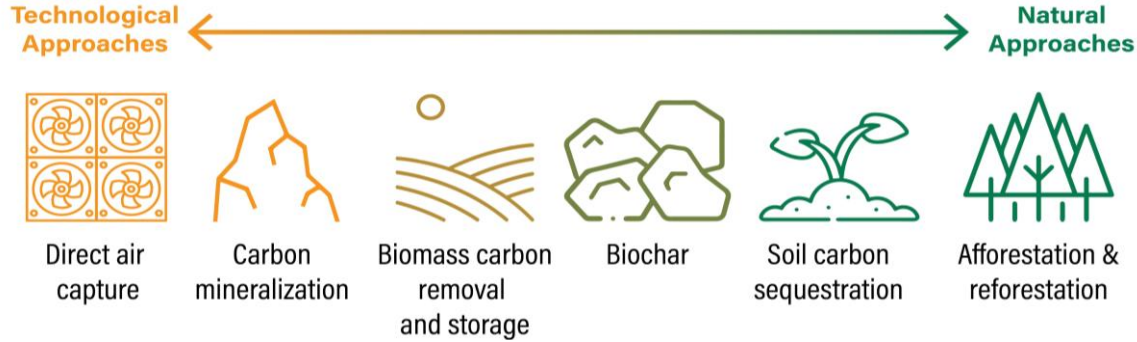
# WHY WE NEED CARBON DIOXIDE REMOVAL

Greenhouse gas emissions (stylised pathway)

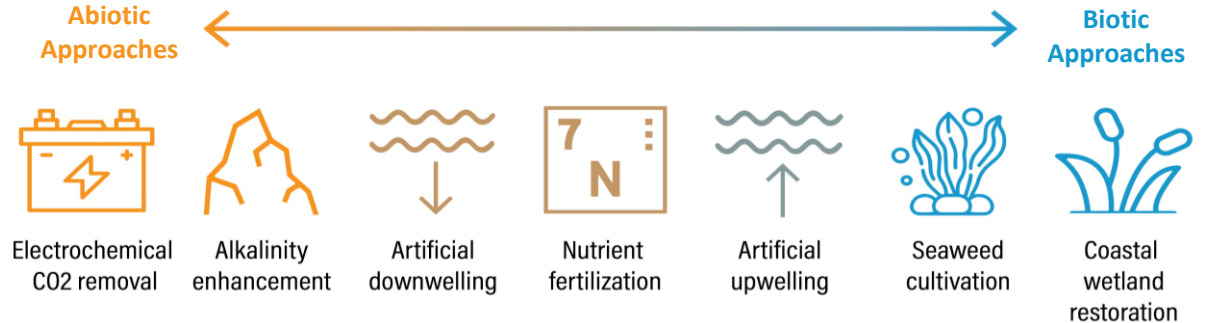


# CARBON REMOVAL INCLUDES MANY THINGS

## Carbon removal approaches on land

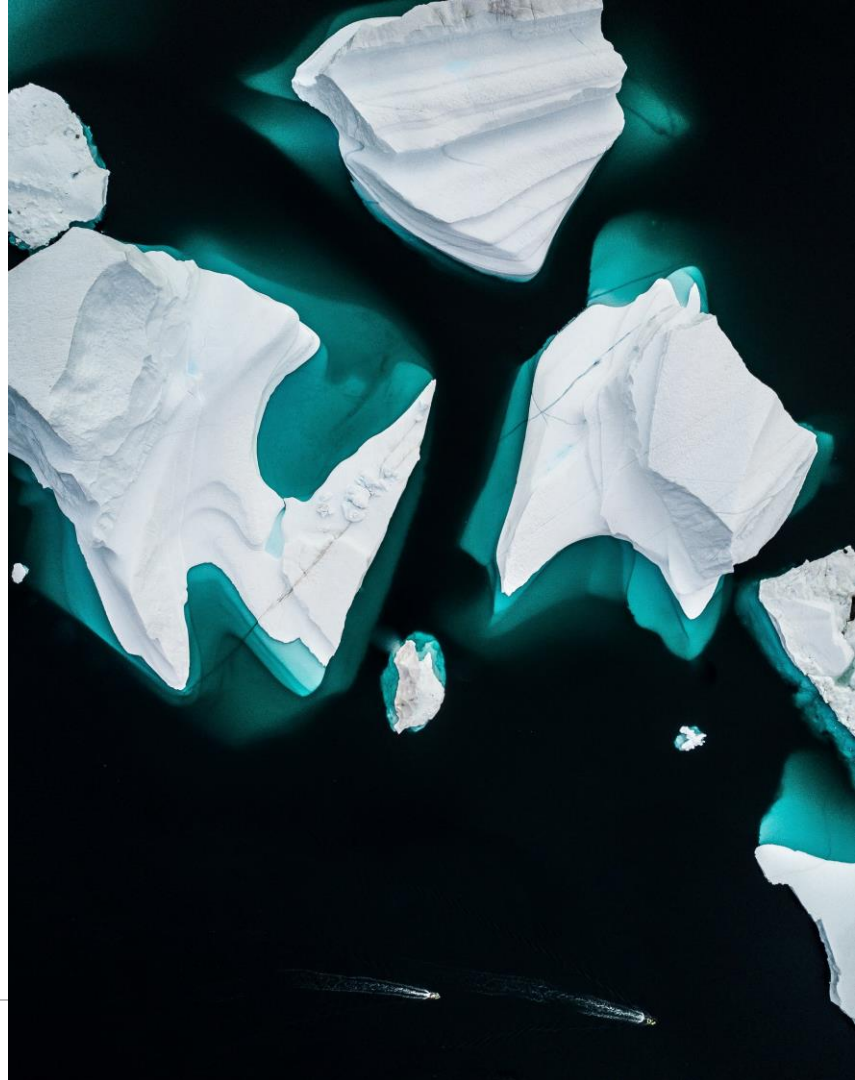


## Carbon removal approaches in the ocean

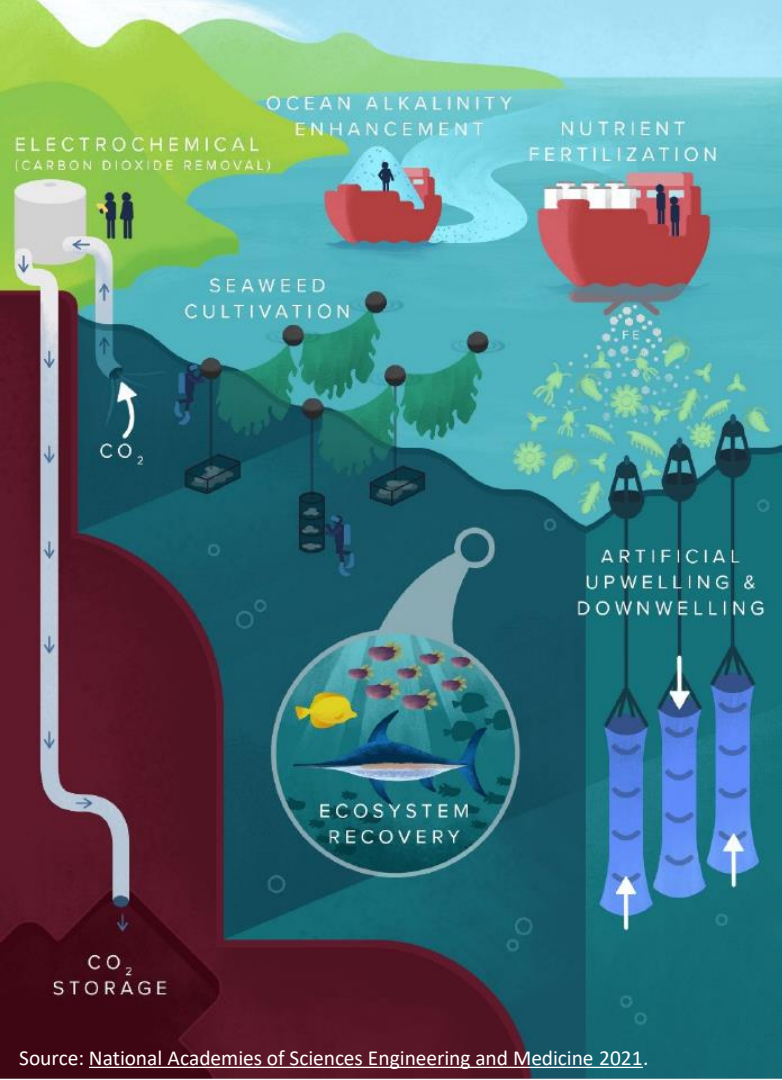


# WHY OCEAN CDR?

- Vast area, 70% of globe
- Significant demonstrated capacity to store carbon
- Can diversify portfolio of carbon removal approaches
- Reduces pressure on land-based resources







# WHAT ARE OCEAN CDR APPROACHES?

- Biotic approaches:
  - Coastal wetland restoration
  - Seaweed cultivation
  - Ocean fertilization
  - Artificial upwelling
- Abiotic approaches:
  - Ocean alkalinity enhancement
  - Electrochemical techniques
  - Artificial downwelling

# SEAWEED CULTIVATION



- **What:** Cultivation of seaweed then purposeful sinking to the deep ocean for sequestration
- **Uncertainties:** Optimal cultivation and harvesting methods, MRV, permanence
- **Development efforts:** Running Tide, Seafields, Seaweed Generation, ARPRA-E MARINER

# OCEAN ALKALINITY ENHANCEMENT



- **What:** Addition of ground alkaline materials to surface waters that react with dissolved CO<sub>2</sub> lock it away
- **Uncertainties:** Environmental impacts in the ocean and from feedstock extraction; MRV
- **Development efforts:** Vesta, Carbon to Sea Initiative, PNNL, PMEL

# COMPLEXITIES OF OCEAN CDR

- Small knowledge base
  - Transboundary nature of the ocean
  - Challenges with measurement, reporting, and verification (MRV)
  - Lack of fit-for-purpose governance framework
  - Importance of public perception and social license
- 





# POTENTIAL OF OCEAN CDR

With more attention and investment, ocean CDR could:

- Potentially provide multi-gigaton scale removal
- Help maintain the U.S. position as a leader in technology development and innovation
- For some approaches, provide other, non-carbon, benefits like reducing ocean acidification
- Provide jobs



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THANK YOU!

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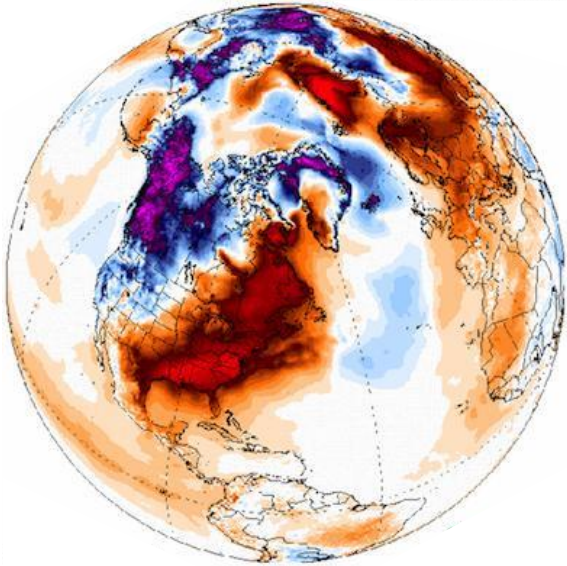


**Equatic**

**EESI Briefing: Demystifying Ocean Carbon  
Dioxide Removal**

April 16, 2024

# Two global challenges: Ending fossil fuel reliance and removing legacy carbon emissions



## Reduction: 90% lower GHG emissions vs. today

- ... at a manageable economic cost
- ... while peak oil or peak coal have not happened yet
- ... and all societies need to use energy to raise living standards

## Removal: All IPCC scenarios require removals

- ... at manageable economic cost
- ... with measurability, irreversibility and additionality
- ... while avoiding negative impact on ecosystems and arable land

Equatic uses the ocean to:

Produce green hydrogen

*and*

Remove carbon dioxide



# Why Equatic uses the ocean

>85% of the world's carbon is in the ocean

We use electrolysis and air contact to accelerate removal

Efficient, permanent carbon storage on a planetary scale

Carbon is currently stored in:



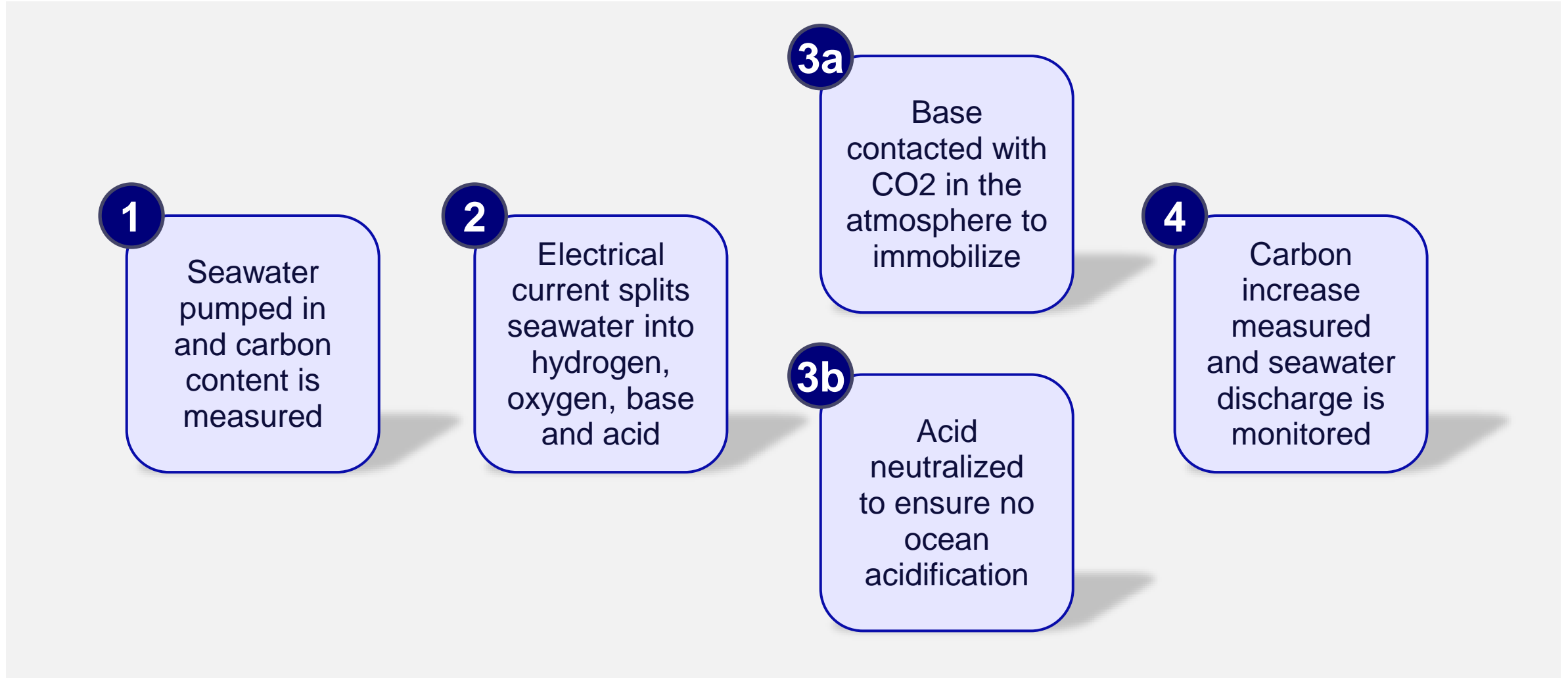
- Equatic's technology captures and stores carbon dioxide in two forms that are prevalent and stable in the ocean:

- **CaCO<sub>3</sub> solids**
- **HCO<sub>3</sub><sup>-</sup> ions** (dissolved)

*~40,000Gt of carbon is stored in the ocean in these two forms today*

- Energy advantaged
- Widely available siting not in competition with arable land
- 10,000-1,000,000,000 year carbon storage
- No CO<sub>2</sub> transportation or CO<sub>2</sub> storage costs
- No risk of leakage

# The process for CDR and green H2 production



# Accelerating a natural process

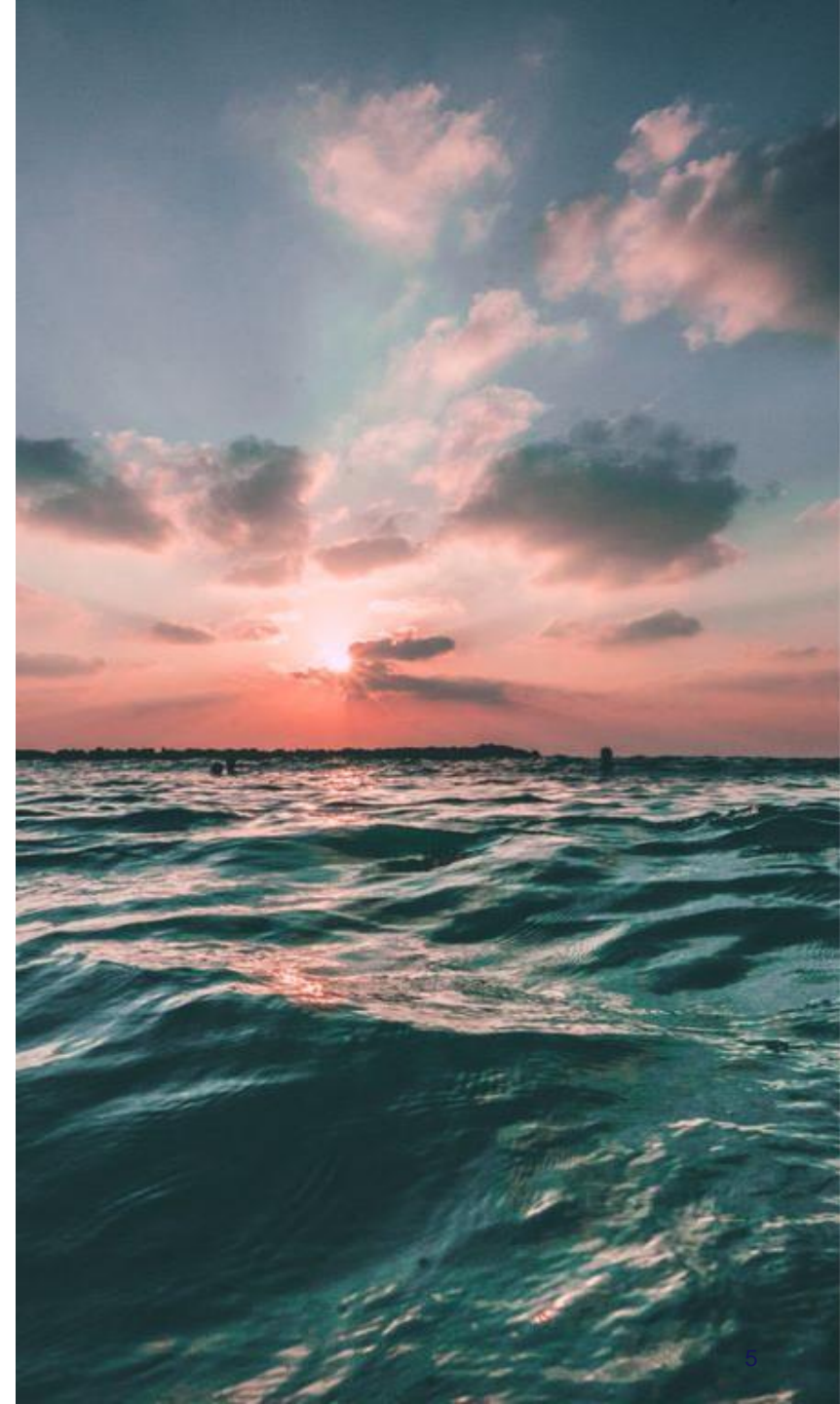
Equatic's approach mimics natural CO<sub>2</sub> storage pathways:

- Ocean (slightly alkaline at pH 8.2) absorbs ~25% of CO<sub>2</sub> emissions
- Rain (slightly acidic at pH 5.5) gets neutralized by dissolving rock on its path to the ocean

What's different is that the Equatic process operates inside of a purpose-build coastal plant, which means that we can:

- Dramatically accelerate the rate of CO<sub>2</sub> removal
- Precisely measure the amount of CO<sub>2</sub> permanently immobilized

Equatic's 30MW plant can remove **1 tonne of CO<sub>2</sub> every 5 minutes**, whereas an equivalent area of open ocean would take 12 months to remove the same amount of CO<sub>2</sub>



# Equatic: What we mean by high-quality CDR

## Measurable

The Equatic process is intentionally designed and engineered to measure CDR within a closed system. This means we have continuous, unambiguous data about operational performance and exact monitoring of CO<sub>2</sub> removed is possible at any point in time.

## Verifiable

Third-party ISO 14064-2:2019 methodology that provides rules for eligibility, means of quantification, monitoring instructions, reporting requirements and verification parameters. This ensures net negative CO<sub>2</sub> and provides an auditable record of the whole process.

## Permanent

Equatic securely stores CO<sub>2</sub> as mineralized (bi)carbonates. Aqueous bicarbonates immobilizes CO<sub>2</sub> for more than 10,000 years, and solid carbonates immobilizes CO<sub>2</sub> for up to billions of years. There is no risk of reversal from these immobilization pathways.

## Additional

Seawater-mediated electrolysis has been developed to remove carbon dioxide from the atmosphere. Plant commissioning and operations depends on the sale of CDR to customers. Every tonne removed is additional.

## Energy Efficient

Flow electrolysis is engineered to ensure rapid reactions. The Equatic process operates at low current densities and Ohmic losses, at high Faradaic efficiencies, and produces green hydrogen. Taken together this means the energy footprint per tonne of CDR is best-in-class.

## Credible

The carbon market is growing rapidly. As in any new industry, transparency and credibility are necessary to build trust with buyers, governments and communities. Put plainly, Equatic uses data and not speculative estimates to generate carbon credits.

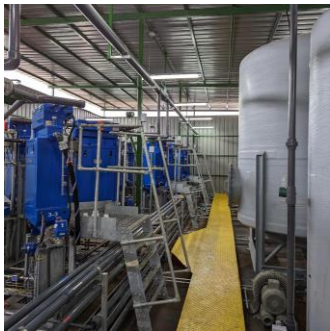
# CDR project deployment

## Pilot

2023



**Pilot #1  
Los Angeles  
March 2023**



**Pilot #2  
Singapore  
April 2023**

100 kg CDR per day  
3 kg of hydrogen per day

## Demonstration

2024-2025



**“Equatic-1” Singapore**

10 tonnes of CDR per day  
300 kg of hydrogen per day

## Commercial

2026+



**Future Equatic plant**

300 tonnes of CDR per day  
9 tonnes of hydrogen per day

# Policy and Regulation

- Community
- Permitting
- Employment
- Demand signals

# Marine Carbon Dioxide Removal (mCDR)

# Today's remarks

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- Context: mCDR research needs
- Responsible development and scaling of U.S. mCDR research
- Research governance
- Monitoring, Reporting, & Verification (MRV) Complexities
- Need for a clear regulatory regime



# Context: mCDR Research Needs

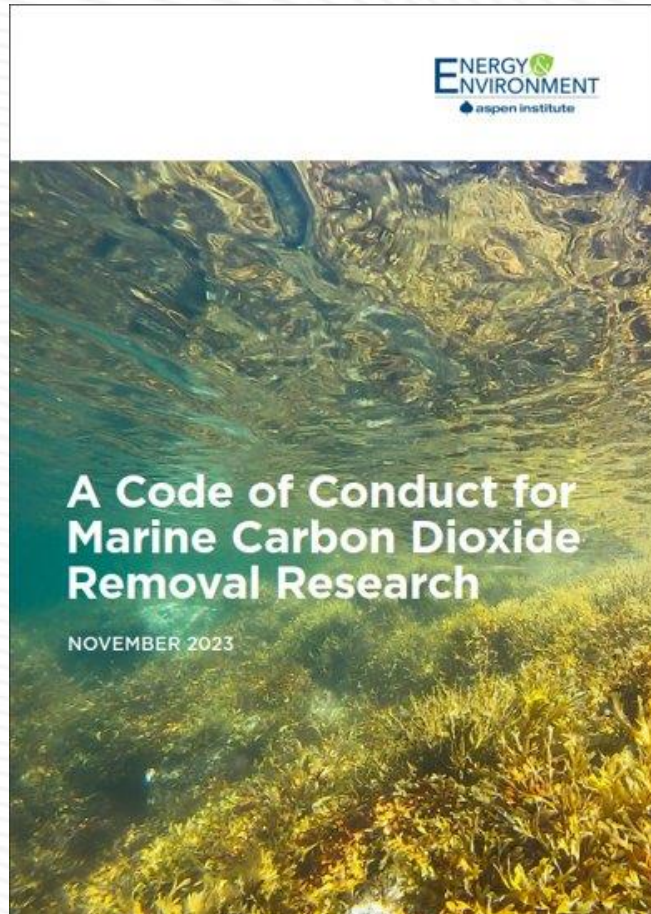
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***mCDR research needs to produce multidisciplinary, decision-supporting information!***

- Research must inform decision-making challenges facing us:
  - Who makes what decisions?
  - What information is relevant?
  - When should activities be scaled up or closed out?
  - Who's responsible for problems?
  - Who benefits and how? Is anything harmed?
  - How do mCDR activities fit in among other marine uses?
  - How does mCDR interact with the global mitigation portfolio? Any limits?

# Responsible development & scaling of U.S. mCDR research

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- CoCs used in many fields to encourage responsible research
- Create common norms and shared principles, e.g., regarding transparency, public review, and benefits sharing
- Especially useful for complex issues with potential to affect people and the environment

# 3 phases of responsible research described in mCDR CoC

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## Planning

- Whether, when, where, and how to conduct research?
- Project design, possible impacts, identification of stakeholder, siting, permitting

## Executing

- Monitoring positive and negative project impacts, accountability, liability, reporting, transparency, oversight, decisions about scaling up/scaling back

## Concluding

- Moving to next level of development?
- Communication of results, remediation of adverse outcomes, fair distribution of benefits, decommissioning.

# Research governance

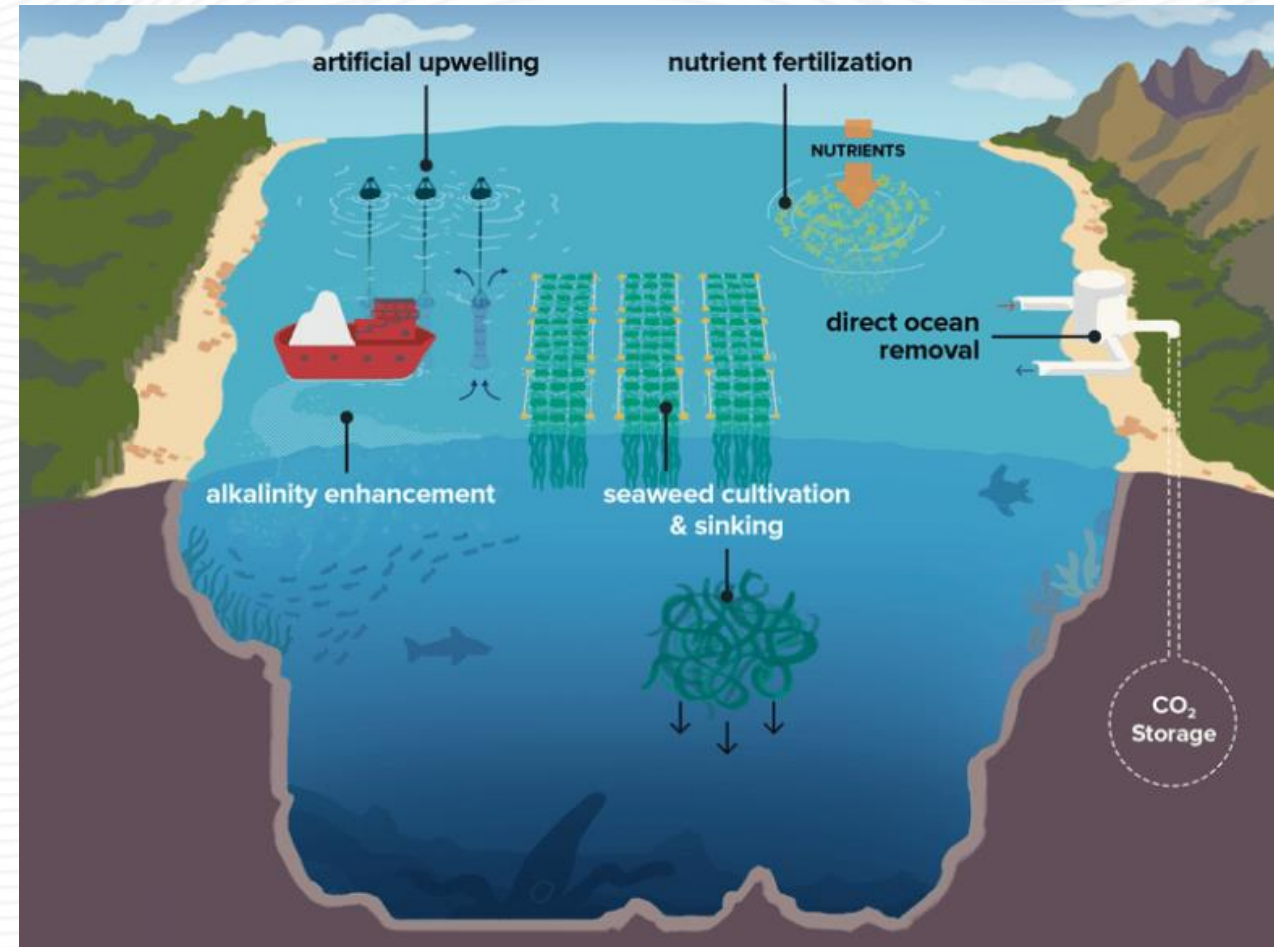
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*Funders have a key role! They can:*

- Require documented use of research CoC
- Require adherence to permits and protocols
- Require and support data sharing & reasonable IP rights
- Tie future funding to past performance on above issues
- Help coordinate research community and develop joint activities and resources

# MRV complexities

- MRV is central to counting mCDR's contributions to GHG mitigation.
- MRV is more straightforward for some mCDR methods than others.
- There is no mCDR MRV protocol now; developing one will depend on modeling and observational investments.



# Need for a clear regulatory regime

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- Research governance and permitting are evolving quickly
- Guidance is needed about what constitutes experiments vs. implementation and rogue/unregulated behavior
- Guidance is needed about who holds authority/has final say
- Who is liable for experiments? For deployment?

Thank you!

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# Marine Carbon Dioxide Removal

## NOAA Research efforts and future directions

Gabby Kitch, PhD

Marine Carbon Dioxide Removal Lead  
NOAA Ocean Acidification Program



NOAA OCEAN ACIDIFICATION PROGRAM







APRIL 20, 2023

## FACT SHEET: President Biden to Catalyze Global Climate Action through the Major Economies Forum on Energy and Climate

Executive Order 14008 of January 27, 2021

**Tackling the Climate Crisis at Home and Abroad**



EXECUTIVE OFFICE OF THE PRESIDENT  
WASHINGTON, D.C. 20503



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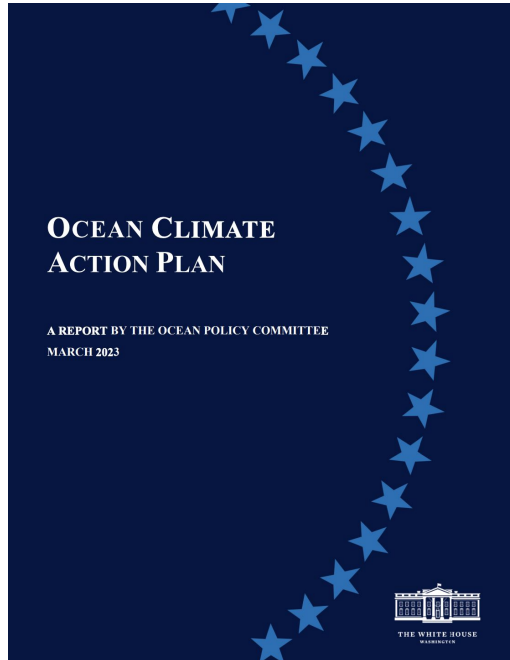
MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

FROM: SHALANDA D. YOUNG *Shalanda D. Young*  
ACTING DIRECTOR  
OFFICE OF MANAGEMENT AND BUDGET

DR. ERIC S. LANDER *Eric S. Lander*  
DIRECTOR  
OFFICE OF SCIENCE AND TECHNOLOGY POLICY

SUBJECT: Multi-Agency Research and Development Priorities for the FY 2023 Budget

# The USG mCDR Fast Track Action Committee



**The goal:**  
The FTAC will develop a research plan on mCDR

**NOAA's role:**  
NOAA is co-chairing the FTAC with the White House Office of Science Technology and Policy



**FTAC FRN**



# What is NOAA's Role?

NOAA potential mCDR assets are across the agency and are described in:



## Overview of Current NOAA Assets

### Observing Networks

Global and local ocean and atmospheric observing; tech development

### Modeling, Scaling, and Projection of CDR Pathways

Earth system and process study models

### Environmental Impacts

Ecosystem system monitoring, ecosystem modeling, laboratory research

### Decision Support

Data management, marine spatial planning, aquaculture research, collaborative and conservation research

**Investing in research and infrastructure, however current resources and infrastructure are not sufficient for scaling mCDR approaches**

# NOAA's mCDR research portfolio

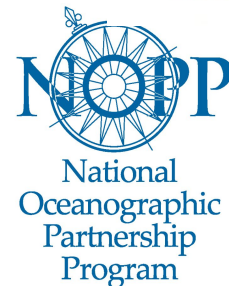
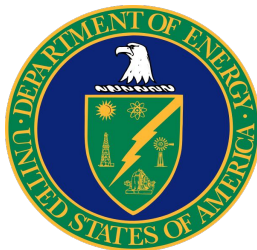
## Leveraging National Oceanographic Partnership Program (NOPP)

### FY2023 portfolio: 17 mCDR projects (\$24.3M)

- Includes \$14M in Inflation Reduction Act Funding
- 47 Institutions and 79 Principal Investigators

### FY2022 portfolio: EASE OA (\$1.05M)

- Electrochemical Acid Sequestration to Ease Ocean Acidification
- Partnership between PNNL, University of Washington, PMEL, and Ebb Carbon



<https://oceanacidification.noaa.gov/project-search>

<https://oceanacidification.noaa.gov/fy23-nopp-mcdr-awards/>

mCDR Pls

UC San Diego



Oregon State University



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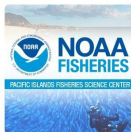
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# What is next?

- NOAA is directly involved in the FTAC (co-chair and member)
- NOAA formalizing relationships with multiple agencies on mCDR
- NOAA views their role in Earth System Observing as critical to determine if CDR is a valid and responsible climate solution
  - NOAA is currently drafting an implementation plan to discuss concrete actions to engage in the mCDR space
  - NOAA implementation plan will be closely related to the NOAA Research Strategy