Applicant Instructions: Prepurchase track

Thank you so much for your work on carbon dioxide removal (CDR), and thank you in advance for taking the time to apply for Frontier's purchase. Please read the following information carefully and in full before beginning your application, as well as take a look at Frontier's Fall 2022 Request for Proposals which includes information regarding our target purchase criteria, how we review applications, and what our team is looking for. For your reference, all previously submitted applications are available here (2020-2021) and here (2022 onwards).

We invite you to attend one of two application coaching sessions we will be hosting at 9 am PDT on Sept 20 and 10 am PDT on Oct 4 for general application guidance. If you have any further questions as you work through, please email us at suppliers@frontierclimate.com.

Timeline

- **October 7, 2022 9:00 pm PDT:** This application is due. You are welcome to submit early.
- **Mid October:** Frontier will review your application for completeness and basic scientific validity with respect to our criteria. Qualified applications will be sent to our expert reviewers for review against the criteria we outlined in the RFP. Each application will receive 2 scientific reviews and 1 governance review.
- **Early November:** Frontier will share anonymous reviewer comments and questions with you, and give you two days to submit a response to these comments, if you choose to.
- **Mid November:** Frontier will invite a subset of applicants to advance to a video interview to discuss your application.
- **Late November:** Frontier finalizes decisions and notifies applicants of prepurchase and small offtake (FYI, a separate template) awards. Together, Frontier and teams define renewal criteria, project milestones, and tonnage pricing within Frontier's standard purchase agreement templates. Larger offtake applicants will be notified if they are Finalists and invited for additional diligence that we will perform in early 2023.
- **Mid December:** Frontier will announce prepurchase and small offtake purchases and upload applications to Frontier's public GitHub.
- **First half of 2023:** Frontier's review team will conduct additional diligence with larger offtake Finalists, including a site visit to your facility.
- **Mid 2023:** Frontier signs larger offtake agreements.

How to apply

Step 1: Determine which category supplements apply to your project

- This document includes the General Application as well as all category supplements. All applicants should fill out the General Application, as well as whichever (typically 1 - 2) supplements apply to your approach.
- You should fill out applicable supplements IN ADDITION to the General Application.
- Using examples from Frontier's existing portfolio:
  - AspiraDAC would fill out the DAC supplement AND the Geologic Injection supplement.
  - Lithos Carbon would fill out the Surface Mineralization/Enhanced Weathering supplement
  - Running Tide would fill out the Biomass supplement AND the Ocean supplement.
  - CarbonBuilt would fill out the CO_2 Utilization to storage supplement.
- If it's not clear which supplements apply to your project, please ask at suppliers@frontierclimate.com.

Step 2: Delete the supplements that don't apply to you.

- This results in a document with the General Application and your applicable supplements only. Please delete these first four pages of instructions too!

Step 3: Fill out the application in this document.

- If you have any questions, attend one of two application coaching sessions we will be hosting at 9 am PDT on Sept 20 and 10 am PDT on Oct 4 for general application guidance or email us at suppliers@frontierclimate.com. Please reach out with questions as early in the application process as possible.

Step 4: Complete the techno-economic analysis (TEA) spreadsheet.

- We included a Google Sheet containing a TEA in the same Google Drive folder (specific to your application) as this template. Instructions on how to fill it out are included in the START HERE tab.
- We recorded a webinar with instructions for filling out the spreadsheet. The passcode is provided in your application invitation. We encourage you to review the spreadsheet early on and ask any questions you might have–either by email or attending an application coaching session.

Step 5: Prepare any materials you would like to submit confidentially [optional].

- We remain committed to a public RFP process because commercial-scale permanent CDR is a nascent field, and we are trying to advance transparency and knowledge-sharing across the ecosystem. However, companies applying for a prepurchase will be able to share select information confidentially.

- A confidential addendum, which can be up to six pages, may be submitted. It should be limited only to select data (e.g., specific site locations or supplier names, material formulations, revealing performance data, business plans, etc.) you wish to exclude from the main application. This confidential addendum and the TEA spreadsheet will not be made public.
- To submit a confidential addendum, create a Google Doc or upload a Word or PDF to the same Google Drive folder as this application and the TEA. All of your application materials must be in this folder.
- Frontier's expert reviewers have non-disclosure agreements (NDAs) in place with Frontier. If you have any concerns around confidentiality, please contact our team to discuss.

Step 5: Submit your application by October 7, 2022 9:00 pm PDT

- This application, the TEA spreadsheet, and confidential addendum (if applicable) must be in the Google Drive folder by this time.
- **Your submission constitutes your consent for Frontier to make your full application and all of its content - excluding the TEA spreadsheet and confidential addendum– available publicly under a CC-0 "Public Domain" License, regardless of whether or not Frontier selects you for purchase.** For more details, see "Why we make applications public" below.

What we're looking for

Please refer to Frontier's [Fall 2022 Request for Proposals] for a characterization of projects Frontier is excited to support and details on our selection process. There, we discuss the three lenses we use when making purchase decisions: approach, execution, and portfolio. Our approach criteria are:

Criteria	Description
Durability	Stores carbon permanently (>1,000 years)
Physical footprint	Takes advantage of carbon sinks less constrained by arable land
Cost	Has a path to being affordable at scale (<$100 per ton)
Capacity	Has a path to being a meaningful part of the carbon removal solution portfolio (>0.5 gigatons per year)
Net negativity	Results in a net reduction in atmospheric carbon dioxide
Additionality	Results in net new carbon removed, rather than taking credit for removal that was already going to occur
Verifiability	Has a path to using scientifically rigorous and transparent methods for monitoring and verification
Safety and legality	Is working towards the highest standards of safety, compliance, and local environmental outcomes; actively mitigates risks and negative environmental and other externalities on an ongoing basis

Why we make all applications public

All applications to our earlier purchase cycles were made public, and can be accessed here and here. We're grateful to all our applicants for providing this level of transparency; hopefully this will enable impact beyond the dollar amount of any particular purchase we may make, including visibility and the opportunity for potential collaborators and investors to connect with you. Making applications public enables subsequent academic works and independent analysis from nonprofits like CarbonPlan (examples here, here), and we've heard from a wide range of investors, engineers, and scientists that the shared applications are a valuable source of data on the current state of the field and opportunities for advancement. For these reasons, we're again making applications from this purchase cycle primarily public.

That said, in previous cycles, some companies have told us that this level of transparency can be challenging, particularly if the company is in stealth or in the process of patent filing. We understand the need to balance transparency with protecting business-sensitive information, and thus will accept a confidential addendum that will not be published. We still expect as much information as possible to be included in the public-facing portion of the application so that it is a comprehensive, standalone representation of the merits of what you're building.

Fine print

We intend to make the selection process as informal as possible. However, we do expect that (a) the content of your application is, to the best of your knowledge, complete and correct; (b) you do not include any content in your application that breaches any third party's rights, or discloses any third party's confidential information; (c) you understand that we will publicly publish your application, excluding the TEA spreadsheet and materials in the confidential addendum, at the conclusion of the selection process. You also understand that Frontier is not obliged to explain why or how it decided to purchase the CDR that it did, and that Frontier may decide to not purchase CDR from your application or make an offer to purchase less than what you proposed. Finally, if you are selected as a recipient for funding, Frontier will not be under any obligation to provide you with funding until such time as you and Frontier sign a formal written agreement containing the funding commitment.

Acknowledgements

Frontier gratefully acknowledges assistance and discussions from the following, who helped improve this application template and our purchasing process:

- AirMiners environmental justice working group for their many suggestions on the Public Engagement and Environmental Justice section
- CarbonPlan for their partnership on shaping measurement, verification and reporting requirements
- M. Van der Spek (Heriot-Watt University) for developing the TEA spreadsheet
- Microsoft and XPRIZE Foundation for perspective on life cycle analysis (LCA) and TEA tools

[Company Name]

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

Sinkco Labs

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

Copenhagen, Denmark

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

Viji Thomas

Brief company or organization description <20 words

Sinkcolabs use algae biomass to sequester carbon in deep-sea sediment while producing compounds as co-benefits.

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 figure 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.<1500 words

<u>Technical summary:</u>
Sinkco Labs couples marine photosynthesis to carbon sequestration.
We leverage the power of seaweeds to capture and sequester atmospheric CO_2 in deep-sea sediments, at geological timescales all while employing low energy and water efficient processes.

<u>The biology:</u>

[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.

We rely on large scale pond aquaculture of fast growing algae species, such as *Ulva sp.* and *Gracilaria sp.* for rapid and efficient atmospheric CO_2 fixation. The remnant biomass, which is carbon rich, is then sequestered into deep-sea sediments (~4,000 m depth) using our proprietary delivery technology -SINKCORE.

Carbon sequestration at geological timescales:

We sequester carbon by using a novel biogeomimetic approach, building on existing deep-sea carbon dioxide removal (CDR) technologies, while adding significant improvements and addressing the fulcral flaws of those technologies.
Our unique deployment approach - Burial of Organics in Sub Sediment (BOSS) - consists of two major systems: the SINKCORE and the TRIMSY.
Together they ensure the burial of encapsulated biomass below the sediment in the abyssal plain (deeper than 3, 500 m), which assures the permanent capture of carbon. The encapsulation of the biomass offers physical protection against grazing by macrofauna and meiofauna, which would already be limited due to the low total fauna present (Wei et al., 2010). Low temperatures and high pressures compromise the enzymatic processes of the bacteria attached to our biomass, resulting in a much slower degradation (Turley CM, 2000; de Jesus Mendes et al, 2007). Our biogeo mimetic approach protects the organic matter exudating from our biomass from bacterial degradation (Hedges et al., 2001; H Cheng et al., 2012). Most importantly, any fractional CO_2 that might be formed by degrading our biomass will be trapped into clathrates, not dissolving into the water column (Fahed Qureshi et al, 2022). This ensures an environmentally safer way to store captured CO_2 for millions of years (Ocean Vision, 2022; GESAMP, 2019).

The aim of the SINKCORE technology is to, using only gravity, transport carbon from the ocean's surface to the deep sea with enough velocity to ensure full penetration of the device under the sediment surface.
The SINKCORE consists of a hemp canvas sleeve into which algal biomass is compressed and mixed with a high density proprietary mineral mix. A piston pressurizes the payload to form a rigid cylinder and expel excess moisture and a ceramic nose cap and bamboo fins are added to the cylinder to form the complete SINKCORE. A natural hydrophobic coating is added to passively increase the sinking velocity. The clay penetrator tip stabilizing fins ensure a vertical sinking and the deepest possible penetration.

Figure 1: Computer rendering of the SINKORE (left); Photo of SINKCORE under construction (right).

The TRIMSY (Transport and Immersion System) is optimized for use with the SINKCORE, although it can be used with other containers to deliver organic or inorganic matter to the deep-sea. The Trimmsy is designed to be used by any ship capable of transporting containers on deck.

The Trimmsy consists of a modified shipping container of any standard size. It contains one or several mechanical racks where the SINKCORE hangs through the means of a fast release hook. The rack operates autonomously, guided by an integrated computer + GPS system, to release the SINKCORE at pre-programmed geographic coordinates.

The Trimmsy has an extension of the rack that extends over the board of the ship, to allow the SINKCORE to be released overboard and into the ocean. This extension can include weather-proofing side panels. This extension can also include a sleeve chute to ease the fall of the SINKCORE into the ocean. The Trimmsy can be equipped with a GPS and a computer to release the SINKCORE or equivalent container at pre-programmed geographic coordinates. The computer logs the geographic coordinates of the release of a SINKCORE.

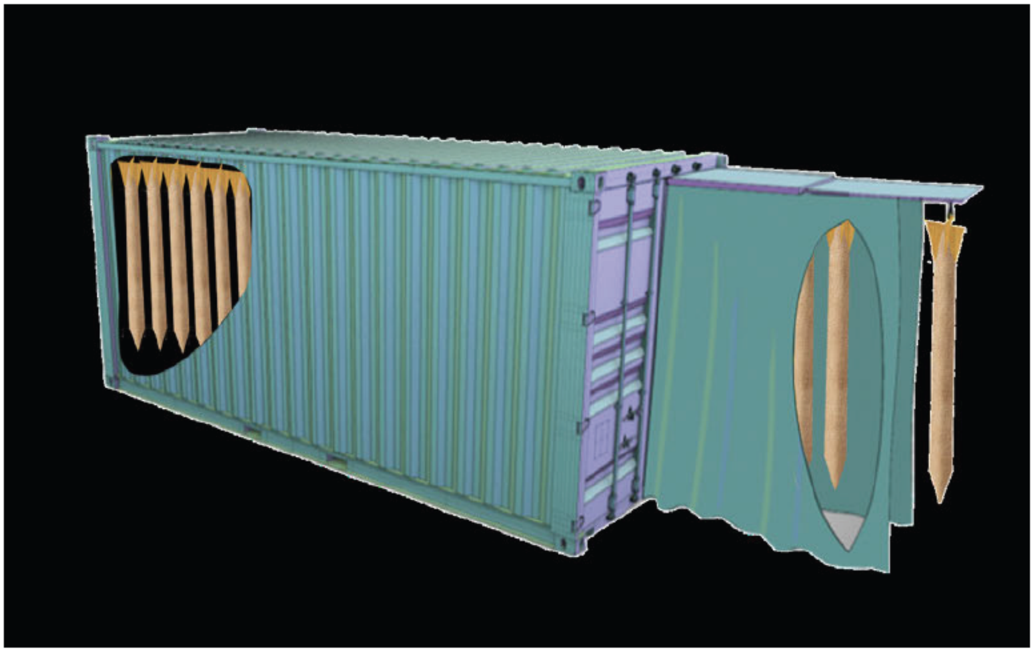


Figure 2: Computer rendition of the TRIMSY.

Figure 3. Field work in collaboration with local fishermen with a 2 m SINKCORE prototype.

Locations:

- R&D and pilot-scale tests are to be done in Europe, with various partner groups, in France, Portugal and Denmark. For MRV we will base our sel on existing similar MRV experimental processes carried by Running tides.
- Scale-up: The final Atlantis units are to be built near-shore
- Later seaweed cultivation with an offshore platform.

Our Differentiator:

The stand out aspect of this technology lies in the energy efficiency of the overall process and our patented C-delivery tool which enables transportation to the sub-sediment at depths that ensure permanent C storage, unlike previous technologies of other initiatives. Our main focus to ensure the long term capture of C is to ensure the durability of the sinking process. The biomass is stored beneath the sediment to reduce uncertainty related to C remineralization to the water column and eventual resurfacing and degassing to the atmosphere due to the deep-sea recirculation. The storage method reduces the area of the seafloor impacted by storing the biomass vertically. This also benefits monitoring approaches as there is a smaller area of sediment to monitor the impacts on the surrounding environment.

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. <500 words

SINKCORE:
SINKCORE is a gravity-driven surface-to-sediment delivery system. Its efficiency has been calculated through rigorous mathematical modeling based on the model. The results of this modeling are shown in Figure 3. Also, a simulation was conducted using AutoCad Fusion 360 Event Simulation which measures the impact, penetration and suitability of the design and materials. Prototypes have been studied *in situ* to validate the speed, density and shape of the SINKCORE, as well as later, a Phase I optimization study. Initial prototype models were made of high density materials to verify the potential of sinkage (Figure 4). Data generated by *in situ* experiments showed that the model underestimated the sinking potential of the SINKCORE, reaching a sub-sediment depth of 120% of the model forecast, proving that cores can fully penetrate below the sediment surface when having a minimum density of 1642 $kg.m^3$, which will result in an impact speed of 65km/h. A third party LCA was conducted on the technology and verified its validity. Currently, a Phase II *in situ* material optimization study is being carried out as well as engaging with collaborators for the SINKCORE manufacturing. We are also currently engaging with two leading EU oceanographic partners to prepare our wider scale pilot demonstration study.

The advances of the project have been shared with the coalition entity Ocean Vision with enthusiasm and received support from expert scientists, including jury members from previous projects such as Running Tide.

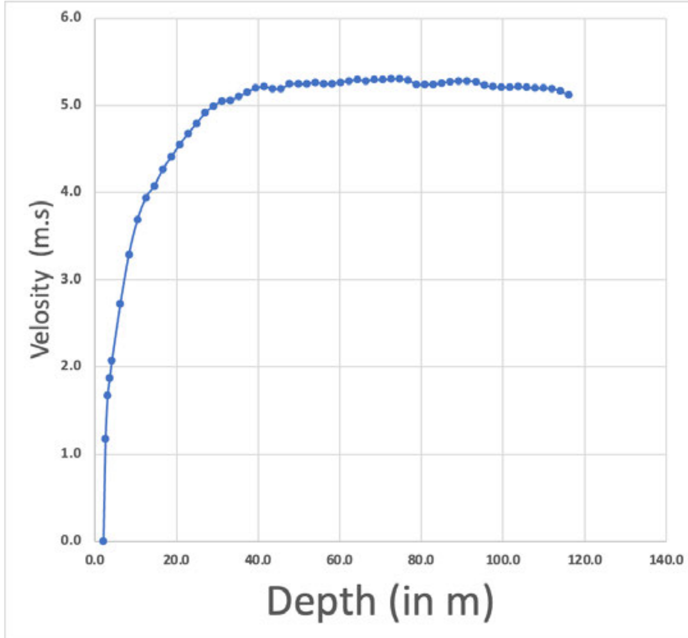


Figure 3. Modeling of speed and depth requirements.

Figure 4. Preparation of SINKCORE initial trials.

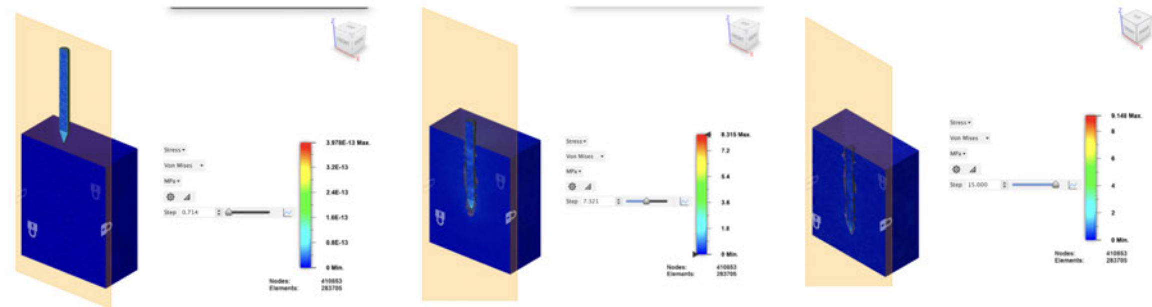


Figure 5. Example of the simulation with FUSION 360 AUTOCAD for the preliminary study of the structural material of the sinkcores. Video simulation of a cross section of the SINKCORE penetrating the deep sea sediment.

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?
Energy / ton of CO2 net (Capture)	171 MJ/ $tCO_{2\ gross}$	168 MJ/ tCO_2 gross	1) The cultivation of our feedstock is generally not energetically demanding as we use an integrated multi trophic aquaculture (ITMA) system, where the energy required by the pump, and the nutrients needed are highly reduced compared to a classic pond system.
Energy / ton of CO2 net (Storage)	1089 MJ/ tCO_2 gross	665 MJ/ tCO_2 gross	1) By reducing the water content in our algae from 85% to 40 %, we increase the density of carbon in our SINKCORE, hence reducing the overall distance required for its transport at sea. 2) Automated production line

			with a belt converter for the filling of our SINKCORE and loading in the Trimssy container further diminishes the energetic demand of the system.
Overall Energetic demand Capture + Storage	1261 MJ/ tCO_2 gross	834 MJ/ tCO_2 gross	Review energy
Emission to Removal (Capture)	0.062	0.022	1) The emission relative to the production of fertilizer is reduced by 80%, as we will be able to recycle the nutrients present in our biomass during our phase of algae cultivation.
Emission to Removal (Storage)	0.054	0.033	1) By reducing the water content in our algae from 85% to 45 %, we increase the density of carbon in our SINKCORE, hence reducing the emission relative to the distance required for its transport at sea. 2) Because more carbon is compacted in each SINKCORE, the number of SINKCORE required is diminished and the emission relative to their manufacturing decreases.
Cost MRV / tCO_2	406$/ tCO_2	7$/ tCO_2	As a result of David Ho's (University of Hawaii) efforts to increase MRV research funding in the US, it is estimated that one day it will be possible to quantify the carbon flux between air and sea. As a result, we estimate that we have the tool required

			to lower the cost of our MRV / tCO 2 regarding the flux of carbon air-sea as well as the risk of leakage by the time of our NOAK. We still accounted for a small amount of MRV cost in order to carry long term monitoring on the durability of our carbon storage via *in situ* sensors.

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?

Collectively our team is composed of professors, postdocs, PhDs and entrepreneurs in the fields of molecular biology, deep-sea ecology, carbon cycling, hydro/structural dynamics and ocean engineering, climate science, bioprocess engineering and sustainability. Operation are subdivided into 2 core groups being managed by our specialists:

1. Carbon capture and storage:

That will be managed by Pedro De Jesus Mendes (PhD), who specializes in ocean carbon fluxes, as well as marine technology. Working with him, Marta Maria Cecchetto (PhD), is an expert in deep-sea ecology and biogeochemistry,.
Advising to that group is Hamid Sarlak (PhD), a fluid dynamicist and marine engineer and is currently an Assoc. Prof. of Aero- and Fluid Dynamics at the technical University of Denmark.

2. Strategic operations ;

Guenter Rottenfusser (PhD) has been working at BCG for 15 years where he has worked with many large multinational corporations across various industries. Many of the projects included global markets and the key focus of most projects was on Europe, South and North America.
Viji Thomas with consulting in F&B experience in 4 continents has experience leading teams with different backgrounds (designers, architects, shareholders, operations). He has experience supporting team members and creating synergy inside a group. He has deep connections within the F&B industry. He’s a bio-process engineering drop-out.
Victor Choquet is a Doctorate candidate in Deep-Sea Ecology and Biogeochemistry impact assessment, with a background in Marine Biology and bioengineering. Senior in R&D coordination and early prototyping.

Next to recruit: - Algae cultivation facility manager - Regulatory affairs lawyer and advisor

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
CDR : IPMA, CIMA	• Pilot environmental impact assessment	confirmed project partner
CDR : AWI, NIOZ, OV	• Deep-sea deployment and environmental impact assessment.	discussing terms of collaboration
Undisclosed partner	• Assistance, potential collaboration	initial connection
Organization	• Airminor launchpad&Booster / BMW foundation/ Laci/ ClimAccelerator	confirmed project partner
Aggregate producer Clay + sand	• Collaborator for the SINKCORE mixing	currently supported by the university of Algarve using local aggregate on the university ground. For the project, we will need new partners.
Undisclosed	• Collaborator for the Trimssy system.	Initial connection established.

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?

The total timeline of our proposal from start of development to end of CDR delivery will occur from Q2 2024, until Q4 2025.

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.

> We will begin to cultivate algae for the purpose of capturing carbon dioxide in Q3 2024. The algae delivered to the ponds between Q4 2024 and Q4 2025 (in time for the algae to grow in our 4.5 acre ponds).

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	30
2024	150
2025	300
2026	1 500
2027	15 000
2028	150 000
2029	500 000
2030	1 000 000
2031	20 000 000
2032	500 000 000

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	Pilot demonstration (30 tons) & 6-month MMRV. The aim is to gather data with expert scientists, and oceanographic centers on the potentially long-term risk reduction of our approach, and air sea carbon flux.	Q3 2023 – Q1 2024
2	Delivery System Optimization: structural material, nutrient recycling, carbon compacting, and increase in the size of the SINKCORE to a 5.5 m long SINKCORE.	Today to Q3 2023

3	Automation, offshore cultivation system, Trimsy and sinkcore manufacturing.	Q4 2026

j. What is your IP strategy? Please link to relevant patents, pending or granted, that are available publicly (if applicable). <200 words

A proactive approach has been taken by Cooley in filing our intellectual property in several countries around the world.
Currently, we do not have any public information available. Both of our provisional patents will be converted to full patents in October 2022 and April 2023, respectively. As part of the due diligence process, we will be pleased to share them with you.

k. How are you going to finance this project? <300 words

Currently, we have received funding from friends and family, as well as an uncapped convertible note from a US foundation and incubator.
We also have been recently accepted in the current Carbon Removal ClimAccelerator 2022 batch. Additionally we have 5 verbal commitments for investments closing later this year. Furthermore, we are working on additional grants to support our high cost of ocean CDR testing.

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.). <200 words

We have partnered with AIRMINERS (US) and an undisclosed foundation to sell carbon credits. These organizations both have extensive networks and already put us in contact with potential buyers such as the Zurich Insurance Group, an undisclosed entity. Additionally we are proactively reaching out to companies in our personal networks (such as BCG) as well to explore their willingness to acquire carbon credits from Sinkco Labs.

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. <200 words

n/a

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

Regulatory	Ocean Vision advice. Pro CDR country for pilots. To gain the moral engagement of environmental groups, there will be a high budget for MRV in order to accelerate the safety impact ratio of our verification confidence level (VCL).
Seaweed biomass	Collaboration with marine aquaculture farms. IP on offshore cultivation system. Recycling of fertilizer during extraction.
MRV	Please see section 4.

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? *< 300 words, including number/range of durability estimate*

> The novel concept of burial of encapsulated biomass below the sediment in the abyssal plain (deeper than 3,500 m), ensures a potentially permanent capture of carbon. The encapsulation of the biomass offers physical protection against grazing by macrofauna and meiofauna, which would already be limited due to the low total fauna present (Wei et al., 2010). Low temperatures and high pressures compromise the enzymatic processes of the bacteria attached to our biomass, resulting in a much slower degradation (Turley CM, 2000; de Jesus Mendes et al, 2007). Our biogeomimetic approach protects the organic matter exudating from our biomass from bacterial degradation (Hedges et al., 2001; H Cheng et al., 2012). Most importantly, any fractional CO_2 that might be formed by degrading our biomass will be trapped into clathrates, not dissolving into the water column (Fahed Qureshi et al, 2022). This ensures an environmentally safer way to store captured CO_2 for millions of years (Ocean Vision, 2022; GESAMP, 2019).
> Any minimal amount of carbon that might escape to the water column will return to contact with the atmosphere in 300 - 1200 years, depending in which oceanic basin we are deploying (Matsumoto, 2007).

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? <200 words

> Our approach has a theoretical storage permanence of 98% CO_2 retention over millions of years, considering a 2% deployment failure. Even then, the captured CO_2 in those failed deployments will have a retention time in the order of thousands of years.

We are evaluating this theoretical framework against in situ experiments and computer modeling, with the support of world-leading oceanographic centers and reviewed by pre-eminent scientists. Although there is always a level of uncertainty associated with ocean carbon sequestration, our methodology was designed to minimize it. Physical and biological risks like leakage, decomposition and damage were taken into account when developing our prototypes. The uncertainty regarding future CO_2 surfacing associated with other companies was minimized by increasing the depth and conditions of deployment. The risk of creation of hypoxia areas in the sediment was reduced to a minimum by our methodology. One possible risk is the long lasting effects to the deep-sea benthic environment due to sediment resuspension. However, the effect of our method is much smaller than other ocean CDR methods or deep sea mining. Due to our accuracy of delivery and targeting areas of very low biodiversity, our local impact will be similar to naturally occurring dropstones.

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	494 tCO_2
Describe how you calculated that value	Our SINKCORE holds 1.006 ton of algae per unit SINKCORE. The moisture content of this algae is 66%. This algae carbon content is tested in the laboratory by elemental analyser and contains 41% of carbon content. The stoichiometric factor of carbon to CO_2 is 44/12. We propose to deploy 959 SINKCORE units. ((1.006 * (1-66%)*41%) * 44/12 * 959 = 494 $tCO_{2\ gross.}$ In our algae we are uncertain whether our initial carbon originates from the atmosphere or not, as the carbon flux between the air and surface water is difficult to monitor. For this, we account for 25 % factor uncertainty. Moreover, we still have uncertainty regarding the potential leakage of our carbon from the sediment layer back to the surface. For this, we account for 5% uncertainty. Finally we account for 2% uncertainty for other processes of our system

	(please refer to section 4.) Overall our uncertainty factor equals 32%. Estimating our gross carbon removal including our uncertainty, we do 494 $tCO_{2\ gross.}$ * (1-32%) = 336 $tCO_{2\ gross.}$

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.

To date, we have captured 234kg of CO_2.

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 not include this number in your gross or net CDR calculations; it's just to help us understand potential co-benefits of your approach.

n/a

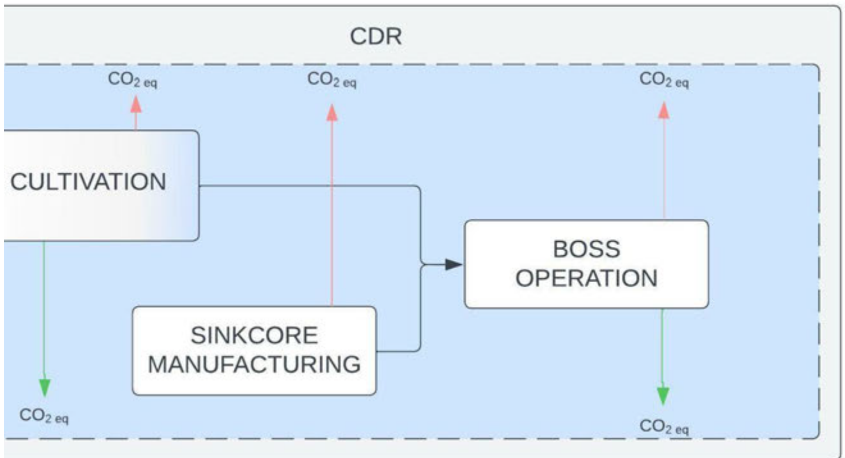
d. How many GROSS EMISSIONS will occur over the project lifetime? Divide that value by the gross CDR to get the emissions / removal ratio. Subtract it from the gross CDR to get the net CDR for this project.

Gross project emissions over the project timeline *(should correspond to the boundary conditions described below this table)*	58 tCO_2
Emissions / removal ratio *(gross project emissions / gross CDR–must be less than one for net-negative CDR systems)*	0.116 (accounting uncertainty: 0.171)
Net CDR over the project timeline *(gross CDR - gross project emissions)*	437 tCO2 (accounting uncertainty: 279 tCO_2)

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.



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? <100 words

Our LCA includes a cradle to grave scope. Please refer to our LCA and LCA report, in our addendum.

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.**
Algae cultivation	0.062 tCO_2	A basic biomass stoichiometric calculation was used to estimate the carbon content of our feedstock. Stoichiometric reaction was used in our LCA to estimate CO_2 equivalents of our ARB, and the results were further validated by external commission experiments.

SINKCORE Manufacturing	0.038 tCO_2	The emissions were estimated via LCA and SPD software. Metrics were verified with literature.
BOSS operation	0.016 tCO_2	The emissions were estimated via LCA and SPD software. Metrics were verified with literature.

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. <300 words

An elemental analyser was used to directly measure carbon in the SINKCORE. A third party collaborator also repeated the analysis externally.

Based on existing literature and comparisons with similar projects, we quantified the carbon trapped in the sediment. The encapsulation of the biomass offers physical protection against grazing by macrofauna and meiofauna, which would already be limited due to the low total fauna present (Chih-Lin Wei *et al.*, 2010). Low temperatures and high pressures compromise the enzymatic processes of the bacteria attached to our biomass, resulting in a much slower degradation (Turley CM, 2000; de Jesus Mendes et al, 2007). Our biogeo mimetic approach protects the organic matter exudating from our biomass from bacterial degradation (Hedges et al, 2001; H Cheng, et al, 2012). Any fractional CO_2 that might be formed by degrading our biomass will be trapped into clathrates, not dissolving into the water column (Qureshi et al, 2022). This ensures an environmentally safer way to store captured CO_2 for millions of years.

Reference:

de Jesus Mendes, P. A., Maier, I., & Thomsen, L. (2007). Effect of physical variables on particle critical erosion shear stress: Hydrostatic pressure, slope and changes in water density. Estuarine, Coastal and Shelf Science, 75(3), 317–326. https://doi.org/10.1016/j.ecss.2007.04.035

Fahed Qureshi, M., Zheng, J., Khandelwal, H., Venkataraman, P., Usadi, A., Barckholtz, T. A., Mhadeshwar, A. B., & Linga, P. (2022). Laboratory demonstration of the stability of CO2 hydrates in deep-oceanic sediments. Chemical Engineering Journal, 432, 134290. https://doi.org/10.1016/j.cej.2021.134290

Hedges, J. I., Baldock, J. A., Gélinas, Y., Lee, C., Peterson, M., & Wakeham, S. G. (2001). Evidence for non-selective preservation of organic matter in sinking marine particles. Nature, 409(6822), 801–804. https://doi.org/10.1038/35057247

Hefa Cheng, Erdan Hu, Yuanan Hu. Impact of mineral micropores on transport and fate of organic contaminants: A review. Journal of Contaminant Hydrology Volumes 129–130, 15 March 2012, Pages 80-90

Matsumoto, K. (2007) Radiocarbon-based circulation age of the world oceans. Journal of Geophysical Research Oceans, Volume112, IssueC9 https://doi.org/10.1029/2007JC004095

Turley, C. (2000). Bacteria in the cold deep-sea benthic boundary layer and sedimentâ€“water interface of the NE Atlantic. FEMS Microbiology Ecology, 33(2), 89–99. https://doi.org/10.1111/j.1574-6941.2000.tb00731.x

Wei, C. L., Rowe, G. T., Briones, E. E., Boetius, A., Soltwedel, T., Caley, M. J., Soliman, Y., Huettmann, F., Qu, F., Yu, Z., Pitcher, C. R., Haedrich, R. L., Wicksten, M. K., Rex, M. A., Baguley, J. G., Sharma, J., Danovaro, R., MacDonald, I. R., Nunnally, C. C., … Narayanaswamy, B. E. (2010). Global patterns and predictions of seafloor biomass using random forests. PLoS ONE, 5(12). https://doi.org/10.1371/journal.pone.0015323

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.)* *<200 words*

Statistically selected SINKCORE will be equipped with transponders for easy location via ROV Visual inspection of the site, water and sediment samples and sensor transects can be done to assess the evolution of the sequestration site. We have approached the AWI (Germany) and the NIOZ, (in the Netherlands) and both institutes demonstrated interest in aiding us test our technology and evaluate its effects. The terms of these collaborations are presently being discussed. We developed the first version of our MRV protocol a few months ago. As a result of the recent conference on MRV organized by the Wood Hole Institute, we have identified several institutes and researchers with whom we will be collaborating on our pilot demonstration in the fourth quarter of 2023. Namely we will contact Adrienne J. Sutton from the University of Marylandand the NOAA to discuss the potential involvement of their sensors and

support on their Draft of Ocean CDR Strategy. Dariia Atamanchuk from the Gothenburg University and Jaime Palter from the University of Rhode Island will be contacted for the development of an autonomous system. In addition, we will contact the RCMV, which has recently deployed three research vessels equipped with the most efficient sensors available in order to establish air-sea fluxes.

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.
1) Macroalgae harvest (Carbon Capture)	<1% The quantification of the feedstock carbon content is achieved by elemental analyser on each batch harvested.
2) Leakage (Carbon Capture)	<1% Fraction of biomass carbon not sunk to depth. Our algae could be subject to microbial activity resulting in CO_2 emission via respiration. For this our algae is stored in a storage tank and later in a refrigerated container unit until it is sunk in the deep sea. We will evaluate this uncertainty by

	sampling the algae carbon content at each step during our demonstration pilot in Q4 2023.
3) Surface competition effects (Carbon Capture)	<1% for our ponds In the case of our NOAK, we add 5% to the wild cultivation system. Our offshore cultivation system could deplete nutrients locally affecting fishery and ecosystem productivity. As a result, we have identified cultivation areas with abundant nutrients, thereby reducing the risk of harm].
4) Air-sea gas exchange (Carbon Capture)	It is possible that 25% of DIC-depleted water that loses contact with the atmosphere before equilibration will reduce atmospheric drawdown in the near future (decades to centuries). It is possible for carbon initially stored in the water column to resurface and accumulate in our biomass in areas of upwelling. As a result, the carbon that we store in the deep sea could correspond to a carbon avoidance rather than a carbon removal. As part of our MRV experiments, we will monitor the carbon flux in our ponds as well as collaborate with scientists using novel materials. However, our biomass is grown in ponds that use algae as nutrient filter for outflow water of fish aquacultures, so the initial DIC present in the water is minimal compared to the incorporated CO_2 due to aeration and fish respiration.
5) Materials & energy (emission)	<1% the embodied emissions of any materials consumed during operation, like mineral feedstocks. The emission relative the aggregate production, transport, SINKCORE manufacturing will be carefully established with the support of the organization in charge. The energetic value involved in the process will be demanded and reported. ISO 140 44 will be elaborated.
6) Storage monitoring and maintenance (durability of our Carbon Storage)	<5% uncertainties regarding the long-term fate of our algae buried in sediment. The algae could be consumed by anaerobic bacteria. With the help our our collaborators, we will deploy *in situ* sensors and conduct periodic sampling.

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? <50 words

A total 32 % uncertainty should be discounted until we gather further evidence supporting the VCL of our system.

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.? <200 words

Yes, included in this project is the future in situ observation of deployments via ROV visual inspection of the site, water and sediment samples and sensor transects. This will allow us to assess the evolution of the sequestration site and biomass therein. As mentioned above, collaborations with the AWI and the NIOZ are presently being discussed to address this.

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)?

The MRV is an integral part of our project. The Ocean Vision Scientific community is currently supporting us in the development of our second edition of the MRV protocol.

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).

Including the uncertainty discount in the net removal volume proposed in response to question 4(d) our levelized price is $1,838 /t$CO_2$

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

Component	**Levelized price of net CDR for this project ($/tonne)**
Capex	1138
Opex (excluding measurement)	224
Quantification of net removal (field measurements, modeling, etc.)[2]	395
Third party verification and registry fees (if applicable)	66
Total	1838

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?**
Opex Carbon Capture	$80 /t$CO_2$	51 /tCO_2	1) The emission relative to the production of fertilizer is reduced by 80%, as we will be able to recycle the nutrients present in our biomass
Opex Carbon Storage	$144 /t$CO_2$	$48 /t$CO_2$	1) By reducing the water content of our algae from 85% to 55%, using different types of mechanical press, we are able to increase the density of carbon in our SINKCORE, thus reducing

[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.

			the overall distance required for its transportation at sea. 2) Our SINKCORE will be filled automatically by a belt converter and loaded into a Trimssy container through an automated production line. 3) We estimate that the shipping company will discount the cost of our TRIMSY transportation from 10% (Project) to 30% (NOAK) since we allow the company to achieve a high level of sustainability in its marketing. 4) Automated production line with a belt converter for the filling of our SINKCORE and loading in the TRIMSY container.
Capex Carbon Capture	$1,336 /t$CO_2$	$51 /t$CO_2$	1) The installation of our ponds will decrease from 50% installation cost to 30%. Our NOAK's overall prediction will be greatly reduced as the economic lifetime of our system increases. Finally, we will use our patent-drafted method of algae cultivation offshore.
Capex Carbon Storage	$102 /t$CO_2$	$5 /t$CO_2$	1) Our initial cost is very high as we estimated a factor of 6X the cost of the retail price of a container, to be modified into a Trimmy system during our Project. Our factor for the NOAK is assumed to be reduced down to 1X of this cost. 2) The upgrade of our Trimssy system will increase the overall economic lifespan of our plant,

			resulting in a significant reduction in our storage capital expenditure costs.
MRV Cost	\$409 /tCO_2	\$8 /tCO_2	1) As a result of David Ho's (University of Hawaii) efforts to increase MRV research funding in the US, it is estimated that one day it will be possible to quantify the carbon flux air sea. As a result, we estimate that we have the tool required to lower the cost of our \$MRV / tCO_2 regarding the flux of carbon air-sea as well as the risk of leakage by the time our NOAK scale is established. A small amount will be allocated for long-term monitoring of the durability of our carbon storage system through in situ sensors. Our percentage of uncertainty was assumed to decrease from 32% to 5% for our NOAK scale.
Overall Cost	\$1,838 /tCO_2	\$163 /tCO_2	[Taking into account our percentage of uncertainty as well as the TEA].

d. What aspects of your cost analysis are you least confident in? <100 words

> Due to the fact that we are still in the process of obtaining quotes, we are least confident about the cost of our MRV protocol.
> Operating personnel and maintenance personnel requirements are still uncertain.
> Finally, the cost of transportation in the future is uncertain. We will experience a significant increase in the cost of SINKCORE delivery if container transportation is valued higher. If this is the case, we have also considered the possibility of acquiring our own sea vessel. Despite the fact that such a method will increase our overall operating expenses by 25%, it could serve as a reliable and viable alternative.

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.). <200 words

The Capex was not initially taken into account in our model.

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.) <50 words

A regulatory framework that allows ocean CDR to be granted a commercial permit by the EPA.
It is imperative that Frontier educate the public about emission reduction and avoidance, as well as types of credit performance, in order to ensure that citizens' money is spent on more efficient CDRs (as Bill Gate did in explaining renewable energy and the fight against greenwashing).

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. <300 words

As a social stakeholder, environmental groups have often played an important role in the application of large-scale ocean research. Before applying for large-scale demonstrations at sea, Mark Reiss of the Environmental Protection Agency advised us that we must earn their trust. Further, Mark highly recommends that we establish a relationship with the scientific community, which is the first step in gaining moral support. Currently, only the NOAA and DOE are permitted to deliver research permits in the United States. Protocols of research permits are still being drafted by the EPA. We have identified political stakeholders in the US (Will Burn of the American University institute for carbon removal, Romany Webb from the Sabin center for climate change law, and finally, in Europe, Fabien Ramos). The conference recommended that we involve local communities as much as possible in the scientific deployment of our method, but also governmental bodies and universities.

Our early exchanges with experts such as James Barry (MBARI, USA) and Carlos Duarte (King Abdulaziz College, South Arabia) highlighted the potential risks posed by biomass cultivation and sinking. Particularly their concern regarding the lack of scientific evidence supporting the safe use of such a method in the long term. As a result of such warnings, we were able to pivot earlier on for a safer approach to ocean CDR.

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.*<300 words.

As previously mentioned we have engaged with leading scientists and the EPA. Our company has begun more frequent exchanges with Ocean Vision in order to prepare our demonstration and organize a legal and scientific jury for our demonstration pilot scheduled for Q4 2023. Our team has produced a FAQ that will be added to our website in the near future.

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? <100 words.

As a result of the engagement with the Environmental Protection Agency, and James Barry, we have been able to develop a safer and more efficient approach. As a result, we have learned that MRV quality is more important than CO_2 quantity stored. Moreover, we plan to conduct research in countries with pro-CDR laws, such as Iceland and Kenya, which will facilitate our scientific research.
Finally, we are planning to collaborate with scientists from the NOAA and Hawaii University, which are currently developing an autonomous system of sea drones designed to carry out the MRV of algae cultivation and storage. By using their equipment, they will be able to measure the carbon flux in the surface ocean and obtain more reliable data regarding the origin of the carbon captured by our system. As a result, we aim to benefit all similar ocean CDRs and make scientific advances in this area.

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? <100 words.

From our perspective, at a larger scale, we would have implemented an internal framework, which our licensed group partners would have to follow. As new regulations will be implemented, and we will ensure that we comply with it.

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.<200 words

> A number of environmental justice considerations have been identified. In the first instance, there is the potential depletion of nutrients in the surface waters while we cultivate our kelp offshore due to surface competition. In order to avoid depletion of nutrients there, natural upwelling places have been identified.
> A second consideration is the creation of new jobs in the coastal area (farmers, maintenance and operations personnel, and ship crews).
> A further requirement is the transparency of scientific data, the review by a jury, and the ability to gain the trust of the public.
> Since we plan to extend our ponds in existing aquaculture areas, and build our plant near the port, our potential environmental impact on the plant sitting, as well as our ponds will be limited.

b. How do you intend to address any identified **environmental justice** concerns and / or take advantage of opportunities for positive impact? <300 words

> Our biogeomimetic approach ensures that virtually 100% of our immersed biomass is sequestered for a scale of millions of years to perpetuity, with minimal risk of future upwelling of CO_2 back to the atmosphere, with minimal impact to the immersion area.
> We are planning on starting collaboration with world-renowned research centers (AWI, NIOZ, NOAA, Wood Hole institute) to further evaluate our method.
> Our biomass is sourced primarily by natural in-house sustainable harvesting and could potentially be complemented by collecting naturally occuring harmful algal blooms. We work together with local environmental authorities to tailor the cultivation strategy to the particular location, ensuring the environmental soundness of our practices, such as with the Portuguese environmental authorities to produce biomass in the most sustainable way.
> To address our position regarding environmental justice, all of our pilots and initial development are being made in the EU and USA.
> We have already conducted a bioaccumulation bioassay to assess the safety of our sinking algae in the deep sea according to the EPA standard protocol. Our bioassay was third party verified by Eurofins, in Lisbon, Portugal (we are happy to share it in our addemun if needed).

[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

An independent assessment of the impact will be conducted after our demonstration pilot. Finally we will engage with environmental groups. In general America (depending on specific location of deployment): US coast guards, environmental agency, natural resources agency for each state. In order to achieve this, Ocean Vision will assist us in identifying the location that is most conducive to our demonstration pilot.
We will apply the standard working hours in accordance with the International Bill of Human Rights (UN, Paris, 1948).
As part of our current research, we have collaborated with the Portuguese public research center and obtained a permit. In this project, fishermen and the local research center CIMA, part of the University of the Algarve, have been involved.

8. Legal and Regulatory Compliance

a. What legal opinions, if any, have you received regarding deployment of your solution? <100 words.

In terms of scientific, moral, and legal advice, we have received advice from the EPA (Mark Reiss). For example, Running Tide's first pilot in collaboration with Ocean Vision provided confirmation of this fact.
Will Burn advised us in several conferences how important it is to collaborate with government entities and research centers. In this regard, we have already been in close contact with Ocean Vision and are planning to present at COP 27. As part of our pilot, we will work with DOE and NOAA (possibly under Ocean Vision supervision). We intend to ask Will Burn from the American Institute and Romany Webb from Sabin center for climate change law to take part in the jury board review. Finally, we intend to ask Airminers, with whom we previously collaborated, to assist us in reviewing our protocol compliance with legal and regulatory requirements.

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.
<100 words

We require immersion licenses from the country we operate from, being local licenses or exceptions to the London Convention/Protocol. We have taken steps to obtain a license to operate within EU waters (see 8.c). We have signed a Protocol of Collaboration with the Portuguese Institute for Sea an Atmosphere (IPMA) to conduct pilot sequestration efforts (already initiated). Contacts were initiated with non-EU countries to obtain local immersion licenses, and our next step is to present our project to the authorities in order to start operating as soon as possible.

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?
<100 words

As noted above, we require immersion licenses under the London Convention/Protocol. We are advised by Dr Fredrik Haag (Head of the Office for London Convention/Protocol & Ocean Affairs, IMO), Dr Chris Vivian (Chair of GESAMP WG 41 on Ocean Interventions for Climate Change Mitigation) and Prof Pedro Madureira (Deputy Head of the Task Group for the Extension of the Continental Shelf) on the steps to take to obtain a license to operate within EU waters. Our next step is to apply for a Portuguese research license (for 100 000 tons) that would allow us to do the pilot deployments at full depth.

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.
<100 words

We have several options regarding where to implement our project. Unfortunately we are not yet clear on the regulatory framework of each local jurisdiction, so due diligence will have to be made on a case to case basis. Methods of ocean based CDR are frequently under the umbrella of older, less appropriate legislation, so we foresee that legislation will weigh on our choice of implementation site.

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.
<50 words

Although the Energy Future Initiative currently proposes an extension of the 45Q tax credit to several methods of CDR in order to promote innovation, no actual legal body was established. As a result, if this should occur, we will ensure that we are not double counting our carbon credits.

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))*	287 tCO_2

Delivery window *(at what point should Frontier consider your contract complete? Should match 1(f))*	Q2 2024 to Q4 2025
Levelized Price (\$/metric tonne CO_2) *(This is the price per tonne of your offer to us for the tonnage described above)*	\$1,838 /tCO_2

Application Supplement: Biomass

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

Feedstock and Physical Footprint

1. What type(s) of biomass does your project rely on?

   Seaweeds, primarily *Ulva*, *Gracilaria sp* and *kelp.*

2. How is the biomass grown (e.g., kelp) or sourced (e.g., waste corn stover)? Do you have supply agreements established?

   Biomass will be grown by in-house facilities, preliminary in open ponds then later can be scaled by both open ponds and offshore

3. Describe the logistics of collecting your waste biomass, including transport. How much carbon emissions are associated with these logistics, and how much does it cost? How do you envision this to evolve with scale?<200 words

   n/a

4. Please fill out the table below regarding your feedstock's physical footprint. If you don't know (e.g. you procure your biomass from a seller who doesn't communicate their land use), indicate that in the table.

	Area of land or sea (km^2) in 2022	**Competing/existing project area use (if applicable)**
Feedstock cultivation	E.g. 1 km^2 (floating kelp array) OR N/A (procuring waste biomass)	
Processing	E.g. 0.1 km^2 (boat yard, manufacturing facility) OR 0.5 km^2 (manufacturing facility for mobile biochar plants)	
Long-term Storage	E.g. N/A (uncertainty in final state of kelp) OR 2 km^2 (ag fields in which biochar is deployed)	

Capacity

5. How much CDR is feasible globally per year using the biomass you identified in question 1 above? Please include a reference to support this potential capacity.<100 words

Our application is not limited to the three species that we are currently focusing on. The top three producers by country (in decreasing order of rank) are Chile, China and Norway for wild species (mainly brown and red) and Chilean kelp; as well as China, Indonesia, and the Republic of Korea and the Philippines for cultured species (mainly *Eucheuma*, *Japanese kelp*, *Gracilaria* and *Undaria pinnatifida*). According to CEVA (2015) and FAO (2014), 61% of the species produced today are used as texturisers. Assuming a 14% average annual increase in seaweed production by 2050, a total of 500 M tons of dry seaweed is predicted to be produced in the world, representing in CO_2 one percent of global emissions (The World Bank, no date given).

Additionality and Ecosystem Impacts

6. What applications/sectors your biomass feedstock could be used for other than CDR? (i.e., what is the counterfactual fate of the biomass feedstock) <100 words

n/a

7. There are many potential uses for waste biomass, including avoiding emissions and various other approaches to CDR. What are the merits and advantages of your proposed approach in comparison to the alternative? <200 words

Other approaches generally require transport, which we do not as our algae biomass is generated directly in our plant facility. Other CDR methods use waste biomass to carry pyrolysis before ground storage. Yet such a process does require more energy and often rely on the solar grid to reduce their emission to removal ratio. Finally our system of ITMA ponds cultivation means that we are able to cultivate seaweed in a controlled environment.

8. We recognize that both biomass production (i.e., growing kelp) and biomass storage (i.e., sinking in the ocean) can have complex interactions with ecological, social, and economic systems. What are the specific, potential negative impacts (or important unknowns) you have identified, and what are your specific plans for mitigating those impacts (or resolving the unknowns)? <300 words

Due to the patterns of global circulation driven by density gradients, widely referred to as the thermohaline circulation, surface waters eventually sink below the photic

zone limiting sea-air gas exchange and successfully cutting off CO_2 from the atmosphere for approximately 1,000 years. Here, the deep sea provides an important regulating service by absorbing atmospheric CO_2 and contributing to buffer Earth's climate. However, even with present marine CDR technologies such as, only one third of the biomass grown at the surface gets captured below 1,000 m, and is only stored for 800 - 1,000 years (Stripe Spring21 CDR Purchase Application).
Our unique deployment approach is designed to prevent any degradation during biomass sinkage, so that all our algae biomass reaches the seafloor, at depths greater than 3,000 m.

There are many advantages to our deployments when compared to other companies:

- Lower temperature. At 2 C, the enzymatic processes of the bacteria attached to our biomass are compromised, resulting in a much slower degradation of organic matter;

- Higher pressure. Higher pressures (3 to 4 times higher than at 1000m) inhibit the metabolism of the bacteria attached to our biomass, compounding the organic matter preservation;

- Mineral matrix. Our biogeomimetic approach protects the organic matter exudating from our biomass from bacterial degradation;

- Physical protection. The encapsulation of the biomass will offer a degree of protection against grazing by macrofauna and meiofauna;

- Clathrate formation. The CO_2 that can be formed by degrading our biomass will be trapped into clathrates, not dissolving into the water column.

These advantages ensure significantly longer sequestration times, estimated to be in the range of millions of years.

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. <200 words

Our deployment area is to be thinned out across the oceanic basins, from tens to thousands of nautical miles from the coastline. Since the deployment is to be done by vessels of opportunity, within an agreement with shipping companies, the deployment will be done below shipping channels, but with zero risk of impacting human activities.

2. Please describe your physical footprint in detail. Consider **surface area**, **depth**, expected **interaction with ocea**n **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.

Our physical footprint consists in temporary, isolated holes in the sediment surface, at more than 3,000 m depth. We don't expect any interactions with ocean currents, or the water column in general. Our pond biomass cultivation presents no risk to local ecosystems, in fact helping prevent coastal eutrophication. Our offshore cultivation system with kelp will be implemented in areas of natural upwelling or artificially high nutrient concentrations, where nutrient competition is minimized, therefore avoiding any risk of nutrient depletion and negative impacts on local ecosystems.

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. <200 words

At that scale our footprint would consist of circa 100 000 000 temporary, isolated holes in the sediment surface (much less than one per km^2), at more than 3, 000m depth, with no expected interactions with ocean currents, or the water column in general. Our offshore cultivation system with kelp will be implemented in areas where nutrient competition is minimized, and will occupy 30,000 km^2, distributed by our several locations around the world.

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? <200 words

Delivery to the sequestration site is done through container ships. Although there is no historical precedent for this particular methodology, the concept is straightforward and has a high potential to scale. Our method consists of easily scalable aquaculture ponds, currently used for removal of excess nutrients from outflow waters. For the cultivation of our kelp offshore, we are currently drafting a patent allowing us to maximize the cultivation of our kelp offshore.

Externalities and Ecosystem Impacts

5. What are potential negative impacts of your approach on ocean ecosystems?<200 words

Additionally to the risk of surface ocean competition effect previously mentioned in 2.a of this section, physical and biological risks like leakage, decomposition and damage were taken into account and minimized. The uncertainty regarding future CO_2 surfacing associated with other companies was minimized by increasing the depth and conditions of deployment. The risk of creation of hypoxia areas in the sediment, quite significant in other ocean carbon sequestration approaches, was reduced to a minimum by our methodology.
One possible impact to the deep-sea benthic environment might be sediment resuspension. However, the effect of our method is both decidedly inferior to the methods of other similar companies, and order of magnitude inferior to enterprises like deep sea mining. Since we can achieve a pinpoint accuracy of delivery and basin-wide dispersion of deployments, targeting areas of very low biodiversity, our local impact will be similar to naturally occurring dropstones.

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? <200 words

Our biomass consists in non calcifying algae, grown in ponds as nutrient filters for fish aquacultures. This means that our biomass reduces eutrophication in coastal areas, and does not reduce alkalinity, thus not contributing to ocean acidification.
At the point of sequestration we expect that all successful deployments remain isolated from the water column, and the carbon permanently sequestered, creating a small anoxic sediment layer around the SINKCORE, but otherwise not significantly affecting the environment.