Energy & Environmental Research Center (EERC)

HYDROLYTIC SOFTENING FOR OCEAN CARBON DIOXIDE REMOVAL

DE-FE0032418

2024 FECM/NETL Carbon Management Research Project Review Meeting

August 5–9, 2024

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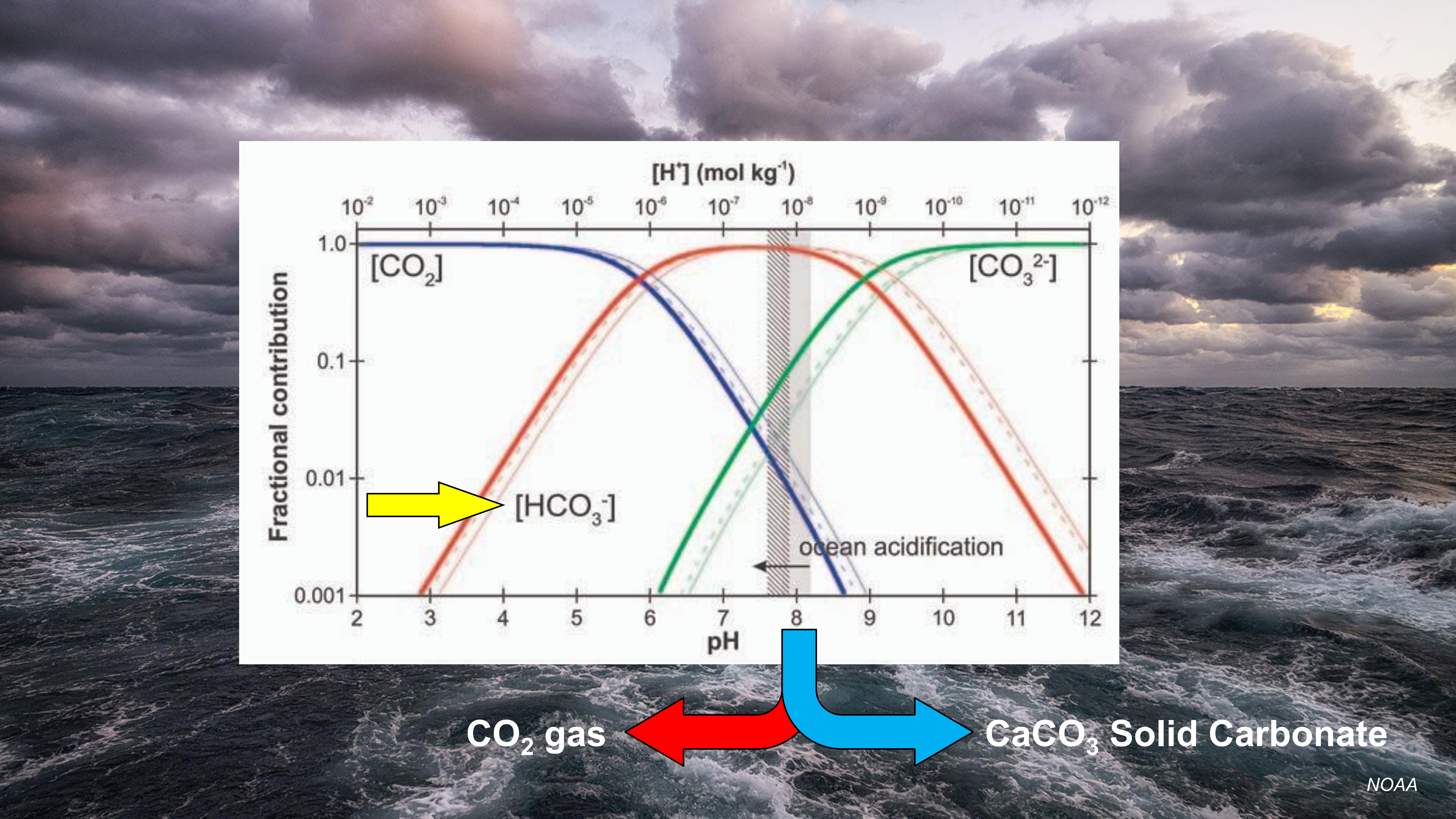
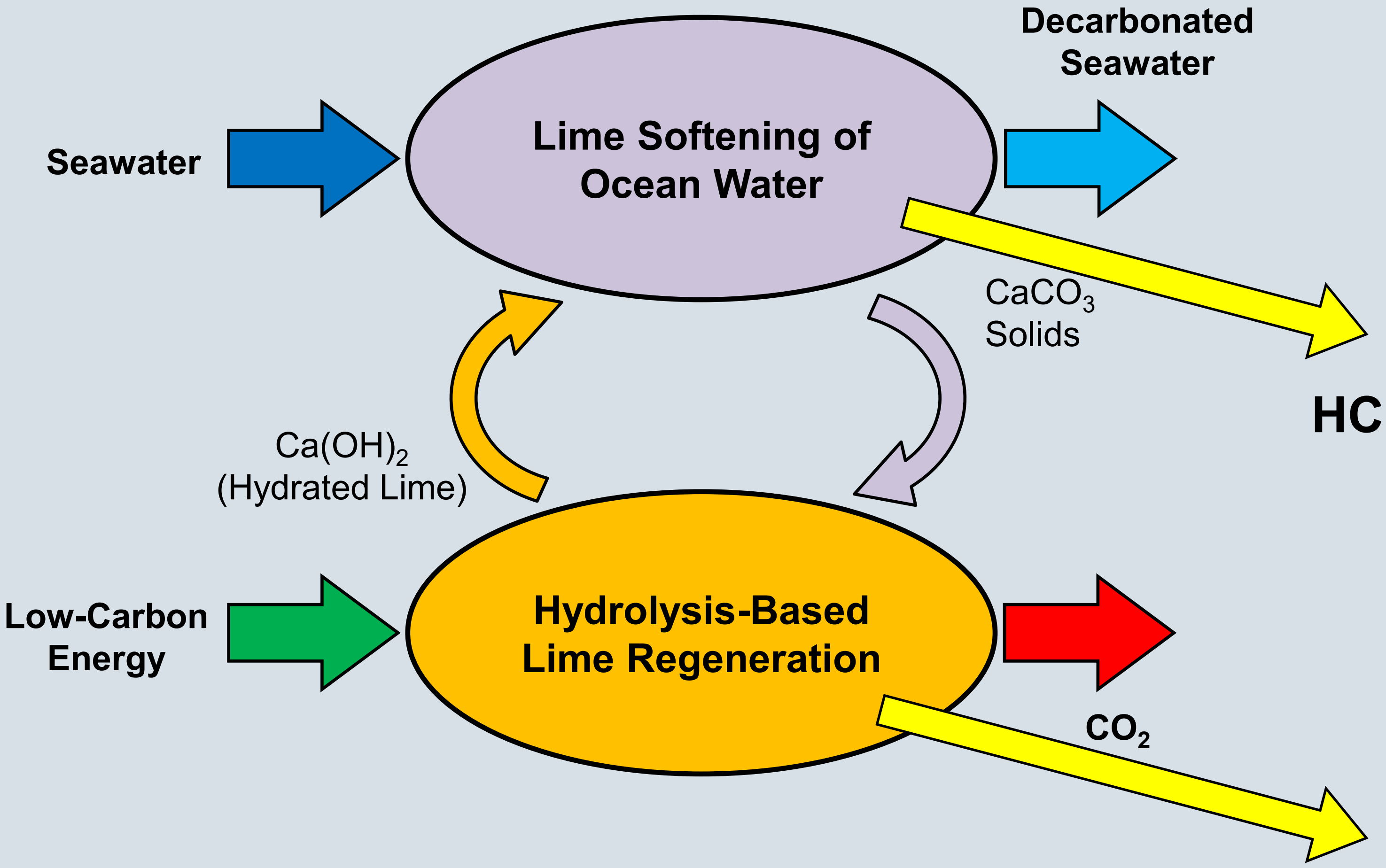
DE-FE0032418 PROJECT OVERVIEW

- **Funding Opportunity:** DE-FOA-0002614, Modification 000006
- **Area of Interest:** 2F, Field Validation of Abiotic Ocean-Based Carbon Removal
- **Team:** EERC and CarbonBlue
- **DOE Program Manager:** Zachary Roberts
- **Phase 1 Duration:** 12/20/23–12/19/24
- **Administrative Review:** 12/20/24–09/19/25
- **DOE Funding:** $188,748
- **Cost Share:** $47,187
- **Overall Goal:** Plan a field test to validate hydrolytic softening as a near-term, scalable, and cost-effective method to draw down atmospheric CO_2 by removing CO_2 absorbed into the oceans.


[H+] (mol kg-1)
10-2
10-3
10-4
10-5
10-6
10-7
10-8
10-9
10-10
10-11
10-12
Fractional contribution
1.0
0.1
0.01
0.001
[CO2]
[CO32-]
[HCO3-]
ocean acidification
2
3
4
5
6
7
8
9
10
11
12
pH
CO2 gas
CaCO3 Solid Carbonate
NOAA

HYDROLYTIC SOFTENING

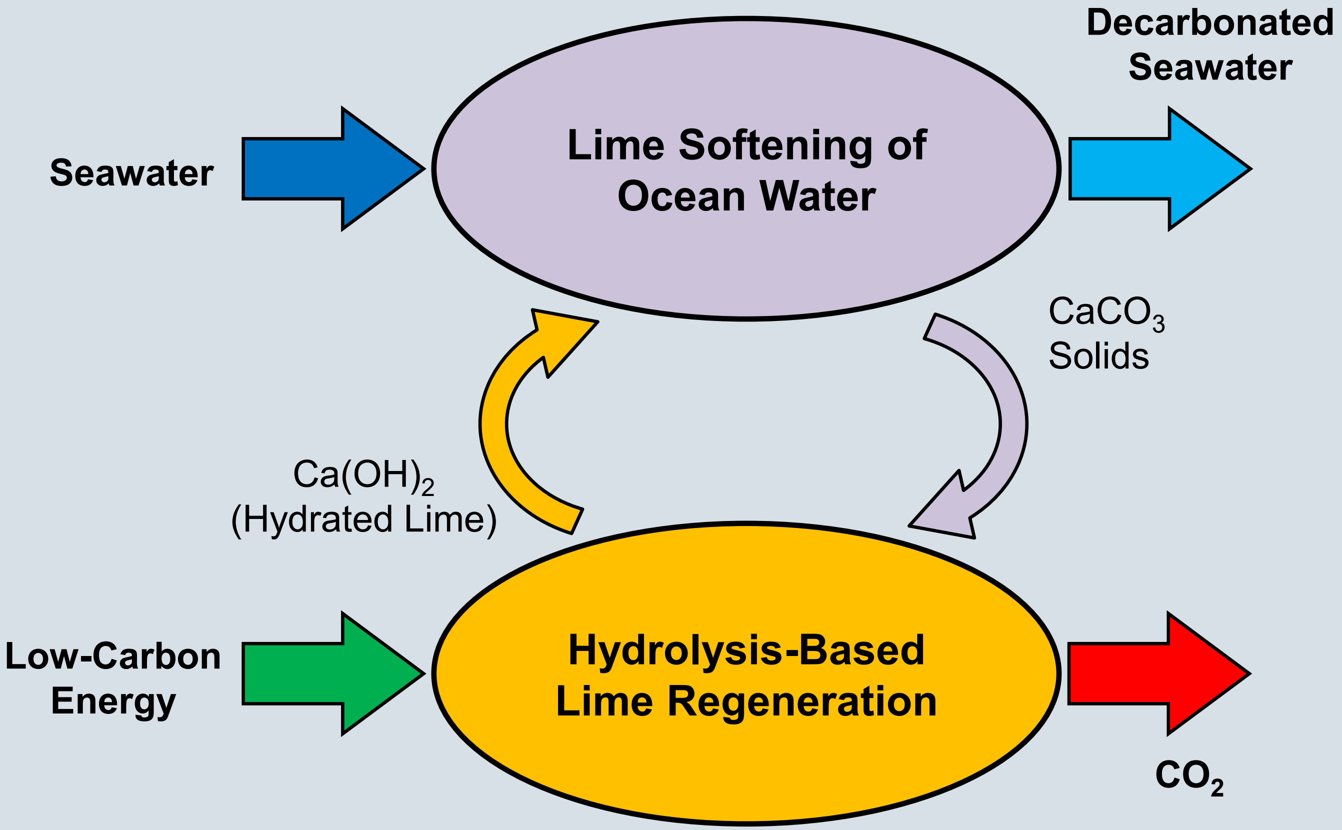


Net Governing Reactions

$$HCO_3^- \text{ (aq)} + Ca(OH)_2 \rightarrow CaCO_3 \text{ (s)} + H_2O$$

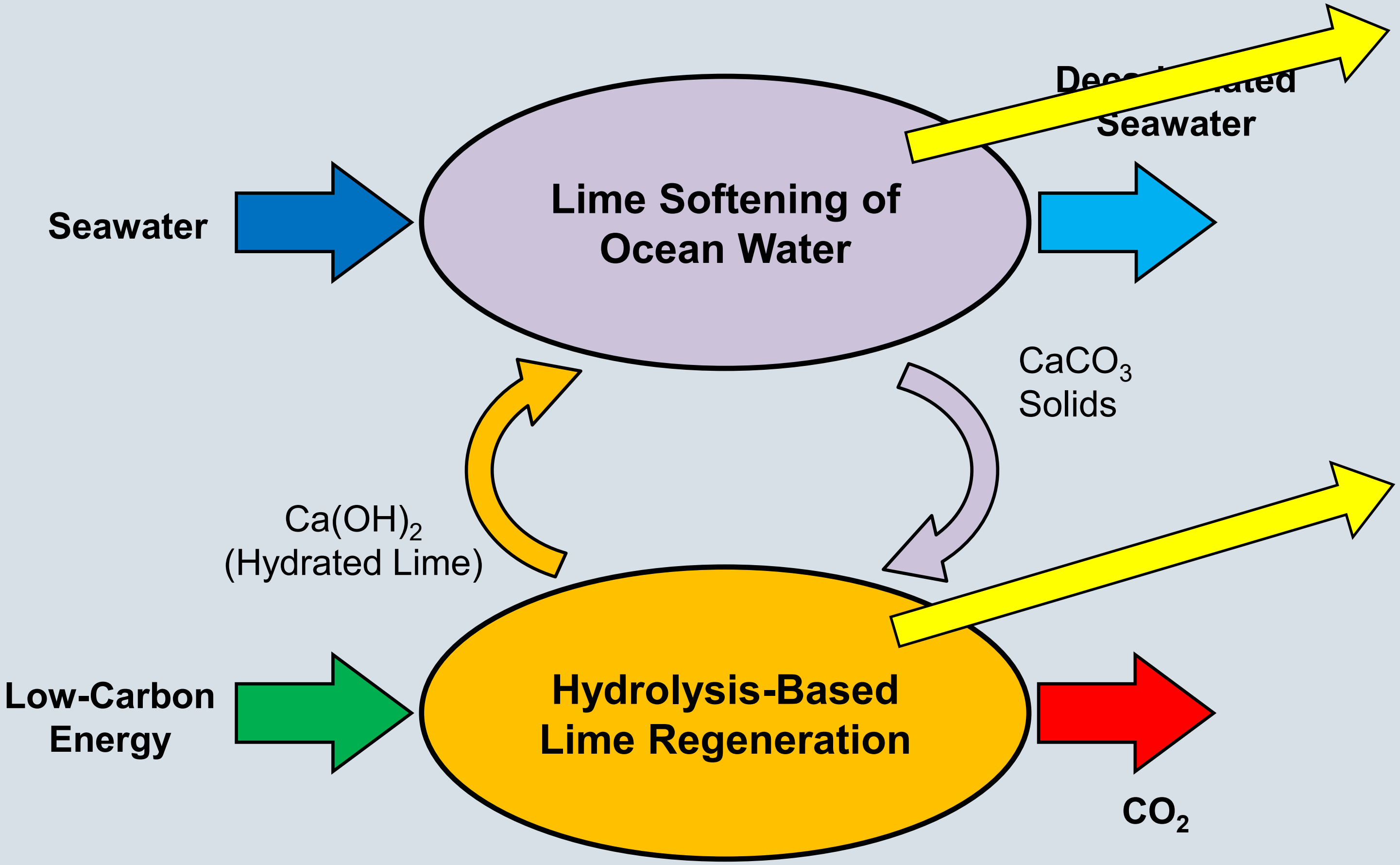
$$CaCO_3 + H_2O \rightarrow Ca(OH)_2 + CO_2$$

FEATURES



- **Proven capture approach.** Lime softening is a common pretreatment technique with a long history.
- **Minimal impact.** Targeted CO_2 removal, all other species returned to the ocean.
- **Adaptable.** Applicable to a wide range of water compositions from changes caused by tides, precipitation, etc.

KEY CHALLENGES AND MITIGATIONS



CAPEX i.e., large and potentially costly precipitation reactor.

- Develop cost-effective designs that match the relatively benign process conditions and simple function.
- Leverage the economy of scale for thermochemical equipment.

OPEX i.e., regeneration energy cost.

- Optimize hydrolysis regeneration.
  - Yields $Ca(OH)_2$ directly to avoid exergy loss with calcination and lime slaking.
  - Can use multiple forms of energy including electricity, and low- and high-grade heat.
- Decouple the energy intensive step to match available resources.

PROJECT SCOPE

Phase 1 Objectives: Develop the technical plans and assemble a multidisciplinary team to evaluate hydrolytic softening's techno-economic performance, environmental impact, and societal impacts under a potential Phase 2 field validation test.

Task Structure

- Task 1 – Project Management and Reporting
- Task 2 – Community Benefits Plan
- Task 3 – Conceptual Design
- Task 4 – Field Validation Preparation

Success Criteria Evaluations

- Levelized cost target
- Life cycle target
- Transferable jobs
- Environmental impact
- Commercial interest

MILESTONES

Milestone	Description	Target Completion
M1	Updated Project Management Plan submitted	January 19, 2024
M2	Initial Technology Maturation Plan (TMP) submitted	March 19, 2024
M3	Updated J40 Plan Development Proposal (PDP) and Engagement PDP submitted	March 19, 2024
M4	Field Validation Test Scenario for the Regulatory and Permitting Analysis Identified	June 19, 2024
M5	Social Characterization Analysis Completed	June 19, 2024
M6	Refined Heat and Mass Balance for the Validation System Completed	August 19, 2024
M7	Energy and Environmental Justice Assessment Completed	August 19, 2024
M8	Organizations comprising the cross-cutting validation team identified	September 19, 2024
M9	Identification of job and skill categories needed as compared to current scenario jobs and skill categories	November 19, 2024
M10	Content summarizing the project and positive impacts this project would have on the environment and disadvantaged communities developed and distributed	November 19, 2024
M11	SPDT, Preliminary TEA, Preliminary LCA, TGA, Final TMP, and Technology EH&S Risk Assessment submitted	December 19, 2024
M12	Conceptual Design Package submitted	December 19, 2024
M13	R&D Community Benefits Plan submitted	December 19, 2024

Project kickoff preliminaries (M1–M3)

Identify field test scenario (M4–M5)

Today

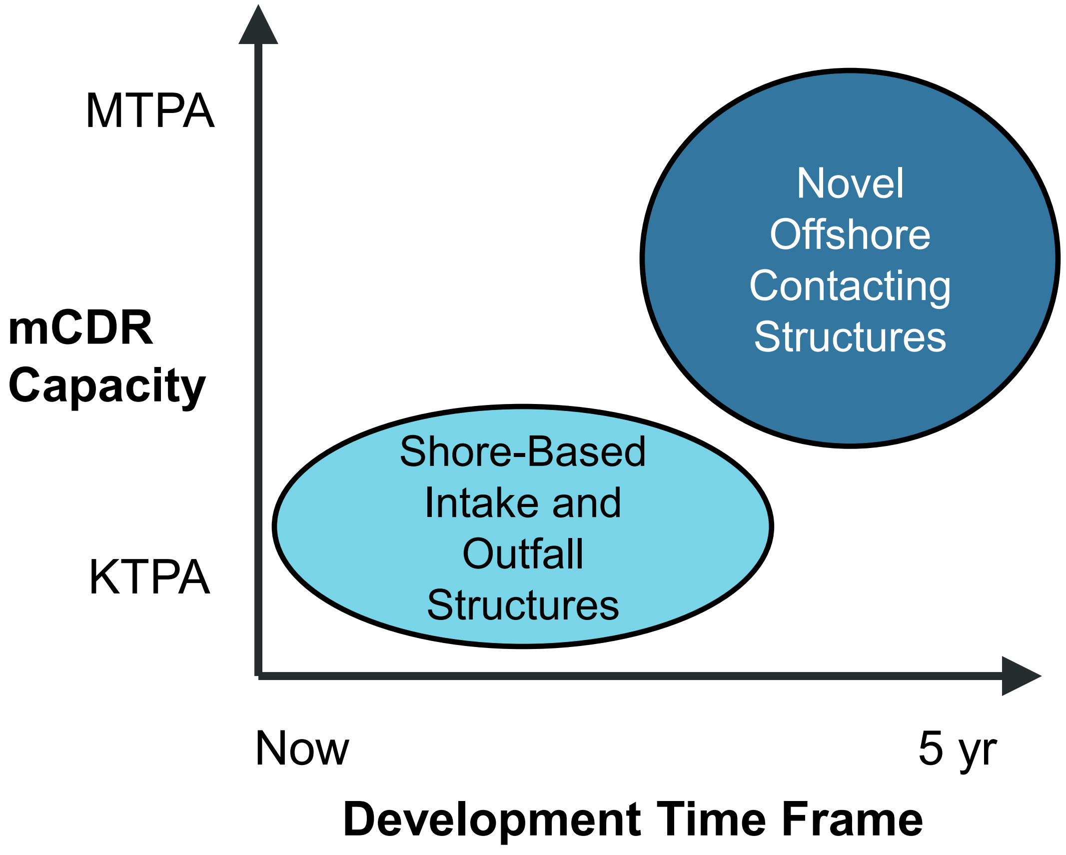
Choose validation team and update design calculations (M6–M8)

Application package deliverables (M9–M13)

FIELD TEST SCENARIO

- Field test planning assumes an onshore validation system located at an industrial port.
- Such systems could ultimately attain KTPA-scale marine carbon dioxide removal (mCDR). For context:
  - Desalination plant (50 mgpd water production) → ~10 KTPA potential.
  - Seawater-cooled nuclear power plant (1 GWe) → ~130 KTPA potential.
- However, approaching MTPA-scale CDR will likely require novel, offshore seawater infrastructure.

Qualitative Comparison of Hydrolytic Softening Deployment Schemes



TPA: metric tons per annum of CO_2 removal.

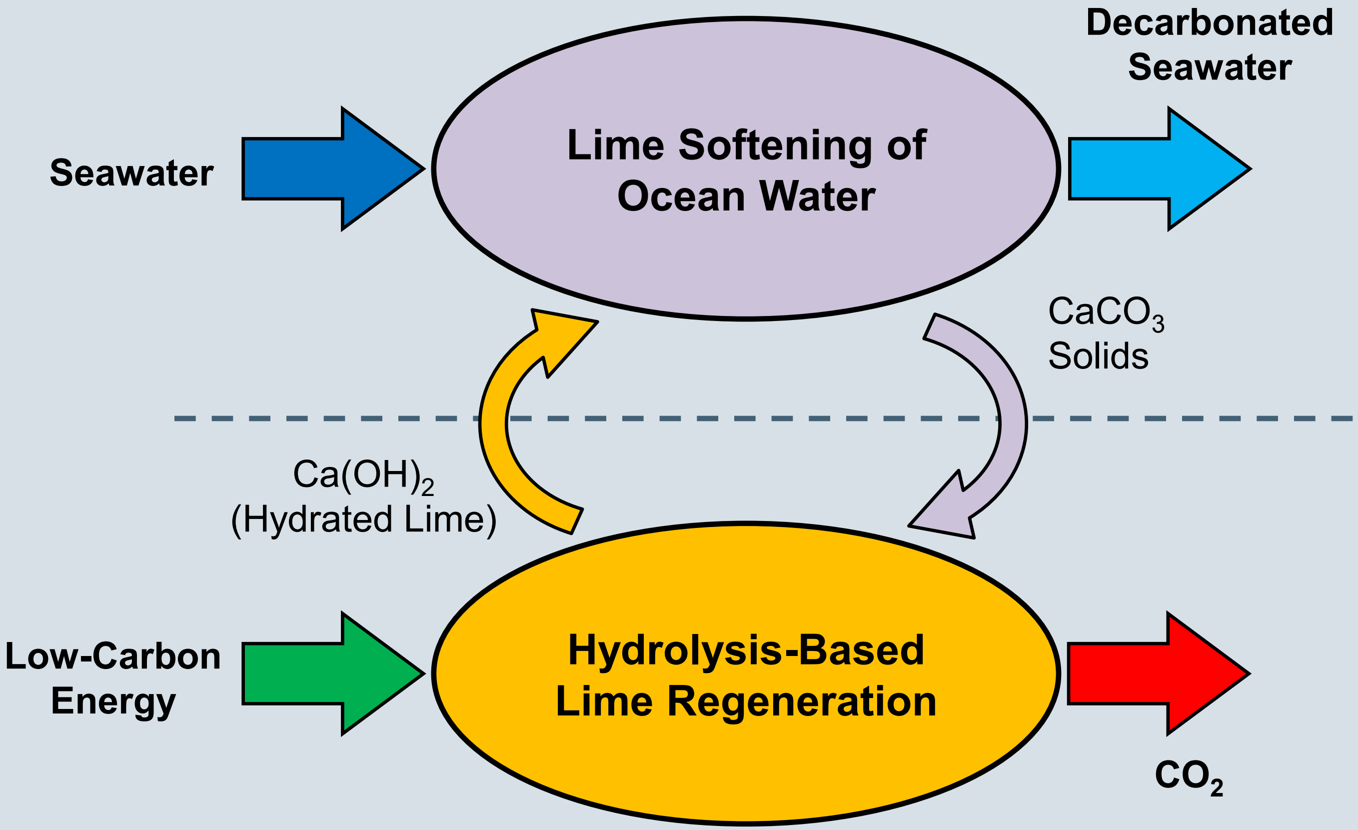
LESSONS LEARNED

- Repurposing offshore platforms for large-scale ocean contacting could be an attractive use of infrastructure that would otherwise be difficult to recreate.
- Potential offshore pitfalls:
  - **Permitting.** Repurposing raises end-of-life liability concerns that could slow development.
  - **Low-carbon power.** Infrastructure is generally not in place today to power mCDR; decoupled operation might be advantageous in the absence of offshore renewable power development.

Gulf Offshore Research Institute.

Active GOM platforms; BSEE.gov.

DECOUPLED POTENTIAL



Needed Resources

High-Volume Seawater Access

Energy and CO_2 Offtake

Stable intermediaries allow regeneration to occur at a different time and/or place than capture to maximize available resources.

COMMUNITY BENEFITS PLANNING

6/19/2024

Social Characterization Analysis complete.

8/19/2024

Energy and Environmental Justice Assessment completed.

11/19/2024

- Information on the project's beneficial potential disseminated.
- Potential for maintaining and growing an offshore workforce evaluated.

12/19/2024

R&D Community Benefits Plan submitted.

SUMMARY

- Hydrolytic softening is based on a proven, scalable technique to separate CO_2 from seawater.
- The individual process steps can be performed at different times and/or places to optimize the available resources of:
  - Ocean access.
  - Low-carbon power.
  - CO_2 offtake.
- By project completion, the team will have the conceptual system design, subject matter collaborators, and preliminary analyses in place to pursue a future field validation.

CarbonBlue technology test bed for CO_2 mineralization.

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APPENDIX

PROJECT ORGANIZATION

Project Partners & Advisors
Department of Energy
Carbon Blue

Organization
EERC

Principal Investigator
Christopher L. Martin

Task 1
Project Management and Planning

Lead
Christopher L. Martin

Task 2
R&D Community Benefits Plan (CBP)

Lead
Charlene R. Crocker

Task 3
Conceptual Design of Hydrolytic Softening Process for Ocean CDR

Lead
Mark A. Musich

Task 4
Field Validation Preparation

Lead
Christopher L. Martin

PROJECT SCHEDULE