Seaweed Generation

Carbon Removal Purchase Application

General Application

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

Company or organization name

Seaweed Generation

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

UK

Name of person filling out this application

Patricia (Paddy) Estridge, Mike Allen, Duncan Smallman

Email address of person filling out this application

[redacted]

Brief company or organization description

<10 words

Ocean based CDR using problematic seaweed

1. Overall CDR solution (All criteria)

a. Provide a technical explanation of the proposed project, including as much specificity regarding location(s), scale, timeline, and participants as possible. Feel free to include figures and system schematics.

<1500 words

Seaweed Generation is an ocean based CDR company, focusing on kickstarting ocean CDR with the problematic *Sargassum* blooms that blight coasts, from West Africa to Mexico each year [1].

The Sargassum Problem

Sargassum, a naturally occurring form of floating seaweed, has grown explosively in the central Atlantic, covering an area the size of Brazil. The massive increase is thought to be caused by fertilizer runoff and soil erosion providing unprecedented nutrients to existing Sargassum in the Sargo Sea.

Since 2011, the annually occurring beachings have transformed into nothing short of an unmanageable tragedy. Piles of rotting seaweed reach higher than a fully grown adult's head. Economies that rely on tourism have been severely damaged, fishing vessels are unable to get into the sea for months on end, and when they do, they catch nothing but seaweed. Reefs are being smothered and turtles prevented from nesting. When it rots, *Sargassum* releases a cocktail of heavy metals, including high levels of arsenic, and an unimaginable stench, that spreads for miles around.

This climate related tragedy has a silver lining. *Sargassum*, when dried, contains between 27.41% - 29.23% carbon [2]. Conservatively, 6 tonnes of *Sargassum* has absorbed 1 tonne of CO2. The > 20 million unwanted tonnes[3] of annual *Sargassum* passing through the Caribbean region and traveling through the Gulf of Mexico has absorbed over 3 million tonnes of CO2.

This CO2 is rereleased back into the atmosphere when the, now coastal, biomass rots, is eaten, or simply does not reach the deep ocean. An estimated 10% of *Sargassum* [4] ultimately sinks to the deep ocean, which is accounted for in our additionality calculations later in the application.

Permanent carbon sequestration using this problematic *Sargassum* is an activity that can start now, scale fast, and be used to kick start ocean based CDR at scale.

Our Process

In our process, the biomass is intercepted, captured, compacted and dropped to >1000m depth. Carbon that reaches the deep ocean, below 1000m, will remain out of the atmosphere for many hundreds of years [3].

Biomass that reaches the deep ocean will realize one of two fates. Either it will break down and become dissolved in deep ocean waters, where the natural water cycle is sufficiently slow for it to remain (if undisturbed) for many hundreds of years [3].

Or, it will become incorporated into the sea bed, partaking in the sedimentation process, where it will become locked away for millennia.

It is worth noting that this process has often resulted in the formation of crude oil deposits, the exploitation of which has led to our current predicament. This process is natural, proven, relentless and ongoing.

We have developed and successfully tested key components of a low cost, low energy, reusable and incredibly scalable process to complete these steps.

We guide the *Sargassum* using strategically placed barriers. We then capture, compress and bale it in the water, using wind and currents to ensure we are doing so as passively as possible. We sink those uniform bales to deep water (> 1000m deep), using our double-sided sinking system to take the bales below 400m, far below the point where *Sargassum* becomes negatively buoyant (150m). There, the bales are released, and the biomass sinks to the sea floor.

Our CDR process is unusual, in that it can be extensively documented. We know exactly how much seaweed we sink, we know where we sink it and how deep it is, and we know that once we sink it, there is a high degree of confidence in the durability of our removal.

We record video (providing additional volume and sinking rate/density data), GPS coordinates, depth and time date data for every one of our unique sinking events. Our customers receive evidence for all of their purchases, which we store on our inhouse (and very low energy) blockchain. A small number of copies of our blockchain will be held, for security purposes, by trusted 3rd parties, to ensure that records cannot be changed or manipulated retrospectively, making our evidence base even more trustworthy.

We have designed our capture and sinking process to allow for the addition of automated components and machinery at every step. Our goal, over the next few years, is to reach the point where capture, collection, compression and sinking can happen without human intervention, whilst simultaneously providing the verification and digital evidence to record our activity.

Our Pilot

Process development and testing will take place in 2022, and continual CDR will begin in early 2023, during which we are projecting a 2,000 tCO_2 annual capacity per operation. Our activities will take place in the waters of Antigua and Barbuda, and St Kitts and Nevis. In each country, we have sought permission for research scale operations, to capture, sink and monitor in designated areas. In these areas, we will sink the biomass in variable densities, so that we can extrapolate out the effects that megatonnes and gigatonnes of biomass would have when spread out at similar densities in global oceans.

We will be able to monitor the sea bed where we release it, take CO_2, acidity, and salinity readings, and study the surrounding ecology. We will also be able to retrieve and deeply analyze seabed cores. A great many questions are being asked about the effect that increasing deep ocean biomass might have. Whilst we are confident that the addition of biomass will have little to no effect, we believe that it is worthwhile being sure.

Additionally, we will be able to specifically monitor the biomass that we sink, and establish a better sense of how much deep ocean biomass becomes integrated in the sea bed, and therefore how much of it will be locked away for multiple millennia.

We plan to share these findings widely with the scientific community.

Long Term Opportunity

We fundamentally believe that macroalgae is the most scalable option on Earth for CO_2 absorption, and that the deep ocean is the most scalable option on Earth for long term storage. Our approach is intended to test and scale alternative challenges to those already being tackled by our pioneering peers in the ocean CDR space.

Our challenge is not one of biomass or certainty of removal, it is one of operational scale. We are focused on working with governments whose countries suffer from *Sargassum* inundations, with designated areas for early sinking trials. Within these areas, our deeply experienced science team can monitor any effects of additional biomass in the deep sea.

The upper ceiling for CDR using only existing problematic *Sargassum* is around 3 megatonnes of CO_2 a year. To reach gigatonnes, it will be essential and necessary to cultivate macroalgae on a global scale. The specific species in each location will vary depending on what naturally grows successfully in each area, but we plan to start propagation of *Sargassum* and other species within the next 3 years, reusing our technology and existing infrastructure.

Much of our marine infrastructure for capture, particularly marine based automation, will be highly applicable to scaleable cultivation. Our ultimate goal is large scale, automated ocean based macroalgae cultivation for CDR.

We are already cultivating several species of macroalgae (Sugar Kelp, Atlantic Wakame) in Scotland and the South West of the UK, and are beginning to develop technology for greater yields, easier automated deployment and suitable for rough ocean waters.

By 2027, we are projecting that we will be capable of megatonne scale removal, 25% of which will be from cultivation, and have costs per tonne of well under $100. We are projected to achieve gigatone scale CDR by 2037

[1] The Seaweed Bloom That Covered an Ocean
[2] Sargassum Inundations in Turks and Caicos: Methane Potential and Proximate, Ultimate, Lipid, Amino Acid, Metal and Metalloid Analyses, John James Milledge et al
[3] Substantial role of macroalgae in marine carbon sequestration by Krause-Jensen and Duarte, pages 737-742 in Nature Geoscience, volume 9, October 2016

b. What is your role in this project, and who are the other actors that make this a full carbon removal solution? *(E.g. I am a broker. I sell carbon removal that is generated from a partnership between DAC Company and Injection Company. DAC Company owns the plant and produces compressed CO_2. DAC Company pays Injection Company for storage and long-term monitoring.)*

<50 words

Seaweed Generation is both capturing and removing carbon in this project.

Where 3rd parties are part of our process, they are governments granting their permissions for our activities in their waters, or scientists with whom we will collaborate to research and monitor the longevity and effects of our sequestration.

c. What are the three most important risks your project faces?

<300 words

The problematic *Sargassum* blooms are unpredictable in size, timing and location.
Mitigation: We are using drones, alongside machine learning and satellite data to reliably predict the location and direction of the blooms.

Offshore working during hurricane season may hinder activities for short periods of the year.
Mitigation: No one wants to work at sea during a hurricane, this will be avoided at all costs. Hurricane activity may promote the movement of seaweed material towards the coast and increase the need to remove it directly from beaches.

Operational efficiency
Mitigation: Our biggest source of uncertainty is how fast and efficient our processes will be on a continual basis. We have tested and are confident of our capture, baling

and sinking processes, but a continual operation has not yet been tested. We are not dealing with uncertainty in terms of biomass or sinking, but rather in the operational efficiency of our planned process.

Since the beginning of this project, we have had to adapt and innovate in a multitude of areas. Necessity being the mother of invention, we foresee many further innovations being essential as we learn and scale.

d. If any, please link to your patents, pending or granted, that are available publicly.

- *List of links*

Not yet publicly available. UK Patent Pending, Application Number GB2204699.9

e. Who's the team working on this? What's your team's unfair advantage in building this solution? What skills do you not yet have on the team today that you are most urgently looking to recruit?

<300 words

Seaweed Generation has a highly talented team which includes Paddy Estridge, Professor Mike Allen, Dan Schaub, Duncan Smallman, PhD, and Jason Molle; each team member brings a unique skill set and professional experience, but shares the same ethos and can-do mindset.

Paddy is our CEO, the bold and fearless leader who brought everyone together. A software engineer with a past life with Google and Betterment, Paddy is our guiding compass and keeps us focused on the task at hand.

Mike is our CSO, a Professor at Exeter University, a marine biotechnologist. Mike's published research (>100 papers) includes work on algal physiology, biorefinery development, genetic modification, underwater robotics, aerial drones, environmental remediation, bioreactor development, dewatering technologies and novel sanitation systems. His humor is best left at >1000m on the seabed.

Duncan is our Chief Cultivator, an eco warrior marine biologist with a lifelong passion for the sea. His passion for all things seaweed knows no bounds. Duncan has 9 years of experience in cultivating seaweed. He is also an avid seafarer, with over a decade of commercial marine experience under his belt, a qualified diver and has experience conducting underwater monitoring.

Dan, our Head of Engineering, is a programming aficionado and software engineer of great renown. With over 12 years experience at New York startups like Betterment

and Wellsheet, he's taken on a new one by building out our evidence based blockchain. He's also diving into our machine learning and automation challenges. Paul Gray, Senior Mechanical Engineer and boat builder, who specializes in water management. He has years of experience in coming up with scalable, durable and robust solutions for systems that come under immense pressure and complications due to the presence of water. An avid seafarer, he spends his spare time building and repairing boats, for fun, and for other people. He has experience in converting fossil fuel powered vessels to solar power, and can fix up any vessel you could throw at him. We are currently looking to add a marine robotics expert to our team. We have a host of high potential prospects ready for when we gain commercial traction.

2. Timeline and Durability (Criteria #4 and Criteria #5)

a. Please fill out the table below.

	Timeline for Offer to Stripe
Project duration *Over what duration will you be actively running your DAC plant, spreading olivine, growing and sinking kelp, etc. to deliver on your offer to Stripe? E.g. Jun 2022 - Jun 2023. The end of this duration determines when Stripe will consider renewing our contract with you based on performance.*	*<10 words* 14 months May 1 2023 - June 31 2024
When does carbon removal occur? *We recognize that some solutions deliver carbon removal during the project duration (e.g. DAC + injection), while others deliver carbon removal gradually after the project duration (e.g. spreading olivine for long-term mineralization). Over what timeframe will carbon removal occur?* *E.g. Jun 2022 - Jun 2023 OR 100 years.*	*<10 words* May 1 2023 - June 31 2024

Distribution of that carbon removal over time *For the time frame described above, please detail how you anticipate your carbon removal capacity will be distributed. E.g. "50% in year one, 25% each year thereafter" or "Evenly distributed over the whole time frame". We're asking here specifically about the physical carbon removal process here, NOT the "Project duration". Indicate any uncertainties, eg "We anticipate a steady decline in annualized carbon removal from year one into the out-years, but this depends on unknowns re our mineralization kinetics".*	*<50 words* 1% May 2023 (15 tCO_2) 3% June 2023 (45 tCO_2) 10% July 2023 (147 tCO_2) 15% August 2023 (220 tCO_2) 20% September 2023 (294 tCO_2) 20% October 2023 (294 tCO_2) 20% May 2024 (294 tCO_2) 21% June 2024 (162 tCO_2)
Durability *Over what duration you can assure durable carbon storage for this offer (e.g, these rocks, this kelp, this injection site)? E.g. 1000 years.*	*<10 words* > 1000 years

b. What are the upper and lower bounds on your durability claimed above in table 2(a)?

Number/range Lower - 1000 years, when dissolved in deep ocean waters Upper - 10,000 to millions of years when embedded into deep ocean sediment

c. Have you measured this durability directly, if so, how? Otherwise, if you're relying on the literature, please cite data that justifies your claim. *(E.g. We rely on findings from Paper_1 and Paper_2 to estimate permanence of mineralization, and here are the reasons why these findings apply to our system. OR We have evidence from this pilot project we ran that biomass sinks to D ocean depth. If biomass reaches these depths, here's what we assume happens based on Paper_1 and Paper_2.)*

<200 words The first step in durability is getting the biomass to below 1000m. Using sensor probes to provide quantitative data, we have successfully deposited 3 bales of *Sargassum* seaweed to the seabed at a depth of 700m in <7 minutes. A 1000m deep seabed could be achieved in <10 minutes.

Direct measurement of durability over time is difficult in the deep ocean. With time, the biomass will either be buried or dissolved, and therefore difficult to monitor.

The long term durability of deep ocean carbon is well documented. First, decomposition of material is extremely slow at depth, so there is a high likelihood that the biomass will become sedimented.

Second, assuming carbon is dissolved into the water, the cycling of deep sea water into the layer above is thought to be in excess of 100 years. It then takes several hundred more to reach the surface.

Resources

Tracers in the Sea, Broecker & Peng, 1982

Sequestration of macroalgal carbon: the elephant in the Blue Carbon Room. Krause-jensen *et al.* 2018

Substantial role of macroalgae in marine carbon sequestration, Krause-Jensen & Duarte, 2016.

Removing 10 Gigatons of Carbon Dioxide", Tim Flannery, https://www.youtube.com/watch?v=SRVnitJIr2c

d. 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

Sargassum biomass appears on the beaches of the Caribbean for large periods of the year.The root cause of its polluting growth is fertilizer runoff from intensive agricultural practices. Our solution removes it and locks it away indefinitely in the deep ocean. In the unlikely event it defies physics and returns to the surface, it would be akin to the current situation.

Our seabeds are largely unexplored due to their inaccessibility, however, unlike the surface of our planet, they are not hotbeds for macrolife. Microbial activity dominates the deep ocean, the impact of an additional gigatonne of organic material will add to localized system productivity, but will have little to no impact on surface life.

It is currently estimated that 10% of *Sargassum* ends up on the seafloor under current conditions. If 100% successful, our sinking will result in just 10x more material on the seabed. At these depths, there is little to no human activity to disrupt it, other than our planned monitoring activities.

e. How will you quantify the actual permanence/durability of the carbon sequestered by your project? 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

We will monitor the sinking of the material (integral to establishing the effects of our system), and monitor the seabed regularly for the status of the material and environmental integrity.

Our data and evidence will be made available to the scientists on our team, collaborating scientists, and to the wider scientific community. We believe that our ability to monitor the areas where we are conducting ocean based CDR will answer many of the questions that exist for biomass based CDR, and help to advance this high potential industry as a whole.

Direct measurements are difficult, but not impossible. When appropriate to do so, we will collaborate with the academic community (we have already identified world leading experts to engage with) to share our infrastructure and resources in order to undertake a highly robust research program utilizing techniques involving biological tracers and stable isotope analysis. This will provide independent scientific verification of our carbon sequestration process.

3. Gross Capacity (Criteria #2)

a. Please fill out the table below. **All tonnage should be described in metric tonnes here and throughout the application.**

	Offer to Stripe (metric tonnes CO_2) over the timeline detailed in the table in 2(a)

Gross carbon removal Do not subtract for embodied/lifecycle emissions or permanence, we will ask you to subtract this later	*E.g. XXX tCO_2* 1,470 tCO2
If applicable, additional avoided emissions e.g. for carbon mineralization in concrete production, removal would be the CO_2 utilized in concrete production and avoided emissions would be the emissions reductions associated with traditional concrete production	*E.g. XXX tCO_2* N/A

b. Show your work for 3(a). How did you calculate these numbers? If you have significant uncertainties in your capacity, what drives those? *(E.g. This specific species sequesters X tCO_2/t biomass. Each deployment of our solution grows on average Y t biomass. We assume Z% of the biomass is sequestered permanently. We are offering two deployments to Stripe. X*Y*Z*2 = 350 tCO_2 = Gross removal. OR Each tower of our mineralization reactor captures between X and Y tons CO_2/yr, all of which we have the capacity to inject. However, the range between X and Y is large, because we have significant uncertainty in how our reactors will perform under various environmental conditions)*

<150 words

Dried *Sargassum* contains between 27.41% - 29.23% carbon [1]. A 1 tonne bale of wet material weighs 160 kg when dried. Taking the average of 28.32%, 45.312kg of the dried biomass is carbon, meaning it has absorbed 166.145kg of CO2 (CO2 being 3.6667 x carbon in molecular weight).

We calculate that our additionality is 86%. 10% of *Sargassum* is estimated to reach the deep ocean naturally. We are allowing a further 4% buffer for unknowns, such as chemical variations in the composition of *Sargassum* in different seasons (we will analyze this).

We offer to capture, bale and sink 10,300 tonnes of *Sargassum* well below 1000m in the Atlantic Ocean and Caribbean Sea, representing just over 1,470 tonnes of CO2 removal.

[1] Substantial role of macroalgae in marine carbon sequestration by Krause-Jensen and Duarte, pages 737-742 in Nature Geoscience, volume 9, October 2016

c. What is your total overall capacity to sequester carbon at this time, e.g. gross tonnes / year / (deployment / plant / acre / etc.)? Here we are talking about your project / technology as a whole, so this number may be larger than the specific capacity offered to Stripe and described above in 3(b). We ask this to understand where your technology currently stands, and to give context for the values you provided in 3(b).

 # metric tonnes CO_2/yr

2,000 tCO2

d. We are curious about the foundational assumptions or models you use to make projections about your solution's capacity. Please explain how you make these estimates, and whether you have ground-truthed your methods with direct measurement of a real system (e.g. a proof of concept experiment, pilot project, prior deployment, etc.). We welcome citations, numbers, and links to real data! *(E.g. We assume our sorbent has X absorption rate and Y desorption rate. This aligns with [Sorbent_Paper_Citation]. Our pilot plant performance over [Time_Range] confirmed this assumption achieving Z tCO_2 capture with T tons of sorbent.)*

<200 words

Our projected maximum annual capacity is 2,000 tCO2/yr for a full season (*Sargassum* season runs May - October in our operational territories). This is an estimate based on our current plans for 1 small scale deployment.

We are making an estimate of 2,000 tCO2, which equates to 14,000 tonnes of wet *Sargassum* sunk per year. Over the 6 month season, that is approximately 2,000 tonnes a month, or 80 per day (25 days pcm).

Our estimates are based on a conservative average density of *Sargassum* of 0.2kg/m2 [1] in waters traveling at 2 knots (4km/hr) with a 100m wide 'capture area'.

Our bottleneck is the capacity of our system to sink, which can conservatively sink two 1 tonne bales every 10 minutes. This is a clear area for optimization.

It is worth noting that variability in weather and *Sargassum* flow, whilst accounted for in the estimate of 0.2kg/m2 on average for all water passing through our system (*Sargassum* mats and rafts are plentiful, but they don't cover the entire sea), will be assessed deeply in our project.

[1] Remote Sensing of *Sargassum* Biomass, Nutrients, and Pigments, Mengqiu Wang et al

e. Documentation: If you have them, please provide links to any other information that may help us understand your project in detail. This could include a project website, third-party documentation, project specific research, data sets, etc.

- *Up to 5 links*

Please see our website and the paper: Testing the climate intervention potential of ocean afforestation using the Great Atlantic Sargassum Belt by Bach et al, published on-line in Nature Communications, 7 May 2021

This project was inspired by the work of our CSO Mike Allen to valorise *Sargassum* biomass by using hydrothermal processing techniques to create biofuel and fertilizer products in the GCRF, Roddenberry Foundation and Newton Fund supported www.PhycoMex.Uk project.

Mike has successfully characterized *Sargassum* biomass with a view to developing biorefineries and biotechnological processes from material obtained locally in the UK, across the Caribbean (Mexico, Dominican Republic, Jamaica); following extensive and ongoing work to create biofuel products [1] and fertilizers and recycling plastics [2] at industrial scale.

After two decades of R&D in this space, Mike believes the CDR approach outlined in this proposal to Stripe is the most viable, useful and appropriate way to make use of *Sargassum* and fight the current climate crisis.

[1] Hydrothermal liquefaction of macroalgae for the production of renewable biofuels

[2] Assessing the Conversion of Various Nylon Polymers in the Hydrothermal Liquefaction of Macroalgae; Co-liquefaction of macroalgae with common marine plastic pollutants

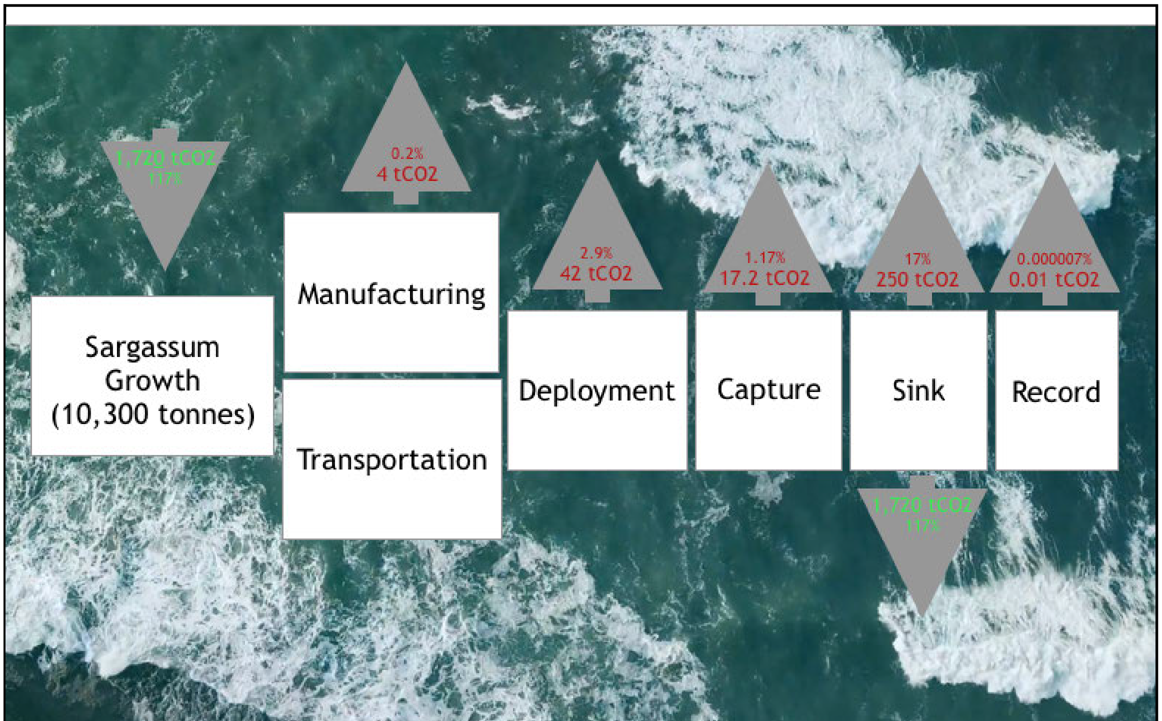
4. Net Capacity / Life Cycle Analysis (Criteria #6 and Criteria #8)

a. Please fill out the table below to help us understand your system's efficiency, and how much your lifecycle deducts from your gross carbon removal capacity.

	Offer to Stripe (metric tonnes CO_2)
Gross carbon removal	*Should equal the first row in table 3(a)* 1,470 tCO2
Gross project emissions	*Should correspond to the boundary conditions described below this table in 4(b) and 4(c)*

	63.21 tCO2
Emissions / removal ratio	*Gross project emissions / gross carbon removal: should be less than one for net-negative carbon removal systems, e.g. the amount emitted is less than the amount removed* 4.3% (4.270007%)
Net carbon removal	*Gross carbon removal - Gross project emissions* 1,412 tCO2

b. Provide a carbon balance or “process flow” diagram for your carbon removal solution, visualizing the numbers above in table 4(a). Please include all carbon flows and sources of energy, feedstocks, and emissions, with numbers wherever possible *(E.g. see the generic diagram below from the [CDR Primer](), [Charm’s application]() from 2020 for a simple example, or [CarbonCure’s]() for a more complex example).* If you’ve had a third-party LCA performed, please link to it.



c. 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

Theoretically, emissions for our system can be 0%, or extremely close to it, when we switch to electric and sail power for our vessels.

We have accounted for using fossil fuel based marine engines as we learn and scale.

We have also included manufacturing by suppliers, and the transportation needed to receive them.

We plan to purchase pre-used vessels. We have not added these emissions. Following purchase, we will revise our calculations, but expect it to be negligible when spread over multiple years.

We are accounting for a small amount of computing power for our blockchain and computational needs.

d. Please justify all numbers used 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.

<200 words

Our carbon content numbers are modeled from scientific papers and analysis of *Sargassum*, [1], and from our own measurements to confirm the wet to dry ratios of *Sargassum* from the central Atlantic, due to variations in literature across different species and geographies.

Our manufacturing emissions are modeled on machinery from suppliers and expected transportation needs to receive materials for ongoing operations. These will be supplier specific, but we have assigned a generous margin. Our equipment will be reusable many times over.

We have modeled our fuel numbers based on suitable vessel purchases, coupled with projections for the needs of our sea based operations.

Further optimizations are possible, planned and expected; switching engines for electric where appropriate, or for more modern and fuel efficient engines, and using sail versus fuel based vessels.

Our numbers are based on pre mitigation methods.

We have built our blockchain in house to ensure that our system remains close to zero emissions. We have allowed a small portion to be certain that we are always more than covering the energy required.

[1] Sargassum Inundations in Turks and Caicos: Methane Potential and Proximate, Ultimate, Lipid, Amino Acid, Metal and Metalloid Analyses, John James Milledge et al

e. If you can't provide sufficient detail above in 4(d), please point us to a third-party independent verification, or tell us what an independent verifier would measure about your process to validate the numbers you've provided.

<100 words We plan to record all of our emissions robustly, and declare them publicly. Third party verification will be another vital step for our project's trustworthiness, and we plan to be fully transparent to customers and interested parties on our CDR and the emissions associated with it.

5. Learning Curve and Costs (Backward-looking) (Criteria #2 and #3)

We are interested in understanding the learning curve of different carbon removal technologies (i.e. the relationship between accumulated experience producing or deploying a technology, and technology costs). To this end, we are curious to know how much additional deployment Stripe's procurement of your solution would result in. (There are no right or wrong answers here. If your project is selected we may ask for more information related to this topic so we can better evaluate progress.)

a. Please define and explain your unit of deployment. (*E.g.* # of plants, # of modules)

<50 words A unit of deployment is 1 tonne of wet *Sargassum*, equating to 143kg of CO2 removal at our 86% additionality ratio.

b. How many units have you deployed from the origin of your project up until today? Please fill out the table below, adding rows as needed. Ranges are acceptable.

Year	Units deployed (#)	Unit cost ($/unit)	Unit gross capacity (tCO_2/unit)	Notes
2022	530	$34.30	0.143	*<50 words* Predicted deployment for 2022
2021	3	$600	0.0033	*<50 words* Costs driven by expensive day-rental vessels and small

				scale. 3 units of 10kg, 20kg and 30kg.
2020	N/A	N/A	N/A	*<50 words*
...				

c. Qualitatively, how and why have your deployment costs changed thus far? *(E.g. Our costs have been stable because we're still in the first cycle of deployment, our costs have increased due to an unexpected engineering challenge, our costs are falling because we're innovating next stage designs, or our costs are falling because with larger scale deployment the procurement cost of third party equipment is declining.)*

<50 words Historical costs are high due to chartering day-rental vessels, and purchasing equipment at a very small scale. Our continual deployment costs will be increasingly lower due to vessel purchases and long term monitoring equipment (in which case the CAPEX is amortized over 10 years), coupled with innovations in our process.

d. How many additional units would be deployed if Stripe bought your offer? The two numbers below should multiply to equal the first row in table 3(a).

# of units	Unit gross capacity (tCO_2/unit)
Number 10,300	*# tCO_2/unit* 0.143

6. Cost and Milestones (Forward-looking) (Criteria #2 and #3)

We are open to purchasing high cost carbon removal today with the expectation the cost per ton will rapidly decline over time. We ask these questions to get a better understanding of your potential growth and the inflection points that shape your cost trajectory. 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 expect to work with you to understand your milestones and their verification in more depth. If you have any reservations sharing the information below in the public application format, please contact the Stripe team.

a. What is your cost per ton of CO_2 today?

\$/ton CO_2

\$270 tCO2

b. Help us understand, in broad strokes, what's included vs excluded in the cost in 6(a) above. We don't need a breakdown of each, but rather an understanding of what's "in" versus "out." Consider describing your CAPEX/OPEX blend, non-levelized CAPEX costs, assumptions around energy costs, etc.

<100 words

The above costs include:

CAPEX:

10 year amortized costs of vessels

2 year amortized costs of recording and monitoring equipment

2 year amortized costs of barriers and bale equipment

2 year amortized costs of uncrewed / semi autonomous vehicles

OPEX:

Vessel maintenance, deployment and fuel

Labor and crews

It does not include:

R&D for cultivation

R&D for further automation

c. How do you expect your costs to decline over time? Specifically, what do you estimate your cost range will be as you reach megaton and then gigaton scale? We recognize that at this point, these are speculative and directional estimates, but we would like to understand the shape of your costs over time.

\$/ton CO_2

Megaton 2027 - \$49

Gigatonne 2037 - \$43

d. Where are the primary areas you expect to be able to achieve cost declines? E.g., what are the primary assumptions and sensitivities driving your cost projection? What would need to be true for a long-term cost of <$100/ton to be achievable with your technology? (i.e., you are able to negotiate an x% reduction in CAPEX at scale and purchase renewable electricity at $y/kWh)

<300 words

We expect to make significant savings or optimisations at scale in a multitude of areas:

- Infrastructure and efficiency improvement at scale - 60% increase in processing
- Increase and large scale use of automation - 50% increase in processing
- Manufacture of vessels in house - 20% reduction in CAPEX
- Manufacture of equipment in house - 10% reduction in CAPEX
- Investment in renewables and reduction in fuel costs - 3% reduction in OPEX
- Controlled cultivation of biomass with low cost automated growing structures - TBC

e. In a worst case scenario, what would your range of cost per ton be? We've been doing a lot of purchasing over the past few years and have started to see a few pieces that have tripped people up in achieving their projected cost reductions: owned vs leased land, renewable electricity cost, higher vendor equipment costs, deployment site adjustments, technical performance optimization, supporting plant infrastructure, construction overruns, etc. As a result, we'll likely push on the achievability of the cost declines you've identified to understand your assumptions and how you've considered ancillary costs. We would love to see your team kick the tires here, too.

<300 words

In 2021, in our first trial run at a new and untested site, using day rental vessels, one off purchases of equipment, and learning as we went along, we achieved a cost of $600 per unit. This is our absolute worst case scenario under our current operational conditions.

There are, however, a number of areas where costs could arise. We are assigning 20% of our CAPEX for maintenance, but this could be more than expected. Similarly, in an inflationary market, costs of vessels and supplies are increasing, in some cases at high speed.

A potential curve ball may come from future legislation in a rapidly developing field. For example, The Government of Barbados intends to put forward legislation that specifies that 50% of carbon removal, unless otherwise agreed, would be assigned to the government. This is a situation we are monitoring and are prepared to adapt to.

We expect to offer territories where we are operating specifically (i.e. with a permitted drop zone) a portion of our removal in the future. However, given the benefits to their countries in managing *Sargassum*, we expect that allowances will be made to enable development and innovation, and for our operations in their waters.

f. List and describe **up to three** key upcoming milestones, with the latest no further than Q2 2024, that you'll need to achieve in order to scale up the capacity of your approach.

Milestone #	Milestone description	Why is this milestone important to your ability to scale? (200 words)	Target for achievement (eg Q4 2021)	How could we verify that you've achieved this milestone?
1	*<100 words* Deployment of first full operation	*<200 words* Will make our annual capacity of removal up to 2,000 tCO_2	Q2 2023	*<100 words* Announcements and photographic evidence.
2	*<100 words* Deployment of 2 new operations	*<200 words* Increase capacity to at least 6,000 tCO_2 a year	Q2 2024	*<100 words* Announcements and photographic evidence.
3	*<100 words* Development of automated uncrewed vehicles to aid in guiding barriers	*<200 words* Increases efficiency of the system and area of collection	Q3 2023	*<100 words* Announcements and photographic evidence.

i. How do these milestones impact the total gross capacity of your system, if at all?

Milestone #	Anticipated total gross capacity prior to achieving milestone (ranges are acceptable)	Anticipated total gross capacity after achieving milestone (ranges are acceptable)	If those numbers are different, why? (100 words)
1	*Should match 3(c)* 2,000 tCO_2	2,000 tCO_2	*<100 words* Already a planned development baked into our

			numbers.
2	2,000 tCO2	6,000 tCO2	*<100 words* This would triple our capacity.
3	2,000 tCO2	2,500 tCO2 For a single operation. Projected over time to be much more.	*<100 words* Increase the capture capacity of a single operation

g. How do these milestones impact your costs, if at all?

Milestone #	Anticipated cost/ton prior to achieving milestone (ranges are acceptable)	Anticipated cost/ton after achieving milestone (ranges are acceptable)	If those numbers are different, why? (100 words)
1	*Should match 6(a)* $270	$270	*<100 words*
2	$270	$220 - $250	*<100 words* More scale will allow us to spread central costs.
3	$270	$240 - $260 (Based on milestone 3 independently from milestone 2)	*<100 words* More scale per unit will allow us to spread all CAPEX and OPEX costs out.

h. If you could ask one person in the world to do one thing to most enable your project to achieve its ultimate potential, who would you ask and what would you ask them to do?

<50 words We would ask Elon Musk to tweet his support for ocean based CDR.

i. Other than purchasing, what could Stripe do to help your project?

<50 words Raise awareness of our project to key future project partners: governments with control over suitable sinking zones, industrial partners active in marine automation, satellite imagery and machine learning.

7. Public Engagement (Criteria #7)

In alignment with Criteria 7, Stripe requires projects to consider and address potential social, political, and ecosystem risks associated with their deployments. Projects with effective public engagement tend to do the following:

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

The following questions are for us to help us gain an understanding of your public engagement strategy and how your project is working to follow the White House Council on Environmental Quality's [draft guidance on responsible CCU/S 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 your 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 Our project has grown naturally over the past year, as we have identified and developed relationships with key stakeholders crucial to our success. To achieve gigatonne removal will require governmental endorsement and the establishment of robust, resilient and mutually beneficial working relationships. To this end, we have actively engaged with the Ministry of Fisheries of St Kitts and Nevis where we started our initial trials. We have recently met with the Government of Antigua and Barbuda. Both countries are supportive of our project, and official approvals are underway. Other locations impacted, and governments with whom we have either engaged, or plan to engage, include, Mexico, Belize, Ghana, St Martens, Guadeloupe, Barbados, Jamaica, and others in the Caribbean region. We also see the global scientific community as a vital stakeholder. We have also engaged with Exeter University, their affiliate, Global Systems Institute and other members of the scientific

community. The University of West Indies Five Islands in Antigua has also been consulted and will be a scientific research partner on this project.

Our CSO, through Exeter University, is an Affiliate of [The Sargasso Sea Commission] and a member of the 'Readiness of [ICOS] [Integrated Carbon Observation System] for Necessities of Integrated Global Observations' ([RINGO]) Oceans Interest Group, and will ensure open and honest dialogue always occurs relating to the health, resilience and productivity of the region.

Locally to the regions where we are operating, fishing associations, tourism groups and ecological communities will all be important stakeholders, as they are the most impacted by *Sargassum*.

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.*

<100 words

We have personally held online meetings with **The Honorable Dean Jonas**, MP, Cabinet Minister, Antigua and Barbuda, Minister of Blue Economy and **Her Excellency Karen-Mae Hill**, High Commissioner of Antigua and Barbuda.

In St Kitts and Nevis, we have engaged with the **Director - Department of Marine Resources, Marc Williams**, and his office. Who are very supportive of our initiative.

In West Africa, we have met with the **Ghana Environmental Advocacy group** and **Hon. Emmanuel Armah Kofi Buahand**, MP of the Ellembelle district in Western Ghana.

We have also personally reached out to members of the scientific community.

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

There's a strong initial feeling that sinking seaweed is a 'waste of resource', followed by a grudging realization that there are currently no economically viable uses for the *Sargassum* biomass.

CDR in response to the climate emergency is not always regarded as a valuable activity because the income stream is not a physical product to be sold. We have modified our approach to emphasize that island nations can not only provide a valuable contribution to the climate problem, but they can actually take a global lead in providing a solution. This change of emphasis is opening doors for us.

d. Going forward, do you have changes planned that you have not yet implemented? How do you anticipate that your processes for (a) and (b) will change as you execute on the work described in this application?

<100 words

No changes related to public engagement so far. We had already planned to complete monitoring and to share data with local scientists, in addition to working closely with local communities.

We will be working closely with local communities and governments to measure any effects that our activities have on *Sargassum* beachings.

8. Environmental Justice (Criteria #7)

a. What are the potential environmental justice considerations, if any, that you have identified associated with your project? Who are the key stakeholders?

<100 words

Sargassum beachings are a massive scale environmental disaster for the local populations of West Africa, the Caribbean and Mexico. More often than not, these communities are reliant on tourism or fishing income, both of which are being negatively affected by these influxes.

The poorer the location affected by Sargassum, the less likely their governments are to be able to clear the issue.

We are conscious that fishing may be impacted in some way by large scale collection and cultivation of macroalgae, which we plan to mitigate.

b. How do you intend to address any identified environmental justice concerns?

<300 words

We estimate that the effects of our activities would be largely positive. The same Island nations suffering from *Sargassum* influxes also face high impacts from rising sea levels and increases in extreme weather. Our activities would directly alleviate the *Sargassum*, and offer the local population a chance to take part in activities that could slow the increase in broader climate change.

Our project looks to use local labor where possible therefore providing alternative, safe and longer term employment. We will keep up the dialogue we have already started with other seafarers and actively work with fisheries and tourism businesses to ensure fair use and fair access. Our collection is passive and will not impede use of this common resource.

Only near coastal *Sargassum* is being removed, none from the Sargasso Sea or immediately adjacent to the Sargasso Sea and therefore the impact as a fish nursery will be limited. Removal of *Sargassum* will solve a major environmental justice issue of access to beaches and the sea for island communities.

9. Legal and Regulatory Compliance (Criteria #7)

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

<100 words
As we are working directly with governments and have sought their permission to operate in their waters, we are not anticipating the need for further legal opinions above and beyond adhering to local employment, safety and maritime laws.

b. What domestic permits or other forms of formal permission do you require, if any, to engage in the research or deployment of your project? 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 are in the process of obtaining permission from the Ministry of Fisheries of St Kitts and Nevis and the Government of Antigua and Barbuda for rights to sink seaweed offshore in their territorial waters.

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
Not that we are aware of.

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

Our activities will take place near shore where clear 'ownership' of the free floating seaweed can be ascertained. In the future, as we expand our scale of operation we will move into international waters, in which case we expect that the rules of the London Convention would apply. However, as we are capturing and sinking naturally occurring local biomass, we have been advised that the activity would not be considered dumping.

e. Has your CDR project received tax credits from any government compliance programs to-date? Do you intend to receive any tax credits during the proposed delivery window for Stripe's purchase? If so, which one(s)? (50 words)

<50 words Not to date. In Antigua and Barbuda, we may receive importation tax relief for our activities but it would not take the form of a credit.

10. Offer to Stripe

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

	Offer to Stripe
Net carbon removal *metric tonnes CO_2*	*Should match the last row in table 4(a), "Net carbon removal"* 1,412 tCO2
Delivery window *at what point should Stripe consider your contract complete?*	*Should match the first row in table 2(a), "Project duration* May 1 2023 - June 31 2024
Price ($/metric tonne CO_2) ***Note on currencies:*** *while we welcome applicants from anywhere in the world, our purchases will be executed exclusively in USD ($). If your prices are typically denominated in another currency, please convert that to USD and let us know here.*	*This is the price per ton of your offer to us for the tonnage described above. Please quote us a price and describe any difference between this and the costs described in (6)* $400 (Ex. VAT) Margins built in to allow us to scale our operational capacity.

Application Supplement: Biomass

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

Feedstock and Physical Footprint (Criteria #1)

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

<100 words   Naturally occurring *Sargassum* (seaweed) growth and in the future, cultivated macroalgae

2. Are you growing that biomass yourself, or procuring it, and from whom?

<200 words   We are capturing it ourselves. We will cultivate *Sargassum* and other macroalgae the future.

3. 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)* Currently N/A	Possibly, but unlikely, fishing. It is rare for fishermen to go to such deep water.
Processing	*E.g. 0.1 km^2 (boat yard, manufacturing facility)* OR *0.5 km^2 (manufacturing facility for mobile biochar plants)* 0km2	N/A
Long-term Storage	*E.g. N/A (uncertainty in final state of kelp)* OR *2 km^2 (ag fields in which biochar is deployed)*	N/A

	Our two drop zones in Antigua and Barbuda and St Kitts and Nevis are 1,300 ha each.	

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

	Projected # of km^2 enabling 100Mt/yr	**Projected competing project area use (if applicable)**
Feedstock cultivation	*Sargassum*: 110,000km2 for 100mt (average of 6.5 kg/m2 of sargassum) More likely this would be cultivation of many types of macroalgae in appropriate areas. *Sugar kelp*: 50,000km2 for 100mt For our (under development) cultivation rig, the yield for sugar kelp is projected to be upto 13 kg/m2 *Fucoids* (wracks such as saw-wrack and knotted wrack): 120,000km2 for 100mt Projected to grow up to 6kg/m2 on our cultivation rig. Wild seeds naturally, lowering lab needs.	Fishing, maritime shipping. Cultivation of an excellent natural habitat is very likely to increase fish breeding and therefore yields around cultivation areas. Our cultivation systems will be modular and are being designed to be compatible with co use cases, such as net fishing.
Processing	0.5km2 for equipment manufacture, boat yards and seaweed nursery facilities	Distributed in multiple locations globally, likely to be warehouse style workshops close to coasts. In terms of competing use cases, probably other marine

		users, manufacturing or production and office space. These facilities are already in existence all over the world, we don't foresee any changes to current land use.
Long-term Storage	Deep ocean below 1000m. The ocean is 361 million square kilometers, and nearly 90% of that is below 1000m.	Highly unlikely to be disturbed, perhaps deep sea mining might do so one day. If this happens, it is unlikely that the biomass we are sinking will have converged at such a density that it would surface anything more than a fraction of our removal.

Permanence, Additionality, Ecosystem Impacts (Criteria #4, #6, and #7)

5. How is your biomass processed to ensure its permanence? What inputs does this process require (e.g. energy, water) and how do you source these inputs? (You should have already included their associated carbon intensities in your LCA in Section 6.)

<200 words We gather, compress and sink it below 1000m. No other processing required. Our equipment is reusable, and none of it is left behind.

6. (Criteria 6) If you didn't exist, what's the alternative use(s) of your feedstock? What factors would determine this outcome? *(E.g. Alternative uses for biomass include X & Y. We are currently the only party willing to pay for this biomass resource. It's not clear how X & Y would compete for the biomass resources we use. OR Biomass resource would not have been produced but for our project.)*

<50 words Mike has spent most of his career on valorising algae, the last 5 on *Sargassum,* a field in which he is now considered a world leader. There are small scale uses, but *Sargassum* is a poor and unreliable feedstock, and is generally a nuisance that causes economic and ecological harm.

7. We recognize that both biomass production and biomass storage can have complex interactions with ecological, social, and economic systems. What are the specific negative impacts (or important unknowns) you have identified, and what are your specific plans for mitigating those impacts (or resolving the unknowns)? *(200 words)*

<200 words The negative impacts have generally happened well before we become involved. Fertilizer runoff and soil erosion are causing the *Sargassum* population explosion. Socially, ecologically and economically, we believe that our project will have a very positive effect on the areas that we are operating in. At large scale, we will be able to offer a large impact on the *Sargassum* influxes, allowing the return of economic activities that were present before they became such a blight.

8. Biomass-based solutions are currently being deployed around the world. Please discuss the merits and advantages of your solution in comparison to other approaches in this space.

<200 words Ocean based CDR using seaweed is one of, if not the, most scalable permanent CDR method. Ours stands out because we are using a nuisance seaweed to kickstart our CDR, solving two problems in one, and because we have invented a process that can capture and sink it with very low energy outputs, and at a fast falling cost.

Application Supplement: Ocean

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

Physical Footprint (Criteria #1)

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

<200 words Our deployment area has been determined through consultation with and approval from the relevant local authorities. It takes advantage of the unique tectonic geology of the Caribbean islands which run along plate boundaries creating deep sea conditions relatively close to a safe harbor. It is away from the immediate coastline and occurs where the ocean depth is greater than 1000m. The deployment areas are away from major navigation and shipping channels.

Animal activity within these excess and large *Sargassum* aggregates is still an active area of research which we will feed into. There simply is not the luxury of time to wait for this research to be completed to gain a full picture of animal activity, as the biggest threat to all upper oceanic life is climate change and the changing chemistry and thermatic conditions that it causes. Our project aims to protect that which calls *Sargassum* home by dealing with only problematic biomass. We have built deterrents and easy escapes into our system, such as bright colors, shallow nets, and wide net gauges. In addition to the noise from our activities, we believe effects on animals will be low. We can add further deterrents if necessary.

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.

<200 words

N/A

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

N/A

See biomass supplement

Potential to Scale (Criteria #2 and #3)

4. Building large systems on or in the ocean is hard. What are your core engineering challenges and constraints? Is there any historical precedent for the work you propose?

<200 words

Both the fishing industry, and the shipping industry, are relevant in terms of historical precedent. Certainly in terms of scale and logistical complexity.

Getting to that scale is a tremendous engineering and logistical challenge. To begin with, we are operating within the waters of countries suffering from too much biomass. Our initial pilots are small in scale, will be conducted relatively close to shore, will enable us to develop and optimize the processes that we have, and develop the existing marine expertise on our team.

Our biggest engineering challenges are likely to occur due to extreme weather, which at first we will avoid. As we develop our equipment, we will design and build components that are designed specifically to handle extreme marine weather.

Over time, we will streamline our processes, optimize our efficiency, and add automated components and machinery to increase efficiencies. Our processes and equipment will initially be adapted from the fishing industry. Our process is specifically developed to allow gradual integration of automation. Areas for improvement are plentiful, but our focus is to initially get a continual process working at a small scale, and innovate further from there.

Externalities and Ecosystem Impacts (Criteria #7)

5. How will you quantify and monitor the impact of your solution on ocean ecosystems, specifically with respect to eutrophication and alkalinity/pH, and, if applicable, ocean turbidity?

<200 words

We will use genetic barcoding to monitor species diversity of the deep sea ocean floor, and take regular salinity, CO_2 and pH measurements. We will analyze the C:N ratio of the *Sargassum* along with N concentration of the areas where we are operating.

It is widely thought that the presence of seaweed cultivation will lower the acidity of the waters around it, and take up nutrients that may otherwise cause algae blooms.

To monitor changes where *Sargassum* no longer lands, biodiversity monitoring, pH, light penetration and nutrient levels will be monitored. Dissolved O_2 and alkalinity prior to removal then throughout removal can be undertaken.