General Application

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

Company or organization name

Climate Foundation

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

USA with operations in the Philippines and Australia

Name of person filling out this application

Dr. Brian von Herzen

Email address of person filling out this application

info@climatefoundation.org

Brief company or organization description

Marine Permaculture Alliance focuses on regenerating life in the ocean and balancing carbon out of the atmosphere and into the deep ocean

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.

For our offer to Stripe, the Climate Foundation will fix and store deep-ocean carbon over a broad specified area in Visayas, Philippines. Our operations are scheduled to expand considerably each year as we are expecting permits next quarter for a preliminary dozen hectares in anticipation of providing irrigation services for an entire 200-hectare historical seaweed farming site in the Visayas, Philippines. Bank and private equity discussions are presently underway for financing this project. Stripe purchases will help to secure this private financing. We will work directly with local Filipino seaweed farmers to restore production and increase their yields.

We will be sinking seaweed equivalent to a net sequestration of 800 tonnes of CO_2 at a price of US$600 per tonne within a period of 4 years. During the project's early stages, as a backup option, we may initially procure seaweed locally from commercial farmers as we scale up. The storage in the deep ocean will be additional as we are intervening to make it happen. The seaweed can be grown at multiple sites in the Visayas and will be towed with a solar powered pump boat to the Bohol Sea, which has depths of over 1,000m (see Figure 8 for an example). A broad specified area will be used for sinking seaweed as carbon export to avoid putting all the carbon in one place on the seafloor, minimizing local impacts.

Sinking seaweeds to a depth of over 1000m ensures its carbon will remain in place for hundreds of years before outcropping to the surface of the ocean in the Northeastern Pacific. The species of seaweed used will be *Eucheumatoid Spp (Eucheumatoids).* Prior to the sequestration, the C:P ratio for the seaweed will be determined; however, for the purposes of this application, we assume, a C:P ratio of approximately 485:1, derived from a mean of red seaweeds taken from Rao and Indusekhar (1987). Thus, for every 117 C atoms upwelled, approximately 485 will be fixed in the *Eucheumatoid* seaweeds that sink by themselves rapidly. We anticipate that at a conservative estimate it will be below 1000m in <48 hours, although this sinking can be accelerated by compactly baling seaweeds. The sinking of these bales will be monitored using sidescan sonar to monitor the sinking of the seaweed. Monitoring will be combined with radiocarbon dating of the deep ocean water's age to demonstrate the long-term sequestration of our intervention.

Our current team of over a dozen staff in the Philippines are leading this project, although the team will expand as we scale. Remote operational support will be provided by Climate Foundation team members working in North America, Australasia and Europe.

This project will demonstrate, for the first time, that regenerating deep ocean carbon export and storage by growing and sinking macroalgae can serve as an economical and effective source of blue carbon removal. Our project will serve to effectively and logically demonstrate the potential of deep ocean sequestration through macroalgae, and will accelerate efforts to develop and accredit a deep ocean macroalgae carbon export methodology, so that a number of nearshore and offshore seaweed farmers can engage in similar projects that use macroalgae as a source of carbon export. Demonstrating the carbon removal potential of offshore macroalgae cultivation can also help accelerate the development of the industry by giving it greater credibility among carbon-conscious funders and by providing additional potential revenue streams from carbon credits. The Climate Foundation is currently being encouraged and supported by industry and multiple certification bodies, including Verra, ACCU, and Nori, to detail and co-develop these carbon capture methodologies.

Background

Marine Permaculture (MP) regenerates ocean life with permaculture design principles applied to marine environments, while developing high value seaweed products and sequestering carbon. Across the tropics, warming waters increase ocean stratification, decreasing natural upwelling essential for primary production. As a result, seaweed forests are in steep decline in many tropical, sub-tropical and temperate waters, notably off the coasts of Tasmania and California, both of which have seen a decimation of their natural seaweed ecosystems and their associated marine life (Wernberg and Straub, 2016). Warming surface temperatures are also severely affecting smallholder seaweed farmers and their communities in Southeast Asia, who have seen their yields plummet in recent years, with devastating consequences for coastal economies.

The decline of tropical seaweed forests is a concern for climate mitigation. Seaweeds have some of the highest carbon:phosphorus ratios and carbon fixation rates of any ecosystem on the planet, with rates of 2500-3000 g-C/m^2/year (Egan and Yarish, 1990; Mann 1972; Wu et al. 1984; Gao and McKinley, 1994; Muraoka 2004; Buschmann et al., 2008). The primary carbon sequestration function provided by macroalgae is their role as “carbon conveyor belts” that export particulate organic carbon (POC) and dissolved organic carbon (DOC) into the deep ocean. There is much evidence documenting the presence of seaweed in the deep ocean, including discovery of macroalgae DNA in ocean depths of 4,000m and distances approaching 5000km from land (Ortega, et al., 2019), hypothesizing that globally macroalgae naturally export 679 TgC yr. Once sunk at a depth of between 500 - 1,000 meters this carbon is removed from the atmospheric carbon cycle for centuries to millennia (Krause-Jensen and Duarte, 2016; Herzog et al., 2013), enabling it to qualify for long-term carbon sequestration (see Figure 1 for a diagram of how kelp forests fix and sequester carbon and Figure 2 for a diagram of carbon sequestration and the biological carbon pump). Enhancing such natural processes by sinking macroalgae into the deep ocean, which currently hold ~12 times more carbon than terrestrial ecosystems (Ontl and Schulte, 2012), therefore represents a substantial and widely overlooked opportunity for carbon balance.

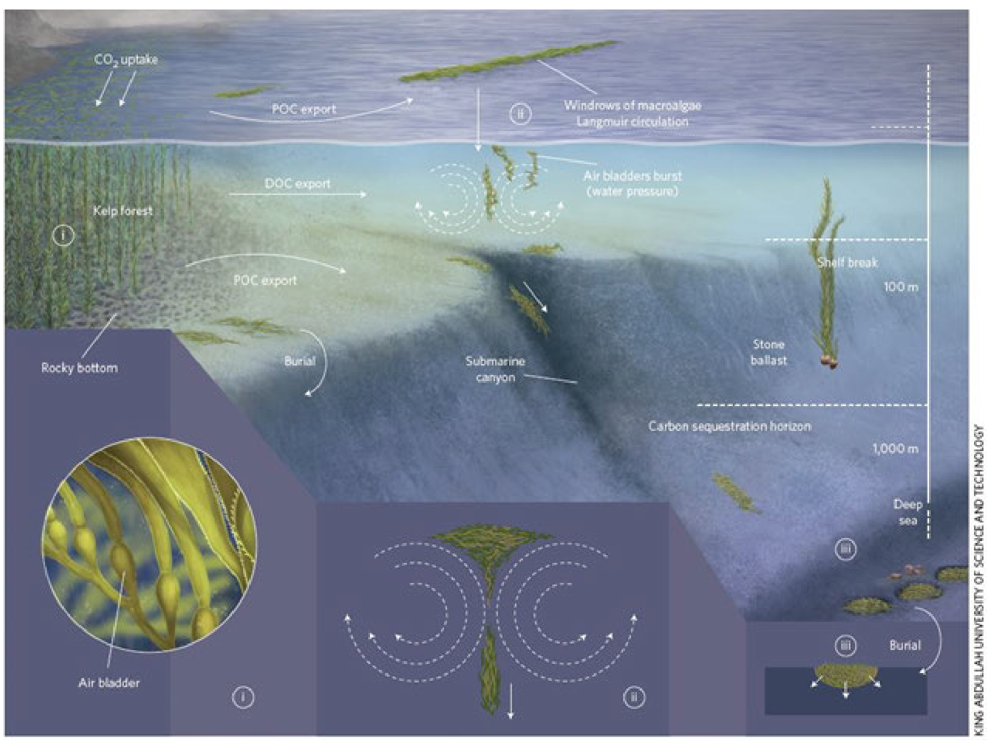


Figure 1: Dorte Krause-Jensen, & Carlos M. Duarte. (2016). Substantial role of macroalgae in marine carbon sequestration. Nature Geoscience, 9(10), 737-742.

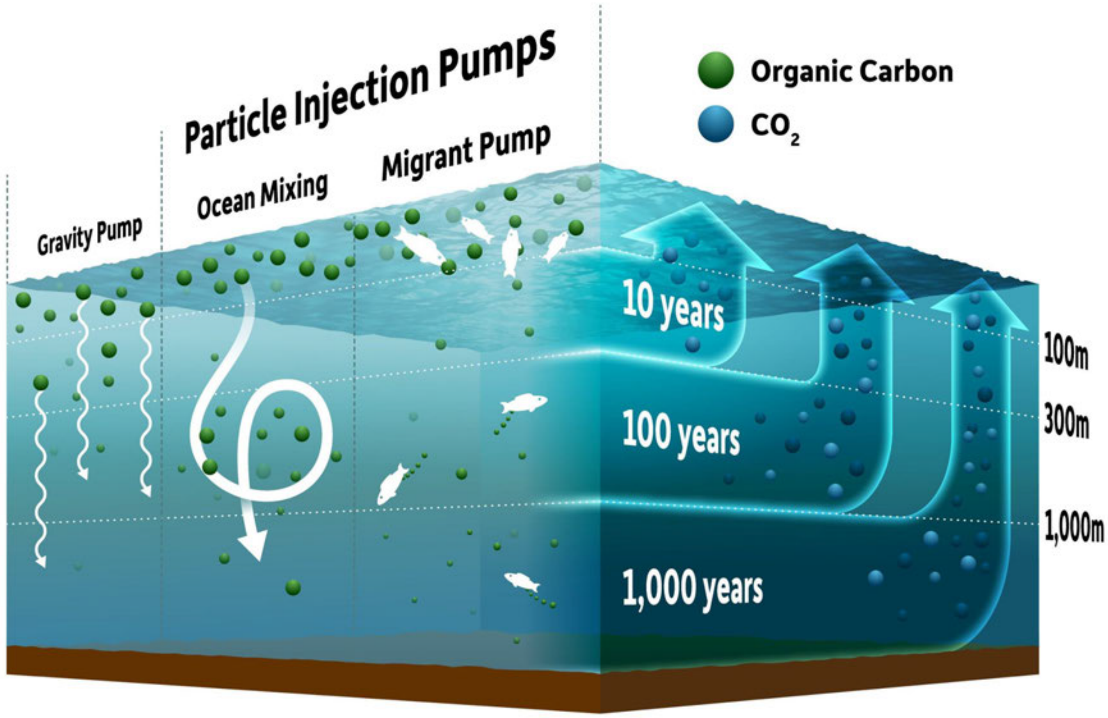


Figure 2: Diagram of the biological carbon pump and it's sequestration time at different depths
Source: https://phys.org/news/2019-04-view-ocean-impact-climate.html

To mitigate against the impacts of warming waters on seaweed production, the Climate Foundation has developed MP, which we have refined since 2007 (see Figure 3 for images of our deployments and Figure 4 for diagrams of our 100m² platform designed with our partner Hatch). MP synthesis and development over this period stems from our multi-milion-dollar investments over the past decade. MP systems restore natural upwelling of cool, nutrient-rich water from depths of 100-500m using local renewable energy sources, such as wave energy or solar. This restoration is combined with an irrigation substrate from which seaweeds can grow. Doing so can not only rescue production but can also extend the growing season and increase yields. Our trials in the Philippines have increased annual production of *Eucheumatoids by* 2-4x while also improving crop quality, demonstrating the effectiveness of our deep-water irrigation system on seaweed growth (see Figures 5 and 6). MP can help seaweed farmers increase productivity and also provide resilience to marine heatwaves associated with climate disruption. MP deepwater irrigation can dramatically increase the amount of cultivable ocean area by facilitating seaweed growth offshore. Given that nutrient limitations are key factors for seaweed growth, MP irrigation has enormous potential to scale across tropical and temperate waters.

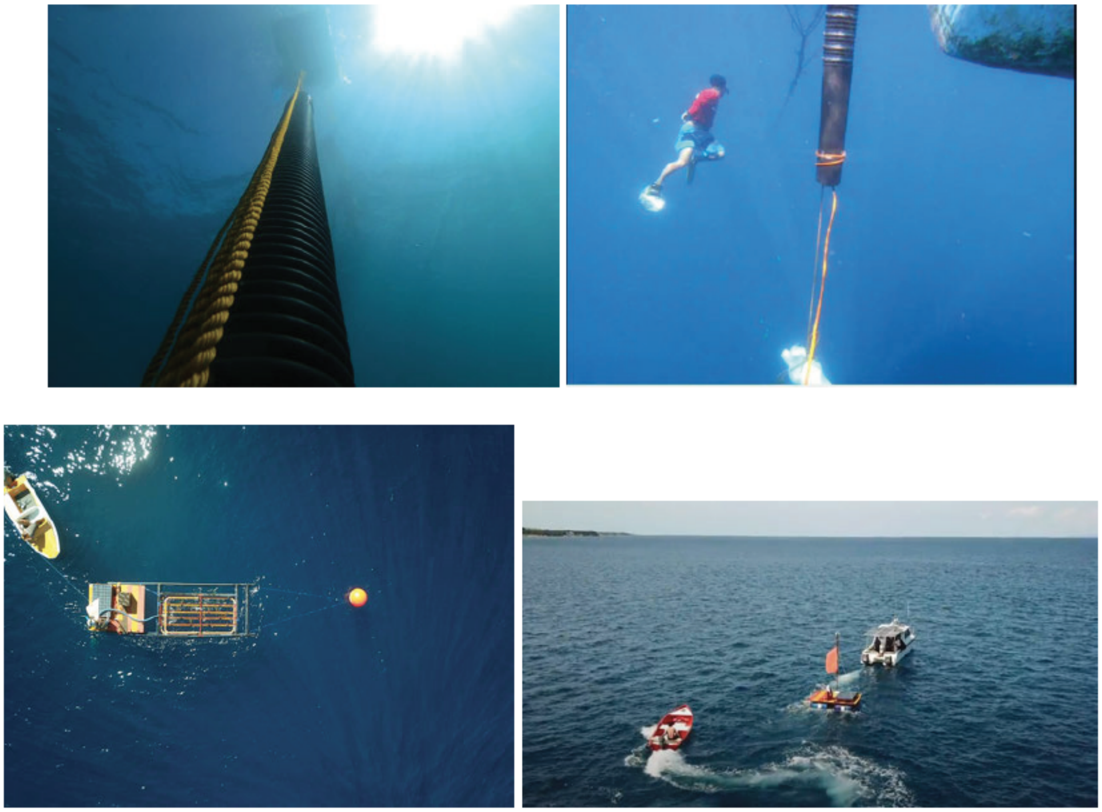
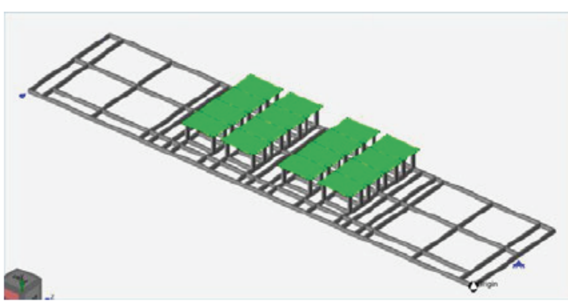
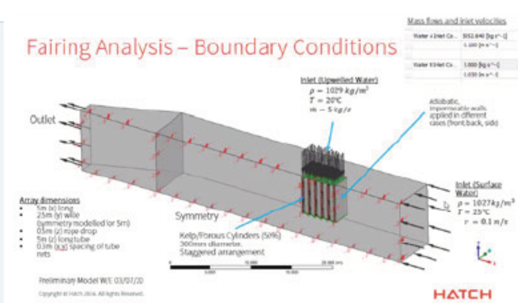
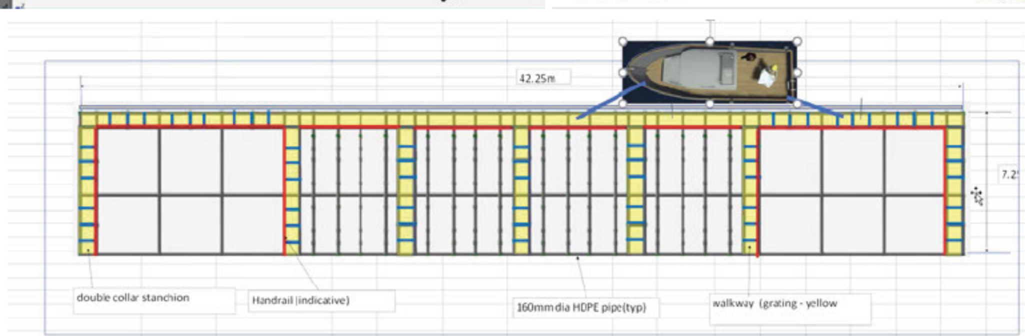
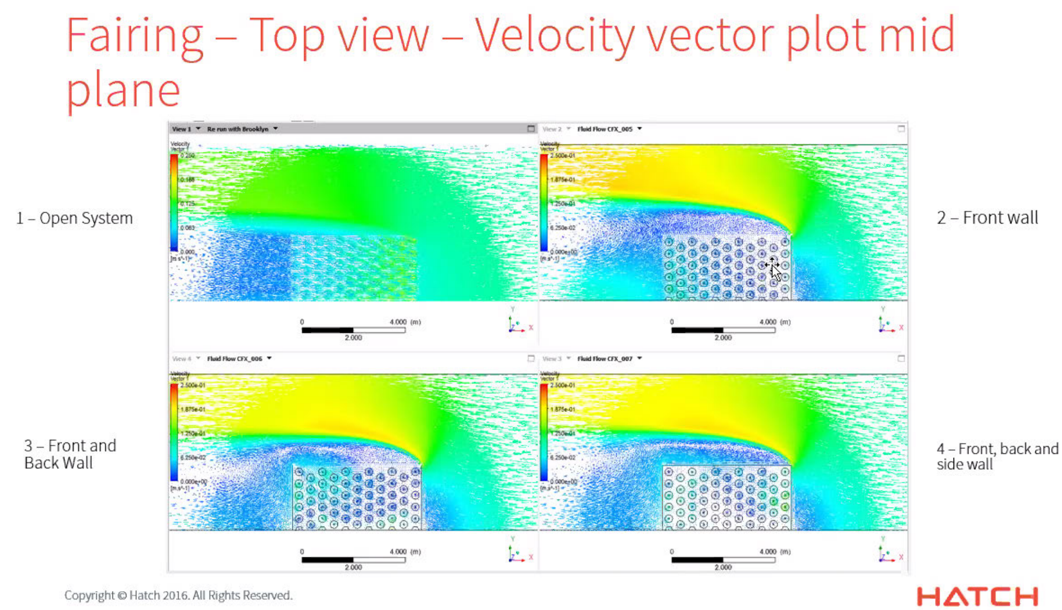


Figure 3: Photographs from early proof-of-concept deployments in the Philippines









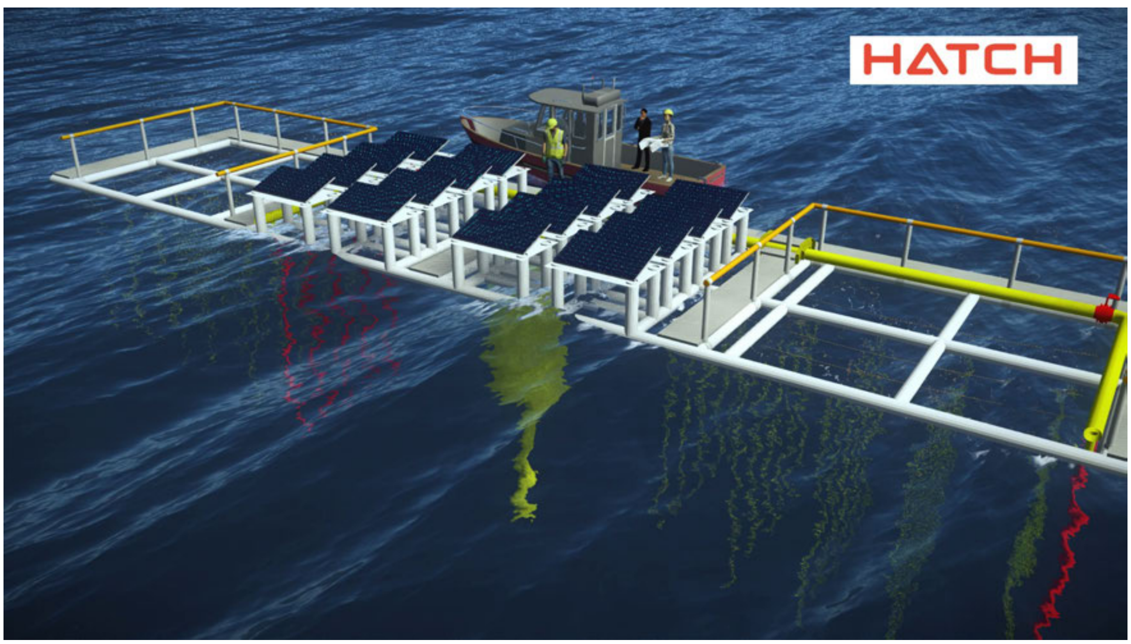


Figure 4a, 4b:Diagrams of a 100m² MP platform co-developed with Hatch, Ltd engineering services.

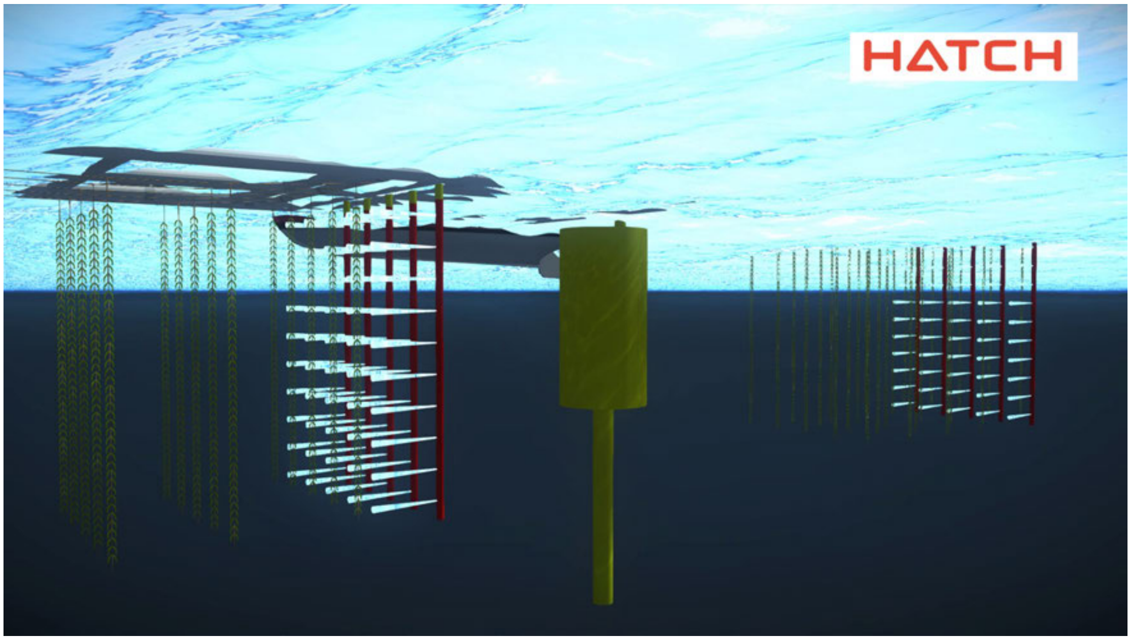


Figure 4c:Diagram of a 100m² MP platform co-developed with Hatch, Ltd engineering services.

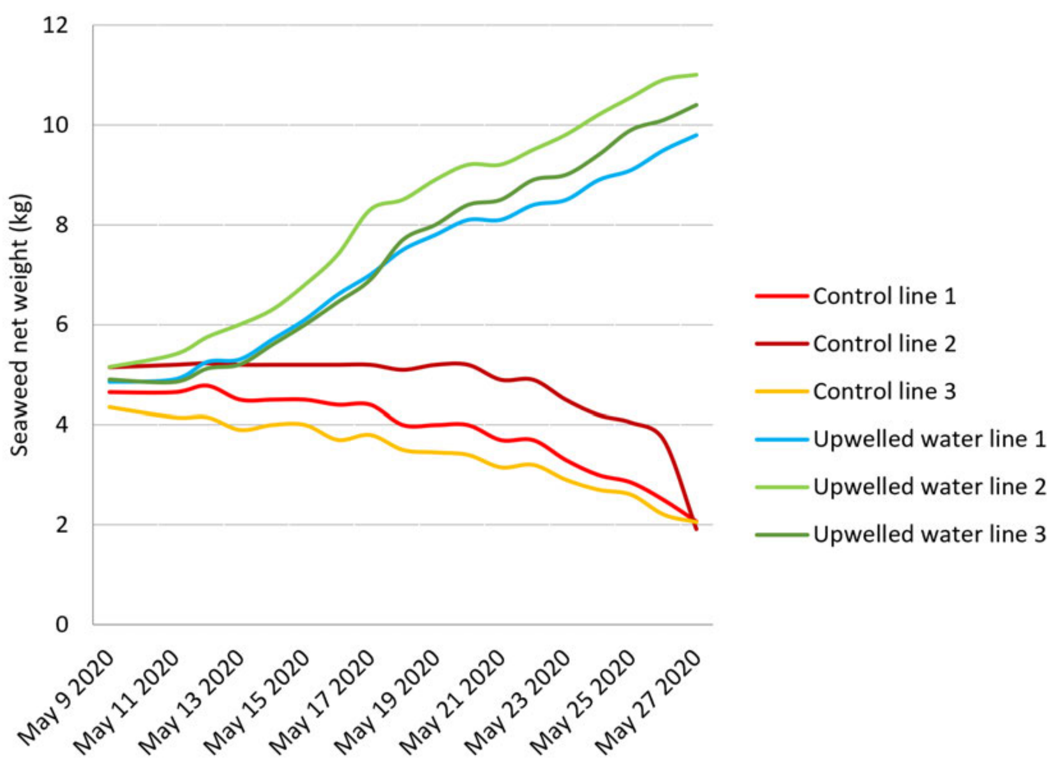


Figure 5: Kappahycus spp. net weights with irrigation from surface water (orange, red and grey) and upwelled water (blue, green and yellow) between May 9th and May 27th, 2020. From Climate Foundation trials in the Philippines.

Figure 6: Kappaphycus alvarezii grown in MP trials in the Philippines. Left: strain of Kappaphycus alvarezii cultivated using traditional mariculture methods. Right: same strain grown from upwelling trough trials. Note the darker colour and thicker stems, which indicate healthier and more carrageenan rich seaweed.

Our long-term vision for MP is for an at-scale distributed network of square-kilometer-sized arrays that are managed by local coastal and island communities, self-organised into cooperatives. A portion of the seaweed produced can be regularly harvested and processed in an at-sea biorefinery, from which high-value extracts for products such as nutraceuticals, hydrocolloids and bio-fertilizers can be generated. The residual seaweed can then be sunk overboard as a source of carbon export. Further carbon sequestration can be achieved by sinking additional seaweed if required. In the long-term, this co-use model could pioneer the concept of carbon negative products as the carbon sequestered can more than offset emissions generated from seaweed products, even enabling carbon to be sequestered at a negative cost. Additional revenues can be generated from a sustainable harvest of the fisheries sustained by each MP array. By building up from small-scale prototypes, we intend to demonstrate a technology that can be replicated in tropical and temperate oceans worldwide. By working with smallholder seaweed communities in the Global South, we aim to also demonstrate that innovation within the regenerative blue economy can be community driven and bottom-up. We estimate that open-ocean MP covering merely 0.08% of oceans globally could sequester a gigatonne of CO_2e each year, at costs ultimately well below $100/tonne (see our *Frontiers in Climate* pre-print for more details).

Figure 7 outlines the net carbon sequestration provided by a MP array. In order to measure the carbon export, we track levels of phosphorus in the water that serve as an indicator of the carbon content as shown by the Redfield ratio of Carbon to Phosphorus. Conservatively, upwelled water has a C:P ratio of approximately 117:1 Most macroalgae have very high C:P ratios ranging from 220:1 to 800:1. Although carbon will be upwelled from below 500m, the net intervention will be carbon negative as the portion of the harvest that is sunk as carbon export has a much higher C:P ratio. Furthermore, plankton and diazotrophs will fix any unused phosphorus and fix carbon at the standard Redfield ratio, ensuring that our interventions are at least carbon neutral.

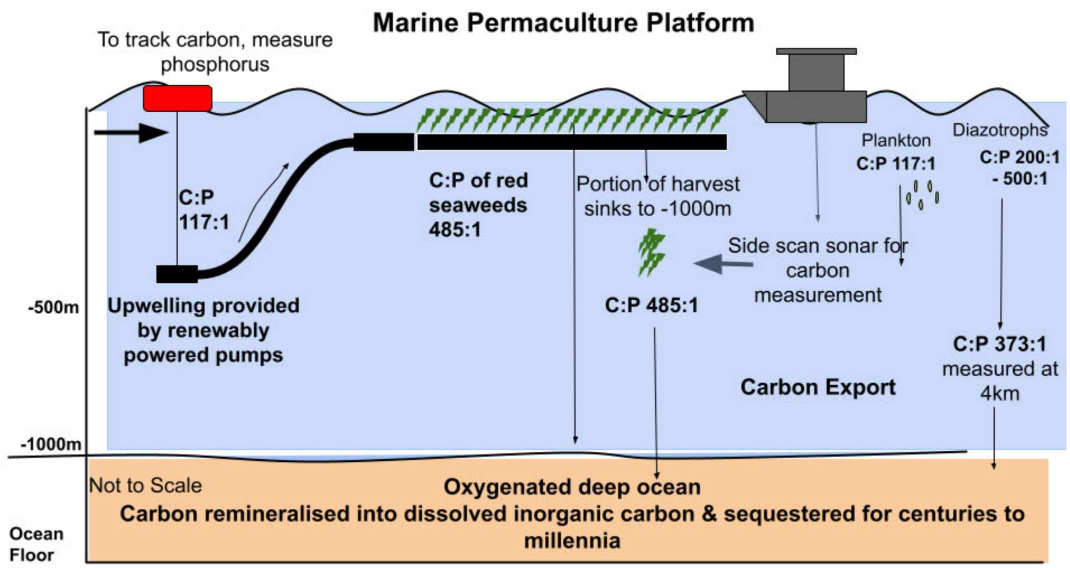


Figure 7: Diagram of a MP Platform tracking the Carbon Export

Figure 8: An example of a solar powered pump boat of the type we will use to transport seaweed. Source: https://www.youtube.com/watch?v=qmYyJfdT-cI

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.)*

The Climate Foundation is presently growing and sinking macroalgae as carbon export, monitoring its sinking and calculating its progress through deep ocean currents to verify long-term carbon sequestration timescales. While we do not depend on outside partners, we work with local farmer cooperatives to accelerate scaling and deployment of MP across tropical to temperate seas.

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

1. Ensuring favorable economics of an MP site depend upon sustainable scaling economies. Generating sufficient capital formation to enable scaling and achieve sufficient cost-curve reductions to achieve profitability is thus a critical challenge.
2. Regulatory constraints and governance issues can be a risk to projects aiming to use macroalgae for carbon sequestration, especially if it is perceived to be their sole purpose. Projects aiming to use macroalgae for carbon drawdown need to ensure mariculture as the primary purpose with carbon sequestration serving as an additional benefit, as has been done with MP. While MP is presently exempt from the list of prohibited activities outlined in Annex 4 of Article 6*bis* of the London Protocol (which is not presently in force), although these could change in the future. Given that MP is regenerating natural processes and providing ecological and economic benefits, we anticipate that our trials will continue with considerable social support.
3. Resilience in rough open-ocean conditions and extreme weather events have the potential to disrupt operation of the platforms and associated harvesting activities. We are trialing platforms in deep waters nearshore prior to deploying in the open ocean. Marine Solar technology is currently being tested successfully under Category 4 events. MP array architecture is following these design considerations to build greater resilience into our operations. There is a strong trend within the fish mariculture industry to move fish pens away from coastal locations, which may provide further positive synergy with MP development.

   We have conducted multivariable analysis on MP projects and have analysed and identified pathways to address other risks. Internal documents on risk analysis may be made available upon request.

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

Title: Structures and methods for simultaneously growing photosynthetic organisms and harvesting solar energy

Submitted in the following jurisdictions:

Country	Publ. No	Publ. Date
US	20190297789	3-Oct-19
ES	202090043	17-Nov-20
AU	2019243572	3-Oct-19
WO	2019/191512	3-Oct-19

Several additional relevant patents are pending but have not been published yet.

stripe

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 2021 - Jun 2022. The end of this duration determines when Stripe will consider renewing our contract with you based on performance.*	June 2021 - June 2025
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.*	June 2021-June 2025
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".*	In total we can deliver over 800 tonnes of carbon sequestration over four years. We anticipate to provide: 5 tonnes (0.625%) in Y1 (Q2 2022). 25 tonnes (3.125%) in Y2 (Q2 2023). 200 tonnes (25%) in Y3 (Q2 2024). 570 tonnes (71.25%) in Y4 (Q2 2025)
Durability *Over what duration you can assure durable*	Carbon is removed for close to 1000yrs once sunk below 1,000m.

carbon storage for this offer (e.g, these rocks, this kelp, this injection site)? E.g. 1000 years.	

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

Once sunk below the sequestration horizon, sequestration duration depends on ocean currents. Water masses in the ocean flow along isopycnal planes, and deep water in most of the oceans takes at least 1000 years to reach the surface. Thus, any carbon dissolved in a water mass will remain in that mass, and out of the atmosphere-surface ocean system, until the water mass is returned to the surface.

We rely on maps of the age of ocean deep water masses, based on ^{14}C dating and other techniques. Gebbie and Huybers (2011) have found that deep ocean water at a depth of 2500m in the North Pacific can be no younger than 1100 yr old. Furthermore, data from the Marianas Trench shows radiocarbon ages of >1000 years for all depths >1000 meters (Shan et al. 2020) (see Figure 9).

Table 1

Concentration and $\delta^{13}C$ and $\Delta^{14}C$ values measured in DIC and DOC collected in the Mariana Trench during 2015 and 2016.

Depth (m)	DIC				DOC			
	μmol/kg	$\delta^{13}C$ (%)	$\Delta^{14}C$ (%)	Ag(yr BP)e	μM	$\delta^{13}C$ (%)	$\Delta^{14}C$ (%)	Ag(yr BP)e
MT-1 (11.3641°N, 142.9066°E)								
2015.12								
2	1785	0.37	38	Modern	58	−21.7	−195 ± 6	1800
1000	2236	−0.48	−186	1650	41	−21.2	−487	5362
1760	2181	−0.70	−231	2060	43	−22.1	−501 ± 10	5584
3700	2141	−0.79	−220	1945	41	−21.5	−511	5747
5370	2169	−0.32	−203	1745	42	−21.7	−517 ± 18	5846
8730	2178	−0.42	−201	1734	38	−22.2	−527	6014
2017.2.								
2	1880	0.62	36	Modern	87	−21.5	−189 ± 12	1683
53	1981	0.33	23.	Modern	82	−22.4	−282	2660
100	2074	−0.43	17	Modern	79	−22.1	−276 ± 11	2595
150	2121	0.16	18	Modern	58	−21.7	−368	3687
200	2170	−0.53	1.1	Modern	57	−22.2	−364	3687
500	2185	−0.44	−101	798	48	−21.6	−390 ± 9	3976
1000	2210	−0.44	−179	1514	40	−22.1	−469	5080
1500	2180	−0.54	−222	1950	42	−22.6	−512	5758
2000	2182	−0.92	−236	2100	40	−22.4	−517 ± 16	5844
3000	2165	−0.55	−234	2079	39	−22.1	−532	6100
4000	2170	−0.05	−218	1910	43	−21.7	−524	5963
6050	2146	−0.30	−202	1740	41	−22.4	−529 ± 7	6048
8000	2138	−0.11	−201	1734	38	−22.6	−538	6180
10000	n.d.				40	−22.9	−535 ± 14	6150

Note: The DOC $\Delta^{14}C$ values with errors represent duplicate measurements.

Figure 9 Demonstrating age of deep water with depth in the Marianas Trench. Source: Shan et al., 2020.

At a minimum, we expect a carbon storage of 1000 years based on the radiocarbon dates of water at 1000-6000 meters depth in the Western Pacific (Marianas Trench data). The maximum timescale for deepwater outcropping to the surface would be several thousand years based on the maximum radiocarbon dates and the 4000-year timescale of the ocean conveyor.

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.)*

Our methodology relies on the well-documented biological pump, whereby the carbon content of ocean water increases with depth, due to the sinking of organic matter from surface to depth. Once carbon sinks below 1000m, it will flow with the water parcel until that water parcel moves along constant density surfaces and returns to the surface. Thus it does not re-enter the atmospheric carbon cycle until the water mass surfaces. The median time to outcropping of the water to the surface approaches 1000 years in multiple locations. Our methodological approach is supported by multiple academic studies including Krause-Jensen and Duarte (2016) ; Boyd et al. (2019) ; Herzog et al. (2003) ; (Matsumoto, 2007) and Shan et al. (2020).

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?

Biogeochemical analysis indicates that once carbon is sunk to the deep ocean (500-1000m or deeper), it will remain in the deepwater until that water mass reaches the surface. Uncertainties/risks include:

- What percentage of the seaweed successfully reaches the required depth.
    - At a very conservative estimate, the sinking speed of seaweeds through the water column can be estimated to be at least 500m/day, although it is likely considerably faster (Wernberg and Filbee-Dexter, 2018 ; Johnson and Richardson, 1977). Furthermore, this process can be enhanced by compactly baling seaweeds.
    - Carbon export will be monitored with side scan sonar that will track seaweed sinking through the water column.
    - When sinking, we expect up to 1% may be lost if the macroalgae is baled and that up to 10% may be lost if sunk loose.
- Length of time until water mass reaches surface (1000+ years)
    - The median time to surface exceeds 1000 years for depths over 1000m as indicated by radiocarbon dating (see Figure 9 above).
- Effect on benthic ocean. In small-scale trials, the risk is negligible, but in large-scale deployments we will monitor for effects on dissolved oxygen and other indicators.
- We do not anticipate substantial socio-economic risks at this time.

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.)*

Our approach is based on measurement of the macroalgae carbon export sinking through the water column combined with robust estimates of deep ocean currents and their outcropping time to determine carbon sequestration permanence.

Sidescan sonar will track seaweed sunk from the surface to 500+m below the surface to measure the quantity of seaweed reaching below the carbon sequestration export horizon. Once at the ocean floor, the macroalgae will be remineralised into dissolved inorganic carbon.

Quantification of the long-term permanence of the carbon sequestration will be determined through reference to best-available science of deep ocean mapping showing radiocarbon ages and northeasterly flow in the abyssal Pacific, which validates the millenium timescale of the carbon storage deeper than 1000m. Oceanographic evidence for the Pacific currents has confirmed this timescale at over 1000 years, enabling it to qualify for long-term carbon sequestration. See the Marianas Trench article reference for radiocarbon ages. All ages deeper than 1000m are 1000-2000 years in the portion of the Pacific where we are scaling our operations.

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	1245 tonnes
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)*

To a first approximation, each metric tonne of dry seaweed (30% moisture) contains approximately one tonne of CO_2e.

Conservatively, we assume each hectare of MP grows 50 dry tonnes of biomass per year, based on the following calculations:

- Macroalgae fixes up to 2500 gC / m^2 / year. With the typical carbohydrate makeup of commercial seaweeds, we calculate that commercially relevant seaweeds would grow up to 62.5 tonnes of dry biomass per hectare per year, or up to 90 tonnes at 30%

moisture.

- Independently, data on red seaweed growth in the Philippines has shown:
  - 10 kg/m^2 wet mass per 45 days
  - → 80 kg/m^2 wet per year
  - → 10 kg/m^2/ year dry with 0% moisture
  - = 100 dry tonnes / Ha / year

For each tonne of seaweed that we sink, we assume

- 10% of C comes out in solution
- If sunk as bales, 1% of C is lost in sinking
- If sunk loose, 10% is lost in sinking

We also account for the carbon that is upwelled from depth. Assuming a seaweed C:P ratio of 485:1, and a deepwater C:P ratio of 117:1, we find that we upwell approximately 25% of the C that is fixed in the growing seaweed.

Thus, overall, we expect that 36-45% of the total C that we sequester will be offset by C released in the upper water.

We plan to bale the seaweed, in order to increase sinking efficiency and improve the ability to track sinking with side scan sonar.

Thus, in order to sequester net 800 tonnes CO_2e:

Primary option: sinking baled seaweed: gross sequestration = 800 / (1-0.36) = 1250 tonnes CO_2e

Backup option: sinking loose seaweed: gross sequestration = 800 / (1-.45) = 1454 tonnes CO_2e

In sum, assuming 100 tonnes of dry (30% moisture) seaweed / ha / year, we will need ~12 ha-years of growth. This represents a large increase over our existing capacity; however, we believe we will have the investment and permits required for this level of expansion.

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).

At present we are still in the pilot phase, testing MP technology. Our capacity is therefore at <1 tonne CO_2 today operating over a small pilot test site, growing to 200m^2 which has been funded and is in deployment. However, we are confident that we will be able to leverage the required investment, permits and expertise to meet our offer of 800 tonnes of net carbon removal.

We will need to build frational hectares in the first year, increasing to multiple hectares in years 3 and 4, to produce the seaweed required.

We have contingencies to meet the delivery targets if required. If necessary, commercial cultivation of *Eucheumatoid seaweeds* within the Philippines will be procured if in the unlikely event we are unable to cultivate sufficient seaweed ourselves. As a last resort, we may also procure harvested *Sargassum* from locations with excess seaweed.

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.)*

The basis of our net carbon sequestration estimates rests on scientific studies regarding the carbon content of the *Eucheumatoids* and C:P ratios in deep ocean water.

Our projections on the seaweed growth capacity of our arrays per hectare are based on pilot trials we have already conducted to date that have demonstrated an increased productivity of a factor of 2-4 (see Figure 5 in Section 1).

Our projections of our overall capacity are based on the area for which we are obtaining permits to grow seaweeds (~12 hectares) and the capital investment we are set to leverage for this project (up to US$15 million in private capital).

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*

Suggested Links

CF webpage on Marine Permaculture

https://www.climatefoundation.org/what-is-marine-permaculture.html

Webpage on Marine Permaculture from the 2040 film website:
https://whatsyour2040.com/marine-permaculture/#:~:text=Marine%20permaculture%20could%20provide%20food,around%20kelp%20and%20seaweed%20farming.

Christophe Jospe Medium Article

https://medium.com/nori-carbon-removal/five-ways-farming-at-sea-is-a-climate-game-changer-6b1e4108b2e

Link to Frontiers pre-print

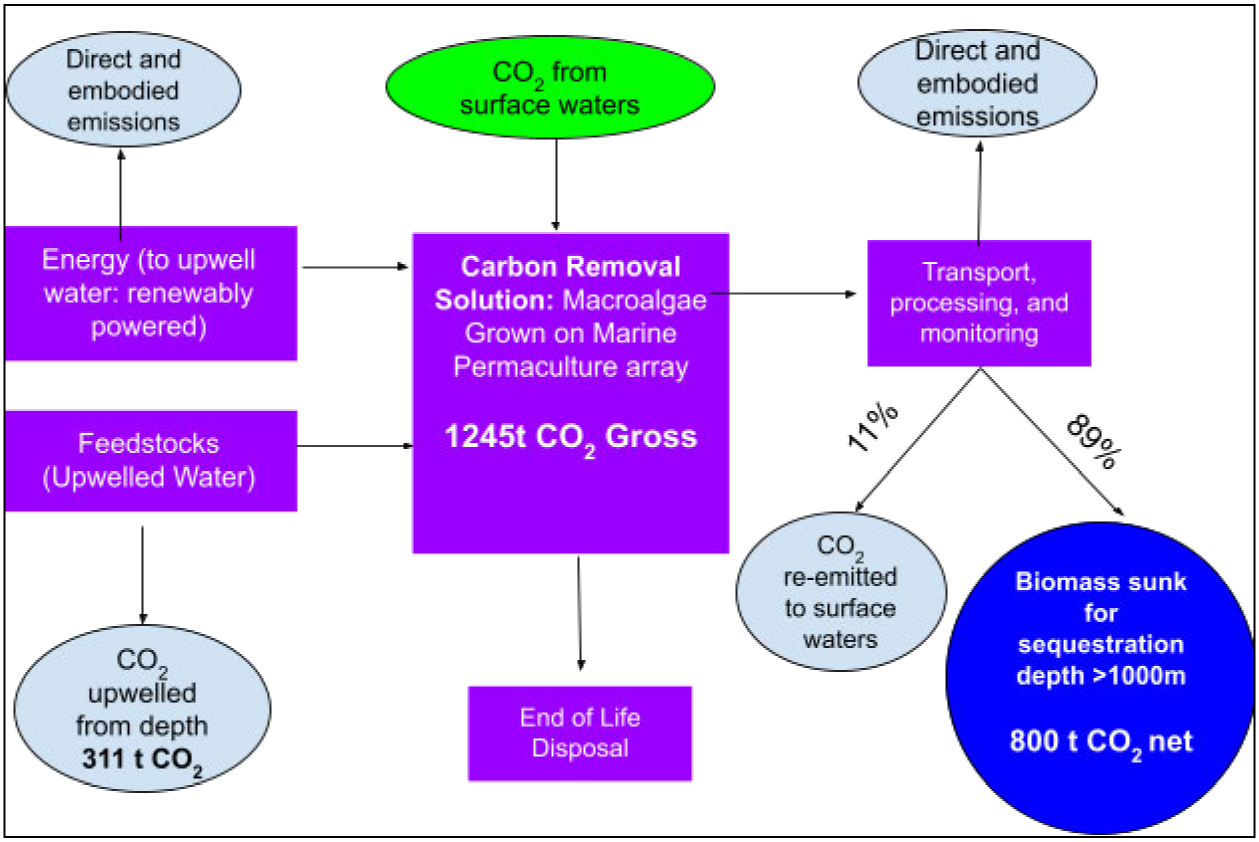
Recent MP summary, presentations and podcasts

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)* 1245
Gross project emissions	*Should correspond to the boundary conditions described below this table in 4(b) and 4(c)* Upwelled carbon: 1245 * .25 = 311.25 tonnes CO_2e Secondary emissions: 88 tonnes CO_2e Total: 400 CO_2e
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* 400/1245 = 0.32
Net carbon removal	*Gross carbon removal - Gross project emissions* 800 tonnes

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?

In our calculations, we include:

- The energy used to upwell water, and to transport, refine, and sink seaweed
  - To the greatest extent possible, energy will come from renewable sources
- The carbon upwelled with the deepwater

We have noted but not explicitly calculated

- The embodied emissions in the pipes and materials for the Marine Permaculture arrays

We have not had an external LCA completed, but intend to so.

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](#).

The Redfield C:P ratio is well known. P is conserved since it does not go into the atmosphere. All P not used for seaweed goes to making plankton at the same Redfield C:P ratio as the upwelled water (nominally a zero-sum game). The red seaweed has a C:P of 485:1, or 4 times higher than baseline Redfield ratio.

We used published C:P ratios for red algae to approximate the C:P ratio in the *Eucheumatoids* We will verify that experimentally.

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.)

We have not conducted a third party verification. Factors a verifier might examine include:

- The C:P ratio of upwelled water.
- The C:P ratio of *Eucheumatoids.*
- The energy to upwell water is carbon free.
- That upwelled carbon not fixed by macroalgae is fixed and sunk by microalgae.
- The energy used in transporting macroalgae to sinking sites is carbon free.
- Depth of sinking site/associated currents.
- That macroalgae sinks below 1000m and the percentage that does so (verifiable with GPS-linked ID numbers for each bale).
- That 1000m qualifies as a long-term sequestration horizon.

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)*

Our unit of deployment is the ocean area under Marine Permaculture cultivation in operation.

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	200m2	$750k including engineering cost	1	Philippines
2020	<100m2	$600k including engineering cost	0.5	Philippines
2019	<100m2	$300k including engineering cost	0.3	Australia
2018	<10m2	$200k including engineering cost	0.1	Indonesia

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.)*

Most of the costs are non-recurring engineering costs. Now that we have validated 4x the biological response of commercial seaweeds to deepwater irrigation, we can scale more efficiently to hectares. We anticipate that our opex and capex costs will decline as we scale to hectare arrays.

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)
12 Hectare-Years	# tCO_2/unit up to 100 tonnes/hectare/year

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?

$600/tonne for *Eucheumatoid* seaweeds dry == $600/tCO2e

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."

Seaweed production cost at $400/dry tonne landed on shore with later transport, sinking and monitoring costs of $200 per tonne are included. Non recurring engineering costs are not included above.

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	>200m2	Key step toward hectare-scale deployment	Q4 2021	video, images
2	.4 ha	Demonstrates capacity for scaling and that the structure can work at a larger scale.	Q3 2022	video, images
3	3 ha	Demonstration and validation of hectare-scale	Q2 2023	video, images, site visit if requested by

		deployment		Stripe

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	<1 tonne	5 tonnes	Quantity of carbon sequestration increases in line with capacity and greater area in m^2
2	5 tonnes	40 tonnes	
3	40 tonnes	300 tonnes	

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)* $ 600/tonne		
2	$ 600/tonne		
3	$ 600/tonne		

Milestones do not impact costs until we reach hectare scale and demonstrate commercial scale and reach financial viability.

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?

Fund the development of the first 350 hectares for $85M to develop the industry to the 100-hectare scale and produce products of food, feed and fertilizer, with gross margin to spare. Once the industry is seeded it can be privately financed to scale 3x per year, achieving 1 gigatonne of fixation by the mid 2030's.

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

Widely publish and disseminate information about the potential of deep ocean sequestration through macroalgae blue carbon export to further validate this form of carbon sequestration and motivate additional investment. Facilitating introductions to prospective subsequent investors would also help.

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?

Stakeholders comprise local coastal users, primarily seaweed farmers and fishermen. These groups' livelihoods are at risk from impacts of warming water temperatures associated with climate disruption and benefit from climate resilience through MP irrigation. To illustrate, a marine heatwave in Indonesia in 2015 led to a 60% decline in production of seaweed, leading to the abandonment of 50% of seaweed farms. MP restores year-round production, increasing yields and revenues and securing livelihoods.

Other stakeholders include government regulators, by-product purchasers, local shipping companies, ocean conservationists and, if deployed at scale, local tourism industries. These have been identified through previous and ongoing development work on MP.

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 our stakeholders over five years of MP trials with seaweed growing communities in Southeast Asia, primarily the Philippines. We are co-creating MP with these stakeholders for whom we intend to provide deepwater irrigation as part of this project. We have also engaged the local Filipino government through multiple seminars and briefings on MP. We are expecting a permit to conduct MP over a dozen-hectare area next quarter.

We have partnered with Coast 4C, which has considerable experience in engaging with coastal communities in the Philippines and Madagascar to assist their sustainable development, enable MP, and minimize the effects of climate change.

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?

These engagements have demonstrated the vulnerability of smallholder seaweed farmers to climate change. Lack of crop insurance means marine heatwaves can plunge farmers into poverty.

MP has been developed from engagement with multiple stakeholders including governance outcomes developed over the past decade. The regenerative power of MP ensures that we can provide food security for billions and ecosystem life support, while measuring the carbon drawdown of these regenerative interventions.

In response, we are developing a MP Alliance to ensure access to our technology is broadly available. In the long term, the Alliance will pioneer the creation of community owned, resilient 100-HA arrays, managed by local cooperatives. Our upcoming project over a dozen hectares in collaboration with local farmers serves as a proof of concept, scalable to a 200-hectare cooperative.

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?

As we scale towards 100-hectare offshore arrays, we will create a MP Alliance to ensure that access to our technology is broadly available. Moving offshore also ensures less contention for local resources.

We also aim to create a distributed economic model whereby 100-hectare MP arrays are community owned and managed by seaweed cooperatives, co-created with local communities. External NGOs with experience in creating community owned enterprises, like Coast 4C, can facilitate their creation and expansion. We will also engage with local conservation groups to ensure that arrays are strategically located alongside Marine Protected Areas for best-practice impacts on local marine life.

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

Tropical seaweed farmers are on the front lines of climate disruption, despite having done little to cause the problem. Securing and climate-proofing their livelihoods thus concerns environmental justice. Furthermore, entire populations of nomadic fishermen have suffered from environmental decline and marginalization between multiple countries. Lagrangian, self-guided MP enables these communities to restore their livelihoods while retaining their cultural heritage and traditional lifestyles.

The global expansion and modernisation of the seaweed industry also raises concerns for environmental justice, as small-scale farmers risk disrupted livelihoods from falling crop prices and mechanisation. MP pioneers an alternative, distributed economic model for seaweed cultivation with inclusive value chains. It also shows that innovation within the regenerative blue economy can be community-driven from the bottom up.

11. Legal and Regulatory Compliance (Criteria #7)

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

We have legal permits for our activities in the Philippines. Our Filipino project lead and local liaison, Mr. Perfecto Tubal, has established good relationships with local regulators and is expecting a dozen-hectare permit next quarter. We are confident that we will be able to continue to refine MP in the Philippines.

We have raised the support of a prominent law firm, Minter Ellison, who are providing substantial pro bono advice and support on licensing, permitting, Maritime Law, IP considerations and partnership contracts and who are developing the long-term legal framework for MP.

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 already have operational permits in the Philippines for the deployment of two hectares of MP in the Visayas, Philippines. Permit applications have been submitted for 12 hectares in the Philippines, which is intended to be a primary site for the seaweed grown for Stripe. Now that we have demonstrated successful rescue of production rates of commercial seaweeds year-round, we are scaling that success.

We are also in the process of obtaining a permit to operate MP on the Great Barrier Reef Marine Park, a world heritage listed conservation area, in which we intend to develop a small-scale MP system that can reverse coral bleaching as we first demonstrated in American Samoa.

stripe

We have done preliminary work on MP in international waters and believe that MP is compatible with UNCLOS and would not require further permits there.

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.

Our activities and this proposed project are in line with local and international regulations. We already have permits in place for ongoing work in the Philippines, and expect the approval of further permits to expand the work next quarter. When we begin to operate at scale in international waters, we believe we are in compliance with Article 6*bis* of the London Dumping Protocol, which is not-in-force, as Annex 4 exempts mariculture. Nonetheless, we accept that the regulatory framework for ocean carbon sequestration is evolving. Thus we welcome opportunities for collaboration to enable responsible scaling of offshore MP. In the long-term, we believe our MP structures can be classified as independent self-guided vessels under International Maritime Law, enabling rapid registration and safe right-of-passage.

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.

	Offer to Stripe
Net carbon removal (metric tonnes CO_2)	*Should match the last row in table 4(a), "Net carbon removal"* 800 tonnes
Delivery window (at what point should Stripe consider your contract complete?)	*Should match the first row in table 2(a), "Project duration"* within 48 months of contract signing
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).* $600/metric tonne CO_2e

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?

The biomass used comprise tropical red macroalgae *Kappaphycus Spp*. and *Eucheuma Spp. (Eucheumatoids)*. These species are native to Southeast Asia where they are widely cultivated for use in hydrocolloid markets (e.g. to produce carrageenan and other hydrocolloids).

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

We will be cultivating *Eucheumatoids* ourselves on our Marine Permaculture platforms. In the event that we are unable to grow sufficient quantities of *Eucheumatoids* to meet the demands of the Stripe contract, we may source it from local commercial seaweed farmers. As a backup, in the unlikely event we were not able to scale our operations in the Philippines as planned, we have engaged with our partners operating in the Carribean region who have agreed to provide us with additional *Sargassum Spp. to* which we could apply this methodology and sink over 1000m in appropriate locations to achieve similar carbon sequestration and permanence.

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.

Marine Permaculture will use negligible amounts of land for initial processing, and does not require fertilizers, pesticides, fresh water, or any other agricultural inputs.

	Area of land or sea (km^2) in 2021	**Competing/existing project area use (if applicable)**
Feedstock cultivation	>>200m^2 Marine Permaculture array in 2021.	Historical seaweed farm, not usable today
Processing	0.25 hectare for the first Visayan processing site where we are	

	already making food and fertilizer products.	
Long-term Storage	Storage is distributed across a square kilometer of deep sea.	That sea area remains compatible with other uses after sequestration to 1000m depth.

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	Sequestering 100Mt of CO2 requires we cultivate **156M** dry tonnes of seaweed if baled (100M/0.64). We grow 100 tonnes per hectare, therefore we grow 10,000 tonnes per km^2 Therefore, 156,250,000 / 10,000 = 15,625km^2 of empty open ocean area.	
Processing	At full deployment, at-sea biorefineries will harvest, process, and sink seaweed in one pipelined process; thus, the footprint is primarily simply the footprint of the floating biorefineries.	
Long-term Storage	Storage is distributed across thousands square kilometers of deep sea.	

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.)

We produce food, feed and fertilizer products in an integrated biorefinery process. The residual seaweed does not need to be processed and is sunk to the middle and deep ocean. We can select the fraction of seaweed that will be sunk. This biomass does not need to be processed other than baling; it can be permanently sequestered by sinking it into the deep ocean in its natural state. When baling, we will use renewable energy to compress the seaweed.

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.)*

Since we plan to grow *Eucheumatoids* ourselves, the seaweed would not have been produced without our project. The associated carbon dioxide would not have been fixed and would have remained in the surface ocean and atmosphere. In the unlikely event we would have to source *Eucheumatoids* commercially, they would have been sold into the hydrocolloid market, notably as carrageenan and would not have been sunk. In the unlikely event we should source harvested *Sargassum*, commercial uses are in development, however it mostly washes up and decomposes on beaches, harming tourism and marine ecosystems and rotting to methane and co2e.

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)*

Ecological Most of the deep ocean is well oxygenated. The ecological impacts of our near-term project will be minimal; however, significant scaling could pose ecological challenges that we are aware of and will monitor if concentrated in one place. Large scale production and sinking may affect water oxygen levels and contribute to hypoxia. We will mitigate this concern by sinking macroalgae across a broader region, documenting sink depth and location of each bale and monitoring potential impacts of these activities by sampling water oxygen levels before and after our project. N.B. Macroalgae cultivation provides multiple positive ecological

benefits through provision of ecosystem services, such as absorbing excess nutrients and providing a nursery and habitat for fisheries.

Social/Economic

Cultivating seaweed nearshore can create social/economic problems pertaining to other uses for space (shipping, fishing, leisure etc). However, the area we intend to use for our project is already largely devoted to seaweed farming, so we anticipate few problems of this nature. In the long-term, scaling up production nearshore could compete with other coastal users, demonstrating the importance of moving offshore through innovative mariculture techniques like MP.

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.

Macroalgae beds and reefs have some of the highest carbon fixation rates of any ecosystem on the planet, approaching 2500-3000 gC/m^2/year (Egan and Yarish, 1990; Mann 1972; Wu et al. 1984; Gao and McKinley, 1994; Muraoka 2004; Buschmann et al., 2008). This coupled with the fact that macroalgae require no nutrient inputs or freshwater inputs makes it a uniquely efficient and sustainable form of biomass. Our method of sinking macroalgae biomass in the deep ocean is advantageous as it provides cost-effective, durable and reliable long-term carbon sequestration as opposed to conventional biomass based carbon stocks that are at risk from climate disruption. For example, wild fires through reforestation projects can release sequestered carbon back into the atmosphere.

MP could be among one of the cheapest forms of biomass based sequestration, with pathways to sequestering carbon at a negative cost if operations are combined with at-sea biorefineries that create high value seaweed products. Such products also have the potential to create additional carbon benefits by displacing fossil fuel based alternatives. In this manner it is unique among all solutions known to us. Local ecosystem services are also provided, such as mitigating ocean acidification, excess nutrient pollution and enhancing fish stocks.

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.

> Our seaweeds will be grown in the Visayas, Philippines and will be sunk across a broad, identified area over 1000m deep in the Bohol Sea. Our previous trials and on the ground knowledge provided by our Filipino team have given us experience in selecting sites that cause minimal disruption to other coastal users. Moreover, the area we intend to use for our project is already largely devoted to seaweed farming and so we anticipate few problems of this nature
>
> The social and environmental impacts have been reviewed and addressed. The ecosystem services provided by seaweed farming, including bioremediation services and habitat for fisheries, make our solution regenerative. In the long-term, MP can be regenerative ecologically and sustainable economically, enabling it to generate substantial support and continue its broad social acceptance, enabling it to continue to operate and expand.

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.

> 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.

> N/A

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?

Our core challenges lie with ensuring our deepwater irrigation system can work effectively and that our MP systems are able to withstand rough conditions once we move offshore. Historic precedent is provided by commercial salmon aquaculture fish pens operating off the coast of Tasmania and Norway that use HDPE materials and have withstood 11m-high seas. In collaboration with our partner Hatch Engineering Services,we will be building off the same architecture to design and build our MP systems.

For our initial projects at hectare scale, our systems can be moored. In the long-term, after this contract, GPS remote guidance of MP platforms will enable greater and more cost-effective performance.

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?

We will sink our seaweeds over a broad identified area in order to minimise the impact of sinking seaweed on the local environment. To quantify and monitor for the impact of our activities, we will first establish baselines by measuring the oxygen and alkalinity levels of the water at multiple depths. We will then take further measurements during the middle and end of the project to establish the impact of our intervention. These oxygen samples will be performed with our water sampling equipment that can measure the oxygen levels,the micronutrient levels,the phosphate level and the nitrate levels.

We will also monitor for pre-existing harmful algae blooms upstream and water quality at relevant downstream sites. Remotely operated vehicles have been able to measure the chlorophyll concentrations and wavelength of HABs in the past. These will ultimately be feasible for doing remote site monitoring upstream and downstream of marine permaculture sites.