

Oceanic GHG-Mitigation Hotbed in Cold Water

By John Benson

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1. Introduction

The ocean-waters off of the California Coast are cold. Although this has been a hotbed of surfing almost as long as Hawaii, the surfers today mostly wear wet-suits. Water temperatures range from the low 70°F range near San Diego, to the high 60° range around San Francisco to the low 60° and high 50° range in far Northern California.¹

However lately the oceans around Los Angeles have been a hotbed for carbon dioxide (CO₂) removal. I've known for many years that much of the CO₂ humans pump into the atmosphere, ends up in the oceans and wreaks havoc there. If we start to remove CO₂ from the oceans, the oceans will mostly continue to absorb this greenhouse gas (GHG) at volumes close to today's until we get the level mostly down to pre-industrial levels, but this is not likely to happen for a century or two. So in the meantime we can use the ocean to absorb and transport CO₂. This will make it easier to remove this GHG from the atmosphere by removing it from the ocean.

There are at least two major CO₂ removal ventures in Southern California, each was spawned from a major University, and this post will cover their technologies but will start with one other related subject. Our good corporate citizens are starting to make major bets on these firms.

2. Equatic

*Boeing is partnering with Equatic, a Los Angeles-based startup that removes carbon from the ocean, in a first-of-its-kind deal to buy a massive amount of carbon credits and green hydrogen that's likely worth at least \$50 million...*²

The deal arose from plans for a technology partnership between the companies related to large-scale CO₂ removal facilities Equatic is developing, said Lorenzo Corsini, the startup's principal advisor, who declined to discuss specific details.

"This catalyzes the development of the technology and it's a leap of faith by Boeing," Corsini told Forbes. Boeing is "serious about removing carbon dioxide from the atmosphere and knows that they need to invest upfront to do this."

Equatic ... is part of a new wave of companies with a mission to slow the buildup of climate-warming CO₂ by pulling it out of the atmosphere...

"Reaching aviation's sustainability goals will require a multi-faceted approach and Boeing sees immense value in Equatic's technology," Sheila Remes, Boeing's vice president of environmental sustainability, said in an emailed statement. "We are excited to partner with Equatic on both green hydrogen feedstock and carbon dioxide removal..."

¹ Current Results, Average Temperatures for California's Ocean Beaches,

<https://www.currentresults.com/Weather/California/average-temperatures-california-beaches.php#>

² Alan Ohnsman, Forbes, "Boeing Bets On Startup Equatic With Massive CO₂ Removal, Hydrogen Deal," May 31, 2023, <https://www.forbes.com/sites/alanohnsman/2023/05/31/boeing-bets-on-startup-equatic-with-massive-co2-removal-hydrogen-deal/>



Equatic began operating pilots in Los Angeles and Singapore in April to demonstrate the technology. A larger “pre-commercial” facility is set to open as soon as late next year in Singapore, integrated within an existing desalination plant. It will be able to remove 3,500 metric tons of CO₂ annually. Equatic then wants to have its first commercial plant running in about three years with the capacity to remove 100,000 metric tons of CO₂ and generate 3,500 tons of hydrogen annually. That’s about three times the size of Climeworks’ Mammoth plant under construction in Iceland, which will be able to capture and store 36,000 tons of CO₂ annually when fully operational.

The company is in the process of raising \$100 million for research and plant construction costs...

2.1. Recent Equatic Press Release

Carbon removal company Equatic recently spun out from the UCLA Samueli School of Engineering’s Institute for Carbon Management will deploy the first technology that combines carbon dioxide (CO₂) removal and carbon-negative hydrogen generation. Addressing both legacy and future emissions in a single process, the multi-product climate solution enables decarbonization at the scale, speed and cost necessary to mitigate climate change.³

Alongside the launch, Equatic is announcing that it has entered into a pre-purchase option agreement with Boeing, a leading global aerospace company. Under the agreement, Equatic will remove 62,000 metric tons of carbon dioxide and will deliver 2,100 metric tons of carbon-negative hydrogen to Boeing.

³ Equatic, “Equatic Launches Low-Cost, Gigaton-Scale Technology to Decarbonize at Unprecedented Speed,” May 31, 2023, <https://www.equatic.tech/articles/equatic-launches-low-cost-gigaton-scale-technology-to-decarbonize-at-unprecedented-speed>

“The world has two unprecedented challenges: how to remove and permanently store gigatons of carbon dioxide and how to reduce our reliance on fossil fuels,” says Lorenzo Corsini, Principal Advisor at Equatic. “Equatic’s first-of-its-kind technology solves both. It combines basic principles of chemistry with the natural capabilities of the world’s best carbon removal tool, the ocean, to create the most promising solution for scalable decarbonization — cost-effectively and at a globally-relevant scale.”

The oceans are the world’s largest reservoir of carbon dioxide. One quarter of the world’s daily CO₂ emissions are drawn down into the ocean. Equatic’s technology accelerates and amplifies this natural cycle to remove and durably store CO₂. The entire removal and sequestration process happens within the boundaries of an industrial carbon removal plant, enabling Equatic to precisely measure CO₂ down to the gram.

“To mitigate ongoing and accelerating climate change in the timeframe necessary to avoid irreversible consequences, we need truly disruptive carbon management technologies,” says Lord John Browne, Founder, and Chairman at BeyondNetZero, and the former CEO of BP who is now the Chairman of Equatic’s Advisory Board. “Equatic’s breakthrough technology absorbs carbon dioxide via the oceans and has the added benefit of generating green hydrogen as a by-product. The good news is that the costs are low enough to allow unprecedented scaling and adoption globally.”

Equatic currently operates two carbon removal pilots in Los Angeles and Singapore. One hundred percent of the CO₂ removed from these pilots has been pre-sold, including via pre-purchase agreements with global payment solution provider, Stripe. Equatic expects to reach 100,000 metric tons of carbon removal per year by 2026 and millions of metric tons of carbon removal for less than \$100 per metric ton by 2028.

Furthermore, Equatic will become a dominant producer of carbon-negative hydrogen — hydrogen created from processes that reduce atmospheric CO₂. The hydrogen will be sold as a clean energy source to decarbonize industrial processes, produce electricity for the transportation sector, create Sustainable Aviation Fuels (SAFs) and fuels for trucking, and power the Equatic technology itself.

“The aviation industry has an important role to play in global decarbonization efforts. Reaching aviation’s sustainability goals will require a multi-faceted approach and Boeing sees immense value in Equatic’s technology,” said Sheila Remes, Boeing’s Vice President of Environmental Sustainability. “SAF is enormously important to reaching the commercial aviation industry’s net zero by 2050 goal, and we are excited to partner with Equatic on both green hydrogen feedstock and carbon dioxide removal.”

Equatic emerges from UCLA with over \$30M in initial funding including grants and equity investments from organizations such as:

- *The Chan Zuckerberg Initiative*
- *The Anthony and Jeanne Pritzker Family Foundation*
- *The Grantham Foundation for the Protection of the Environment*
- *The National Science Foundation*
- *YouWeb Incubator*

- *The Nicholas Endowment*
- *Singapore's Temasek Foundation*
- *PUB: Singapore's National Water Agency,*
- *U.S. Department of Energy's (DOE) Office of Fossil Energy and Carbon Management*
- *U.S. DOE Advanced Research Projects Agency-Energy (ARPA-E)*

Equatic's Technology

Author's Comment: Equatic's process, as described below, does not capture CO₂ from the ocean water, but rather uses direct-air capture, and then uses ocean-water as part of the process to mineralize the CO₂, and also to produce hydrogen via electrolysis.

The next firm (Captura, described below) does use ocean-water CO₂ capture, but does not produce hydrogen. Thus the economics are different for each firm, but may well be equivalent at the bottom line, with the lower process cost by Captura being offset by the value of the addition product (green hydrogen) earned by Equatic.

Equatic's carbon removal plant uses four inputs—seawater, air, rock, and renewable electricity—to remove and store CO₂ while simultaneously generating carbon-negative hydrogen. Equatic passes an electrical current through seawater (electrolysis) and then passes atmospheric air through the processed seawater (direct air capture); these steps trap CO₂ in solid minerals and as dissolved substances that are naturally found in the oceans, ensuring that the trapped CO₂ will remain stable for 100,000+ years. Finally, Equatic uses rock to neutralize the processed seawater and ensure that the ocean's chemistry is preserved.

This patented process is the key to delivering scalable, high-quality carbon removal, durable and permanent storage, and accessible, carbon-negative hydrogen fuel. It allows for:

Gigaton-Scale Carbon Removal and Storage. Carbon removal requires CO₂ (1) capture, (2) transport, and (3) permanent storage. Seawater is unique in that it can do all three at once. Equatic amplifies this natural carbon cycle to remove CO₂ from the atmosphere by leveraging the size and scale of the oceans and allows the oceans to serve as an enormous storage reservoir of CO₂.

Multi-Product Solution. The hydrogen gas that is co-produced can be used to power the process itself, or sold as a carbon-negative fuel source. Combining CO₂ removal and hydrogen production within a single industrial footprint and the same process equipment significantly reduces the cost associated with both. It also enables Equatic to create a clean fuel to reduce dependence on fossil fuels, thereby avoiding fossil fuel-related emissions.

Industry-Leading Monitoring, Verification and Reporting: Equatic offers a contained solution that does not rely on the open ocean. As such, Equatic is the only ocean-based carbon removal company that transparently measures removal with extreme certainty. This enables the company to sell highly-sought, high-quality, permanent carbon removal credits.

3. Captura

Founded in 2021, utilizing technology developed in Caltech's laboratories, Captura provides low-cost atmospheric carbon removal by leveraging the world's largest natural CO₂ absorber – the ocean. With minimal impacts on the environment and using only renewable electricity and ocean water as inputs, our patented electrodialysis process generates a stream of pure CO₂ that can then be sequestered or utilized to make other low-carbon products.⁴

With no purpose-built air contactors, no absorbents, and no by-products, Captura's solution enables large-scale carbon removal at a lower cost.

Captura's technology features a flow of ocean water passing through the plant, which is then treated to remove its carbon dioxide content and then returned into the ocean. This decarbonized water then sits in the top layer of the ocean and will then react with the atmosphere to draw down an equivalent quantity of CO₂.

In this way, Captura utilizes the ocean's natural ability to draw down CO₂ from the atmosphere. Without Captura's technology, this well-known effect causes an increase in ocean acidification, as the ocean absorbs 30% of the world's emissions. By removing CO₂ from the ocean, Captura's technology benefits from the ocean's CO₂ absorption capability without increasing ocean acidification.

Equatic says one-quarter (25%) and the above says 30% of CO₂ is absorbed by the ocean. I expect the real amount is variable and location-dependent, but in this range.

The Captura process begins by pulling a stream of filtered ocean water into our system.

Less than 1% of this water is diverted and pre-processed to purify the ocean water into pure salt water. This salt water is then processed in Captura's proprietary electrodialysis technology. Through dissociation, electrodialysis uses renewable electricity to split the salt and water into an acid and an alkali base.

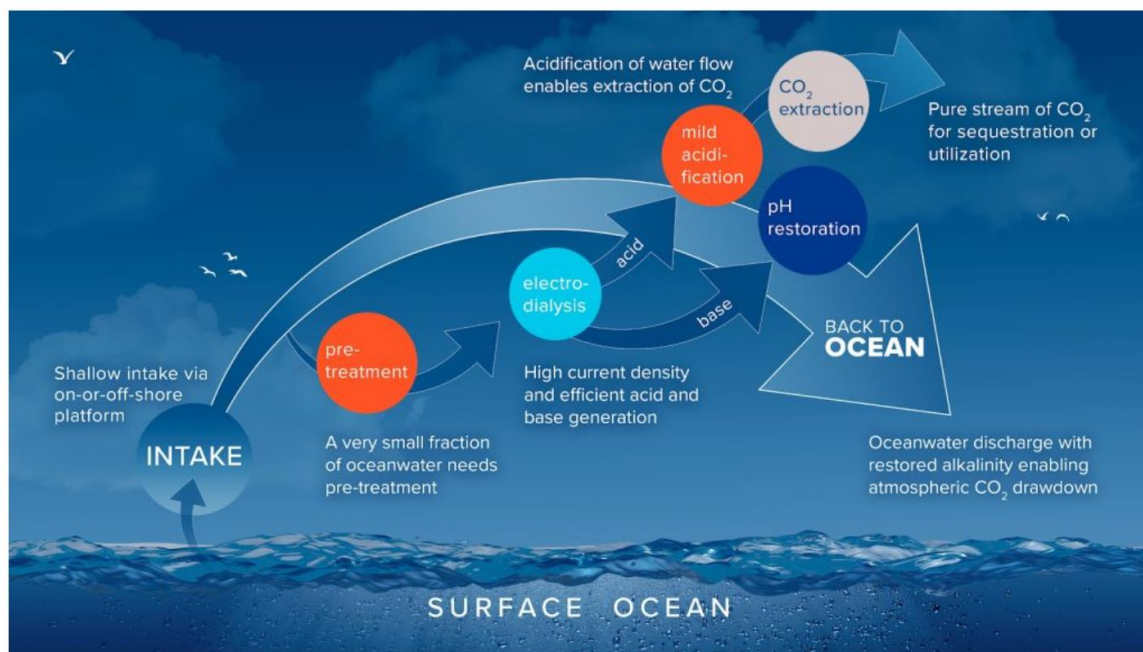
The acid created is then added to the original flow of ocean water through the plant, triggering a chemical process that draws the CO₂ out. We accelerate this process using a gas-liquid contactor and vacuum pump. The carbon dioxide is then captured as a purified stream, ready for subsequent sequestration or utilization.

This leaves a flow of acidic, decarbonized ocean water in the system. The alkaline base is then introduced to neutralize the ocean water flow, which is then returned to the ocean to capture atmospheric CO₂.

In summary, Captura's process uses solely renewable electricity and ocean water to remove CO₂ from the atmosphere with no by-products and no absorbents.

⁴ Captura, "What we do," <https://capturacorp.com/what-we-do/>

The Captura Process



3.1. Evolution

Captura's technology has been fully demonstrated in laboratories at Caltech with imported ocean water. These demonstrations have allowed the Captura team to measure and optimize system performance in advance of an ocean-based pilot.

In the summer of 2022, Captura installed our first ocean-based, stand-alone pilot facility in Newport Beach, CA. The use of a continuous flow of ocean water allows our team to measure system performance and implement system improvements.

Captura has also built its next-generation system which has 100x the capacity of the first. The new, larger system has been successfully operating end-to-end in the company's lab in Pasadena and Captura plans to move it to AltaSea at the Port of Los Angeles in the summer of 2023 to begin ocean field trials.

As more corporations seek out strategies for achieving Net Zero, the demand for carbon removal is expected to grow. Captura's technology is highly scalable, and to facilitate rapid and widespread global deployment we intend to work with partners who will license our technology and build Captura carbon removal plants throughout the world.

This will drive the initial deployment of our technology across the utility sector, the desalination industry, and inactive offshore gas/oil platforms. Longer-term, we envisage dedicated Captura platforms similar to today's ocean-based energy infrastructure.

Combining the inherent scalability of Captura's process with this licensing model allows us to deliver on our mission of providing a globally scalable tool for climate action.

3.2. Investors and Supporter

EQUINOR VENTURES: *Equinor Ventures is Equinor's corporate venture capital arm dedicated to investing in ambitious early phase and growth companies. We believe that the innovation, creativity and agility of startups can drive change, and transition the energy industry towards a low carbon future.*

"Equinor Ventures is committed to investing across a menu of scalable carbon removal technologies. Direct Ocean Capture presents a compelling space for Equinor to leverage its offshore competence. We look forward to working with Captura to help catalyze its technology and business." — Lars Klevjer, Acting Managing Director of Equinor Ventures

ARAMCO VENTURES: *Aramco Ventures is the corporate venturing subsidiary of Aramco, the world's largest leading fully integrated energy and petrochemical enterprise. Headquartered in Dhahran with offices in North America, Europe, and Asia, Aramco Ventures' strategic venturing programs invest globally in startup and high growth companies with technologies of strategic importance to its parent, Aramco, primarily supporting the company's operational decarbonization, new lower-carbon fuels businesses, and digital transformation initiatives. Aramco Ventures also operates Prosperity7, the company's disruptive technologies investment program.*

"Captura's ocean carbon capture represents an innovative and cost-effective approach to reducing atmospheric CO₂. It can also be integrated with desalination infrastructure which is already deployed at large scale in Saudi Arabia. We are excited to support Captura to commercialize this technology." — Bruce Niven, Executive Managing Director of Strategic Venturing at Aramco Ventures

CALIFORNIA INSTITUTE OF TECHNOLOGY (CALTECH): *Caltech is a world-renowned science and engineering institute that marshals some of the world's brightest minds and most innovative tools to address fundamental scientific questions and pressing societal challenges.*

The Institute manages JLP for NASA, sending probes to explore the planets of our solar systems and quantify change on our home planet. Caltech also owns and operates large-scale research facilities such as the Seismological Laboratory and a global network of astronomical observatories, including the Palomar and W.M. Keck Observatories; and cofounded and co-manages LIGO.

FUTURE PLANET CAPITAL: *Future Planet Capital is a venture capital firm investing in founders and businesses solving the world's greatest challenges in climate change, education, health, sustainable growth and security. The firm manages a number of different funds and strategies focused on companies and founders from the world's top universities and research centers. Headquartered in London, Future Planet Capital have made investments in over 300 companies and has around \$400M in committed capital. This includes the Blue Ocean mandate in partnership with the Prince Albert II of Monaco Foundation to advance sustainable, scalable solutions to ocean productivity and preservation.*

“Captura has fast become one of the most promising carbon removal companies on the market by leveraging the world’s greatest natural carbon sink, the ocean. Of all the solutions we’ve seen, Captura stood out, both on technology and track record of delivery. We are thrilled to partner with Steve, CX, Harry and the Captura team as they build commercial, gigaton scale, sub-\$100 carbon removal solutions at a fraction of the capital cost of competing approaches.” — Ed Phillips, Partner at Future Planet Capital

HITACHI VENTURES: *Hitachi Ventures is the strategic corporate venture capital arm of Hitachi, Ltd. We invest in innovative startups with strategic relevance to Hitachi, Ltd. that address society’s key technological challenges in target areas such as mobility, healthcare and smart life, industry, energy and IT. With offices in Munich and Boston, we cover Europe, Israel and North America. We look for leading startups with exciting technologies and business models which we support as investors as well as through strategic collaborations with Hitachi business units.*

“As Hitachi continues to expand in new, promising markets, Captura’s direct ocean carbon capture platform represents both an important growth area and a pathway for continued commitment to Hitachi’s mission of powering social good.” — Masakazu Aoki, Executive Officer, EVP and General Manager, Connective Industries Division, Hitachi, Ltd.

Final author’s comment: The two organizations covered in this paper each have different processes and business models. However, they both are well along in the development process. Each of their processes will accelerate climate change mitigation via removal of the most important greenhouse gas from our biosphere.