Captura

Carbon Dioxide Removal Purchase Application

Fall 2022

General Application - Prepurchase

(The General Application applies to everyone; all applicants should complete this)

Company or organization name

Captura

Company or organization location (we welcome applicants from anywhere in the world)

Pasadena, California, USA

Name(s) of primary point(s) of contact for this application

Steve Oldham, Maya Kashapov

Brief company or organization description

Captura removes atmospheric CO2 by leveraging the ocean, the world's largest carbon absorber, with minimal or zero ocean health impact

1. Project Overview[1]

a. Describe how the proposed technology removes CO_2 from the atmosphere, including as many details as possible. Discuss location(s) and scale. Please include figures and system schematics. Tell us why your system is best-in-class, and how you're differentiated from any other organization working on a similar technology.

Captura offers low-cost carbon removal by leveraging the world's largest, existing, and natural CO2 absorber and air contactor – the ocean. With minimal impacts on the environment, no absorbents or by-products, and using only renewable electricity and ocean water as inputs, our innovative approach

[1] We use "project" throughout this template, but note that term is not intended to denote a single facility. The "project" being proposed to Frontier could include multiple facilities/locations or potentially all the CDR activities of your company.

generates a concentrated stream of CO2 for sequestration. Sequestration can be achieved via any method that takes CO2 as a gas or compressed as a liquid.

Captura's unique process removes CO2 directly from the surface layer of the ocean via pH swing, then benefits from established natural processes (as described in Henry's Law) to draw down an equivalent molar quantity of atmospheric CO2.

The Captura process is shown in figure 1 with a more detailed version available in the confidential material provided separately.

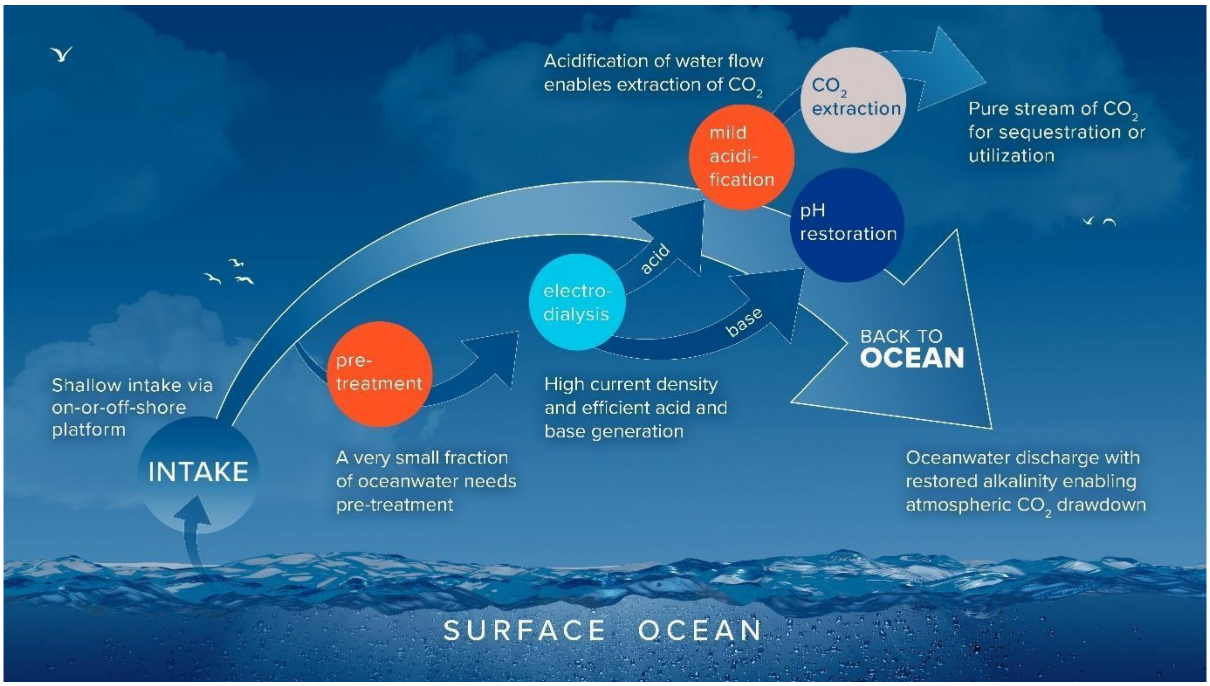


Figure 1: Captura's Process for Atmospheric Carbon Removal

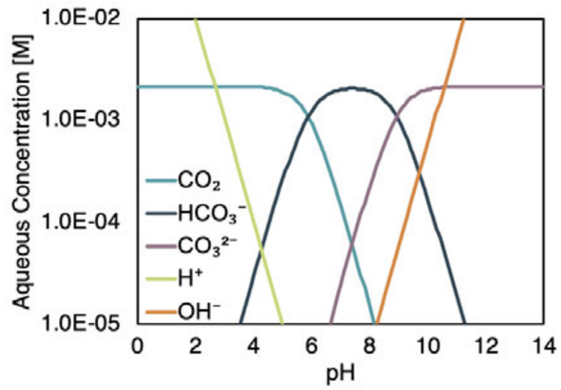
A Captura plant pulls in a stream of filtered ocean water into the system, 0.5% of which is diverted to a proprietary electrodialysis unit. Here, it undergoes dissociation, splitting the salt and water into an acid and alkali base. The generated acid is added to the 99.5% flow of original ocean water intake, triggering a chemical process that releases dissolved CO2 from the ocean water, which is then extracted using a gas-liquid contactor and a rough vacuum pump. The CO2 is captured as a purified gas stream, enabling subsequent sequestration or utilization. The alkaline base water stream is recombined with the acidified stream of ocean water to neutralize it, after which it is returned to the ocean, which returns the ocean water back to its native state, in turn enabling the drawdown of an equivalent molar quantity of atmospheric CO2. .

Ocean CO2 chemistry and Captura's process is described below with red indicating an increase and blue a decrease of specified molecules:

Ocean Acidification – the unwelcome price of the ocean's capacity for CO2 absorption

- Increasing the concentration of atmospheric CO2 increases its concentration in the ocean
- When the concentration of atmospheric CO2 increases, the partial pressure of CO2 in the air above the ocean surface increases

- As the amount of dissolved CO2 in the surface water must be in equilibrium with the partial pressure above the water, CO2 gas dissolves into the ocean water. This is described by Henry's Law (K_H is the Henry's Law constant)
  - $CO_{2\,(aq.)} = K_H * CO_{2(g)}$
- The dissolved CO2 reacts quickly with water to turn into carbonic acid, which is an unstable molecule that dissociates, yielding a proton (H+) and bicarbonate (HCO3_-)
  - $CO_{2(aq.)} + H_2O \rightarrow H_2CO_3$
- Carbonic acid dissociates to form bicarbonate and a proton. The concentration of $CO_{2(aq.)}$, bicarbonate (HCO3_-), carbonate (CO3_2-), proton (H+) and hydroxide (OH-) ions in the ocean water follows the Bjerrum plot, as shown below. The net effect of addition of CO2 (aq.) in the ocean water leads to higher H+ concentration and lower carbonate concentration.



- Dissolved inorganic carbon (DIC) is the sum of dissolved CO2, bicarbonate and carbonate. It is mostly in the form of bicarbonate in the ocean at its ambient pH. Adding CO2 to the ocean does not affect alkalinity (Alk) but it does increase DIC.
  - $DIC = CO_{2(g)} + HCO_3^- + CO_3^{2-}$
  - $CO^{2-}_3 \approx Alk - DIC$
- The release of hydrogen ions (protons) acidifies the ocean surface water.
  - $pH = -\log[H^+]$
- Acidification reduces the ocean's capacity to capture CO2 gas out of the atmosphere since it shifts the proportion of carbon in the ocean towards increasing dissolved CO2 gas in ocean water.

Natural Ocean Drawdown – how the ocean stores CO2

- When organisms make shells from carbonate, they remove some carbon from the water by precipitation and adding acidity. The equilibrium shifts to replace bicarbonate, releasing more hydrogen ions and decreasing the pH. The shells formation further enhances ocean acidification, which is somewhat counter-intuitive, and this process does not lead to ocean drawdown.
  - $Ca^{2+} + CO_3^{2-} \Rightarrow CaCO_3$
  - $HCO_3^- \Rightarrow CO_3^{2-} + H^+$
  - $H_2CO_3 \Rightarrow HCO_3^- + H^+$
- Over a millennial time period, the carbon that is dissolved in the surface water moves deeper, either through physical flow (downwelling),or by conversion to an organic solid mass which precipitates and settles as, for example, decaying biomass. The increase of CO2 in the deep ocean acidifies the water and leads to the dissolution of CaCO3, leading to a buffering of the ocean pH. Unfortunately, this drawdown and buffering is happening too slowly to keep up with the rising anthropogenic atmospheric concentration of CO2.

– $CaCO_3$ -> Ca^{2+} + CO_3^{2-}

- Taking CO2 out of the ocean through aeration raises the pH, then CO2 from the atmosphere dissolves to replace the amount that was lost rapidly. This does not lead to ocean drawdown

Captura Ocean Drawdown – removing atmospheric CO_2 without ocean impact

- The water returned to the ocean in Captura's process has a very low DIC, a higher pH, and unchanged alkalinity.
- The Captura drawdown process is described as follows, a detailed, quantitative map of pH, p_CO2, total alkalinity and DIC can be found in the confidential material separately provided.
  At a very short time-scale (minutes):
  OH- (Captura effluent) + HCO3- (ocean water) CO32- + H2O
  At a longer time-scale (2-4 months in most regions):
  CO2 (air) + CO32- + H2O => 2 HCO3-
- The low concentration of CO2 in the returned water draws CO2 from the atmosphere until the amount of CO2 originally removed is restored to the ocean. This is described by Henry's Law.
  – $CO_{2\,(aq.)} < K_H{*}CO_{2(g)}$
- Equilibrium of water and the atmosphere is instantaneous at the boundary layer. It takes progressively more time to equilibrate large quantities of water with changes in the atmosphere, and this rate is affected by wind speed and mixing rates.

Location and Scaling

By using the ocean as both our air contactor and our absorber, Captura's process lends itself to massive scale. The ocean covers 70% of the world's surface and absorbs ~30% of all CO2 emissions, and thus can be the predominant method of large-scale CO2 removal using Captura's process.

Captura's plants can be situated either on-shore or off-shore and can use either dedicated platforms or make use of existing infrastructure. Ideal locations include the US, Europe, Asia and the Middle East.

Onshore, desalination plants and thermal power plants that use ocean water for cooling provide ideal initial deployment locations owing to the pre-existing infrastructure for water intake and discharge. Offshore, there are thousands of oil or gas platforms. A single platform that has been retired through the energy transition can accommodate ~1M tonnes of Captura carbon removal. Longer term, we envisage dedicated ocean-based platforms in the future as shown in figure 2.

Figure 2: Artists Impression of a Dedicated Captura Plant using Solar Power

Captura's technology lends itself to huge scale. With no air contactors, no absorbents, no rare earth elements, no byproducts, and with modularity in the electrodialysis function and the use of common water-moving equipment, our process can be scaled to meet demand given local power and availability of sequestration sites.

The Captura Difference

Captura differentiates itself through the following unique features:

Lower capital costs

- No purpose-built air contactors
- Widespread use of standard, already-mature industrial equipment (pumping, filtration and gas stripping)
- Ability to leverage existing ocean-based infrastructure such as desalination plants and offshore platforms
- Pre-treatment of only ~0.5% of total ocean water intake
- Highly modular and highly compact design

Lower operating costs

- No absorbents
- No byproducts - eliminates disposal costs
- Increased energy efficiency per tonne of CO_2 removed
- Ability to leverage off-peak renewable electricity

Scalability

- Use of the ocean, which covers 70% of the Earth's surface
- No precious or rare-Earth elements

- No feedstock dependency
- Compatible with ocean locations worldwide
- Produces a stream of CO_2 compatible with multiple sequestration methodologies

Ocean Health

- Requires no change to existing ocean current characteristics
- No addition of absorbents into the ocean
- No change to ocean alkalinity
- Alternatively, technology can enable ocean de-acidification when implemented where deep ocean water mixing currents exist

Social Justice

- Generate job opportunities in the Global South since our systems can be built anywhere there is access to the ocean
- Ocean-based systems with no land-use requirements, avoiding competition with farmland
- Water required is drawn from the ocean or desalination plants that generate waste brine, avoiding fresh water use issues
- Avoiding impacting nearby human communities, especially disadvantaged groups that are already bearing the brunt of climate change
    - No harsh chemicals used or harmful by-products are generated that could impact human health
    - Remote and isolated offshore system locations minimize human disturbance

b. What is the current technology readiness level (TRL)? Please include performance and stability data that you've already generated (including at what scale) to substantiate the status of your tech.

Captura's system design features proprietary electrodialysis technology and conventional water / gas handling equipment combined into a unique, scalable process.

The conventional water / gas handling equipment (filters, pumps, CO_2 stripping, vacuum pumps) are all commercially available – TRL level 9

Captura's overall process is moving into TRL level 6, with ocean water testing underway at Newport Beach with our 1-tonne pilot system (shown in figure 3). We use commercially available membranes in the electrodialysis function for the pilot system.

Figure 3: Captura’s 1-tonne Pilot operating at Newport Beach, California

We are currently building a 100-tonne system which we expect to install at a desalination plant in early 2023, and then upgrade to a 1000-tonne system.

In parallel, we are performing extensive testing on our proprietary membrane technology which enables significant cost reductions. The proprietary membrane technology is at TRL level 4.

Initial results from the 1-tonne system are shown in figure 4. These charts show CO2 concentration >90% in the Captura captured gas stream (the remainder is nitrogen and oxygen which is easily removed) and the fraction of CO2 captured is >90% when the ocean water flows through our equipment.

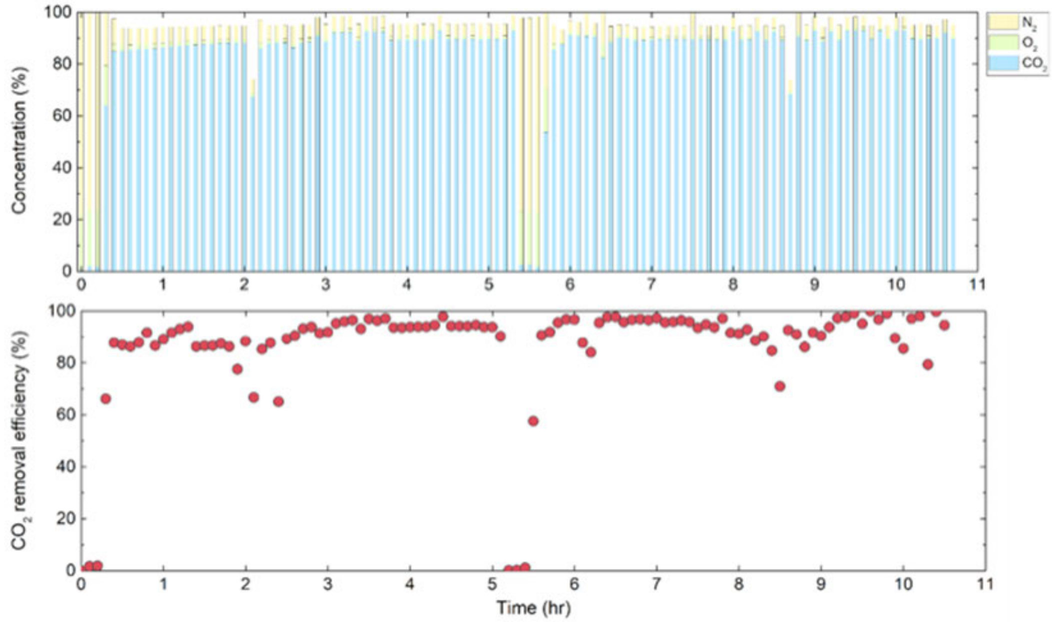


Figure 4: Initial Results from Captura's 1-tonne Pilot

Our proprietary membranes are TRL level 4. Results from the parallel testing of our proprietary membranes can be found in the confidential materials provided separately and show significant improvement compared to commercially available membranes. While the improved performance of our proprietary membranes is important in driving to the lowest cost for carbon removal, existing commercial membranes provide a solution that still results in a cost point competitive with other carbon removal technologies. In the confidential material, we have provided a chart showing the cost point resulting from using standard commercial membranes and the lower costs that result from improved performance in current density, lifetime, and energy efficiency.

c. What are the key performance parameters that differentiate your technology (e.g. energy intensity, reaction kinetics, cycle time, volume per X, quality of Y output)? What is your current measured value and what value are you assuming in your nth-of-a-kind (NOAK) TEA?

Key performance parameter	**Current observed value (units)**	**Value assumed in NOAK TEA (units)**	**Why is it feasible to reach the NOAK value?**
Annual CO2 Capture Capacity	1 ton	1,000,000 tons	Scalability of technology, use of ocean as absorber & air contactor
Membrane – Electrodialysis Efficiency	1.3 MWh/tonne (commercial) 2.4 MWh/tonne (proprietary)	1.4 MWh/tonne of CO2 captured	Improve energy efficiency via proprietary bipolar membrane and next-generation electrodialysis stack design to achieve 1.8-2 V/cell operation
Membrane –	80 mA/cm2	500 mA/cm^2	Proprietary water dissociation

Current Density	(commercial) 500 mA/cm2 (proprietary)		catalysts and bipolar membrane developed at Caltech to achieve high flux operation
Membrane - lifetime	>400 hours	10,000 hours	Improvements on ion exchange membrane binding methods, feed water quality, preventative maintenance cycles and operating parameters to improve membrane lifetime
CO2 Purity	>90%	>90%	Excess gases are oxygen and nitrogen – easily removed if needed
CO2 Capture Efficiency	>90%	95%	Developing proprietary gas liquid contactor materials and device constructs to enable significant CapEx reduction and allow the buildout of series-connected gas-liquid contactor to achieve higher capture efficiency
Electrodialysis Feed Purity	<1 DICAT ppm	0.3 DICAT ppm	Developed a proprietary process for dicational removal using in situ generated feedstocks and achieve low dication feed for electrodialysis

d. Who are the key people at your company who will be working on this? What experience do they have with relevant technology and project development? What skills do you not yet have on the team today that you are most urgently looking to recruit?

Captura was formed at Caltech, enjoying a close relationship with the campus-based research team. Captura's team combines expertise from the carbon removal industry, large scale engineering experience and world class researchers. Our current team is sufficient for our pilot plans. We are recruiting to add more depth and skills in large scale engineering projects.

Steve Oldham – CEO

Former CEO of Carbon Engineering (CE). Steve grew CE from ~15 people to ~150. Significant milestones include building CE's Innovation Centre, raising >$100M in capital, negotiating a major licensing deal with Occidental for multiple large DAC plants and with Airbus for the largest carbon removal purchase to date (400,000 tons).

CX Xiang – CTO & co-founder

Research Professor of Applied Physics and Materials Science at Caltech where the proprietary membrane technology used by Captura was developed. CX's core competencies are in electrochemical devices and systems, and he is the lead researcher on several ARPA-E studies. CX is transitioning into Captura fulltime as his APRA-E research commitments are fulfilled.

Harry Atwater – Chief Science Officer & co-founder

Professor of Applied Physics and Materials Science at Caltech. Harry is an experienced technology entrepreneur and a long-time pioneer in photovoltaics. He is Director of the DOE Energy Innovation Hub and a Member of the National Academy of Engineering. Harry spends his non-Caltech time (~20%) on Captura.

Vlad Sakharov - VP, Engineering

Engineering/Technology leader experienced with management positions (GE, Wabtec, Volvo Group) and large scale international cooperations (CERN, ITER). Vlad directs cross-functional and multidisciplinary teams for New Technology Introduction, New Product Development, Commercialization and Technology Transfer programs in many relevant sectors.

Ibadillah, Cory, Samantha, Soomin, Fenfang – Engineering Team Members

Building and commissioning Captura's pilot systems and their operation

Eowyn, Monica, Ziyuan, Zachary, Emily – Caltech Researchers

Developing and testing the proprietary membrane technology exclusively licensed to Captura

e. Are there other organizations you're partnering with on this project (or need to partner with in order to be successful)? If so, list who they are, what their role in the project is, and their level of commitment (e.g., confirmed project partner, discussing potential collaboration, yet to be approached, etc.).

Partner	**Role in the Project**	**Level of Commitment**
See Confidential Information	Owner of the desalination plant where we plant to install the 100- and 1000-tonne Captura pilots	Concluding a term sheet Captura has backup options should the term sheet not close
Sequestration Partner (e.g. CarbFix, 1PointFive, Encircle Energy, CarbonCure)	We will seek a sequestration partner to store the CO2 from our pilots and are open to suggestions from Frontier	Discussions underway at an early stage
Energy Companies	Installer of large scale commercial Captura projects on decommissioned offshore platforms	Captura is in active discussions with several global energy companies

f. What is the total timeline of your proposal from start of development to end of CDR delivery? If you're building a facility that will be decommissioned, when will that happen?

100-tonne pilot is installed in 2023, upgrading to 1000-tonnes in 2024. Our pilots are long term research instruments, continuously upgraded with improved technology. We have no plans to decommission them.

g. When will CDR occur (start and end dates)? If CDR does not occur uniformly over that time period, describe the distribution of CDR over time. Please include the academic publications, field trial data, or other materials you use to substantiate this distribution.

CDR will start when we upgrade our 100-tonne system to 1000 tonnes in mid-2024. We expect to dedicate ~50% of the 1000-tonne pilot system's capacity to CDR, with the remaining time allocated for system testing, as needed to support our overall R&D program. Our pilots will be an ongoing part of our R&D program for several years.

Our pilots measure the volume of CO2 captured from the ocean so CDR performance is easily quantified.

Captura is open to providing an initial quantity of CDR from the 100-tonne system in 2023 if of interest to Frontier.

h. Please estimate your gross CDR capacity over the coming years (your total capacity, not just for this proposal).

Year	Estimated gross CDR capacity (tonnes)
2023	100 tonnes
2024	Transition to 1000 tonnes expected in mid-2024
2025	1000 tonnes
2026	10,000 tonnes (first commercial desalination project) 100,000 tonnes (first commercial offshore platform project)
2027	As 2026
2028	>1,000,000 tonnes (full commercial offshore platform project)
2029	Additional growth is highly market dependent – no limits on Captura's ability to scale globally given the technology and the use of the ocean
2030	Additional growth is highly market dependent – no limits on Captura's ability to scale globally given the technology and the use of the ocean

i. List and describe at least three key milestones for this project (including prior to when CDR starts), that are needed to achieve the amount of CDR over the proposed timeline.

	Milestone description	Target completion date (eg Q4 2024)
1	Installation of 100-tonne pilot at desalination plant	Q1 2023
2	Upgrade to 1000-tonne pilot	Q2 2024

3	Design phase of commercial project construction initiated (on-shore or off-shore)	Q3 2024
4	First commercial project construction initiated (on-shore or off-shore)	Q1 2025

j. What is your IP strategy? Please link to relevant patents, pending or granted, that are available publicly (if applicable).

Captura works closely with Caltech on IP management for the proprietary electrodialysis and membrane technology. Provisional IPs include i) catalyzed bipolar membrane materials, process, and applications in direct ocean capture, ii) enhanced gas-liquid contactor materials and designs, iii) overall Captura process and stream managements. Non-provisional IP include the electrodialyzer and electrodialysis system for CO2 capture from oceanwater.

k. How are you going to finance this project?

Financing of Captura's work is achieved in a variety of ways.

Initial financing is through grants and early-stage equity:

- The 100-tonne pilot is financed through a commercial contract with SoCalGas ($750k)
- Our R&D and business development work has been financed through our XPRIZE Milestone Award ($1M), ARPA-E ($1.25M), founder equity ($400k) and external equity ($1M)
- The company is currently concluding a Series A raise with support expected from a variety of strategic and financial investors with the funds allocated for on-going R&D and piloting, initial design of commercial systems, ocean modeling and the 1000-tonne system.
- We expect a Series B raise in late 2023 or early 2024 to fund the company through to profitability alongside grant funding from government programs such as the recent US IRA and CHIP Acts.

As the company moves into deployment, we plan to use a licensing business model in which Captura's technology is provided to project developers worldwide, enabling fast and widespread deployment. Project developers will project-finance their plants against the carbon markets (regulated, voluntary or government policy instruments), utilizing both the commercial financing sector (i.e., infrastructure investors) and government programs such as the US Loan Guarantee Program.

Captura will receive a royalty based upon plant revenue, using these funds to focus on continuing to improve our CDR solution through expanded R&D and piloting activities.

l. Do you have other CDR buyers for this project? If so, please describe the anticipated purchase volume and level of commitment (e.g., contract signed, in active discussions, to be approached, etc.).

For our 100-tonne and 1000-tonne pilots, we plan to reserve all of the CDR capacity (50% of total system capacity) for Frontier – we believe Frontier's early advocacy and support for the carbon removal sector provides a win-win opportunity for Captura.

As Captura moves into commercial operations, we fully expect to engage with further CDR buyers across the globe. Captura has initiated briefings with other CDR marketplaces and customers to raise awareness of our technology and solution.

m. What other revenue streams are you expecting from this project (if applicable)? Include the source of revenue and anticipated amount. Examples could include tax credits and co-products.

Currently, we do not expect other revenue streams from the 100-tonne and 1000-tonne pilots. CDR capacity would be provided to Frontier and the remainder of system capacity will be used for testing and upgrades to support our R&D program. We note that the construction of the 100-tonne pilot was funded by SoCalGas under a contract to Captura ($750k).

Captura expects to finance the remainder of its pilot program from our current Series A raise.

It is possible that other entities may be interested in supporting the remaining costs of our 100-tonne and 1000-tonne piloting program. Captura will seek non-dilutive funding opportunities as they arise but plans to reserve the CDR capacity from the pilots for Frontier.

n. Identify risks for this project and how you will mitigate them. Include technical, project execution, ecosystem, financial, and any other risks.

Risk	Mitigation Strategy
No agreement reached with Desalination partner to host the Captura pilots	Captura is actively working to develop backup opportunities for hosting our 100-tonne and 1000-tonne pilots
Air-Sea Interchange and 1-1 correlation of carbon credits	Captura is working with ocean scientists and carbon platforms to confirm that our pathway produces a molar volume of atmospheric CO2 removal equivalent to our measured volume of ocean CO2 removal
Ocean health impacts	Captura is working with the ocean health community to confirm that our process has zero or minimal impact on the ocean
No sequestration partner found	Finding a sequestration partner for small quantities of CO2 is challenging. Captura will approach multiple candidates and welcomes any suggestions from Frontier.

2. Durability

a. Describe how your approach results in permanent CDR (> 1,000 years). Include citations to scientific/technical literature supporting your argument. What are the upper and lower bounds on your durability estimate?

Captura removes CO2 from the ocean, enabling the ocean to remove an equivalent amount of CO2 directly from the atmosphere. The CO2 we remove from the ocean is then available for sequestration by a third party, using approved methods.

The ‘replacement’ CO2 that the ocean then absorbs from the atmosphere is stored in the form of bicarbonate which provides permanent storage for >10,000 years [IPCC Special Report on Carbon dioxide Capture and Storage: Ocean Storage, https://www.ipcc.ch/site/assets/uploads/2018/03/srccs_chapter6-1.pdf]

Captura will work with a variety of sequestration companies to permanently remove the CO2 we capture. Examples with differing approaches include CarbFix, Equinor, 1PointFive, Cella and Encircle Energy.

We expect the sequestration industry to develop significantly over the next decade, backed by Government support and commercial demand. Each commercial Captura plant will partner with a sequestration provider suitable for the plant location, with a site-specific LCA produced for the combination of the Captura capture technology and the sequestration methodology.

Captura sees great benefit in focusing on the most effective, low-cost atmospheric carbon capture solution and utilizing a growing sequestration service industry to provide the permanent removal of the resulting CO2.

For our pilots, Captura is open to partnership with emerging sequestration technologies that can be located in California. We welcome suggestions from Frontier on potential sequestration partners.

We have not provided upper and lower bounds for durability estimates as these will come from the sequestration partner.

b. What durability risks does your project face? Are there physical risks (e.g. leakage, decomposition and decay, damage, etc.)? Are there socioeconomic risks (e.g. mismanagement of storage, decision to consume or combust derived products, etc.)? What fundamental uncertainties exist about the underlying technological or biological process?

As described in the response to 2(a), Captura provides the capture function and relies on the growing sequestration industry for the storage of the resulting CO2.

The sequestration sector is best positioned to answer this question and Captura intends to work with many different sequestration partners as our technology is deployed globally.

We have not commented on fundamental uncertainties of the sequestration process as these will come from the sequestration partner.

3. Gross Removal & Life Cycle Analysis (LCA)

a. How much GROSS CDR will occur over this project’s timeline? All tonnage should be described in **metric tonnes** of CO_2 here and throughout the application. Tell us how you calculated this value (i.e., show your work). If you have uncertainties in the amount of gross CDR, tell us where they come from.

Gross tonnes of CDR over project lifetime	9800 gross tonnes CDR between the years 2024 -2033 for the 1000 tonne pilot
Describe how you calculated that value	The 1000 t/yr scale Captura system will be deployed at a desalination plant detailed in the confidential material, which will hereto in be referred to as “the selected desalination plant”. The desalination plant uses a reverse osmosis process to provide potable water from ocean water to nearby communities, while safely releasing concentrated brine back into the ocean. A desalination plant provides significant near-term advantages for our pilot: an existing permit, rigorous existing measurement protocols and equipment, existing pumping and filtering of ocean water that we require and the brine outflow from these plants is a highly effective inflow to our process. However, the location does come with the constraint of using the energy source already provided to the desalination plant. While leveraging an existing grid interconnection will expedite deployment, it does influence the life cycle greenhouse gas emissions of the pilot as electricity generation is the primary source of emissions. Commercial Captura plants will not have this constraint and can use all renewable energy. Captura’s carbon removal system is comprised of electrodialysis (ED), CO2 stripping, and clarifier units which were co-developed to run as efficiently as possible. Captura will partner with off takers of CO2 and will work with Frontier for guidance on such partnerships, including geologic sequestration as there are several well-studied sites relatively close to the selected desalination plant. In our base case LCA, we assume the captured CO2 is compressed and injected into a pipeline to a geologic sequestration injection site, while treated brine is returned to the ocean. When collocated with a desalination plant, no additional filtering of the intake water is required. The project is expected to have a 98% capacity factor resulting in a capture of 9800 gross tonnes over the lifespan of the project (2024-2033). The LCA is performed for a functional unit of 1 metric tonne of captured CO2. Energy consumption was derived from process flow diagrams developed by Captura and adjusted using scaling factors for equipment provided in Captura’s TEA. Electricity consumption was converted into upstream greenhouse gas emissions, including CO2, CH4, and N2O, based on region-specific life cycle emissions associated with electricity generation. We assume electricity is provided by the grid connection already established at the selected desalination plant. All systems are assumed to operate on grid electricity, and emissions associated with electricity generated are subtracted from the gross tonnes of CO2 capture to derive a net capture of 6906 tonnes-CO2 for the desalination based pilot project. Values for Captura’s carbon intensity are sensitive to the source of electricity (Figure 8). For comparison, an emission factor of 0.011 kg

	CO2eq/kWh can be assumed for wind power. This value for wind was developed by a harmonization analysis conducted by the National Renewable Energy Lab of LCAs of onshore wind electrical generation. If the most energy intensive unit in the Captura process is oversized to run intermittently on wind power, and the rest of the system is run continuously on the grid, the net capture would be 9458 tonnes-CO2. Based on our LCA, the 1000 tonne pilot project Captura system has a carbon intensity (CI) of 0.035 kg CO2eq-emitted/kgCO2-captured if run on the grid and the ED is run on wind power, and 0.295 kg CO2eq-emitted/kgCO2-captured if run only on the grid. This includes emissions associated with capture and sequestration, as described in Section g. Greenhouse gas emissions associated with the system's material manufacturing, delivery and end of life are negligible over the 10-year lifespan of the project. Emissions associated with leaks from the CO2 pipeline and injection site were conservatively included and are minor (0.026% leakage rate per year). An LCA was also performed for the full scale commercial Captura system, which is designed to be deployed on medium to large, retired oil and gas rigs to avoid the capital cost of constructing offshore platforms. At the commercial scale, the Captura system differs from the 1000 tonne pilot project in that it will have its own intake pumping system, it has a 95% capacity factor, and it achieves improved energy efficiency of the ED system at the larger scale of 1 million tonnes. With the planned deployment using wind power, the commercial Captura system would have a CI of 0.021 kg CO2eq-emitted/kgCO2-captured (noted with a star in Figure 8). So, a 1Mt Captura plant will have an annual net capacity of 930,000 tonnes-CO2, assuming a 95% capacity factor.

b. How many tonnes of CO_2 have you captured and stored to date? If relevant to your technology (e.g., DAC), please list captured and stored tons separately.

Captura captures CO2 from our first 1-tonne pilot at the rate of 2.7kg/day, but has not stored the captured CO2 given the small test quantities

c. If applicable, list any avoided emissions that result from your project. For carbon mineralization in concrete production, for example, removal would be the CO_2 utilized in concrete production and avoided emissions would be the emissions reductions associated with traditional concrete production. Do <u>not</u> include this number in your gross or net CDR calculations; it's just to help us understand potential co-benefits of your approach.

We assume captured CO2 is injected into a geologic formation and there are no avoided emissions. We would like to work with other Frontier candidate sequestration technologies to sequester the CO2 we capture with our pilot systems.

d. How many GROSS EMISSIONS will occur over the project lifetime? Divide that value by the gross CDR to get the emissions / removal ratio. Subtract it from the gross CDR to get the net CDR for this project.

Gross project emissions over the project timeline *(should correspond to the boundary conditions described below this table)*	2894 tonnes-CO2eq are expected to be emitted between the years 2024-2033 as we are constrained to run on the regional electricity grid.
Emissions / removal ratio *(gross project emissions / gross CDR–must be less than one for net-negative CDR systems)*	0.295 CO2eq-emitted/kgCO2-captured if run on the regional electricity grid.
Net CDR over the project timeline *(gross CDR - gross project emissions)*	6906 tonnes-CO2eq is the expected net CDR between the years 2024-2033 if run on the regional electricity grid.

e. Provide a process flow diagram (PFD) for your CDR solution, visualizing the project emissions numbers above. This diagram provides the basis for your life cycle analysis (LCA). Some notes:

- The LCA scope should be cradle-to-grave
- For each step in the PFD, include all Scope 1-3 greenhouse gas emissions on a CO_2 equivalent basis
- Do not include CDR claimed by another entity (no double counting)
- For assistance, please:
  - Review the diagram below from the CDR Primer, Charm's application from 2020 for a simple example, or CarbonCure's for a more complex example
  - See University of Michigan's Global CO_2 Initiative resource guide
- If you've had a third-party LCA performed, please link to it.

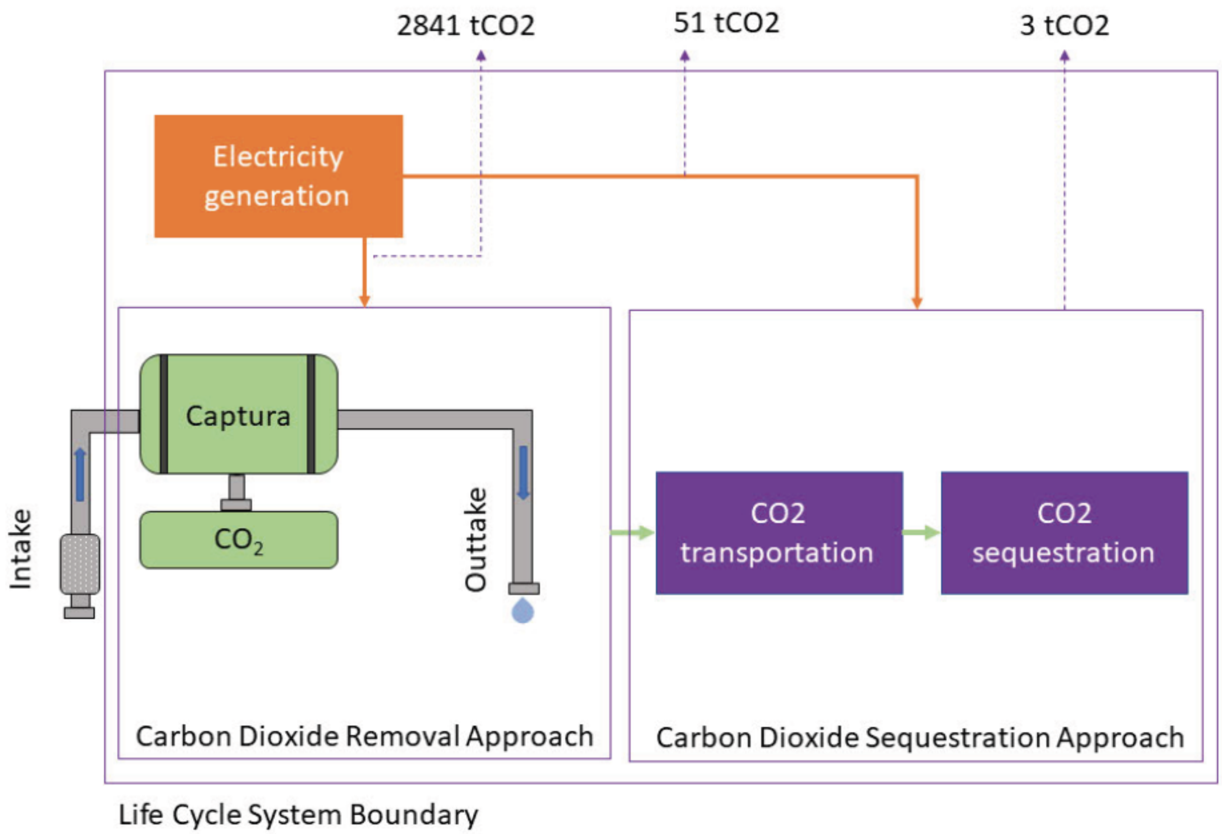


Figure 7. Life cycle system boundary with greenhouse gas emissions from life cycle phases provided for the life span of the 1000 t/yr project at the selected desalination plant.

A third party LCA was performed by an environmental engineering consultant as part of our successful XPRIZE Milestone submission and a link to that is included in the confidential supplement. The same third-party consultant has performed the LCA work in this application.

f. Please articulate and justify the boundary conditions you assumed above: why do your calculations and diagram include or exclude different components of your system?

Processes were included in the system boundary shown in figure 7 if they result in significant energy or material inputs or outputs. CO2 pumping and injection, and electricity generation required top-down modeling, while the rest of the process was modeled bottom up from the process design. As we will not increase the amount of water being processed by the selected desalination facility, intake pumping was not included in the system boundary. Geologic sequestration site development such as drilling associated with the sequestration site was not included.

g. Please justify all numbers used to assign emissions to each process step depicted in your diagram above. Are they solely modeled or have you measured them directly? Have they been independently measured? Your answers can include references to peer-reviewed publications, e.g. Climeworks' LCA paper.

Process Step	CO_2(eq) emissions over the project lifetime (metric tonnes)	Describe how you calculated that number. Include references where appropriate.
Electricity for electrodialysis unit	2757 tonnes	Energy consumption was derived from process flow diagrams developed by Captura (1.9 kWh/kgCO2 captured). An analysis was performed on the emission intensity of the regional electricity grid serving the selected desalination plant. The utility has aggressive targets for lowering electricity related greenhouse gas emissions, aiming for net zero by 2045. Decreasing grid emission factors reported between 2009 and 2020 and a reported target reduction of 52.5% between 2019 and 2030 were used to extrapolate annual emission factors over the lifespan of the Captura project. The average emission factor of the grid over this period is 0.15 kgCO2-eq/kWh.
Electricity for CO2 stripper unit	84 tonnes	Energy consumption was derived from process flow diagrams developed by Captura (0.058 kWh/kgCO2 captured). Emission factor for grid electricity calculated the same as above.
Electricity for compression, pumping, and injection of CO2	51 tonnes	Energy consumed by the compression and injection of CO_2 at 2000 m depth for the 1,000 tonnes CO_2/yr scale project (35 kWh/tonne) was estimated using values from an LCA of ocean geologic sequestration. The energy consumed (0.035 kWh/kgCO2 captured) reflects a system compressing CO_2 to 15.2 MPa into a pipeline and to recompression for injection into a formation (8 MPa/km depth plus overhead pressure). [Reference: Khoo, Hsien H., and Reginald BH Tan. (2006) Life cycle investigation of CO_2 recovery and sequestration. Environmental Science & Technology. 40, 4016-4024.] Emission factor for grid electricity calculated the same as above.
CO2 leakage from pipeline and injection system	3 tonnes	Emissions associated with leaks from the CO_2 pipeline and injection site were conservatively included but were minor (0.026% leakage rate per year, using an average leakage rate for natural gas pipelines).

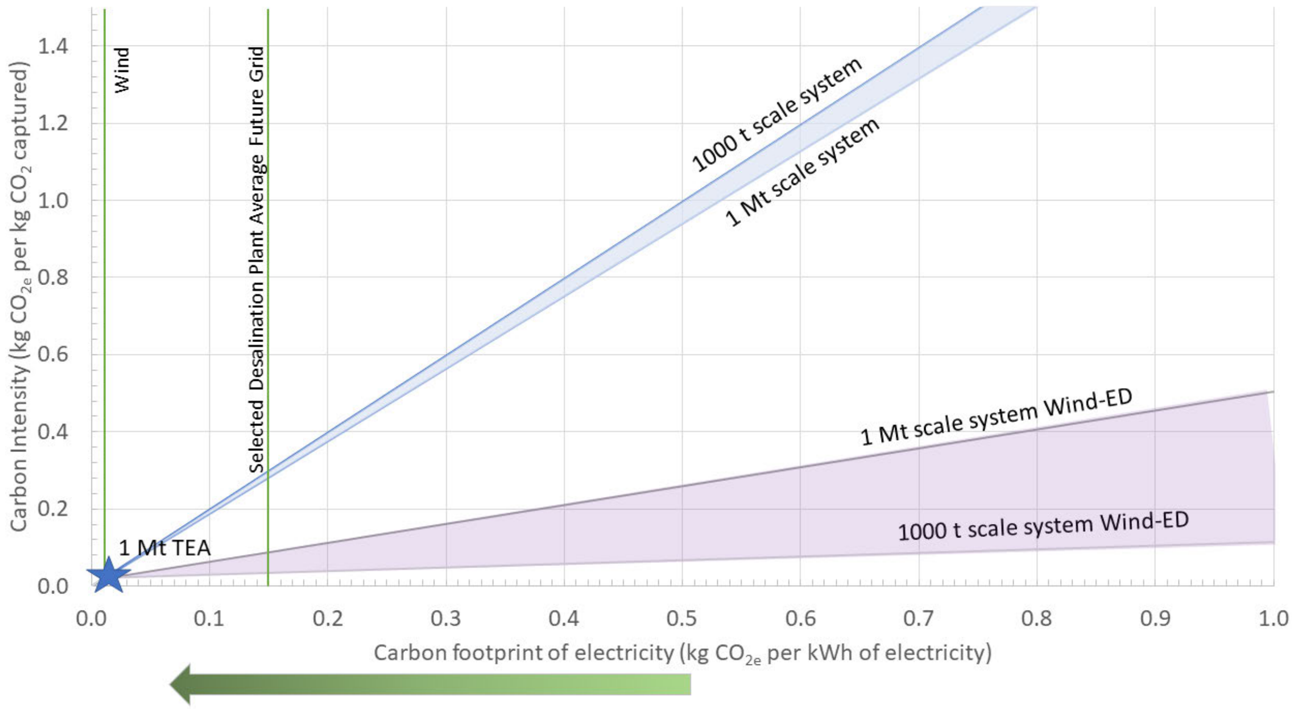


Figure 8. Greenhouse gas emission intensity of the Captura capture and sequestration process in units of CO2 equivalence per unit of CO2 captured, given an emission intensity of the source of electricity. Running the electrodialysis unit (ED) on wind power (purple) will substantially lower the upstream emissions of the Captura process, as compared with a system run only on the same source of electricity (blue). The 1 Mt scale system, as described previously, is the commercial scale Captura system presented in the TEA. It has a higher carbon intensity than the 1000 t scale system in the case where the ED is run on wind power, as we assume the system is not collocated with a desalination facility and has intake pumping energy requirements. Otherwise, it has a slightly lower carbon intensity than the 1000 t scale system due to the improved energy efficiency achieved in the ED unit.

4. Measurement, Reporting, and Verification (MRV)

Section 3 above captures a project's lifecycle emissions, which is one of a number of MRV considerations. In this section, we are looking for additional details on your MRV approach, with a particular focus on the ongoing quantification of carbon removal outcomes and associated uncertainties.

a. Describe your ongoing approach to quantifying the CDR of your project, including methodology, what data is measured vs modeled, monitoring frequency, and key assumptions. If you plan to use an existing protocol, please link to it. Please see Charm's bio-oil sequestration protocol for reference, though note we do not expect proposals to have a protocol at this depth at the prepurchase stage.

The quantity of CO2 directly removed from the intake water stream will be measured as it is a quantity of gas produced and delivered into a pipeline for subsequent injection into a geologic formation. The resulting drawdown that occurs from returning our treated water back into the desalination outflow and then into the ocean is modeled following Henry's Law, as described in section 1a. We are developing in-house capability both in modeling and simulation of ocean-air draw-down process and experimental validation of CO2 absorption kinetics and timescale at a range of conditions for Captura's process.

CO2SYS or similar software packages are used to quantify chemical equilibria for inorganic carbons in oceanwater. We will develop a numerical model for the discharged oceanwater plume near a large-scale direct ocean capture (DOC) system, coupling flow and chemical kinetics, and perform model experiments enabling prediction validation of the three-dimensional pH distribution as functions of depth and lateral distance from an operating DOC system, so as to determine the rate of additional carbon drawdown from the atmosphere in the DOC process.

We will design and construct a lab-scale, controlled atmosphere, experimental convection ocean water tank system for validation of CO_2 drawdown at the air/oceanwater interface. Most existing literature reports a flux at near-equilibrium, e.g., (400 ppm air)/(DIC=2.2 mM, pH=8.1 native oceanwater). The typical residence time for the near-equilibrium case is ~2-4 months. We expect a higher drawdown rate by placing our plants in optimal locations and will quantify the rate of reaction with elevated pH (~8.5) and higher carbonate concentration.

The quantity of electricity consumed by the electrodialysis unit, the CO2 stripper, and any ancillary equipment such as the CO2 compressor will be measured and metered.

b. How will you quantify the durability of the carbon sequestered by your project discussed in 2(b)? If direct measurement is difficult or impossible, how will you rely on models or assumptions, and how will you validate those assumptions? *(E.g. monitoring of injection sites, tracking biomass state and location, estimating decay rates, etc.)*

Captura's RFP response is based on carbon capture from our pilot plant. Finding a sequesterer for small quantities in California is difficult and Captura would be happy to take suggestions from Frontier for sequestration services proposed into your RFP.

For commercial plants, we expect to sequester in geological formations (e.g. depleted oil and gas fields), often undersea, taking advantage of our ocean-based locations.

Technologies for injecting CO2 into geologic formations are mature. Using an existing injection site avoids new permits, well drilling, site assessment, and other upstream processes of establishing a site. Monitoring includes evaluating pressure and monitoring surface and shallow subsurface for leaks. Periodically a well will undergo integrity testing.

No enhanced oil or gas recovery is planned. No emission of the injected CO2 is expected over >100 years.

Sequestration sites are selected for characteristics that prevent CO2 from escaping, with some monitoring of surface water and shallow subsurface water required. The US EPA Safe Drinking Water Act Underground Injection Control (UIC) program (permit Class VI) regulates injection sites and extends even into offshore waters. Following this program will confirm storage permanence, which is important for compliance with the Clean Air Act Greenhouse Gas Accounting Rule.

c. This tool diagrams components that we anticipate should be measured or modeled to quantify CDR and durability outcomes, along with high-level characterizations of the uncertainty type and magnitude for each element. We are asking the net CDR volume to be discounted in order to account for uncertainty and reflect the actual net CDR as accurately as possible. Please complete the table below. Some notes:

- In the first column, list the quantification components from the Quantification Tool relevant to your project (e.g., risk of secondary mineral formation for enhanced weathering, uncertainty in the mass of kelp grown, variability in air-sea gas exchange efficiency for ocean alkalinity enhancement, etc.).
- In the second column, please discuss the magnitude of this uncertainty related to your project and what percentage of the net CDR should be discounted to appropriately reflect these uncertainties. Your estimates should be based on field measurements, modeling, or scientific literature. The magnitude for some of these factors relies on your operational choices (i.e., methodology, deployment site), while others stem from broader field questions, and in some cases, may not be well constrained. We are not looking for precise figures at this stage, but rather to understand how your project is thinking about these questions.
- See this post for details on Frontier's MRV approach and a sample uncertainty discount calculation and this Supplier Measurement & Verification Q&A document for additional guidance.

Quantification component Include each component from the Quantification Tool relevant to your project	**Discuss the uncertainty impact related to your project** Estimate the impact of this component as a percentage of net CDR. Include assumptions and scientific references if possible.
Air gas exchange	The rate of dissolution of CO2 into seawater depends on the rate of mass transfer, which is a surface phenomenon. It is driven by the CO2 concentration in the air and surface water, wind and mixing, and by local solubility. [Reference: Broecker W.S. and T.-H. Peng (1974) Gas Exchange rates between air and sea. Tellus, 26, 21-35.] Regional variations to the pCO2, dissolved inorganic carbon, pH and other key parameters of ocean carbonate chemistry are possible due to differences in timescales of perturbations and equilibration. Diffusion of CO2 into seawater occurs quickly but only at the surface. The rate of mixing at the air-water interface is enhanced by wind-driven convection, with local variability. Based on measurements of global carbonate chemistry, it appears pCO2 is more sensitive to local disturbances, and is somewhat decoupled from temperature and air-sea gas equilibrium predictions than other variables such as the saturation point of aragonite. The saturation point of aragonite is strongly influenced by temperature and dissolved oxygen, explaining why it is relatively homogeneous latitudinally. Air-sea exchanges are on the order of month timescales to fully equilibrate the top 100 m of the ocean and tend to have small effects on surface seawater carbonate chemistry that is altered rapidly through disturbances such as ocean upwelling. In-situ measurements may be possible. The selected desalination plant can provide in-situ measurements of key properties of the carbonate system of the effluent water that will lower uncertainties.

Storage, Leakage	Dependent on the sequestration partner but uncertainty for geologic sequestration is considered low to negligible in the quantification tool. We conservatively include a leakage emission in our above LCA.
Materials	Materials used in the construction of the pilot plant must be manufactured and delivered to the selected desalination facility. There are embodied emissions associated with these steps, however when amortized over the 10-year lifespan of the project, the emissions are negligible. The Captura process generates and then fully utilizes its own chemicals and will not have regular consumables aside from energy.
Energy	Electricity is consumed by the Captura process and for the compression, transportation, and injection of captured CO2 into a geologic sequestration site. The impact of the source of energy on the life cycle emissions is a key sensitivity of the project and has been rigorously modeled and discussed in the above LCA results. The expected 42% reduction in emissions proposed by the regional utility servicing the selected desalination plant will directly impact the life cycle emissions of the project by 15%. However, the commercial Captura process can be located anywhere and can be run completely on renewable energy, removing this uncertainty.
Energy replacement emissions	The 1000 tonne pilot plant would require ~0.2 MW of electric generation capacity, which would be considered an extremely small, distributed generation (<=10 MW) that would not require the local utility to build new base load. At the commercial scale, Captura would deploy its own renewables and would not be taking renewable electricity from other grid users.

d. Based on your responses to 4(c), what percentage of the net CDR do you think should be discounted for each of these factors above and in aggregate to appropriately reflect these uncertainties?

> 0% for air gas exchange (Henry's Law)
> Treated water will be exposed to air with brine effluent, so concerns of inconsistent air-sea exchange will not be a major uncertainty.
>
> 0% for storage, leakage (already included), materials, energy related emissions
>
> 5% for energy as suggested by the quantification tool

e. Will this project help advance quantification approaches or reduce uncertainty for this CDR pathway? If yes, describe what new tools, models or approaches you are developing, what new data will be generated, etc.?

If selected, Captura's proposal to Frontier will be the first application of Captura's CDR pathway – a unique process for carbon removal and subsequent credit generation. As described in 3(a), Captura will measure the quantity of CO2 captured from the ocean water and utilize Henry's Law to justify an equivalent removal of CO2 from the atmosphere as described in 1(a).

In parallel with the pilot project, Captura will be working with ocean scientists to develop a common understanding of the ocean characteristics that affect the rate of CO2 drawdown from the atmosphere. This drawdown rate depends on water currents and average weather characteristics. Air-sea flux data is readily available but has not been used for this purpose before.

Hence, this project is expected to be a world first for this CDR pathway – a key enabler for widespread deployment of the Captura technology and other ocean CDR approaches.

When Captura fields commercial plants, we will continue to measure the CO2 extracted from the ocean and we will also have developed a full ocean model for the selected location, allowing a high degree of confidence in the duration for the resulting ocean drawdown.

f. Describe your intended plan and partners for verifying delivery and registering credits, if known. If a protocol doesn't yet exist for your technology, who will develop it? Will there be a third party auditor to verify delivery against that protocol or the protocol discussed in 4(a)?

We plan to work with all the major CDR pathway companies or entities to have our approach verified. We have briefed many of the major credit marketplaces but, to date, we have found that these companies / entities are focused on existing facilities, making the task of achieving a pre-qualification challenging. We anticipate that the announcement of an agreement with Frontier will help expedite the process.

We are open to having a third-party auditor verify delivery against an applicable protocol, should we find an auditor willing to provide the service.

Note that we do not anticipate supplying credits to any other credit purchaser other than Frontier for the duration of any contract we agree with Frontier.

5. Cost

We are open to purchasing high-cost CDR today with the expectation the cost per tonne will rapidly decline over time. The questions below are meant to capture some of the key numbers and assumptions that you are entering into the separate techno-economic analysis (TEA) spreadsheet (see step 4 in Applicant Instructions). There are no right or wrong answers, but we would prefer high and conservative estimates to low and optimistic. If we select you for purchase, we'll work with you to understand your milestones and their verification in more depth.

a. What is the levelized price per net metric tonne of CO_2 removed for the project you're proposing Frontier purchase from? This does not need to exactly match the cost calculated for "This Project" in the TEA spreadsheet (e.g., it's expected to include a margin), but we will be using the data in that spreadsheet to consider your offer. Please specify whether the price per tonne below includes the uncertainty discount in the net removal volume proposed in response to question 4(d).

\$984 per tonne of CO_2 removed using our 1000-tonne pilot This price is after adjustment for the uncertainty discount and reflects Captura's investment into the 1000-tonne pilot

b. Please break out the components of this levelized price per metric tonne.

Component	Levelized price of net CDR for this project (\$/tonne)
Capex	~70% or \$689/tonne
Opex (excluding measurement)	~30% or \$295/tonne
Quantification of net removal (field measurements, modeling, etc.)[2]	Nominal cost for measurement devices installed in the pilot – included as part of the Capex
Third party verification and registry fees (if applicable)	We do not expect to incur these fees for our pilot
Total	(should match 5(a))

c. Describe the parameters that have the greatest sensitivity to cost (e.g., manufacturing efficiencies, material cost, material lifetime, etc.). For each parameter you identify, tell us what the current value is, and what value you are assuming for your NOAK commercial-scale TEA. If this includes parameters you already identified in 1(c), please repeat them here (if applicable). Broadly, what would need to be true for your approach to achieve a cost of \$100/tonne?

Parameter with high impact on cost	Current value (units)	Value assumed in NOAK TEA (units)	Why is it feasible to reach the NOAK value?
Membrane Performance KPIs	See 1(a)	See 1(a)	R&D progress is very encouraging. See Confidential Information for a plot showing the membrane performance KPI trades vs resulting CO2 cost/tonne. The plot shows that \$100/tonne can be achieved with many combinations of KPIs
Renewable Electricity Pricing	Not Applicable as the pilot is constrained by location to use grid power	\$10 off-peak \$40 on-peak Produces an average of \$15 per MW/h	Our 1Mt plant design overbuilds the electrodialysis function so it only operates for 6 hours but generates sufficient acid and base for the rest of the plant to run 24 hours. Hence, our most energy intensive process operates on off-peak renewable

[2] This and the following line item is not included in the TEA spreadsheet because we want to consider MRV and registry costs separately from traditional capex and opex.

			energy. Pricing used by Captura reflects generic information from US-based renewable energy providers
Capital Cost	Not applicable – we have not built a 1Mt facility yet	$532M Total Overnight Cost derived by the TEA tool	We believe the NOAK CapEx calculation to be conservative. While our electrodialysis function is at TRL-4, the remainder of our equipment is at TRL-9 (standard, pumping, filtration, pre-treatment, gas stripping and vacuum pumps). We used TRL-4 in our NOAK inputs to reflect the lowest TRL level of our technology but ~75% of the Bare Erected Cost is TRL-9 equipment rather than TRL-4. We are therefore confident that our Total Overnight Cost will fall below the $532M derived value.

d. What aspects of your cost analysis are you least confident in?

The capital cost of the first 1Mt system. To date, our focus is the technology and process for carbon removal from the ocean, leading to our current pilot plant operations. We have worked with suppliers to assess equipment costs at large-scale but have not yet worked with the engineering community to derive an optimal large plant design and construction cost. Frontier's TEA is useful in outlining a cost model for the scaling and Captura has recently hired a VP Engineering who will work with engineering companies to develop an initial design and cost estimate of the 1Mt system.

e. How do the CDR costs calculated in the TEA spreadsheet compare with your own models? If there are large differences, please describe why that might be (e.g., you're assuming different learning rates, different multipliers to get from Bare Erected Cost to Total Overnight Cost, favorable contract terms, etc.).

Actually – quite well. The Frontier NOAK TEA estimates $100/tonne and our model estimates ~$80/tonne. The primary difference is in the capital cost for which the NOAK TEA estimates ~125% process and project contingency and we estimate a lower number based on the heavy re-use of existing equipment and processes.

Fundamentally, we regard the Captura system as a standard water handling system (similar to a desalination plant) with a unique electrodialysis function which is ~25% of CapEx. We therefore assign higher contingencies for the electrodialysis but lower values for the rest of the system.

The NOAK TEA treats the entire system as being at the TRL level of the electrodialysis and hence ends up with a much higher capital cost.

As described in 1(d), a major focus for us in the next 12-18 months is working with 3rd parties to develop a design for a large-scale Captura system and a resulting cost estimate.

f. What is one thing that doesn't exist today that would make it easier for you to commercialize your technology? (e.g., improved sensing technologies, increased access to X, etc.)

> A credible carbon credit organization ready to confirm that our process removes the same quantity of CO_2 from the air that we remove from the ocean. The chemistry is clear, but our process is unique and hence not yet validated in the market.

6. Public Engagement

In alignment with Frontier's Safety & Legality criteria, Frontier requires projects to consider and address potential social, political, and ecosystem risks associated with their deployments. Projects with effective public engagement tend to:

- Identify key stakeholders in the area they'll be deploying
- Have mechanisms in place to engage and gather opinions from those stakeholders, take those opinions seriously, and develop active partnerships, iterating the project as necessary

The following questions help us gain an understanding of your public engagement strategy and how your project is working to follow best practices for responsible CDR project development. We recognize that, for early projects, this work may be quite nascent, but we are looking to understand your early approach.

a. Who have you identified as relevant external stakeholders, where are they located, and what process did you use to identify them? Please include discussion of the communities potentially engaging in or impacted by your project's deployment.

> Captura is an early-stage company, so we have not spent significant time on public engagement. We have an active relationship with Bernard David (of the Global CO_2 Initiative and a Scripps Board Member) and he has helped us with initial connections. Our close association with Caltech also provides access to many in the academic community.
>
> Our primary focus for public engagement is the groups associated with ocean health. In the near term, this involves working with the oceanography community to educate them on Captura's process and receive any recommendations they have on mitigating any perception of ocean impact. We have already started that process through a relationship with Ocean Visions and initial conversations with Woods Hole and Scripps. On completion of our Series A raise, we will have funds for active engagement with these groups and we also plan to hire an internal oceanographer.
>
> Longer term, the permit process associated with plant deployment will involve interaction with communities potentially involved in our projects. We expect the majority of Captura's deployment to be ocean-based, rather than shore-based, so direct impact to communities should be limited. Rather, we hope to demonstrate that deployment of our technology can provide continued employment and economic benefit to communities affected by the energy transition.
>
> Captura intends to deploy its technology through licensing partners. Those partners will be established companies with ties into the communities in which they operate. Captura will work with our licensing partners to implement best practices for all community engagement.

b. If applicable, how have you engaged with these stakeholders and communities? Has this work been performed in-house, with external consultants, or with independent advisors? If you do have any reports on public engagement that your team has prepared, please provide. *See Project Vesta's community engagement and governance approach as an example and Arnestein's Ladder of Citizen Participation for a framework on community input.*

> Captura has started a relationship with Ocean Visions under their LaunchPad program, through which we work with selected oceanographers on our process and its interaction with the ocean.
>
> On completion of our Series A fund raise, we will hire internal ocean health expertise alongside further external experts. We also plan to engage both public and government relations expertise, delivering public education about ocean-based CDR as an effective and minimally disruptive tool in the fight against climate change.
>
> Captura intends to deploy its technology through licensing partners. Those partners will be established companies with ties into the communities in which they operate and hence a good understanding of the issues facing local communities, making them well-suited to engage with stakeholders and best serve their interests. Captura will work with our licensing partners to implement best practices for all community engagement.

c. If applicable, what have you learned from these engagements? What modifications have you already made to your project based on this feedback, if any?

> To date, feedback from the oceanographers has been very positive on the Captura process and any potential impact on ocean health. We have discussed ways in which the Captura process can address discharge pH levels, should these be higher than recommended for a particular location, and we have also discussed the potential for our technology to assist in ocean de-acidification in areas where this is causing challenges for marine life.

d. Going forward, do you have changes to your processes for (a) and (b) planned that you have not yet implemented? How do you envision your public engagement strategy at the megaton or gigaton scale?

> Currently, we do not expect to have to adjust our process for specific public engagement concerns, but we will of course be prepared to do so if needed.
>
> As we scale up deployment, we will plan to emphasize the significant benefits our technology provides for carbon removal and ocean health, plus the benefits of local employment and economic activity that result from deployment. We will work with third party advocates on public outreach and will collaborate with local developers for deployment across the globe.

7. Environmental Justice[3]

As a part of Frontier's Safety & Legality criteria, Frontier seeks projects that proactively integrate environmental and social justice considerations into their deployment strategy and decision-making on an ongoing basis.

a. What are the potential environmental justice considerations, if any, that you have identified associated with your project? Who are the key stakeholders? Consider supply chain impacts, worker compensation and safety, plant siting, distribution of impacts, restorative justice/activities, job creation in marginalized communities, etc.

> A significant advantage is our offshore location, away from any human populations. We do not compete for land or freshwater since we require neither. Captura has no rare earth elements or material supply chain impacts: we only use renewable energy and ocean water and avoid limitations from the use of chemical absorbents.
>
> Captura enables job creation in marginalized communities that have borne the brunt of climate change as our technology can be deployed in coastal communities globally. We enable a climate justice solution where carbon removal is deployed in the Global South, paid for by those nations with high historical emissions.
>
> By utilizing existing infrastructure made redundant by the energy transition, we support fossil fuel workers and their communities.
>
> Captura provides a major market for offshore renewable power. We provide large scale carbon removal without requiring the land based renewable power needed for decarbonization. This is beneficial for accelerating the energy transition and phasing out fossil fuels by creating more demand for offshore renewable energy.
>
> Our ocean location, above sequestration sites, avoids the need for land-based CO2 pipelines.
>
> Key stakeholders will be coastal communities that may have our systems within sight or use the ocean as a food source.

b. How do you intend to address any identified environmental justice concerns and / or take advantage of opportunities for positive impact?

> We will need to engage with coastal communities that may have our systems within sight to communicate the purpose and benefits of our systems and educate people on the non-disruptive nature of our solution. Where we reuse existing ocean infrastructure such as oil and gas platforms, there would be no change for communities that have visibility of those platforms. For communities that use the ocean for fishing or other economic activity, we will work with oceanographers to model and mitigate any impact.

[3] For helpful content regarding environmental justice and CDR, please see these resources: C180 and XPRIZE's Environmental Justice Reading Materials, AirMiners Environmental and Social Justice Resource Repository, and the Foundation for Climate Restoration's Resource Database

For global deployment, we will work with licensing partners around the world to offer Captura's technology for local deployment. Our licensing business plan enables in-country partners to site Captura plants at optimal locations, employing local people during construction and operation of the plant. Our licensing partners will be accustomed to business operations in their local region and will be able to work with local communities and government agencies to ensure concerns are addressed and opportunities realized.

8. Legal and Regulatory Compliance

a. What legal opinions, if any, have you received regarding deployment of your solution?

We have not received any legal opinions to date. However, we have talked extensively with owners of current ocean water-based infrastructure (desalination plants and offshore energy platforms) and received positive feedback from both these sectors and no material concerns have been expressed.

b. What permits or other forms of formal permission do you require, if any, to engage in the research or deployment of your project? What else might be required in the future as you scale? Please clearly differentiate between what you have already obtained, what you are currently in the process of obtaining, and what you know you'll need to obtain in the future but have not yet begun the process to do so.

Captura's 1-tonne pilot is operating with ocean water at Caltech's marine lab and is covered by their existing permits. Our 100-tonne and 1000-tonne pilots are planned for an existing desalination facility and are expected to require minimal or no change to the existing permits at that facility.

Deployment of commercial plants will require permitting and we expect to engage expertise from the existing offshore infrastructure sector, including our development partners who will have extensive experience in offshore permitting.

Captura's process fundamentally does not alter ocean water, so we anticipate that permits will be forthcoming, though subject to extensive review.

c. Is your solution potentially subject to regulation under any international legal regimes? If yes, please specify. Have you engaged with these regimes to date?

So far, we do not believe this is the case.

d. In what areas are you uncertain about the legal or regulatory frameworks you'll need to comply with? This could include anything from local governance to international treaties. For some types of projects, we recognize that clear regulatory guidance may not yet exist.

The largest uncertainty is likely the jurisdiction under which permits are granted for offshore operations (which tends to change depending on distance from the shore). However, there is an extensive body of

existing offshore facilities so we will work with the experts from the energy sector to derive the best strategy.

e. Do you intend to receive any tax credits during the proposed delivery window for Frontier's purchase? If so, please explain how you will avoid double counting.

We do not expect to receive tax credits from our pilots as they are expected to be US based and are not of sufficient size to qualify for the US 45Q credit.

9. Offer to Frontier

This table constitutes your **offer to Frontier**, and will form the basis of contract discussions if you are selected for purchase.

Proposed CDR over the project lifetime (tonnes) *(should be net volume after taking into account the uncertainty discount proposed in 4(c))*	508 tonnes Captura is open to providing an initial small quantity of CDR from mid-2023 from our 100-tonne pilot
Delivery window *(at what point should Frontier consider your contract complete? Should match 1(f))*	18 months: Mid 2024 to end 2025 Captura is open to providing an initial small quantity of CDR from mid-2023 from our 100-tonne pilot
Levelized Price (\$/metric tonne CO_2) *(This is the price per tonne of your offer to us for the tonnage described above)*	$984

Frontier

Application Supplement: DAC

(Only fill out this supplement if it applies to you)

Note: these questions are with regards only to air capture: e.g. your air contactors, sorbents or solvents, etc. Separately, there exist Geologic Injection and CO_2 Utilization supplements. We anticipate that most companies filling out this DAC supplement should ALSO fill out one of those supplements to describe their use of the CO_2 stream that's an output of the capture system detailed here.

Physical Footprint

1. What is the physical land footprint of this project, and how do you anticipate this will change over the next few years? This should include your entire physical footprint, i.e., how much land is not available for other use because your project exists. Also, what is the estimated footprint if this approach was removing 100 million tons of CO_2 per year?

Land footprint of this project (km^2)	Zero – Captura's process is ocean based Direct Air Capture
Land footprint of this tech if scaled to 100 million tons of CO_2 removed per year (km^2)	Zero

Capture Materials and Processes

1. What material(s) is/are you using to remove CO_2?

> Just ocean water and renewable electricity. The ocean acts as our air contactor and absorber.

2. How do you source your material(s)? Discuss how this sourcing strategy might change as your solution scales. Note any externalities associated with the sourcing or manufacture of it (e.g., hazardous wastes, mining, etc.). You should have already included the associated carbon intensities in your LCA in Section 3.

> A huge advantage of the Captura approach is that the ocean already exists at massive scale. Essentially, Captura's air contactor and absorbents for Giga-tonne scale already exist, cover 70% of the planet's surface, re-generate naturally, have a proven track record of carbon absorption and there is almost no conflict with their use for Captura deployment.

3. How much energy is required for your process to remove 1 net tonne of CO_2 right now (in GJ/tonne)? Break that down into thermal and electrical energy, if applicable. What energy intensity are you assuming for your NOAK TEA?

<100 words

Captura's energy use is all electrical. Our 1-tonne pilot uses 18 GJ/tonne and our NOAK TEA anticipates 6.4 GJ/tonne. The large difference between the two is mainly due to the inefficient pumping at the very small pilot scale.

4. What is your proposed source of energy for this project? What is its assumed carbon intensity? How will this change over the duration of your project? (You should have already included the associated carbon intensities in your LCA in Section 3).

We plan to install our pilots at a desalination facility and will therefore be tied to the energy grid at that location. The confidential information identifies the likely desalination site.

Commercial plants will deploy either on-shore or off-shore. Onshore plants will use localized renewable energy where feasible or access the local grid power. Offshore plants can utilize shore-based renewable power when they are located within ~50kn of the shore. Over time, we expect to deploy using ocean-based renewable power from wave, wind and solar sources.

5. Besides energy, what other resources do you require (if any, such as water)? Where and how are you sourcing these resources, and what happens to them after they pass through your system? (You should have already included the associated carbon intensities in your LCA in Section 3).

We just require ocean water. Access to ocean water is readily available worldwide and we return ocean water to its native state once absorption of atmospheric CO2 occurs.

6. Do you have experimental data describing how your system's CDR performance changes over time? If so, please include that data here and specify whether it's based on the number of cycles or calendar life.

Our TEA includes a regular replacement cycle for our filters and membranes as we do anticipate a reduction in performance over time. This area is the subject of significant R&D at Captura and is not yet ready for sharing.

7. What happens to your capture medium at end-of-life? Please note if it is hazardous or requires some special disposal, and how you ensure end-of-life safety.

We budget a regular replacement cycle for our filters and membranes. The remaining elements of the system will have very long lifetimes as demonstrated by their commercial use today. As such, the system lifetime is likely to be many decades. At end of life, much of the plant equipment can be recycled for other applications or re-used as scrap metal.

There are no hazardous or rare-earth elements in the Captura technology.

8. Several direct air technologies are currently being deployed around the world. Why does your DAC technology have a better chance to scale and reach low cost than the state of the art?

Fundamentally, Captura uses the ocean as both the air contactor and absorber, with no by-products and no need to re-generate or replace absorbent.

This provides a considerable cost saving as:

- the equipment used to move large volumes of air is typically a dominant part of the capital expense of a DAC plant
- the cost to source and replace (or re-generate) absorbents is significant
- the cost to dispose of byproducts is significant

The use of the ocean also enables lower energy usage and cost:

- Significantly higher concentration of ocean-based CO2 means we move much less ocean water than DAC systems move air
- The low capital cost of electrodialysis allows Captura to overbuild this high-energy function so that it can run for 6 hours a day while the plant runs 24 hours – enabling the use of off-peak energy

Finally, use of the ocean is much better suited for scaling:

- The ocean covers 70% of the world's surface, it exists and it’s zero cost
- No resource competition for fresh water, land utilization or absorbent material

Application Supplement: Ocean

(Only fill out this supplement if it applies to you)

Physical Footprint

1. Describe the geography of your deployment, its relationship to coastlines, shipping channels, other human or animal activity, etc.

> Captura's technology can be deployed in most of the ocean. To remove atmospheric CO2, we need our de-carbonized ocean water to interact with the atmosphere, so we will use locations where the shallow and deep ocean layers have very limited or no interaction. Most of the ocean fits this characteristic. (If our discharged water goes into the deep ocean, we will de-acidify the ocean but not draw down atmospheric CO2.)
>
> The rate of CO2 drawdown from the atmosphere into the ocean is defined by the mixing characteristics of the shallow ocean. This is a well-understood phenomenon and we will seek to deploy plants where the mixing rate is higher, leading to faster atmospheric drawdown.
>
> We expect to deploy mostly offshore, however we do see considerable potential for deployment at existing shore-based facilities (desalination plants or power utilities). Here, our technology can co-exist with their existing purpose and within their existing permits.

2. Please describe your physical footprint in detail. Consider surface area, depth, expected interaction with ocean currents and upwelling/downwelling processes, etc.

   a. If you've also filled out the Biomass supplement and fully articulated these details there, simply write N/A.

> Captura plants are installed on an ocean-based platform or on the shoreline.
>
> We currently estimate a 1 million tonne per annum Captura plant will occupy about 80,000 sq ft and weigh ~6000 tons. This enables such a plant to be installed on a typical oil and gas platform as these platforms reach end of life.
>
> We have no significant dependency on ocean currents but do seek locations with limited up/down welling and a reasonable degree of shallow ocean mixing (see question 1 response).

3. Imagine, hypothetically, that you've scaled up and are sequestering 100Mt of CO_2/yr. Please project your footprint at that scale, considering the same attributes you did above (we recognize this has significant uncertainty, feel free to provide ranges and a brief description).

   a. If you've also filled out the Biomass supplement and fully articulated these details there, simply write N/A.

The easiest way to think of this is that we will have installed our technology on 100 retired oil and gas platforms. Discussions with experts from the energy sector have indicated that ~100 such platforms are retired each year when their oil/gas fields become depleted, and these platforms become uneconomic. As the energy transition proceeds, it is reasonable to expect that this number will increase further. Converting an uneconomic platform (which will frequently sit on top of a potential sequestration site) to a profitable Captura CO2 removal plant will be of interest to the platform owner.

Similarly, the desalination sector can adopt Captura's process with almost no impact – simply adding our technology on to the back of their process which generates brine as a waste product. A similar example is true for shore-based power utilities using ocean water for cooling.

We can therefore envisage a major deployment of Captura's technology with no change to the existing footprint of the offshore energy sector and the onshore power and desalination sectors.

Over time, we envisage purpose-built offshore Captura platforms to continue deployment beyond the capacity of the existing ocean infrastructure.

Potential to Scale

4. Building large systems on or in the ocean is hard. What are your core engineering challenges and constraints (not covered already within 1(n)? Is there any historical precedent for the work you propose?

It is correct that ocean-based infrastructure is more challenging, which is why we intend to deploy first using onshore locations and using existing ocean-based platforms.

Captura is already in discussions with several large energy companies who have extensive experience in offshore installations, and we expect to form partnerships to further develop these interactions.

Captura's technology primarily consists of unique electrodialysis and gas stripping technology, with industry standard water pumping, filtration, and pre-treatment. We therefore see the challenge of offshore installation as very manageable – we are using equipment for water handling that has extensive heritage.

In the near term, Captura's primary challenge is adding the expertise into our team for ocean-based installation. We plan to do so via strategic hires and partnering with established industry experts. In our planned Series A activities, we will do an initial design and cost estimate for a large offshore installation.

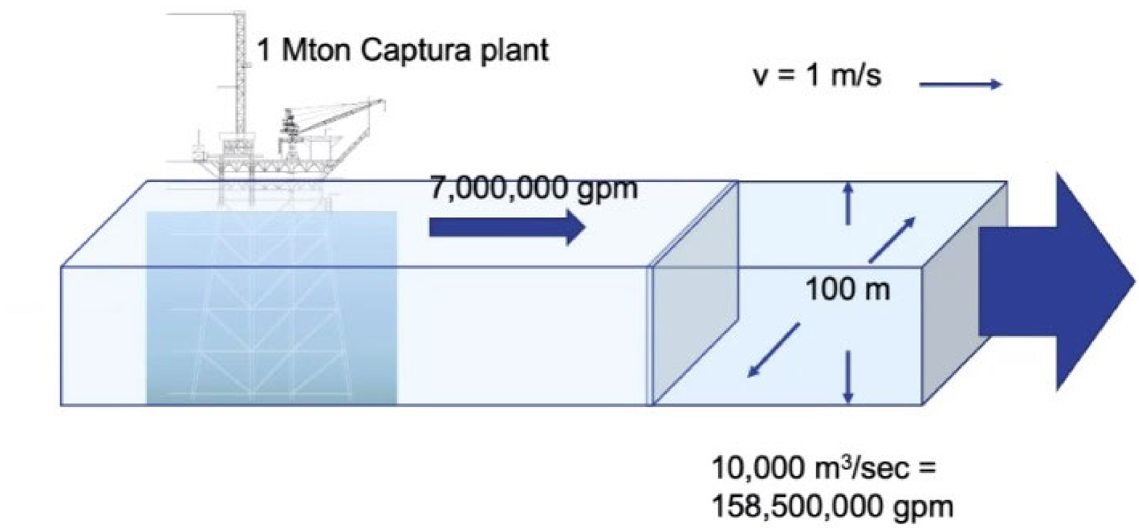
Externalities and Ecosystem Impacts

5. What are potential negative impacts of your approach on ocean ecosystems?

The Captura process adds nothing to the ocean and removes only CO2, which the atmosphere then re-introduces. We therefore expect no lasting negative impacts on ocean ecosystems.

At the outflow of a Captura plant, there will be a plume of de-carbonized and higher pH ocean water. This plume will rapidly integrate with the prevailing ocean current to restore pH and the drawdown of atmospheric CO2 will restore CO2 levels.

The outflow of a Captura plant is relatively small compared to the general ocean movement. The diagram below shows our outflow in the context of 1 meter/second ocean flow. The decarbonized oceanwater from Captura's process after ~5X of dilution from native oceanwater via natural convective mixing will bring down the pH within 8.1 to 8.5 with minimal impact to the ocean ecosystem.



6. How will you mitigate the potential for negative ecosystem impacts (e.g., eutrophication and alkalinity/pH)? How will you quantify and monitor the impact of your solution on ocean ecosystems and organisms?

Our process leaves ocean water in its native state except for a very slight increase in alkalinity which assists in de-acidifying the oceans.

At a particular site, we will model the ocean characteristics so that the short term and localized effect of higher pH and de-carbonized water outflow can be assessed, and any mitigation can be addressed. For example, we could integrate a stream of raw ocean water with our outflow stream to restore pH on outflow.