stripe

General Application

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

Company or organization name

Running Tide Technologies

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

Portland, ME (USA)

Name of person filling out this application

Marty Odlin

Email address of person filling out this application

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Brief company or organization description

Ocean technology and aquaculture company fighting the urgent climate crisis.

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.

<1500 words

In this project we propose a phase 2 deep water kelp farming carbon sequestration experiment. Building on findings from phase 1, currently underway, we anticipate deploying 37,000 macroalgae microfarms across several deployments into the North Atlantic during June

2022 - June 2023. This phase of the experiment will test the performance of our approach at a larger scale, and target the sequestration of 2,000 tCO2.

The experiment is an open-ocean kelp farming project whereby the natural metabolism of macroalgae captures carbon into its biomass as it grows. Kelp is ideal for carbon capture as its dry mass is approximately 30% carbon and it grows quickly and abundantly in many marine geographies. Seaborn assemblies (microfarms) seeded with kelp sporophytes are deployed from offshore vessels into the open ocean. As these free-floating assemblies are carried by ocean currents, kelp growth accumulates mass and captures dissolved ocean carbon. The entire assembly will be mechanically rigged to sink after drifting for a 6-8 month growing season, when the assembly's trajectory takes it over deepwater ocean basins, and the kelp carbon will be delivered to the ocean floor where it is sequestered.

The constituent parts of our microfarm assemblies are designed to be compactly stored onboard a vessel. Mechanical simplicity in the design allows for rapid and automated rigging at deployment time. Running Tide's expertise in the offshore fishing industry and established practice of building low-touch aquaculture solutions positions us to be operationally successful. If scaled, our practice would presens rapidly diminishing marginal costs as larger vessels can be repurposed and retrofitted for our needs.

Kelp mass accumulation consistent with existing aquaculture systems present viable yields for our applications. Running Tide has engaged in kelp farming pilot projects, reproducing and improving upon these yields. Growing kelp on the ocean surface has secondary benefits of adding oxygen to the water column and directly removing carbonic acid from seawater while also buffering against ocean acidification.

Quantification of the various components of our system is achieved through proprietary techniques that Running Tide continues to develop. Foremost, we quantify the biomass of kelp that has accumulated, along with the carbon content of that biomass. Secondly, we determine how many assemblies advect to the desired mid-ocean locations. Finally, we evaluate how many assemblies successfully sink to depth below 1,000 m.

We have determined experimentally that the kelp will descend rapidly to the ocean floor (over a period of hours). We use species of kelp that are naturally negatively buoyant, meaning that they sink. In some cases, the spent microfarm flotation may also provide additional sinking mass.

Carbon in kelp biomass sequestered to the deep ocean will remain stored for timescales in the range of 800-1100 years, or on the geological timescale. The outcome will depend on whether the carbon remains redissolved in seawater or if it becomes buried at the bottom.

Seawater is stratified by density gradients, which are formed by salinity and temperature. The depth of 1,000 m is below the permanent thermocline, below which ambient seawater will not mix with surface waters. We sink our kelp in water deeper than this 1000 m, where oceanographic consensus is that it will be sequestered away from the atmosphere. Once at the seafloor, the kelp will degrade in the ambient seawater, be eaten by deep sea fauna, or buried in accumulating sediment. Kelp that is eaten will be respired back into the seawater or buried along with the body of the consuming animal.

CO2 gas is compressible, and under pressure from the deep ocean it becomes denser than water. This means that the carbon dioxide will not bubble up and escape the ocean back into the atmosphere.

Carbon at the bottom is likely to dissolve into the ocean in the form of bicarbonate (HCO_3^-). Contrary to our intuition from shallow water that dissolved materials will distribute themselves uniformly, however, the ocean does not behave this way. As noted, the ocean consists of several distinct layers, each of which is well mixed with itself, but which do not mix with one another. Kelp carbon that gets dissolved into the ocean will mix within the layer of bottom water, but not remix to the surface.

Dissolved carbon below this depth will be sequestered for approximately 1,000 years due to the patterns of global ocean circulation that govern the time it takes for deep waters to recirculate and be in contact with the atmosphere. The bottom water layers are dense, cold and have low velocity. On the global scale, the oceanic circulation is driven by Earth's rotation, the geology of ocean basins and the large-scale water density gradients. Because these density gradients are due to temperature and salinity, these planetary-scale flow patterns are called the thermohaline circulation; they define a global "conveyor belt" of moving water. Thanks to this conveyor belt, the dissolved carbon on the deep North Atlantic seafloor will not resurface to the atmosphere for 800 - 1,100 years. This puts a lower bound on our sequestration permanence.

The sequestration time scale may be much longer, however, because the organic carbon from the kelp can become buried in ocean sediments at the seafloor at any time during its 1000 year journey along the ocean bottom. If this happens, it will remain buried there for geological timescales and will eventually be subducted along with the seafloor into the Earth's mantle. Burial via sedimentation occurs because of the accumulation of material on the seafloor. In the mid-ocean basins, this sedimentation is primarily driven by organic material that descends from the biosphere far above. Kelp may be buried directly (fragments of macroalgae have been observed in deep water sediment cores) or metabolized by bacteria, sea stars, worms, etc (macroalgal fragments have been found in the guts of crustaceans even in depths between 1,000 - 6,000 m and in the guts of brittle stars at depths between 3,000 - 5,000 m). All of these species' remains are similarly found buried beneath the ocean floor. Running Tide targets deep ocean sites with high burial efficiency, making sedimentation burial a likely outcome.

Our project approach has a variety of strengths when compared to other proposed sequestration techniques. Because photosynthesis-powered kelp metabolism performs the carbon capture, and ocean currents and gravity deliver the kelp to its sequestration location, we minimize the needed anthropogenic energy input to the system. Carbon is sequestered in a vast and underutilized region of the Earth (the seafloor), and carbon sequestered in this manner is removed from the carbon cycle for an order of magnitude longer than most other forms of CCS. This experiment relies on existing biological processes, but does not introduce new ones, constraining the set of secondary ecological impacts. The base case of a single microfarm assembly is simple, modular, and designed to be mass produced.

Unlike other marine CCS approaches that can alter food webs and deoxygenate large areas of the ocean, our experiment has minimal negative environmental impacts. Our approach requires few industrial processes and emits a minimal amount of emissions because the primary drivers are photosynthesis, ocean currents and gravity. We consider adverse impacts of sourcing and releasing non-kelp materials from the assemblies into the open ocean, and conclude a need to rely on green manufacturing techniques and the use of sustainable, biodegradable, and ecologically inert materials. This choice provides additional sequestration benefits as organic matter is carbon rich and many viable materials, especially natural fiber line, can be carbon negative to produce.

Carbon sequestration through our methodology is additional; it does not simply displace sequestration that occurs through other natural processes. Our macroalgae farms grow in the open ocean, far away from coastal macroalgal habitats. Our cultivated biomass is therefore not displacing naturally occurring macroalgae. The open ocean surface-habitat of the North Atlantic is microbe rich; carbon fixing bacteria and eukaryotes contribute to the ocean's natural biological pump. Because growing macroalgae uptakes dissolved inorganic carbon, we can be confident that our cultivated biomass is not fixing carbon that is an output of this pump process and already bound for the deep sea.

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

Running Tide is the primary actor. We create kelp sporophytes in our nursery. We design and build the floating assemblies along with the instrumentation needed to quantify the various components of sequestration. We perform the modeling to target ideal deployment locations and seasons, and perform the post hoc data analysis to determine how much carbon was sequestered.

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

<300 words

1. Biological: Kelp aquaculture yield data is available for near-shore growing, however it is unknown how open ocean growth yields will compare to their coastal counterparts. Nutrient availability, particularly that of nitrates, is lower in the open ocean than near the coasts. Running Tide is conducting ongoing studies of kelp growth in this environment.
2. Regulatory: Running Tide is engaged in careful study of the regulatory environment governing open ocean operations of this kind. Because this specific industrial use of a public common (the high seas) has never before been practiced, there is mismatched guidance over in whose jurisdiction and through what pathway we may proceed. Because the ocean has historically been subject to unsustainable exploitation, Running Tide advocates for, and hopes to realize, an unambiguous regulatory regime in which to operate.

3. Quantification: because of the remote location of the aggregated biomass and successful flux to the deep sea, measurement of carbon capture will need to be inferred (e.g. extrapolation from measured subsets to full population in the presence of a model), and will almost certainly be an underestimate.

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

All patents currently pending

2. Timeline and Permanence (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 2021 - Jun 2022. The end of this duration determines when Stripe will consider renewing our contract with you based on performance.*	*<10 words* Phase 2 offshore experiments from June 2022 - June 2023.
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 2021 - Jun 2022 OR 500 years.*	*<10 words* Continuous removal for 6-8 months from deployment: June 2022 - Feb 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*	*<50 words* Macroalgae is one of the most productive marine vegetated systems and its carbon removal capacity is proportional to biomass

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".	accumulation over the 6-8 month grow out. Uncertainties arise from the consistency in kelp growth and carbon content of the biomass as the kelp encounters varying open ocean conditions (e.g. temperature, salinity, nutrient concentration).
Permanence *Over what duration you can assure durable carbon storage for this offer (e.g. this batch of biochar, these rocks, this kelp, this injection site)? E.g. 1000 years.*	*<10 words* > 800 years

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

Number/range 800 years - 100s of million years (geological permanence)

c. Have you measured this permanence 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

Experiments demonstrating that kelp biomass sinks to 1000 m ocean depths will be conducted Summer 2021 as a part of our phase 1 research. Microfarms equipped with pressure release sensors will allow us to determine the fraction of microfarms that flux to a given depth. Because the mechanism for this flux is a denser-than-water object sinking by means of gravity, we have high confidence that microfarms which begin sinking will migrate all the way to the ocean bottom.

If the macroalgal carbon reaches the depth of 1,000 m, then it is sequestered away from the atmosphere [1]. Running Tide cannot measure this permanence directly, but we rely here on consensus in the oceanographic community.

This consensus is driven by radioisotope evidence of the low velocities of deep-sea currents, and modelling of the residence time in the North Atlantic deep-sea. The latter corresponds to the period after which a water parcel leaves the deep-sea and starts mixing with the rest of the ocean, is about 100 years; it then takes over 1,000 years for these North Atlantic deep waters to resurface to the atmosphere [2, 3].

[1] Krause-Jensen, D., Lavery, P., Serrano, O., Marba, N., Masque, P. & Duarte, C.M. (2018). Sequestration of macroalgal carbon: the elephant in the Blue Carbon room. Biology letters 14, (6):20180236.

[2] Broecker, W.S. (1971) A kinetic model for the chemical composition of sea water. Quaternary Research 1, 188-207.

[3] Broecker, W.S. & Peng, T.-H. (1982) Tracers in the Sea. Lamont-Doherty Geological Observatory, Palisades, N.Y., Eldigio Press.

d. What permanence 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

Once the biomass carbon is sunk to depth, there is no known non-acute natural process that could cause it to surface faster than the ocean mixing dynamic discussed above, and the distribution density on the sea floor will be too low for acute phenomena (i.e. undersea eruption, trawling) to cause sequestration reversal at scale. At depths greater than 1000 m, human activities do not meaningfully disturb the deep ocean water or the seafloor. Carbon stored in this remote region is beyond the reach of socioeconomic turbulence.

We do not rely on any assumed rate of decomposition to derive residence time; if the kelp were instantaneously transformed into dissolved carbon it would still achieve 800-1100 year permanence. And the more slowly the kelp decays, the more of it will be buried under accumulating ocean sediment and achieve geological scale permanence.

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

In the short-term, we rely on modelling and evidence gathering already conducted by oceanographers and marine scientists. The model of the ocean through which we calculate permanence already benefits from mature consensus: if carbon redissolves into the North Atlantic deep waters, it will remain within the ocean interior for over 800-1100 years before resurfacing to the atmosphere, due to the global oceanic circulation patterns; if carbon becomes sediments, it will be sequestered for geological scales.

Determining what quantity of carbon is buried, as opposed to dissolved and resurfaced, is a secondary consideration for us because the latter still provides commercially and environmentally viable permanence. However, in the long run Running Tide will use its activities in the deep ocean waters to generate datasets for marine scientists. We will evaluate this question, and more broadly aid in the exploration of this most remote region of the world.

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	2,000 tCO_2
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	N/A

b. Show your work for 2(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

Sugar Kelp (saccharina latissima) sequesters ~ 0.001 tCO2 / kg biomass (dry weight). Each microfarm yields on average ~ 72 kg biomass (dry weight). We assume that 75% of the microfarms advect to ocean areas over deep water basins and sink to >1000m depth. We are offering to deploy 37,000 microfarms for Stripe. These numbers multiply to ~ 2k tCO2 gross removal.

Uncertainty arises primarily from unknowns about kelp growth response in open ocean conditions. How will yields in these areas differ from experiments conducted in coastal farms given a varying nutrient profile? At what depth can we expect kelp to grow in the open ocean given that light will penetrate deeper into clear water than it does near shore?

The 75% assumption for successful microfarm dispersion is a conservative heuristic to be refined by ongoing pilot projects.

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

Our Portland area hatchery can seed enough kelp to sequester in excess of 50,000 tCO2 / year, which is matched by our ability to deploy offshore.

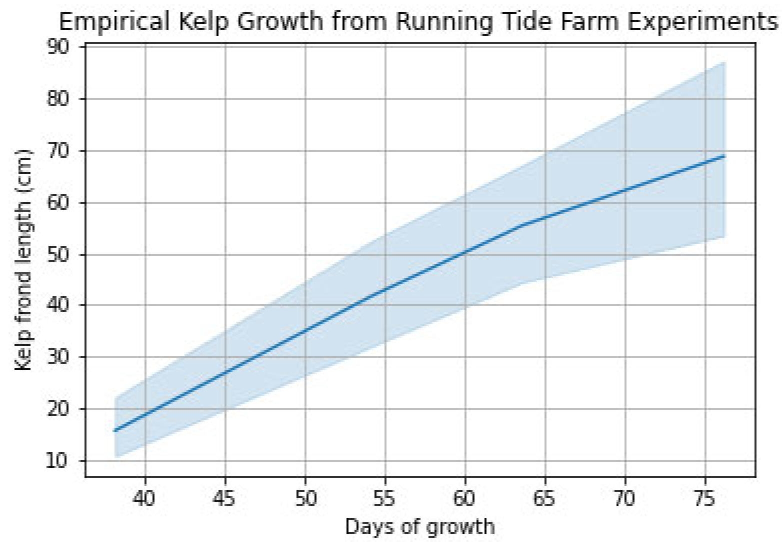
d. We are curious about the foundational assumptions or models you use to make projections about your solution's capacity. Please explain how you make these estimates, and whether you have ground-truthed your methods with direct measurement of a real system (e.g. a proof of concept experiment, pilot 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

Running Tide's foundational assumptions for kelp biomass accumulation come from a survey of relevant literature [1]. We have ground truthed these assumptions by operating experimental kelp farms and found yields consistent with the upper bounds of published results (data inline below). We send samples of our biomass off to third party laboratories to be characterized for carbon content and found similar correspondence with our expectations.

Phase one of this experiment, underway now, will ground truth our dispersion assumptions about open ocean microfarm migration, which thus far has been model driven not empirically based.

[1] Augyte, S., Yarish, C., Redmond, S. & Kim, J.K. (2017). Cultivation of a morphologically distinct strain of the sugar kelp, Saccharina latissima forma angustissima, from coastal Maine, USA, with implications for ecosystem services. Journal of Applied Phycology 29, 1967-1976. doi:10.1007/s10811-017-1102-x.



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*

- An ongoing scientific review of our methods, data, and environmental performance by Ocean Visions is expected to be made available at the end of 2021.
- Otherwise please see our website and media coverage here and here.

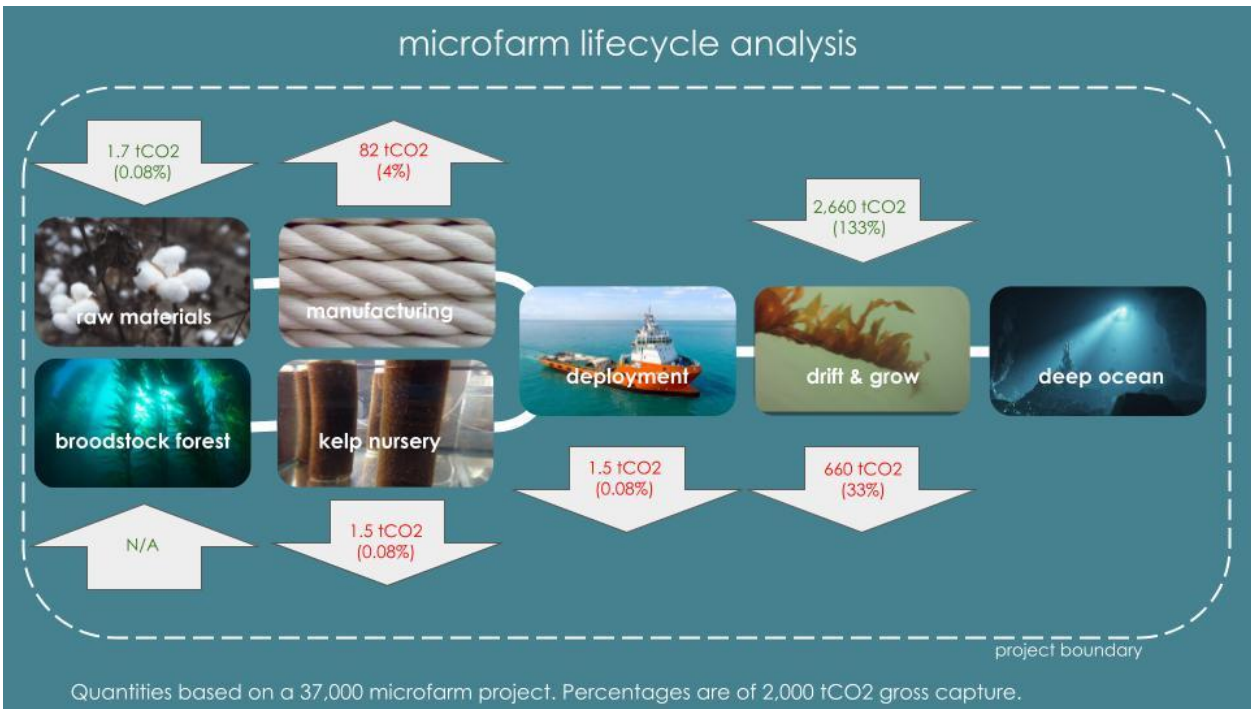
4. Net Capacity / Life Cycle Analysis (Criteria #6 and Criteria #8)

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	2,000 tCO2

Gross project emissions	85 tCO2
Emissions / removal ratio	4.2%
Net carbon removal	1915 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 last year 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?

<200 words The boundary includes embodied carbon for single use materials used in constructing our systems, as well as anthropogenic energy inputs in the form of grid electricity for facilities and diesel fuel for ocean vessels. These resources are included because they would not otherwise be consumed but for our project. The boundary excludes the embodied carbon in satellite networks used to relay in situ measurements from the open ocean back to land. It also excludes computers used to process

data for quantification. These resources are commonly shared, have already been established without demand generated by our experiment, and the marginal energetic cost of operating them is de minimis when amortized over our experiment.

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](https://www.nature.com/articles/s41560-020-00771-9).

<200 words

Drift & Grow: capture is based on endemic kelp species yields and carbon content in literature [1]. Loss of captured carbon during Drift & Grow is based on a 75% successful flux estimate (e.g. the quantity of microfarms that sink at the proper time and are delivered to the deep sea). This is a margin of error heuristic that will be refined in pilot experiments.

The following items are based on Running Tide's internal research, have not been directly measured, or verified by a third party.

A broodstock forest sequesters CO2 and exports it to the deep sea. We do not attempt to quantify this additional sequestration [2].

Raw materials sequestration is based on estimates of natural fiber production as a carbon sink (cottonleads.org)

Manufacturing represents processing and transportation to transform raw materials into constituent parts for our microfarms. These are loose estimations that will ultimately be supplier specific.

Kelp nursery emissions are based on grid power consumption in the Portland, ME area. Projections are based on Running Tide's experience operating a facility of this type and scale.

Deployment emissions based on diesel fuel needs of an appropriately sized vessel are informed by Running Tide's experience in the commercial offshore fishing industry.

[1] Augyte, S., Yarish, C., Redmond, S. & Kim, J.K. (2017). Cultivation of a morphologically distinct strain of the sugar kelp, Saccharina latissima forma angustissima, from coastal Maine, USA, with implications for ecosystem services. Journal of Applied Phycology 29, 1967-1976. doi:10.1007/s10811-017-1102-x.

[2] Mcleod, E., Chmura, G.L., Bouillon, S., Salm, R., Björk, M., Duarte, C.M., Lovelock, C.E., Schlesinger, W.H. & Silliman, B.R. (2011). A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO_2. Frontiers in Ecology and the Environment 9, (10):552-560.

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. (We may request such an audit be performed.)

<100 words Running Tide performs high quality industrial record keeping to track all component parts, as well as the energy budget of our facilities and our vessels. We coordinate with third party suppliers to do the same. These records will substantiate the carbon budget within our LCA project boundary, and we will make them available to appropriate verification auditors.

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 your progress.)

a. Please define and explain your unit of deployment. (*E.g.* # of plants, # of modules) *(50 words)*

<50 words # of microfarms.

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 if necessary.

Year	**Units deployed (#)**	**Unit cost ($/unit)**	**Unit gross capacity (tCO_2/unit)**	**Notes**
2021	10000	27	0.072 tCO2	*<50 words* Projected: combination of stationary deep water forest sites and small scale scientific drifter deployments. Costs are driven by instrumentation.
2020	1600	40	0.04 tCO2	*<50 words* Deployment of stationary inshore microfarms.

2019	50	N/A	N/A	<50 words
2018	5	N/A	N/A	

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

A primary driver of cost has been instrumentation to remotely monitor biomass accumulation. We have pivoted from exploring third party tools to working either in house or with partners to develop scalable custom solutions. After the initial development cost of this work, we expect marginal cost to decline. Experimental deployments also have higher instrumentation density than is projected for commercial deployments.

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)
37,000	0.072 tCO2/unit @ 75% unit success rate

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

We ask these questions to get a better understanding of your growth trajectory and inflection points, there are no right or wrong answers. If we select you for purchase, we'll expect to work with you to understand your milestones and their verification in more depth.

a. What is your cost per ton CO_2 today?

\$150/ton CO_2

The cost backed out from 5b would be $375/tCO2 for our pilot projects. However, these pilots are heavily instrumented as their primary goal is data collection. If we undertook a commercial deployment at today's capability, we would deploy more farms and instrument a smaller percentage of them, for an amortized marginal cost of $150/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."

>100 words

We represent the marginal cost of producing and deploying microfarms to sequester CO2. This includes:

- OPEX of our kelp nursery
- Purchasing materials for microfarm fabrication
- Labor and facilities cost of microfarm fabrication
- Vessel deployment and fuel costs
- Instrumentation purchase and OPEX for quantification

We do not include fixed start up costs:

- CAPEX of building / expanding our kelp nursery facilities
- Development of data science layer to perform quantification

c. List and describe **up to three** key upcoming milestones, with the latest no further than Q2 2023, 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* License and establish a large offshore kelp broodstock forest.	*<200 words* Sustainable harvest of wild sorus tissue limits our ability to scale. If we can seed and outplant kelp that we raise to reproductive maturity we streamline this process and make it sustainable at scale.	Q2 2022	*<100 words* We will be able to demonstrate a permitting record and primary observation of the growing forest (e.g. photography).
2	*<100 words* Improve reliability of sinking mechanism.	*<200 words* We discount our total expected biomass yield by 30% (i.e. multiply it by 0.7) to approximate a	Ongoing indefinitely	*<100 words* Compare empirical results of successful trajectories against 70% baseline.

		quantity of buoys that fail to sink, or sink too soon. This discount could be reduced as we refine this mechanism.		
3	*<100 words* Demonstrate quantification of offshore biomass accumulation through Instrumentation of microfarms.	*<200 words* This is a key component to verification of our lifecycle. Some partners will be happy to accept model and laboratory based yields. Larger public acceptability will be driven by empirical characterization.	Q4 2021	*<100 words* We will share experimental results with appropriate partners.

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)* 10 - 50k tCO_2.	250 - 500k tCO_2 with 2022 goals. Improved cultivation and geographic expansion of broodstock forests will continue to increase capacity.	*<100 words* Sustainable harvest of wild sorus tissue limits our ability to scale. If we can seed and outplant kelp that we raise to reproductive maturity we streamline this process and make it sustainable at scale.
2	10 - 50k tCO_2	10 - 70k tCO_2	*<100 words* Removal of 30% discount increases upper bound by factor of ~1.4. Note that this is true at any scale, i.e. here we show 50k becoming 70k but if we increased our baseline to 500k (e.g. by

			creating a broodstock forest) this innovation would increase capacity to 700k, etc.
3	10 - 50k tCO2.	10 - 50k tCO2.	*<100 words*

d. 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)* 150 $/tCO2	70 $/tCO2	*<100 words* Enabling the ability to scale unlocks economies of scale in all parts of our supply chain (raw materials purchase, processing, deployment, instrumentation costs)
2	150 $/tCO2	107 $/tCO2	*<100 words* Increasing yield by 1.4 for a fixed capital outlay decreases cost by the same factor.
3	150 $/tCO2	150 $/tCO2	*<100 words*

e. 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

President Biden could direct Federal agencies (NOAA and the State Department) to create an unambiguous regulatory and permitting pathway for nature-based ocean CDR, and use diplomatic channels to bring together the world's coastal nations to adopt compatible frameworks.

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

<50 words

Help us educate the public on the need to enable large-scale nature-based Ocean CDR, motivating a broader civic conversation about the urgent need for climate action in the context of economic and ecological considerations.

7. Public Engagement and Environmental Justice (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 some mechanism 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. There are no right or wrong answers, and we recognize that, for early projects, this work may not yet exist or may be quite nascent.

a. Who are your external stakeholders, where are they, and how did you identify them?

We consider our stakeholders to be all inhabitants of planet earth, who face an existential threat as climate change progresses. Being stewards of the marine environment is at the heart of Running Tide's mission, and we have engaged with scientists, law practitioners, commercial fishermen and engineers to design an ocean-friendly technology that minimizes the risk of secondary environmental impacts. We will be regularly updating, communicating with, and seeking dialog with these and additional stakeholders at the community, Federal, and international level.

b. If applicable, how have you engaged with these stakeholders? Has this work been performed in-house, with external consultants, or with independent advisors?

We have engaged with both in-house and external advisors to design microfarms that intentionally minimize any foreseen negative interaction in the open ocean. For instance, with regards to marine mammals, we design to ensure that our devices would not pose an entanglement threat. We spoke with leading marine mammal scientists to determine what breaking strength our kelp lines should aim to be under. We spoke with engineers and boat captains, both in-house and externally to minimize the chance of problematic entanglement in boat propellers. We spoke with in-house and external consultants to fully understand the scope of international regulations on the use of plastics in the ocean, which drove us to build entirely biodegradable microfarms.

We are currently working with an independent marine science advisory panel through Ocean Visions to provide both scientific and technical advice and overall evaluation of the Phase 1 experiment. They will evaluate our innovation, advise on methods of field testing, support impact analysis and optimization, and provide independent external review and assessment of outcomes.

We are also engaging outside legal counsel to advise on our permitting path for ocean carbon dioxide removal in the high seas.

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?

Engaging with stakeholders has helped clarify the set of environmental risks of greatest concern, and the need to build systems that accommodate many potential environmental impacts. Our design process incorporates input parameters and concerns from a variety of stakeholders, as described in (b). We are constantly conducting experiments and iterating to improve our design.

On the policy side, we have learned that there are a variety of international frameworks in place to regulate commercial activities on the ocean, however, none of these are designed to deal with our specific nature-based CDR technique. The range of ocean-related treaties under the United Nations include, but is not limited to: The Law of the Sea, The London Protocol, The Convention on Biological Diversity, The International Seabed Authority, and the International Maritime Organization. Based on initial assessment, no treaty to which the US is a Contracting Party currently exists that would provide the operating framework for this particular nature-based ocean carbon dioxide removal system on the high seas. For that reason, we are actively seeking the advice of the relevant US government agencies.

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?

The bulk of the changes we have planned focus on the industrial supply chain and removing bottlenecks that hinder the scaling of our operation.

Unlocking this scale will impact the set of direct stakeholders and the means of outreach we will use to engage with them. As we expand to global oceans, we will likely deploy from foreign coasts and foreign flag vessels. Foreign governments and international organizations (i.e. NGOs with this focus) will have to be considered. As the scope of our operations scales, so will our impact on the industries in our supply chain. It is difficult to predict what form this new outreach will have to take, but in order to remain committed to a program of social justice we will need to respect the communities of global workers that are integrated into our mission.

e. What environmental justice concerns apply to your project, if any? How do you intend to consider or address them?

The high seas are a global public common that we regard as the frontline of the war against climate change. We are engaging with the scientific community and government agencies to develop a regulatory framework that guides the use of this vast and underutilized resource to bring about climate justice for all. Climate change disproportionately affects the poorest citizens of our planet; those who are both most vulnerable to and least responsible for the problem.

11. Legal and Regulatory Compliance (Criteria #7)

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

We have received legal opinions on how our solution fits within a range of international legal frameworks.

The most common commercial activity in international waters is fishing, and there are a range of treaties that deal specifically with this. While we propose to grow kelp in international waters, this activity is not fishing and therefore that universe of international treaties does not apply.

Under the Law of the Sea, there is specific language on conducting marine research on the high seas, and our research activities clearly fit within this framework. The US is not a Contracting Party to the Law of the Sea, but the US does consider some provisions of the Law of the Sea treaty to be customary international law. However, customary international law is not self executing and there is no specific implementing legislation or regulations in US law that pertains to this specific research proposal.

The London Convention is an international treaty to which the US is a contracting party. It is designed to protect the marine environment from pollution caused by dumping material into the ocean. Given that we place our microfarms in the ocean for the purpose of sequestering carbon, Article III b ii) of the London Convention considers this activity to be something other than dumping: "Dumping" does not include: Placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this

Convention." In accordance with the London Convention, the US has enacted the Ocean Dumping Act, that prohibits the dumping of material taken from US ports into ocean waters. However, the proposed activity does not meet the definition of dumping in the Act, the same as it is not dumping under the London Convention, and the proposed activity is therefore unencumbered by the Act's prohibitions. In1996, several countries negotiated an updated treaty to address ocean dumping, the London Protocol. The US signed the London Protocol but is not a Contracting Party and is not bound by the new agreement.

b. What permits or other forms of formal permission do you require, if any? 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.

We have obtained the following permits to conduct our kelp pilot project:

Hatchery Permits:
Department of Environmental Protection Discharge Permit
Department of Agriculture, Conservation and Forestry Submerged Lands Lease
Department of Environmental Protection Natural Resources Protection Act (NRPA) Permit
United States Army Corps of Engineers Permit

Kelp Growing Permits:
State of Maine Department of Marine Resources Special License
Maine Department of Marine Resources Experimental Lease
Goose Island Army Corps General Permit

c. 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.

Clear regulatory frameworks, in the form of treaties and enacting legislation to which the US is a Contracting Party do not currently exist. We will continue to seek support from US agencies to ensure we operate within the bounds of US international obligations.

12. 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.

Pricing Note (added by Stripe after application review): In our Spring21 purchase, we paid this project $250 per tonne. The project provided the following context for their price:

"The current price reflects Running Tide operations after successful pilot scale projects and before reaching larger deployment sizes. We expect price reduction at larger deployment sizes."

	Offer to Stripe
Net carbon removal (metric tonnes CO_2)	*Should match the last row in table 4(a), "Net carbon removal"* 2,000 tCO2
Delivery window (at what point should Stripe consider your contract complete?)	*Should match the first row in table 2(a), "Project duration"* Q2 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).* 250 $/tCO2 We build in a purchase premium over our marginal cost to support R&D that is based both on development needs to attain long term scale and market research; it is discounted from the price we believe we could command on third party public facing platforms.

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 Ocean grown macroalgal biomass

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

<200 words Running Tide sustainably harvests indigenous sorus tissue, performs sporulation in our facilities, and seeds seaborne microfarms.

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 2021	Competing/existing project area use (if applicable)
Feedstock cultivation	0.001 km2 kelp nursery facility	N/A
Processing	0.01 km^2 existing boat yard and pier in Portland, ME	None; our use does not interfere with existing use.
Long-term Storage	3 million square miles of North Atlantic Ocean bottom	None; this is the most remote and unutilized region of the world.

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	- 0.03 km2 kelp nursery facility - 1000 acre offshore broodstock forest	N/A
Processing	- 0.075 km2 existing boatyard facilities distributed globally - 0.75 km2 fabrication facilities, distributed globally	Boatyard usage does not interfere with existing use. Fabrication facilities are repurposed from existing warehouse spaces.
Long-term Storage	40 million square miles of deep ocean bottom worldwide	None; this is the most remote and unutilized region of the world.

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 Additional anthropogenic processing of biomass is not needed to ensure permanence. Microfarms are transported from near shore deployment sites to their deep water

sequestration sites by natural ocean currents. The fall under their own weight through the water column to the seafloor where they are transformed through either sedimentation burial or benthic fauna respiration into their final long term storage state.

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

Biomass resources would not have been produced but for our project.

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

Our experiment is mimicking existing natural processes which have been on a systematic global decline. For example, over 90% of kelp forests in Northern California have disappeared in recent years. Because wildly occurring macroalgae biomass is naturally exported to the deep-sea during final life stages [1], a side effect of our project is to replete ecosystems that have been depleted due to human activities. Indeed, macroalgae is part of the diet of some benthic animals [2] and macroalgal fragments have been observed down to 7,955 m [3]. These considerations make us confident that the set of ecological interactions produced by our activity will be constrained to those which already naturally occur in these environments.

In considering invasive species, the risk of introducing non-endemic kelp to other parts of the global ocean is low because we select for species that are broadly habituated (Sugar Kelp, for example, is already found across all coasts of the Northern Atlantic). In considering macrofauna, our vertical, free floating, and low-tensile strength, design was developed explicitly to avoid entanglement with marine mammals.

Finally, the risk of a methane release associated with this carbon addition is also very low, as methanogenesis will be minimized by the large amount of sulfate in the deep seawater of the North Atlantic.

[1] Krause-Jensen, D., Lavery, P., Serrano, O., Marba, N., Masque, P. & Duarte, C.M. (2018). Sequestration of macroalgal carbon: the elephant in the Blue Carbon room. Biology letters 14, (6):20180236.

[2] Krause-Jensen, D. & Duarte, C.M. (2016). Substantial role of macroalgae in marine carbon sequestration. Nature Geoscience 9, (10):737–742. doi:10.1038/NGEO2790

[3] Wolff, T. (1979). Macrofaunal utilization of plant remains in the deep sea. Sarsia 64, (1-2):117-143.

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

When compared to forestry solutions, our experiment benefits from a much faster project timeline (~6 month biomass growth vs tens of years) and lower risk of reversal (i.e. in wildfires). We also present diminishing marginal cost at scale, unlike land intensive solutions.

BECCS type solutions similarly require large amounts of land (or coastal farming area) for primary biomass cultivation as well as in utilizing suitable locations for long term carbon storage. Some BECCS solutions are fertilizer intensive. Our experiment requires minimal coastal resources (broodstock forests efficiently generate enough seed for large open ocean farming projects) and is fertilizer free. Harvesting kelp biomass for fuel is labor intensive, a cost driver which we avoid through passive sinking.

Finally, our experiment would outperform most other biomass solutions in its permanence. Not only is 800 year minimum lockup in deep sea currents substantial, but the prospect of burial in ocean sediment is even more tantalizing. Carbon sequestered in this manner may be slowly returned to its pre-industrial state (e.g. as buried hydrocarbon) over the eons to come.

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

Offshore deployment will be achieved by traditional vessels which steam from their ports of call sufficiently offshore for released microfarms to catch prevailing ocean currents. This offshore distance generally corresponds to a few hundred miles from the coast. During these deployments, the vessels will adhere to navigational requirements and best practices as required by the flag-state responsibilities.

The microfarms will be deployed from the vessels into the open water in a localized group and at sufficient intermediate distance to reduce entanglement. From here they will disperse with currents out to sea. Their small size, low breaking strength, and sparse density will minimize interference with commercial and ecological activity.

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

The microfarms were designed to be dispersed by currents throughout the open-ocean; therefore, the physical footprint will be sets of scattered microfarms, with each microfarm occupying less than a square meter at the ocean surface and less than 50 meters vertically in the water column. Once they sink, the microfarms are expected to vertically stack on the seafloor due to their weight, occupying a few cubic meters total.

Running Tide is initially focusing on the open North Atlantic, in which high dispersion is expected; and North Atlantic subpolar gyres, in which low dispersion is expected.

The final density estimates range from 1 microfarm per 16 km2 in a high-dispersion estimate (example, 200,000 microfarms released at once in the open North Atlantic) to 1 microfarms / km2 in a low-dispersion estimate (example, 200,00 microfarms released at once into gyre conditions). In practice we will seek a mixture of these conditions.

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 this scale we would expand our deployment geographies to include all global oceans. Assuming a balanced deployment volume across high and low dispersion sites to achieve uniform microfarm density, we estimate 4 microfarms / km2 at the surface of these waters at any one time and an accumulation of 8 microfarms / km2 at the ocean bottom per year.

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

Running Tide has over 100 personnel years engineering, rigging, and operating in open ocean environments.

The core engineering challenge is to build a flotation system that is robust to open ocean conditions and also calibrated to sink within a designated range of time, or within a designated geographical area, or after having accumulated a designated amount of biomass.
Our solution relies on a large population of small, modular microfarms. A simple and dematerialized system has fewer failure modes. The short material span of the microfarm, together with its property of being free floating, reduces the tensile and shearing forces it will experience from wind and sea. The quantity of microfarms and the area over which they will disperse makes the entire project resilient against acute destruction (i.e. from storms of human interference) which we can expect to occur locally.

As a precedent we look to the ARGO project, which has released thousands of drifting instruments into the world's oceans. These floats have persisted intact and at sea for long durations, demonstrating the viability of this architecture for a large scale project.

The fishing industry has also set a precedent for the deployment of thousands of floating on the high seas that are tracked with GPS to attract tuna. In certain ocean areas, a single boat can deploy and track up to 1,000 Fish Aggregating Devices. These can be deployed into a nation's Exclusive Economic Zone as well as the high seas, and are made to withstand ocean conditions for several years. In recent years, there has been momentum in making these devices out of biodegradable materials.

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

The microfarms being dispersed by the currents, most environmental impacts will be localized and scattered at the surface and on the seafloor. At their sparse density, microfarms will not measurably impact the chemical conditions of these ecosystems. Through our collaboration with Ocean Visions, we are working with an independent panel of marine experts to test our assumptions by means of an environmental assessment which considers both the surface and the seafloor.

At the surface, kelp photosynthesis reduces the concentration of carbonic acid, thereby buffering ocean acidification. Kelp also buffers eutrophication by absorbing nutrients and competing with the short-lived photosynthetic algae that causes anoxic conditions. In considering macrofauna, our vertical, free floating, and low-tensile strength, design was developed explicitly to avoid entanglement with marine mammals.

On the seafloor, the quantity of carbon delivered via our microfarms is minimal compared to what is already present in this region. This together with the vast geographic dispersion of the farms, and the fact that macroalgae is already naturally exported here, makes us confident that we will not adversely disturb this ecosystem.