Life Cycle Analysis and Techno Economic Analysis of Marine Carbon Dioxide Removal

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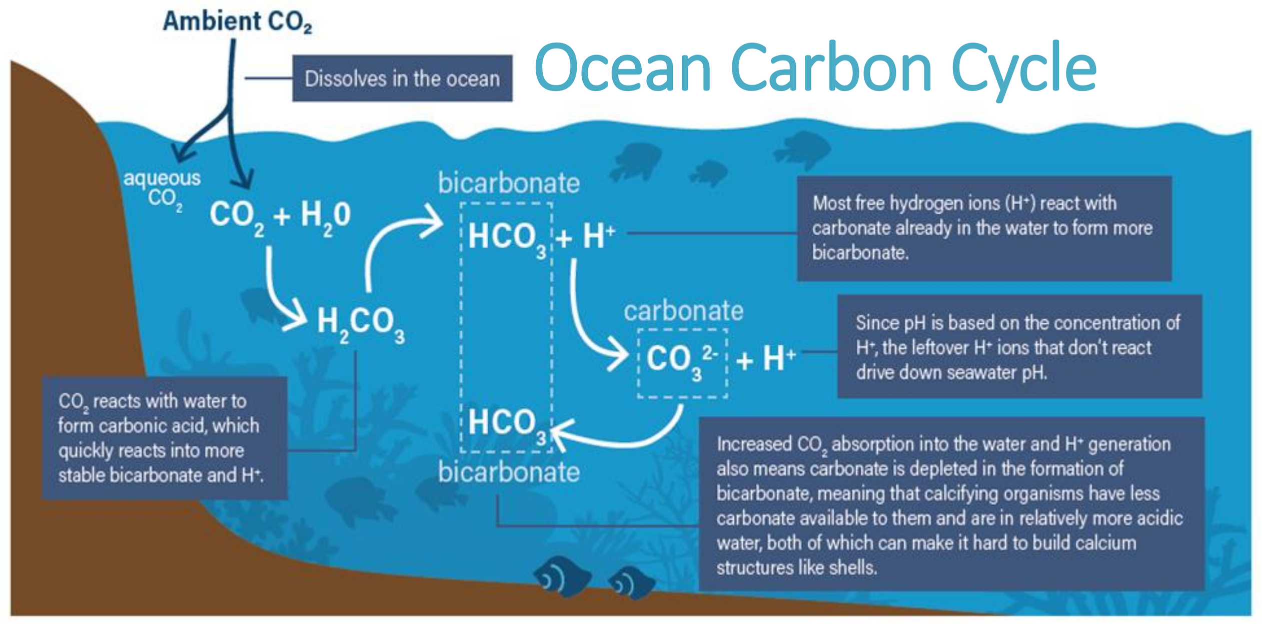
Introduction

- Marine Carbon Dioxide Removal (mCDR) is defined as the indirect removal of CO_2 from the atmosphere “via an enhancement of the downward air-sea flux of CO_2 from the atmosphere to the surface ocean” [1].
- The surface of the ocean is in a constant exchange of CO_2 with the atmosphere and represents the largest exchange of CO_2 with the atmosphere compared to any other reservoir. The ocean carbon cycle can be seen below.



Used with permission from World Resources Institute [2]

TEA Methods

- Cost and performance estimates for three electrochemical mCDR technologies are presented. The reported costs are in May 2023 dollars.

Case	Technology	mCDR Approach	Membrane Process	pH Shift	Capture Rate	CO_2 Product
MEB1[A]	mCDR	Electrochemical Engineering	Bipolar Membrane Electrodialysis (BPMED)	Acidic	63%	CO_2 (g)
MEB2				Basic	63%	
MEC1			Electrolytic Cation Exchange Membrane (CEM)	Acidic	62%	

[A]M for mCDR, E for electrochemical engineering approach, B for bipolar membrane electrodialysis [BPMED] and C for electrolytic cation exchange membrane [CEM]), and pH shift (1 for acidic, 2 for basic), respectively.

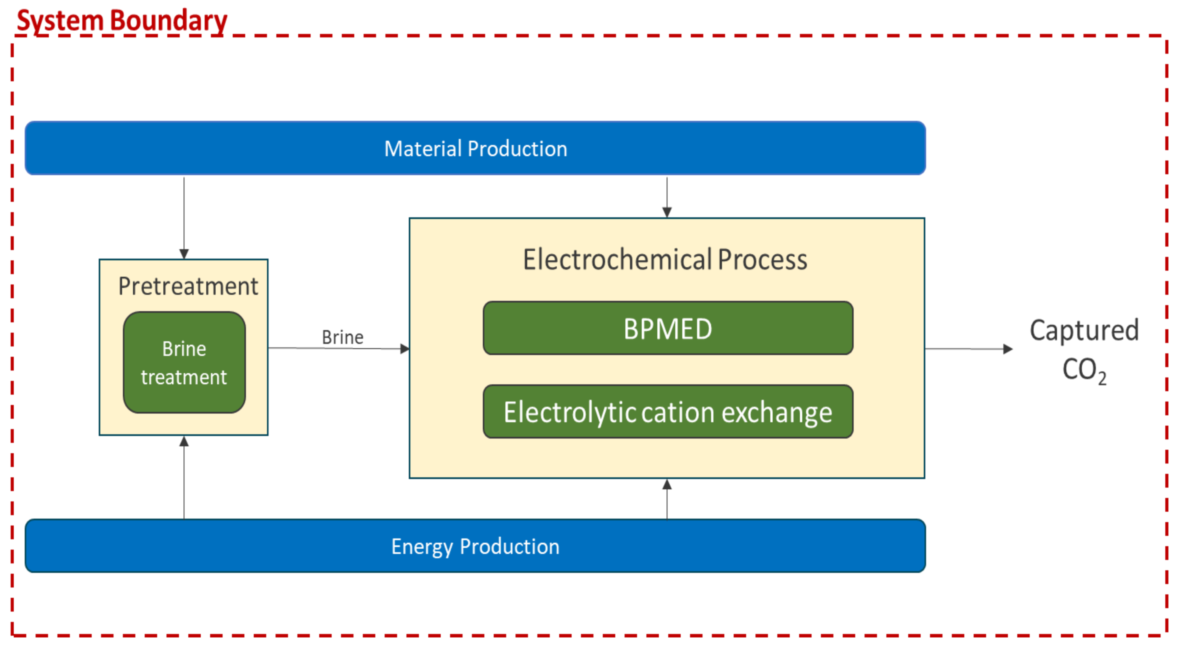
- The scale is based on an expected CO_2 capture rate of an mCDR facility co-located with an average sized desalination plant in the U.S.
- The estimating models are based on a U.S. Florida Atlantic Coast location, and the labor cost was scaled from a Midwest Gulf Coast location.

Performance Summary	MEB1	MEB2	MEC1
Inlet DIC (CO_2e), umol/kg (ppmw)	2,074 (126)	2,074 (126)	2,074 (126)
CO_2 capture rate, %	**63**	**63**	**62**
CO_2 product flow rate (pipeline quality), tonne/yr	13,000	13,000	13,000
H_2 product flow rate, tonne/yr	-	-	1,481
Total auxiliary load, kWe	**11,994**	**16,455**	**71,754**

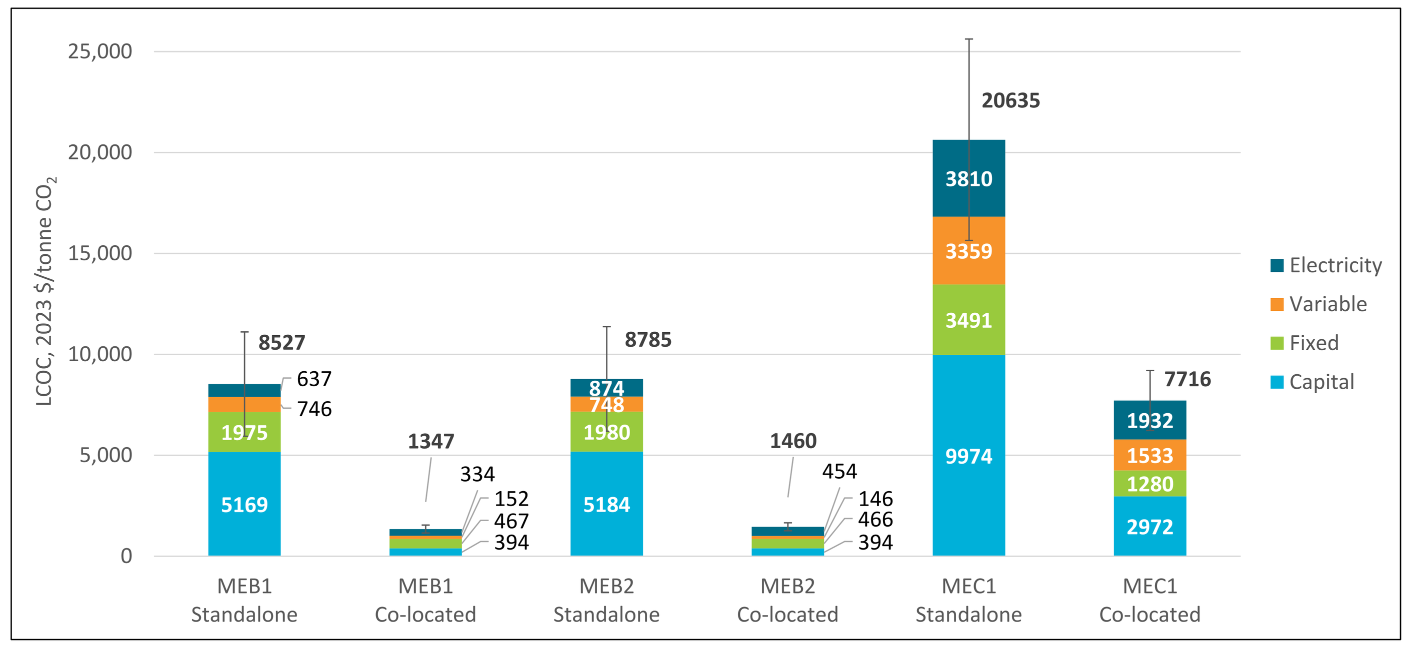
[1] National Academies of Sciences, Engineering, and Medicine. 2021. *A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration*, Washington, D.C.: The National Academies Press.
[2] Lebling, K., E. Northrop, C. McCormick, and E. Bridgwater. 2022. *Towards Responsible and Informed Ocean-Based Carbon Dioxide Removal: Research and Governance Priorities,* Washington, D.C.: World Resources Institute.

LCA Methods

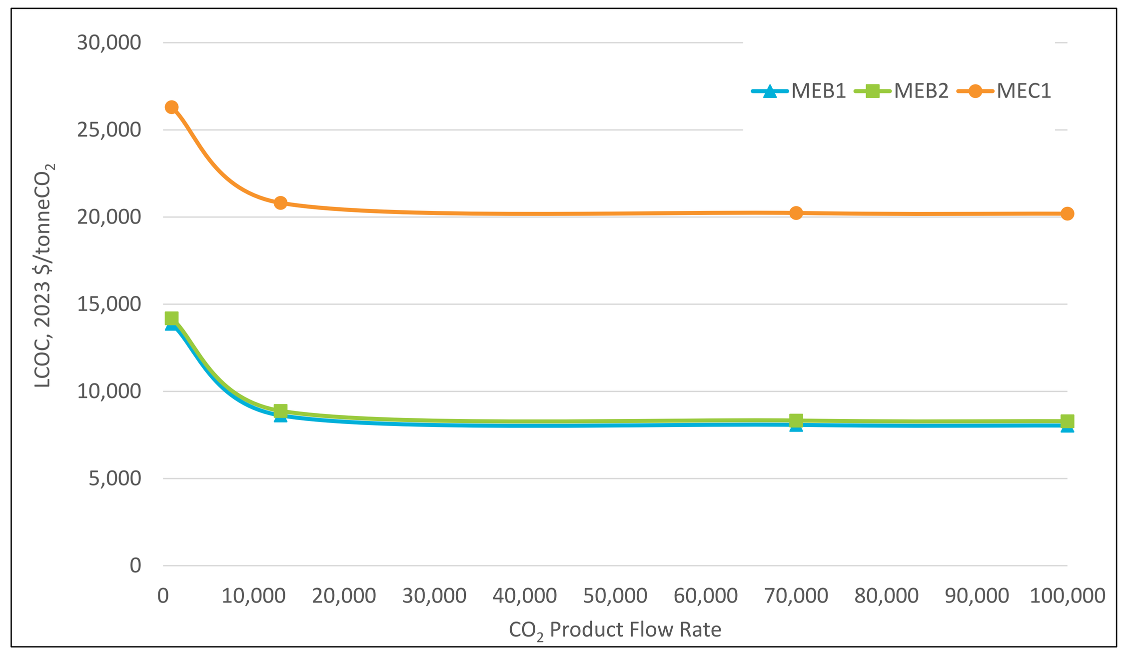
- Boundary: Cradle-to-Gate
- Functional unit: 1 kg of CO2 captured
- Modeling platform: openLCA v2.1.1
- Impact assessment: Traci 2.1 (AR6 100-year time horizon)
- Life cycle inventory: TEA material and energy flows



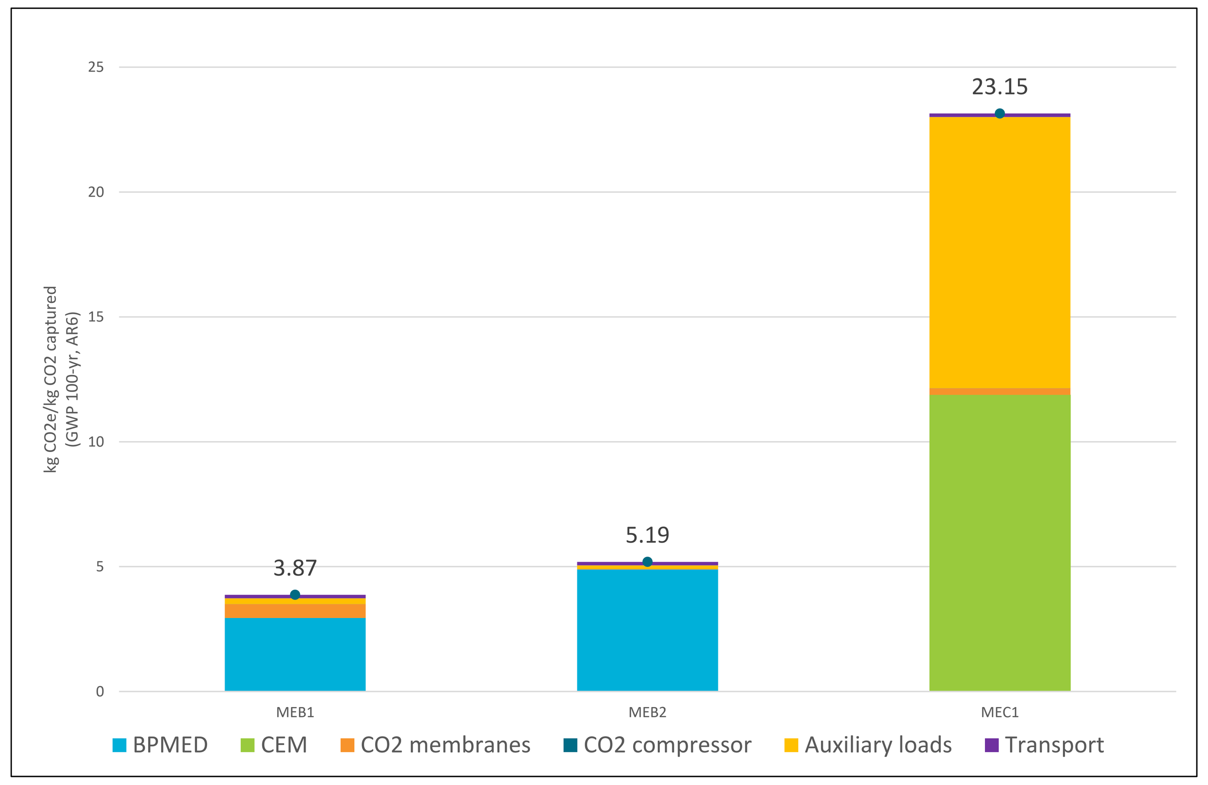
Results



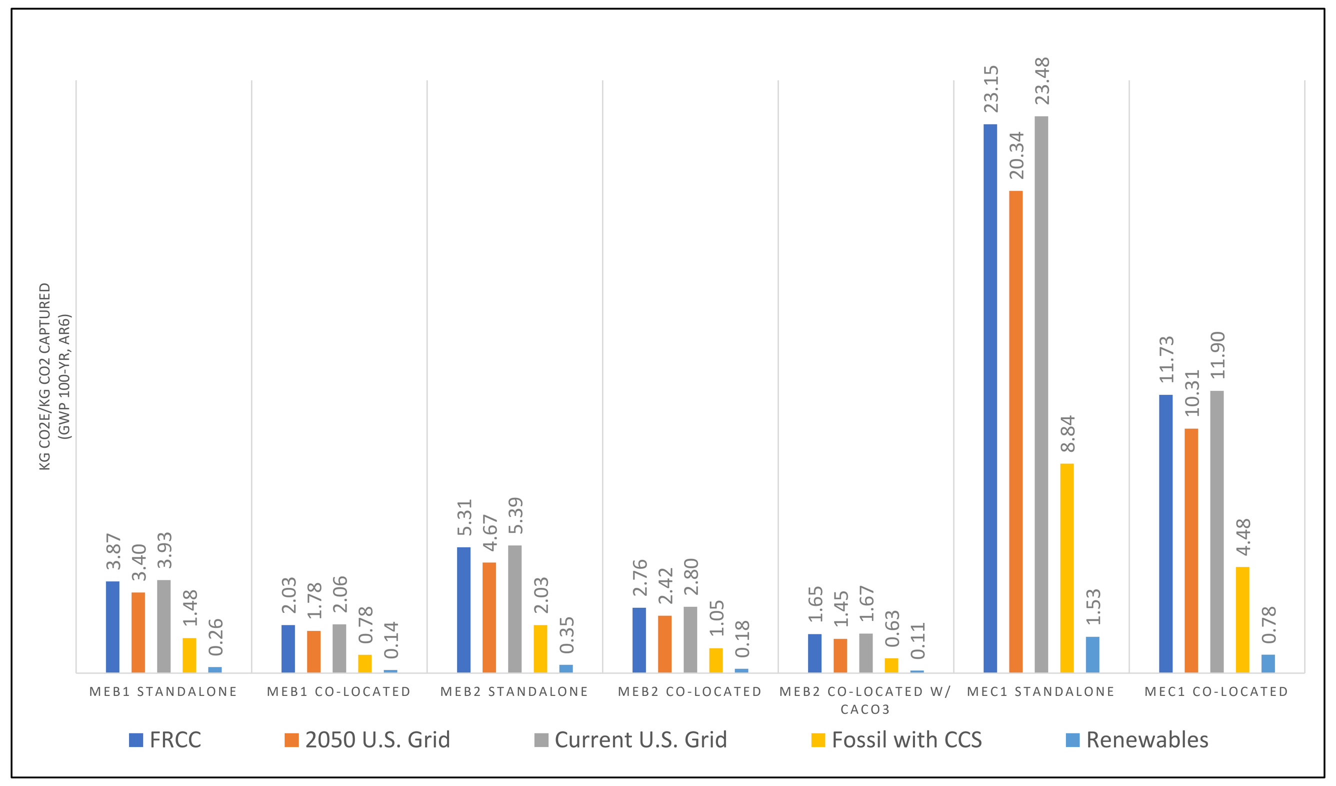
Levelized cost of capture (LCOC) comparison.



Sensitivity of mCDR technologies to plant size.



GWP impacts of standalone and co-located marine CDR facilities.



Sensitivity analysis for different electricity sources scenarios.

Conclusion

- The preliminary TEA indicates that an LCOC > $1,000/tonne CO_2 can be expected for electrochemical mCDR technologies.
- The analysis of environmental impacts highlighted that under certain conditions (renewable electricity source) electrochemical mCDR technologies can be net negative.
- These results are preliminary, based on limited availability of transparent data.

Preliminary Results, Do Not Cite

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