Enabling simultaneous Green Hydrogen Production and Carbon Dioxide Removal

Ryan Tan

Equatic
Director

Temasek Trust
Head, Planet Collaborative
Head, Catalytic Capital for Climate & Health

Equatic

To get to net zero, we need carbon dioxide removal (CDR)

- Current emissions are too high. Even with a greater focus on emission reductions, CO_2 is being released into the atmosphere at record rates
- Some industries have emissions that are practically impossible to eliminate entirely. Carbon removal is needed to address these “residual” emissions
- To meet critical climate targets like the 1.5°C goal of the Paris Agreement, scientists and policy makers agree that carbon removal is necessary to compliment efforts to cut CO_2 emissions

Low cost, engineered solutions are needed to remove billions of tonnes of carbon dioxide annually

Equatic is doing nature's work, just 100,000x faster

THE OCEAN IS THE WORLD'S LARGEST CARBON SINK

40 billion tonnes of CO_2 emitted every year

…of which…

10 billion tonnes of CO_2 is absorbed by the ocean

…resulting in a…

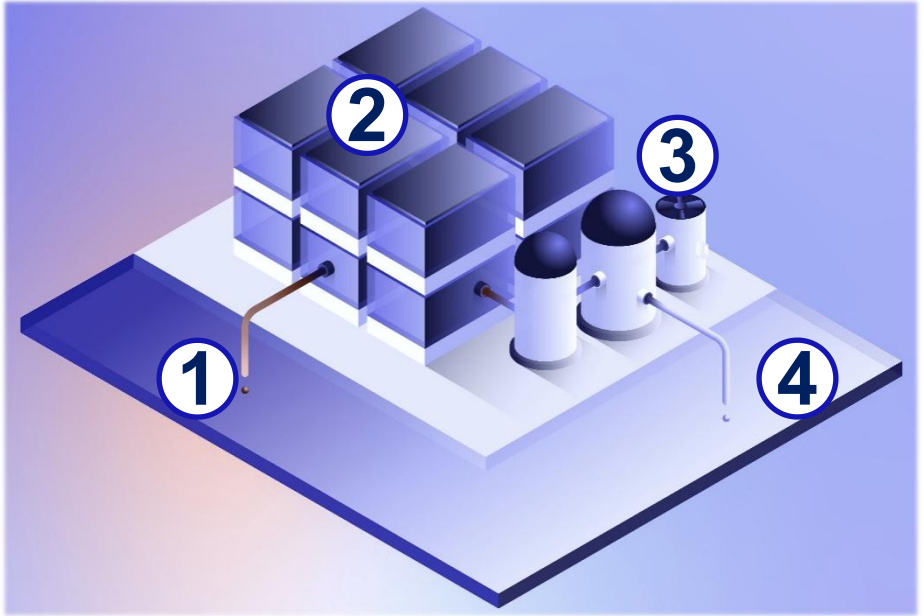
0.02% increase in oceanic carbon

EQUATIC ACCELERATES NATURE'S CARBON SEQUESTRATION PATHWAY

Rapid	Equatic: 5 minutes to remove 1 tonne Ocean: 12 months to remove 1 tonne
Permanent	Up to 1,000,000+ years of storage
Verifiable	ISO 14064-2:2019 ensures auditable measurements of net carbon removal
Efficient	Green hydrogen ensures low net energy footprint per tonne of carbon removed

How to immobilize carbon dioxide for 1,000,000+ years

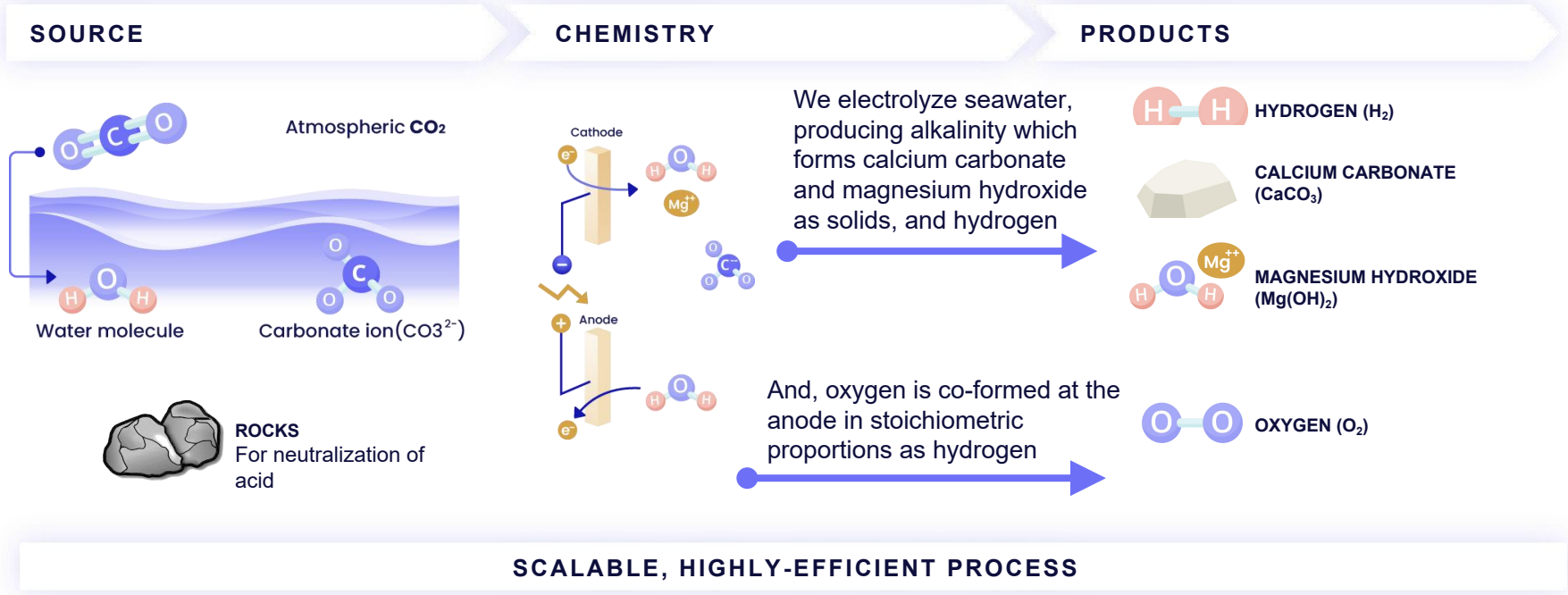
1. Seawater is directly pumped into Equatic's coastal facility
2. CO_2 in the seawater is immobilized by the Equatic electrolyzer (~3 mass %)
3. CO_2 from the air is captured directly inside the facility (~97 mass %)
4. Solids are separated and seawater with residual, dissolved carbon is discharged



1 tonne CO_2 removed AND **30 kg** green hydrogen

Equatic

The (electro-)chemistry behind the process that results in mineral precipitation and CDR, and hydrogen, and oxygen evolution

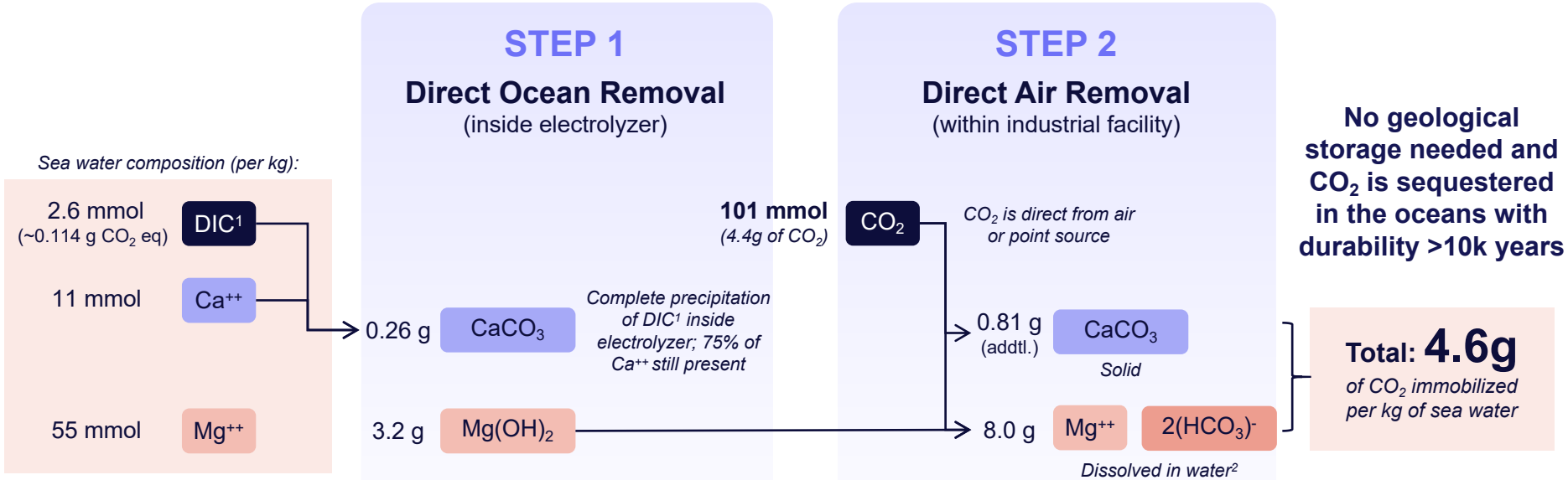


~2.3 MWh per tonne of CO_2 removal is the lowest demand for atmospheric CDR

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

Equatic

Two unique ways to immobilize CO_2 for up to 1,000,000+ years



Two unique pathways to immobilize CO_2 for 1,000,000+ years

1. DIC: dissolved inorganic carbon; 2. 1.7 mol CO_2 are immobilized per mol of $Mg(OH)_2$ dissolved. Source: LaPlante et al, ACS EST Eng (2023)

Equatic

Measurement, reporting & verification (MRV) of every CDR credit

The Importance of Measurement

Paying for carbon credits depends on customer and market trust

Ensure real-time, on-line verification of the amount of CO_2 removed

Demand for and price of carbon credits will be based on robustness of the MRV system

Internal MRV System

CDR will be measured, reported and verified using on-line sensors, and analysis within the battery limits of the plants

Quality Control and Quality Assurance (QC/QA) protocols will ensure consistency of data, data records, and record keeping

Inviolability of MRV/data-records

External Validation

Certification of MRV approach by 3rd-party organizations

Certification of the QMS using best-in-class industry standards

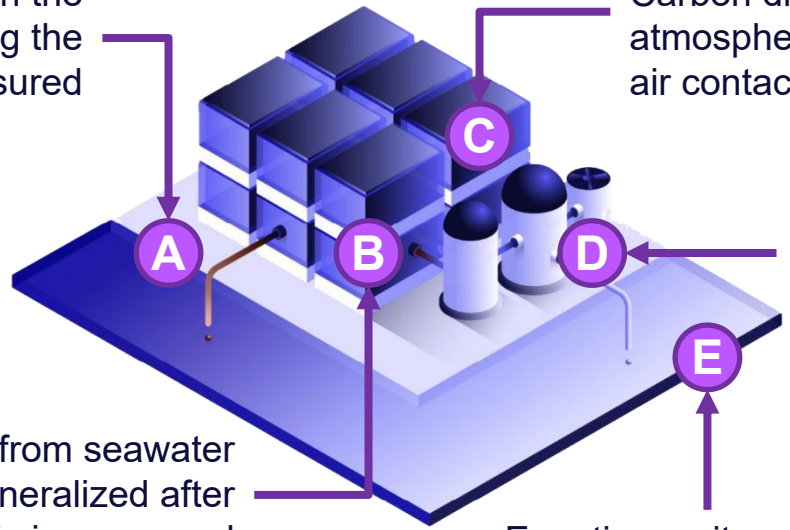
Regular external audits will build and ensure ongoing trust

Equatic

The only ocean CDR company to directly measure carbon removal

CO_2 present in the seawater entering the plant is measured

Carbon dioxide in the atmosphere entering the air contactor is measured



(Bi)carbonate is measured before discharge

CO_2 removed from seawater and mineralized after electrolysis is measured

Equatic monitors native baseline, before and after discharge, to ensure robustness of MRV

ISO — International standard for quantification, monitoring and reporting of GHG removals — Link

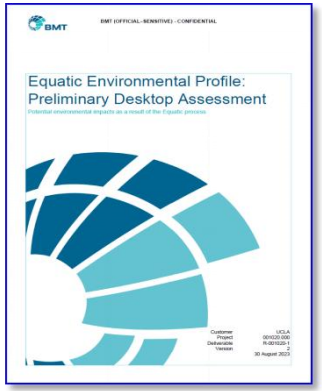
puro.earth — "Direct Air Capture and Ocean Sequestration" protocol published in 2025 — Link

ISOMETRIC — "Electrolytic Seawater Mineralisation" protocol published in 2024 — Link

Equatic

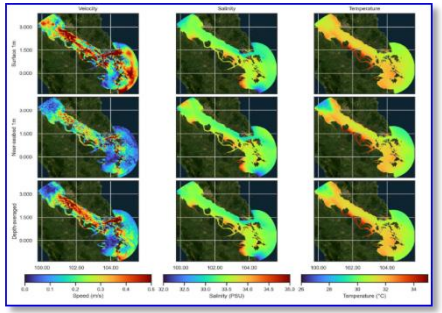
Benign environmental impact and sequential validation is ongoing

Desktop Enviro. Impact Assessment



✓ **Completed:** Negative environmental impact unlikely to occur when conforming to existing discharge regulations

Ocean discharge modelling



✓ **Completed:** Hydrodynamic discharge modelling to assess the impact of Equatic discharge on the coastal environment

Experimental ecotox studies

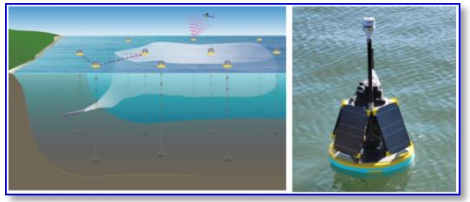
Species	ISO Protocol
marine algae: Phaeodactylum tricornutum	NF EN ISO 10253
copepod: Acartia tonsa	ISO 14669
oyster: Crassostrea gigas	NF ISO 17244
sea urchin: TBD	(reproduction)
fish: cell line SAF-1	OCDE 249

Objective: Identify the first order boundaries of toxicity using recognized protocols

Approach: Evaluate panels of susceptible marine organisms for the discharge

Preliminary results: Measured no-observed-effect concentration (NOEC) so far indicate absence of toxicity

Verification by field studies



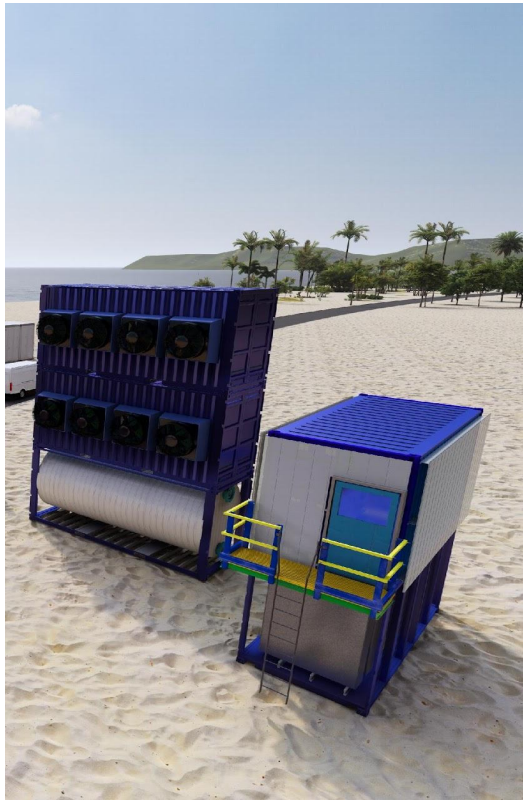
Objective: Measure water chemistry and ground truthing results to evaluate potential smothering issues

Approach: Install buoy array with on-board sensors to measure pre/post/pulse

Timeline: Prior to plant commissioning, and then ongoing during operations

Equatic

Equatic technology will produce three valuable products in Sarawak



Equatic Demonstration Unit in Sarawak

- Showcase a first-of-its-kind CDR technology in an advantaged location (coastal, hydropower, H_2 industry)
- Construct and commission a 1 TPD Equatic electrolyzer unit and balance of plant
- Produce internationally recognized carbon credits (ICROA, ICVCM) and hydrogen

Three products from the Demonstration Unit (per year)

- 365 tonnes of carbon removed and credited
- 10 tonnes of green hydrogen
- 80 tonnes of solid calcium carbonate (limestone)

Equatic

The world's largest ocean-based CDR plant will be online in 2025

Pilot 1 & Pilot 2 (USA & Singapore)

2023

- Two successful pilots in Los Angeles and Singapore
- Performance sustained at nameplate 100 kg/day capacity to validate carbon removal chemistry

Demonstration Plant (Singapore)

2025

- 3,650 tpa CDR + 100 tpa H_2 demonstration plant
- Fully integrated MRV and reporting
- Validates Equatic's manufacturing, vendors and supply chain for future scale out

Commercial Plant

2028-2029

- 100,000 tpa CDR and 3,000 tpa green H2
- Hydroelectricity powers 30 MW electrolyzers
- FEL-1 engineering completed in Dec 2024, and FEL-2 is starting now

Equatic

Demonstration Plant (Singapore): Electrolyzer Module Fabrication

- Equatic is deploying its seawater electrolyzers in Singapore in late 2025 and will number-up in 2026
- Each Equatic electrolyzer removes 365 tonnes of carbon dioxide per year and produces 10 tonnes of hydrogen, and 90 tonnes of calcium carbonate and oxygen co-product
- Electrolyzer has been installed in Singapore and is being integrated with the Balance of Plant (BoP)

Fabrication of Equatic Modular Electrolyzer Unit

Equatic

Demonstration Plant (Singapore): Full-scale stack fabrication

- All assembled stacks tested for voltage, current efficiency, chlorine evolution, internal leakage, and external leakage under pressure
- Once factory acceptance test (FAT) is passed, stacks are stored full of liquid to keep electrodes and membranes conditioned when not in operation
- Electrolyzer is commissioned and set into continuous operations

Compression of stack with hydraulic press

Fully assembled electrolyzer stack undergoing FAT

Equatic

Demonstration Plant (Singapore): Full-scale stack fabrication

Equatic

Demonstration Plant: Oxygen Selective Anode Production

U.S. electroplating line is producing Equatic's proprietary 0.5 m x 0.5 m anodes

Equatic

Project Engineering Studies and Future Site Selection Criteria

- FEL-1 Engineering Study complete (2024)
- FEL-2 Reference Plant Engineering to be complete by end-2026
- Geospatial tool for site selection and techno-economic assessment

Tier 1 criteria: Critical for site selection

Access to coastline

- Objective is to minimize seawater pumping energy required
- 20 acres (equivalent to ~80,000 t CDR per acre over 15-year lifetime)

Access to renewable energy

- 30MW renewable grid power (future plants will consider off-grid)
- Plant can operate on intermittent sources (<5 min start-up time)

Local community and ecosystem

- Responsible industrial deployment under long-standing regulations
- Minimize impact on cultural sites and ecologically sensitive areas

Tier 2 criteria: Beneficial for site selection

Brownfield industrial site

- Take advantage of existing permitting and industry overlays
- Repurpose infrastructure, e.g., discharge pipelines to diffuse effluent

Hydrogen logistics

- Co-location with existing hydrogen transport infrastructure
- Co-location with any offtaker would be supportive, but not required

Equatic

Case Study: Equatic is a part of Boeing's decarbonization efforts

BOEING

Business Approach
Safety & Quality
People & Inclusion
Climate & Environment
Addressing Climate Change
2023 Highlights
2023 Global Collaborations
Decarbonizing Aerospace, Together
Sustainable Operations
Sustainable Product Life Cycle
Responsible Supply Chain
Community
Reporting & Disclosures
49

In 2023, Boeing deepened its engagement in the fifth area of focus for decarbonizing aviation: market-based measures. Boeing made its first investment in permanent carbon removals, while continuing to offset business travel emissions. Our strategy is to increase over time the proportion of permanent removals to traditional offsets in our portfolio. Read more on Page 36.

"As a hard to decarbonize sector, we recognize that many solutions will be needed for commercial aviation to achieve its net-zero commitment, and Equatic offers one of those solutions. Both carbon removals and green hydrogen will be necessary to support the scale up of SAF and decarbonize aviation."

Heather Sheffer
Carbon strategy lead at Boeing

Rendering of a demonstration plant that will remove atmospheric CO2 by electrolyzing seawater. (Credit: Equatic)

Strategy in Action

Boeing Collaborates With Equatic on Carbon Removal Technology

In May 2023, Boeing partnered with Equatic, a carbon dioxide removal company, to support permanent carbon dioxide removal and green hydrogen production.

Under the collaboration, Boeing entered into a pre-purchase option agreement where Equatic will remove 62,000 metric tons of CO2 and will deliver 2,100 metric tons of carbon-negative hydrogen, or green hydrogen.

The first and primary use of hydrogen in aviation should be used to develop and scale SAF, and Boeing intends to use Equatic's green hydrogen to support the industry's need to scale SAF.

Equatic is developing a process that will use seawater, air, rock and renewable electricity to remove carbon and produce green hydrogen. Boeing's commitment to Equatic is part of a larger carbon management strategy that prioritizes an avoid-first, remove-second approach. Equatic technology will play an important role to unlock global-scale decarbonization solutions and will allow Boeing to improve its offset portfolio durability over time. Boeing will diversify investments in permanent carbon removal to strengthen our offset portfolio over time and support important tech development, supporting the voluntary carbon market.

Source: Boeing 2024 Annual Sustainability Report

The 62,000 tonne Equatic-Boeing agreement unlocked:

- 5+ year CDR offtake
- Green hydrogen sales
- Price certainty
- Market development

Importantly, it was the first large-scale CDR purchase by an industrial company with hard-to-abate emissions, providing optionality to access future high-quality CDR credits

Equatic

Equatic Leadership Team

Gaurav N. Sant, Ph.D.

Founder & Chief Technology Officer

- Professor at UCLA Samueli, Director Institute for Carbon Management
- >200 peer-reviewed articles
- Serial Entrepreneur

Edward Muller

Chairman, Equatic

- Chairman of the Advisory Board, UCLA Institute for Carbon Management
- Previously CEO of Genon, Mirant and Edison Mission Energy and Vice Chairman of NRG

Erika LaPlante, Ph.D.

Head of MRV & Environmental Impact Co-Founder

- Assistant Professor, University of California, Davis

David Jassby, Ph.D.

Head of Electrode Materials and Systems, Co-Founder

- Professor at UCLA
- Expert in membrane separations, water treatment, recovery

Equatic Science and Industry Advisory Boards

Science Advisory Board

Emily Carter, Ph.D.

Chair: Science Advisory Board

- Professor in Energy and the Environment, and Professor of Mechanical and Aerospace Engineering, Princeton University

Mark Barteau, Ph.D.

- Professor, Chemical Engineering and Department of Chemistry, Texas A&M University
- Vice President of Research, Texas A&M University

Niall Mac Dowell, Ph.D.

- Professor, Energy Systems Engineering, Imperial College London.

JR DeShazo, Ph.D.

- Dean of the LBJ School of Public Affairs, University of Texas, Austin

Menachem Elimelech, Ph.D.

- Professor, Civil & Environmental and Chemical & Biomolecular Engineering, Rice University

Lynn Brickett

- Former Director, Carbon Capture Division, U.S. Department of Energy

Justin Ries, Ph.D.

- Professor, Marine & Environmental Sciences, Northeastern University

Holly Jean Buck, Ph.D.

- Associate Professor of Environment and Sustainability, University at Buffalo

Industry Advisory Board

Lord John Browne

Chair: Industry Advisory Board

- Former CEO of BP
- Founder & Chairman of BeyondNetZero

Edward Muller

- Chair of the Advisory Board, UCLA ICM
- Former CEO of multiple public-listed companies in (clean) energy field

Catherine McKenna

- Founder and CEO of Climate and Nature Solutions
- Former Canadian Minister of Environment and Climate Change

Peter Relan

- Initial Investor @Discord & BOD Director (ex), Founder YouWeb Incubator, Chairman GotIt!

Jérôme Schmitt

- Previously Head of M&A and Ventures at Total

Caitlyn Fox

- Member of the Advisory Board, UCLA ICM
- Founding team, Chan Zuckerberg Initiative

Dame Dervilla Mitchell

- Former Deputy Chair, Arup

Equatic

Equatic