UCLA Samueli
Civil & Environmental Engineering

Institute for Carbon Management

# UCLA SeaChange: Carbon Sequestration Pilot

DE-FE0032321

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2024 FECM/NETL Carbon Management Research Project Review Meeting

August 5 – 9, 2024

# Project Overview

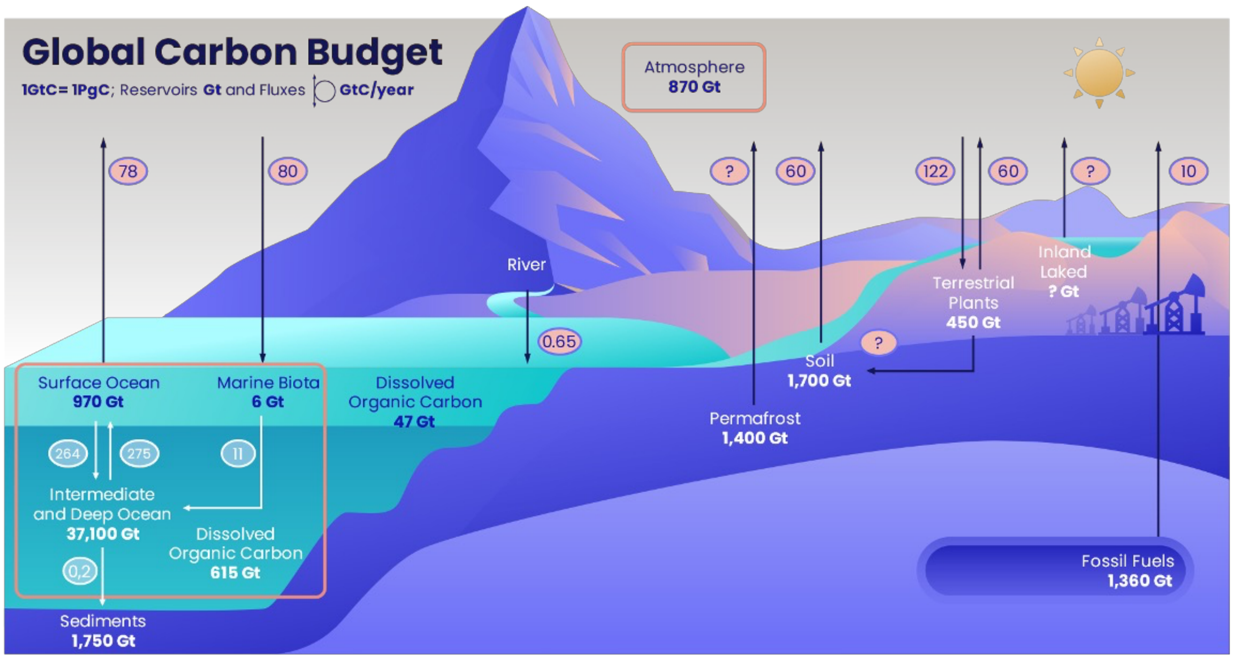
- Funding
  - DOE: $1,600,000
  - Cost-share: $450,000
- Overall Project Performance Dates
  - Project start: Q1 2024
  - Project completion: Q2 2025

# Project Objectives

- Design, build, and commission an electrolyzer unit that will achieve 1 tonne/day (TPD) of carbon removal by way of seawater electrolysis with hydrogen generation
  - Limited energy usage of 2.5 MWh/t of gross energy intensity
- Establish a U.S. based manufacturing line for seawater electrolyzers that will achieve a net levelized cost of <$100/tonne

# There is an ongoing (dynamic) exchange of $CO_2$ between the atmosphere and oceans – and the oceans are the largest reservoir of carbon dioxide

The carbon dioxide concentration in seawater is 150x higher than in air




**Global equilibrium:**
$CO_2$ that is removed from the atmosphere is permanently stabilized in the world's oceans by alkalinity compensation – *implications for "DAC"*

# Technology Background

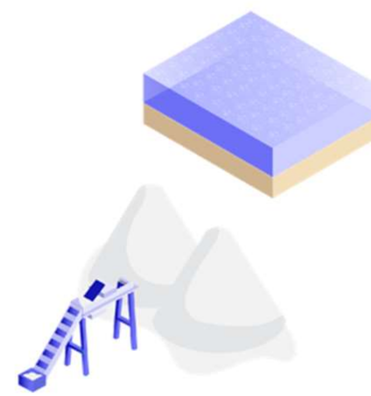
*Stage 1:*
**Seawater Electrolysis**

Renewable electricity is used to split seawater into two streams, hydrogen and oxygen

*Stage 2:*
**Direct Air Capture**

Carbon dioxide is converted into dissolved inorganic carbon and calcium carbonate

*Stage 3:*
**Permanent Storage**

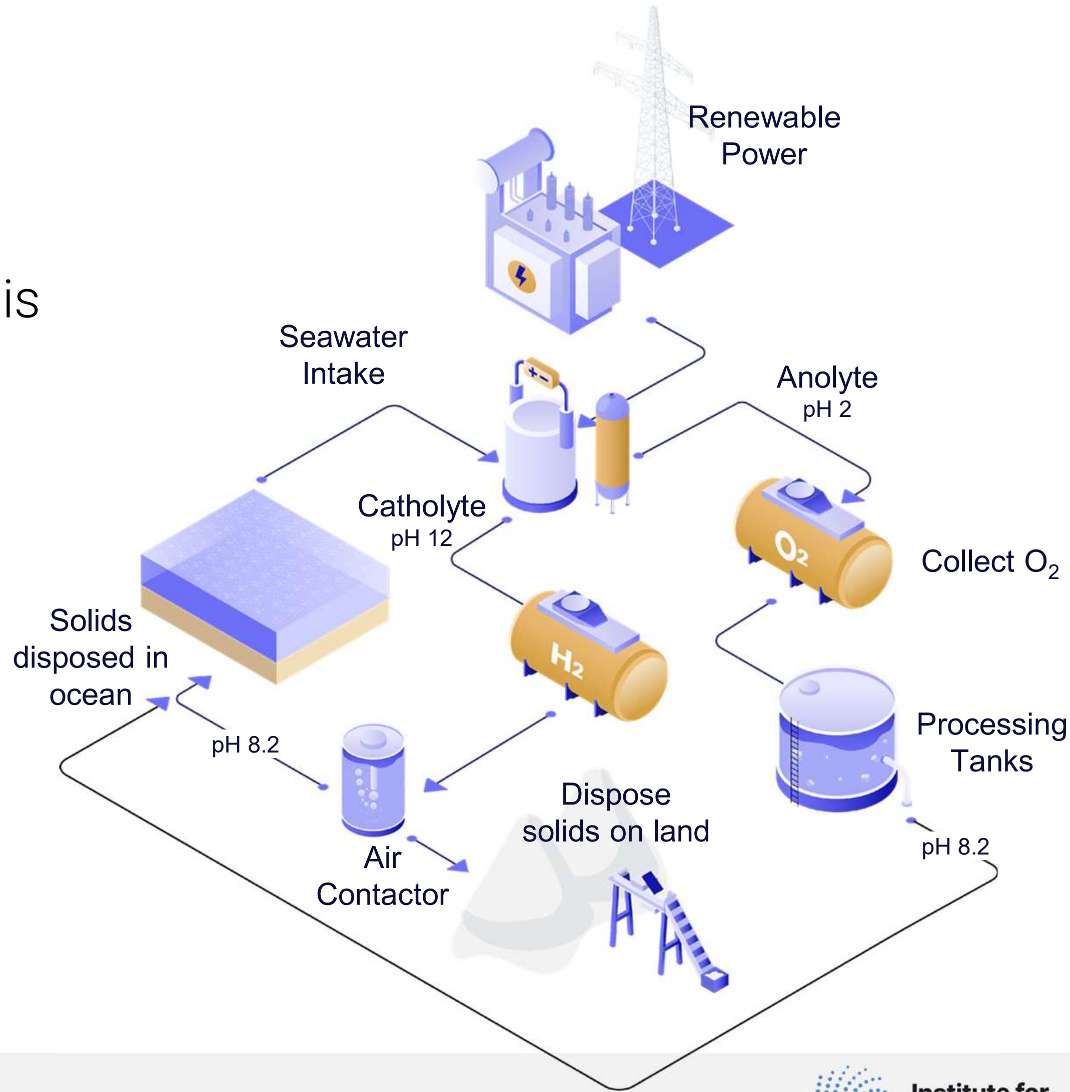


Carbon can then be stored in ocean and on-land for 10,000-1,000,000,000 years

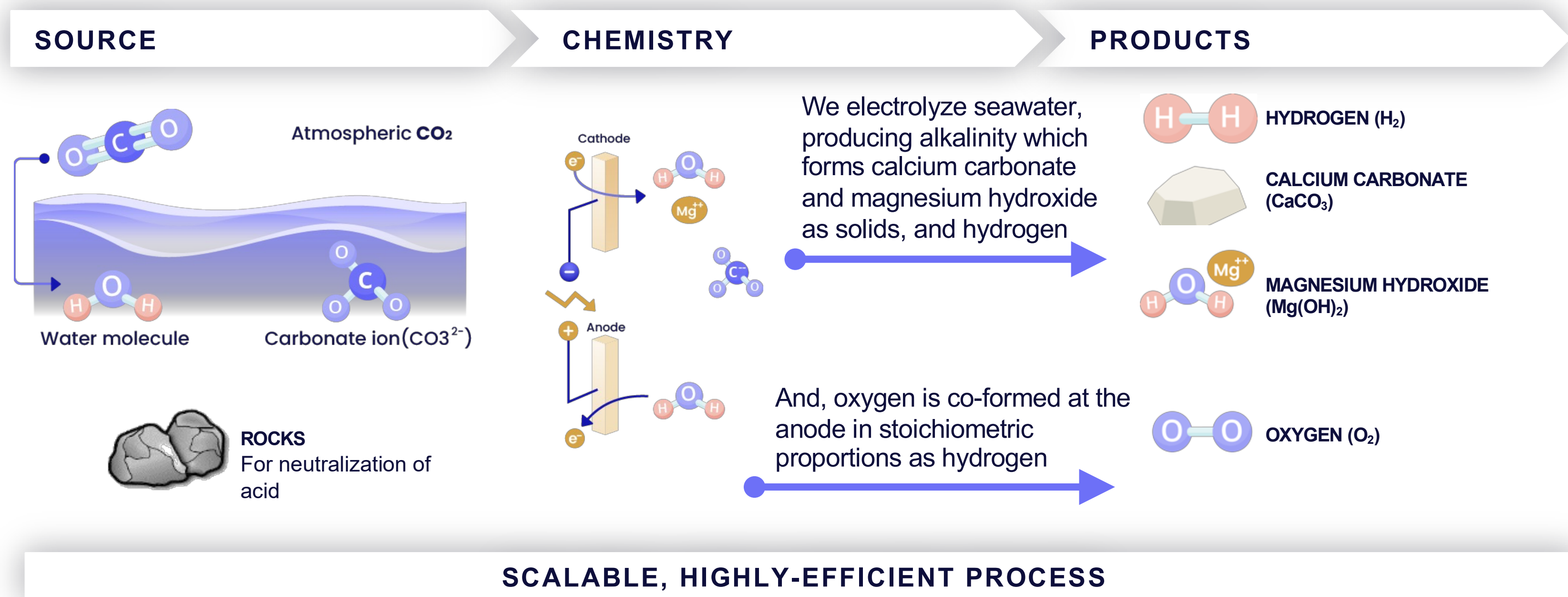
# How it works:

- Flow-through seawater electrolysis

$H_2$ production coupled to CDR



# Technology Background

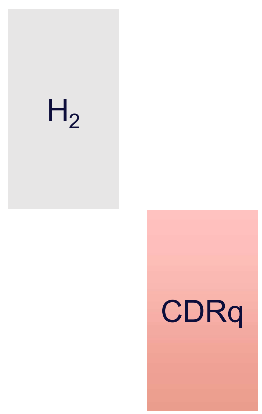



***~2.3 MWh per tonne of $CO_2$ removal is the lowest demand for atmospheric CDR***

- Sources: LaPlante et al, ACS Sust Chem Eng (2021) 9:3:1073-1089 ; LaPlante et al, ACS EST Eng (2023)

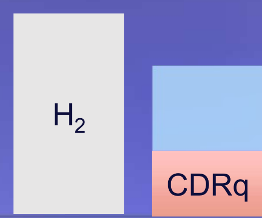
# Not just CDR: Green hydrogen from seawater

### Ocean CDR technology




*A $H_2$ production process with* ***net $CO_2$ capture***

### PEM/alkaline $H_2$ electrolysis




$CO_2$ emissions strongly depend on source of electricity

### Blue/brown $H_2$


$CO_2$ emissions directly linked to the process

# Two 100 kg CDR per day pilots online since March 2023 in Port of Los Angeles and Singapore

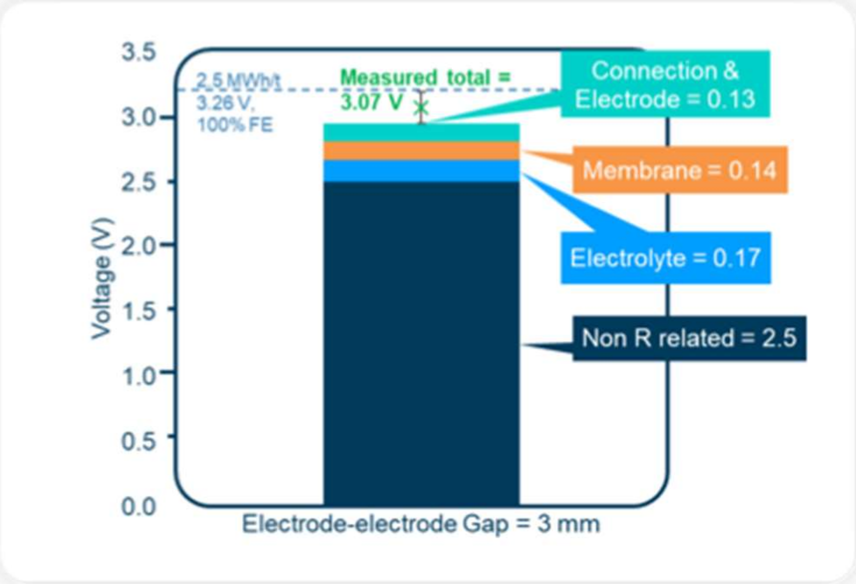
# Technical Approach/Project Scope

- We are developing an electrolyzer to achieve our performance criteria by iterating new designs in a pilot test rig
- Key is to minimize energy usage while maximizing operational stability

| Milestone Title & Description | Planned Completion Date |
|---|---|
| **Milestone A – Kickoff meeting with DOE** | Q1 2024 |
| **Milestone B – Finalized electrolyzer design**.<br>An electrolyzer design engineered to achieve the target GEI of ≤2.5 $MWh/t_{CO2}$. | Q3 2024 |
| **Milestone C – FEL-3 engineering**.<br>To provide an engineering package including a project execution plan, electrolyzer component manufacturing plan, electrolyzer assembly and commissioning procedure, general arrangement layout and 3D model, Equipment specifications (for OTS equipment), Preliminary line list (piping and electrical), Detailed P&ID and Material Selection Diagram (MSD), Detailed control description, including commissioning, startup, and maintenance assumptions. | Q4 2024 |
| **Milestone D – Electrolyzer commissioning and operation**. Design, fabricate, and commission a 100 kW electrolyzer system including the balance of plant. | Q2 2025 |

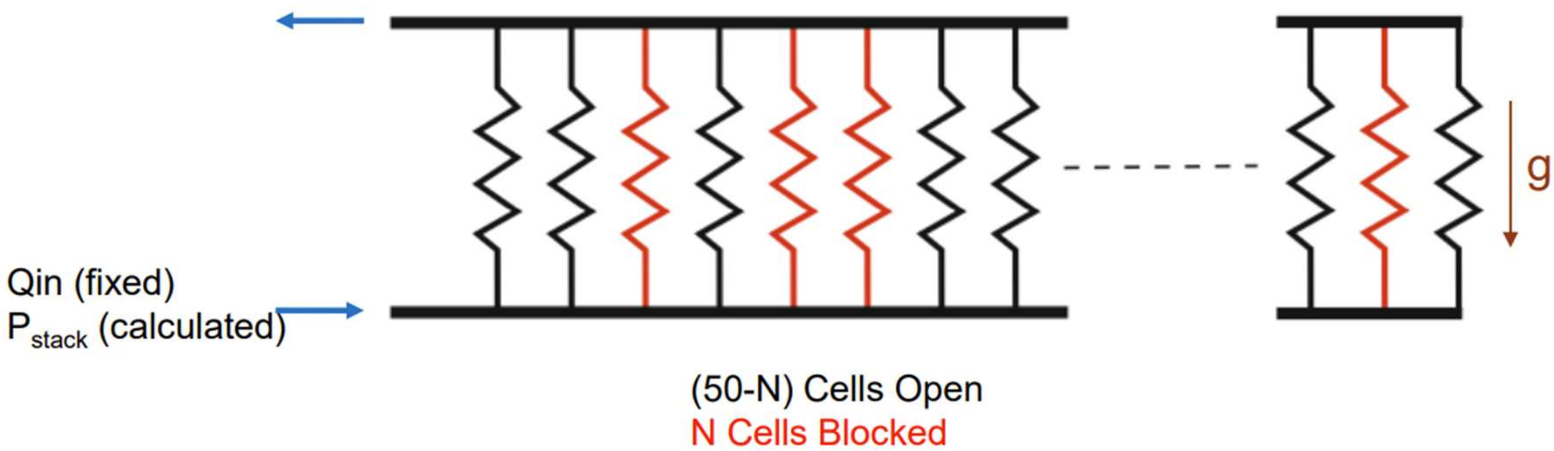
# Progress and Current Status of Project: Energy Contribution

- Measured the contribution of various components to the generalized cell design's energy performance
  - Electrolyte, membrane, and electrodes provide roughly equal voltage increments above the thermodynamic limit



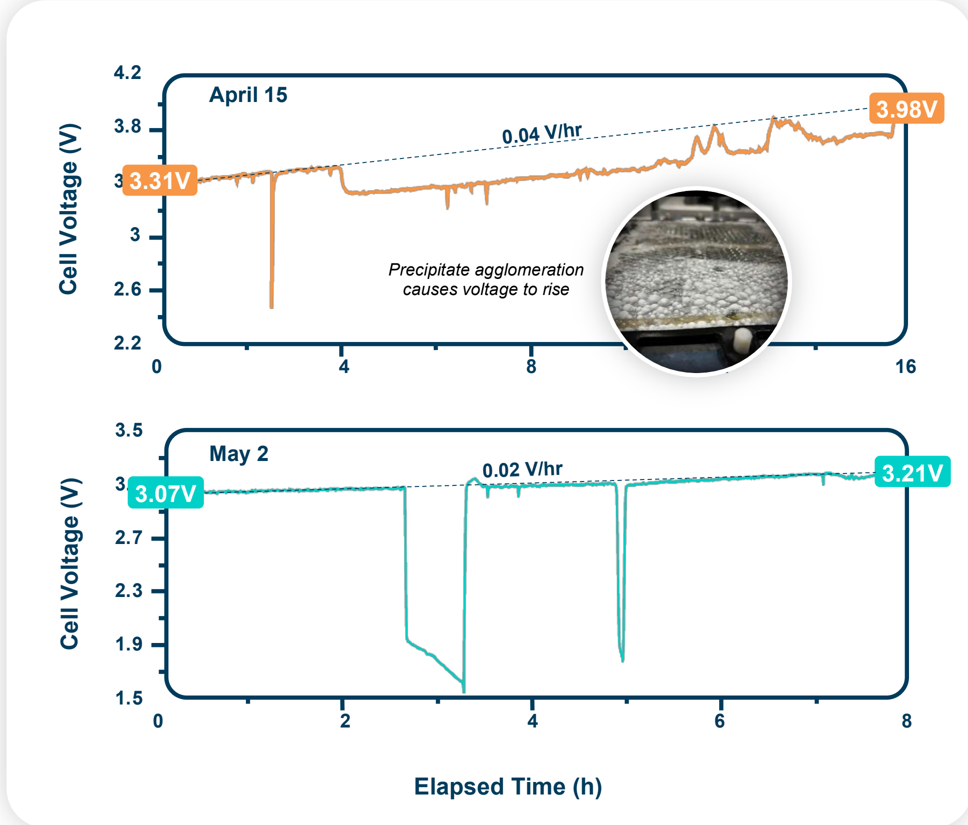
# Progress and Current Status of Project: Flow Modeling

- Modeled stack flow behavior given blocked cells to understand flow dynamics in case of individual cell fouling in large stack
- Results show that low cell blockage % is acceptable and does not meaningfully impact hydrodynamic performance, whereas high blockage (> ~25%) has exponential and cascading effects on flow distribution



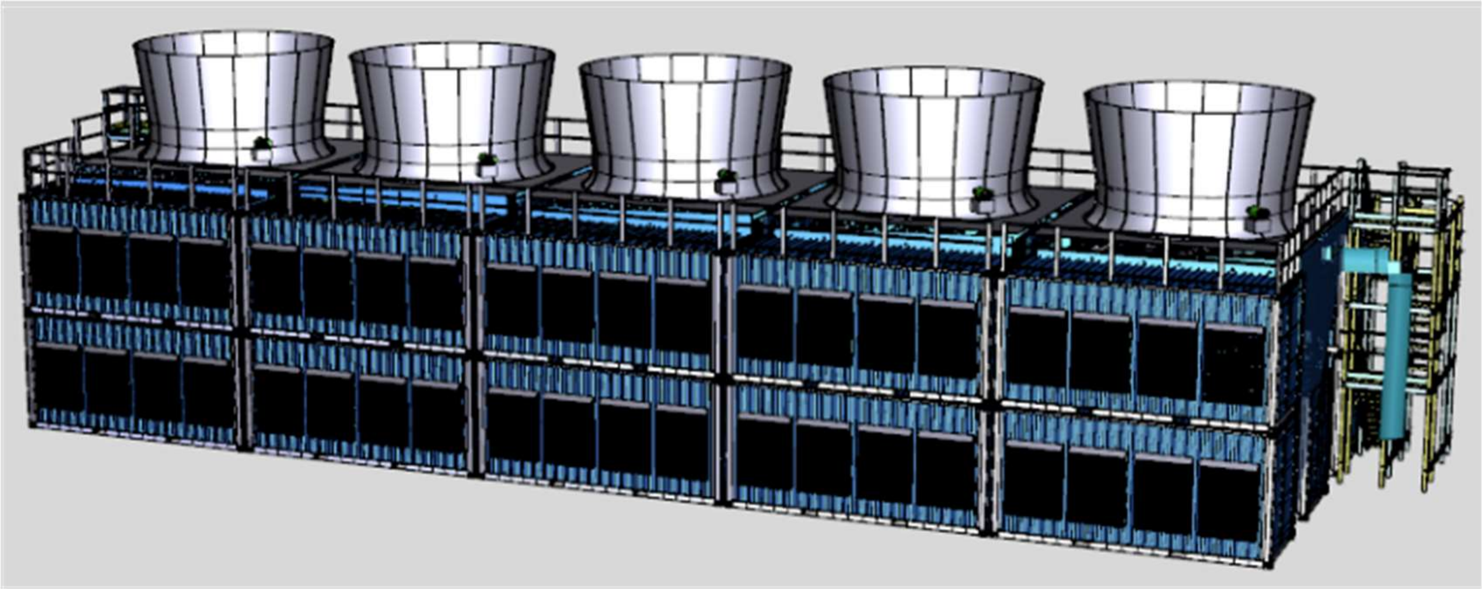
# Progress and Current Status of Project: Electrolyzer Testing

- Demonstrated multiple extended runs (over 6 hours) of stable operation, with a "voltage creep" ranging between 10-40 mV/h
- Acid flush of single-cell system has shown complete recovery of initial voltage, indicating ability to cyclically run cell multiple times
- Primary challenge is to continue to lower initial voltage and manage solids removal from cell



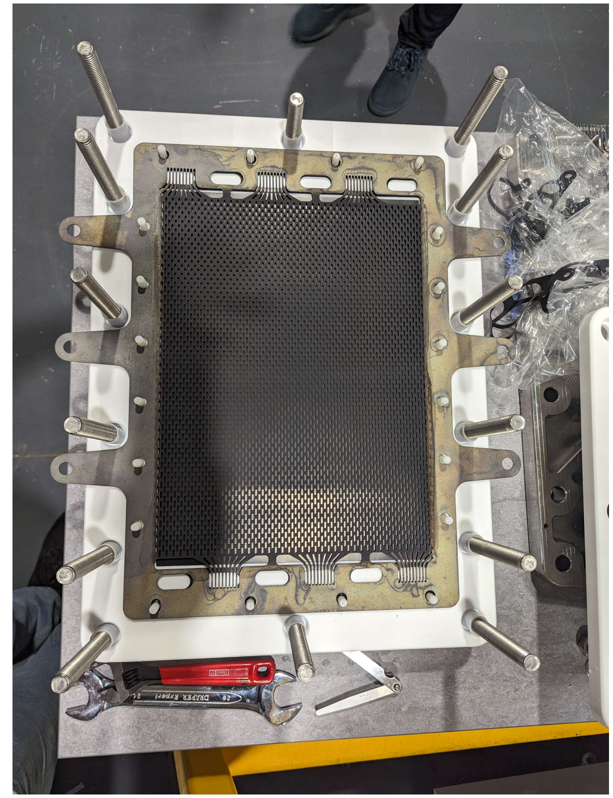
# Progress and Current Status of Project: Carbonation

- Designing and sizing demonstration-scale carbonator based on lab experiments
- Pilot study at the Los Angeles site under development



# Progress and Current Status of Project: Manufacturing

- Building up manufacturing lines, including for proprietary coating processes for oxygen-selective anodes
- Partner's facility in San Diego, CA

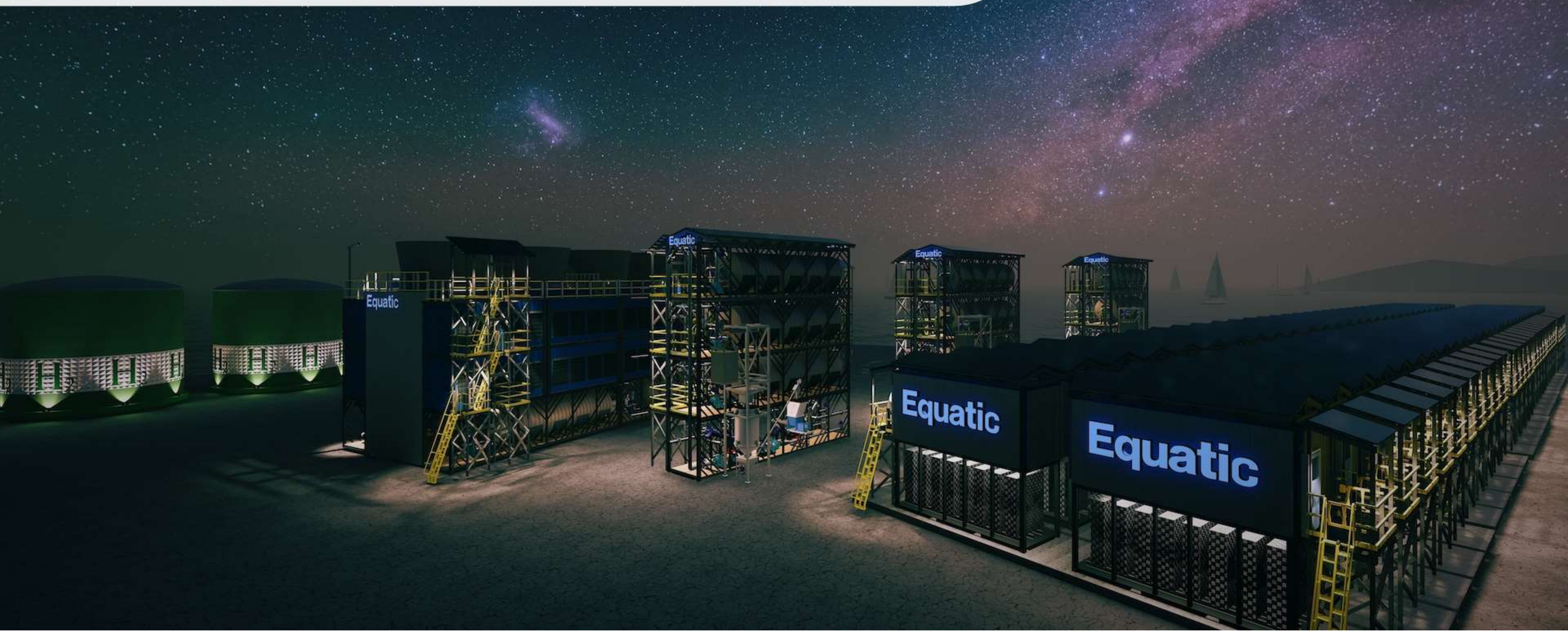


# Plans for future testing/development/commercialization

**~4,000 TPA CDR/Green $H_2$ Plant plant:**
**2025 phased installation in Singapore**

# Plans for future testing/development/commercialization

**~100,000 TPA CDR/Green $H_2$ Plant in Canada: Project Engineering underway**



# Summary

- Key findings to date
  - Voltage in cell rises over time due to solids and gas blinding
  - Voltage can be recovered through acid flush of cell
- Future plans
  - Continue to decrease initial cell voltage
  - Optimize cell geometry for voltage stability
- Unique oxygen selective anodes are key enabler of the technology
- Seawater-based CDR technology is engineered with MRV at the forefront