stripe

General Application

Company or organization name

Ocean-based Climate Solutions, Inc.

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

Santa Fe, NM USA

Name of person filling out this application

Phil Kithil

Email address of person filling out this application

pkithil@ocean-based.com

Brief company or organization description

Since 2005 we've pioneered making ocean upwelling/downwelling practical and low cost.

1. Overall CDR solution (All criteria)

1. 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
Scientific Basis.

Carbon fixation through plant production in the ocean is driven by vertical mixing of nutrient-enriched deep water into surface sunlit layers –achieving net carbon fixation above baseline and net carbon sequestration (CO_2 "offsets"). Ocean gyres, particularly the North Pacific gyre, are areas with relatively low vertical mixing and strong vertical nutrient gradients. Horizontal spatial coherence is very high in these gyres, so measuring impacts of pumped upwelling is simplified. The vast gyre areas where conditions are similar suggests scalability of wave driven pumped upwelling is substantially driven by the number and size of pumps deployed.

Figure 1. Bloom off New Jersey

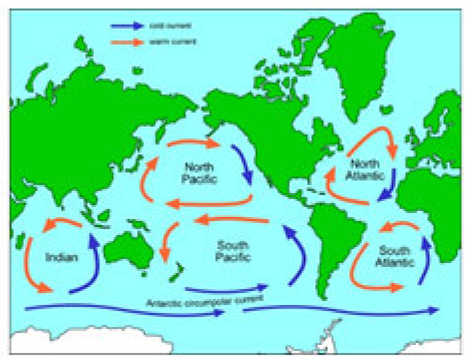


Figure 2. Ocean gyres.

Key to producing net carbon sequestration in these low-nutrient, low-chlorophyll (LNLC) ocean gyres is upwelling deep water containing nutrient concentrations greater than the dissolved CO_2 concentration on a plant stoichiometry basis, i.e. the Redfield ratio.

In a 2008 paper, David Karl and Ricardo Letelier calculated the net sequestration potential from pump driven upwelling using data collected at the long-term monitoring Station ALOHA in the North Pacific gyre near Hawaii. They calculated that upwelling of waters from 200 m or deeper provides excess phosphate which triggers a sequence of nitrate and then phosphate uptake driven blooms of phytoplankton. The secondary phosphate bloom fixes more dissolved CO_2 than is upwelled, resulting in net CO_2 sequestration. Using the Karl-Letelier calculations, we build our pumps with the intake at 500 m to maximize the carbon fixed per unit area relative to vertical length of the pump.

Table 1. Nutrient balance and net CO_2 sequestration potential for precision upwelled waters at Station ALOHA. DIC: dissolved inorganic carbon; r-P: residual phosphorus

Source Water (m)	Total nutrient concentration (µM) DIC	NO_3^-	PO_4^{3-}	Excess nutrient concentration[a] DIC (µM)	P (µM)	DIC:P (mol:mol)	Total P excess plus r-P (µM)	Total N_2 fixation[b] (µM)	Net C sequestered (mmol C m^{-3} upwelled)[c]
100	2046	0.06	0.062	22	0.058	371:1	0.111	5.6	15.2
120	2055	0.32	0.101	29	0.081	357:1	0.134	6.7	15.5
140	2070	0.79	0.137	41	0.088	465:1	0.141	7.0	5.8
160	2075	1.26	0.163	43	0.084	512:1	0.137	6.8	2.5
180	2082	1.98	0.215	45	0.091	492:1	0.144	7.2	2.9
200	2091	2.84	0.276	48	0.099	489:1	0.152	7.6	2.0
250	2100	5.58	0.461	39	0.112	348:1	0.165	8.3	15.7
300	2119	9.99	0.757	29	0.133	217:1	0.186	9.3	32.7
350	2146	14.22	1.044	28	0.155	179:1	0.208	10.4	41.2
400	2173	18.82	1.361	24	0.185	132:1	0.238	11.9	54.5
450	2164	23.35	1.667	−15	0.208	−71:1	0.261	13.0	101.1
500	2199	28.00	2.033	−11	0.283	−37:1	0.336	16.8	121.8
750	2313	40.90	2.985	18	0.429	42	0.482	24.1	141.5
1000	2337	41.58	3.006	38	0.407	92	0.460	23.0	114.9

[a]Excess nutrient is defined as concentration of DIC and r-P at the target depth that would remain in the surface if all the upwelled NO_3^- is removed during the hypothesized Stage-I bloom with Redfield stoichiometry (C_{106}:N_{16}:P_1) after correcting for the average nutrient concentration that is observed in the upper 25 m at Station ALOHA between 1989 and 2005 (DIC = 2024 µM, r-P = 0.053 µM). For example, excess DIC at 300 m is: (2119 µM – 2024 µM) – (9.99 × [106 ÷ 16]) = 29 µM
[b]Total N_2 fixed = total P × (N:P ratio); assumes a molar N:P ratio of 50 (White et al. 2006)
[c]Net C sequestered = total P × (C:P ratio) – excess DIC for that depth; assumes a molar C:P ratio of 331 (White et al. 2006)

Table 1 from Karl and Letelier, 2008.

Upwelling depth (m)	Net C sequestered (u-mol C per m^{-3})	Source data	Annual pumped volume (m^3)	C sequestered (mmol/m^{-3})	Iron upwelling impact on net sequestered C	Convert C to CO2 tons/yr
200	2.0	Karl Table 1	45,121,253	0.54	100%	2.0
250	15.7	Karl Table 1	45,121,253	6.38	100%	23.4
300	32.7	Karl Table 1	45,121,253	17.71	100%	64.9
350	41.2	Karl Table 1	45,121,253	22.53	100%	82.6
400	54.5	Karl Table 1	45,121,253	30.10	100%	110.4
450	101.1	Karl Table 1	45,121,253	56.38	100%	206.7
500	121.8	Karl Table 1	45,121,253	68.59	100%	251.5
550	125.7	Karl Table 1	45,121,253	71.49	100%	262.1
750	141.5	Karl Table 1	45,121,253	83.51	100%	306.2

Table 2. Calculated net CO_2 sequestered by one pump, adapted from Karl and Letelier's 2008 data using volumes pumped from the current pump design (iron upwelling impact assumes zero additional tons CO2 sequestered in this table).

Calculation of Annual Pumped Volume Achievable In Ocean Waves							
	Nominal Pumped Volume (m^3) Data Buoy 51001 - Hawaii						
	2016	2017	2018	2019	Average	Efficiency	Annual Volume
Upwelling <3m	29,161,146	27,522,144	28,988,154	26,989,853	28,165,324	160.9%	45,322,193

Table 3. Annual pumped volume by one pump.

To determine upwelling flow rate, in 2007 we conducted a sea trial of a 0.75m diameter by 152m deep upwelling pump which was substantially identical to our current design except for dimensions. With triaxial accelerometers on the valve flappers recording open/close cycles, and temperature sensors top and bottom, we determined the time for deep cold water to surface. The outlet temperature sensor showed cold water arriving at 08:45:00, about 15 minutes after first upwelling stroke. Dividing tube volume by elapsed time gives flow rate of 0.078 m^3/s.

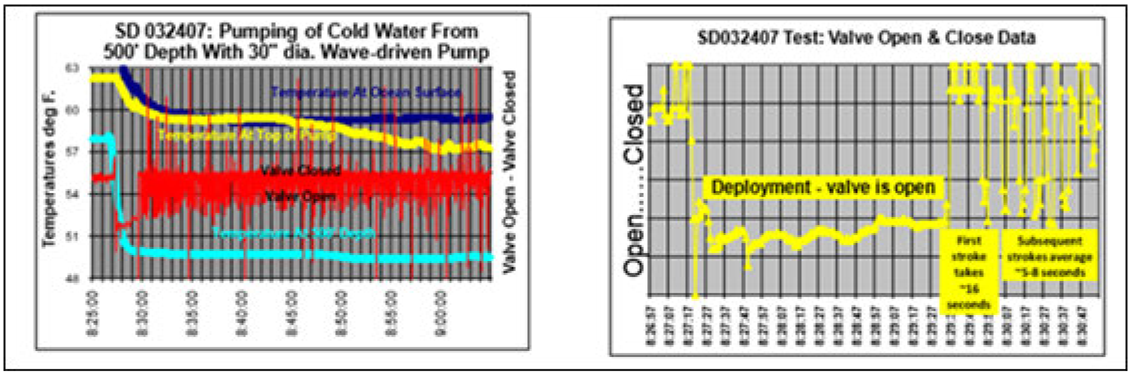


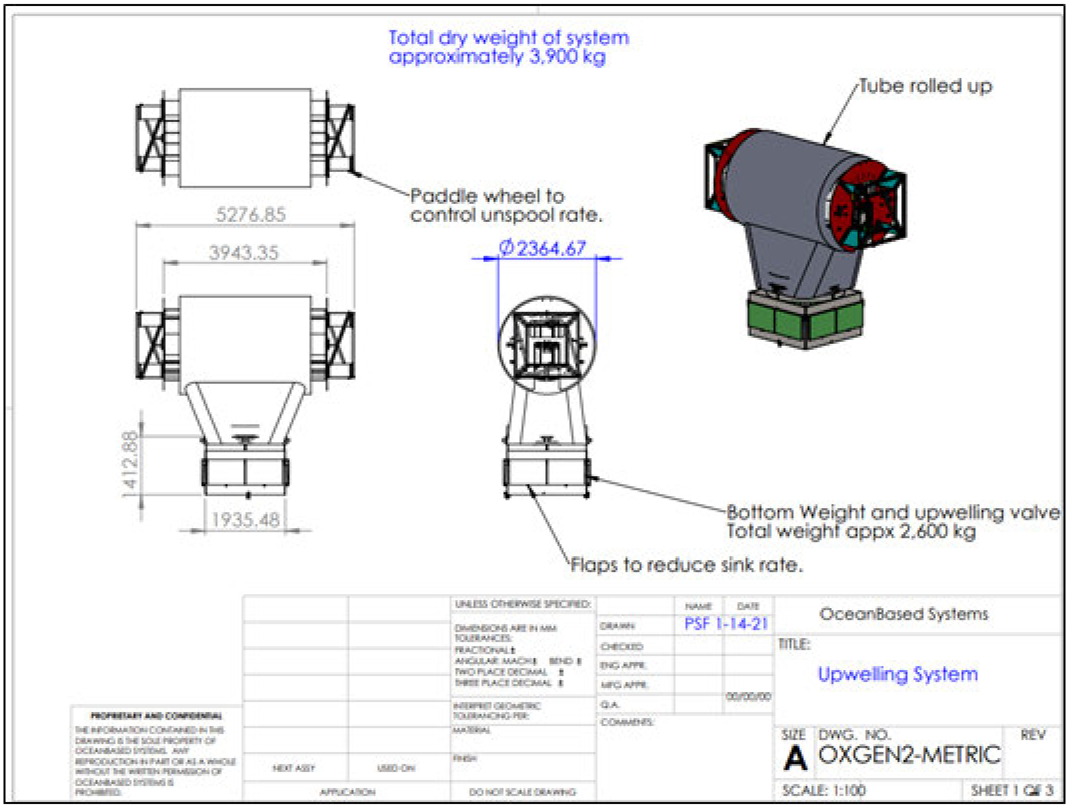
Figure 3. Atmocean test data from 2007.

San Diego NDBC data and calculated flow rate and efficiency 3/24/2007							
Data buoy 46258 3/24/2007			Vertical meters/hour			Flow rate	
WVHT	dpd	apd	dpd	apd	Average		
1.44	12.4	13.9	418.2	372.2	395.2		
Pumped depth				feet	500		
				meters	152.4	Tube volume (m^3)	67.31
Actual minutes to upwell					14.4		
Actual fraction of hour					0.24	Divide by fraction of hour	0.24
Actual meters in one hour					635.9	Cubic meters per hour	280.8
Upwelling efficiency achieved					160.9%	Cubic meters per second	0.078

Table 4. Calculated efficiency and flow rate from our upwelling test in 2007.

Analogous to the salt fountain discovery by Stommel & Arons, this test demonstrated the water inside the tube gains momentum, delivering about 61% greater vertical excursion than the waves.

Pump design.



Location.

The initial location will be in the open ocean approximate 200nm from Oahu, Hawaii. The initial scale will be ten pumps spaced 720m apart (equal to two per square kilometer diagonally).

This location affords access to long-term baseline data from Hawaii Ocean Time Series (HOTS). The HOTS far field data allows for robustly embedding the data from the pumping volume within a scientifically rigorous time series data set. This allows for better understanding of the uncertainty in the carbon sequestration calculations.

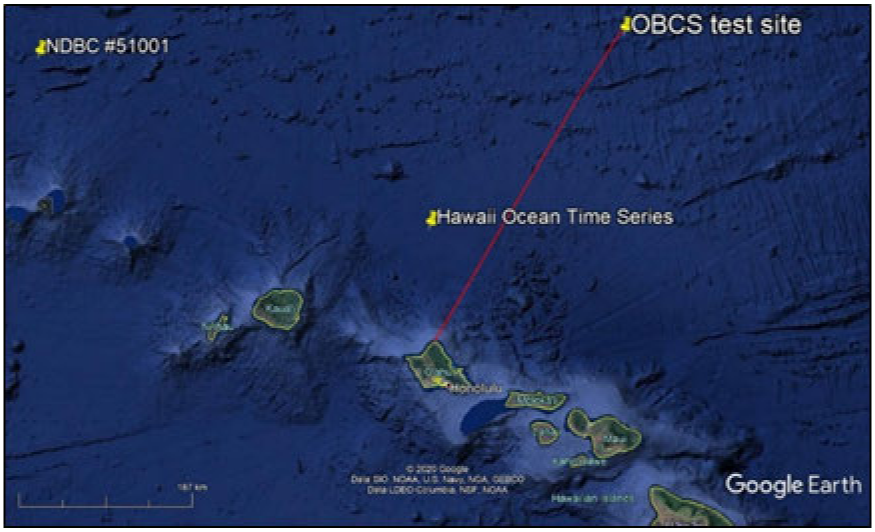


Figure 4. Location of the OBCS deployment site ~200nm from Oahu in the open ocean beyond US EEZ boundary.

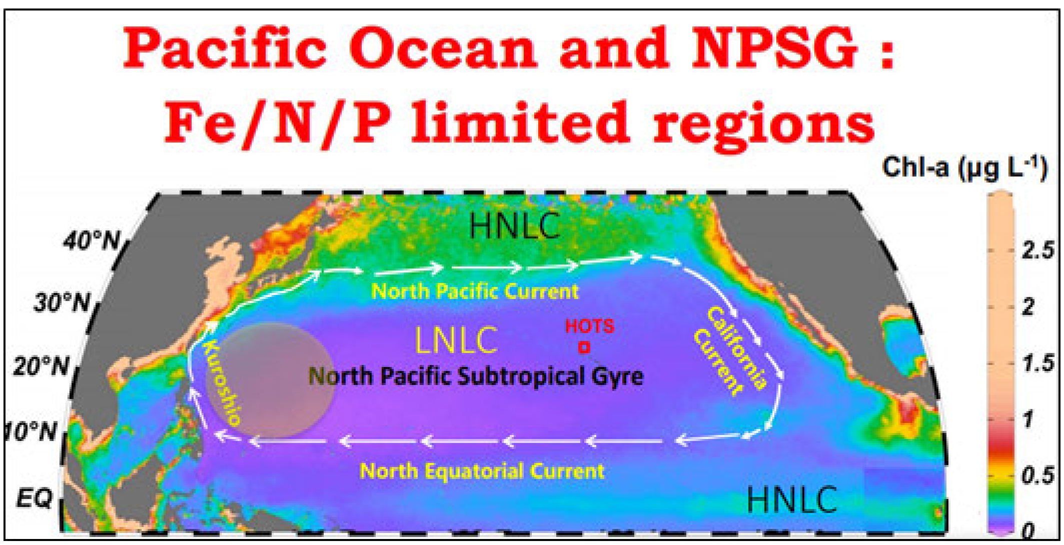


Figure 5. Location of the OBCS test site within the broader context of the North Pacific. Note the size of the LNLC-ideal for demonstrating net CO_2 impact of artificial upwelling using wave driven pumps. Figure courtesy Dr. Fei Chai.

Sequestration beyond the terrestrial biosphere

Artificial upwelling in the LNLC central gyres uses an area of the world that has relatively low impacts from other human endeavors and hence net CO_2 sequestration through pump deployments has little secondary impacts.

Scale-up, seasonality, and additionality.

In the central gyres, horizontal scales are vast, i.e. on the order of 100's to 1000's of kilometers while vertical scales are compact, 10's to 100's of meters. Vertical mixing therefore potentially generates significant impact with relatively small energy inputs. Furthermore, scalability is minimally constrained. While each individual float's impact is spatially constrained to a few square kilometers, the effectiveness of the systemic float program is not limited until a vast number of floats have been deployed. See the "Scaleup" section on page 15 for calculation of scaling necessary to drive the sequestration offsets using artificial upwelling pumps to greater than 0.5 gigatons CO_2 per year.

In the NPSG and other LNLC gyres, productivity is limited by nutrient scarcity – so all new production from pumped upwelling is "additional".

Within the NPSG LNLC area there is little latitudinal limitation as sunlight is adequate through the entire year to drive phytoplankton blooms at least to 30° N.

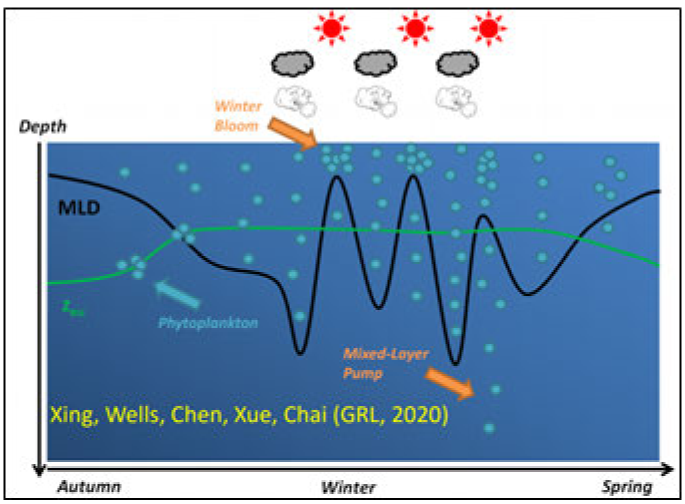
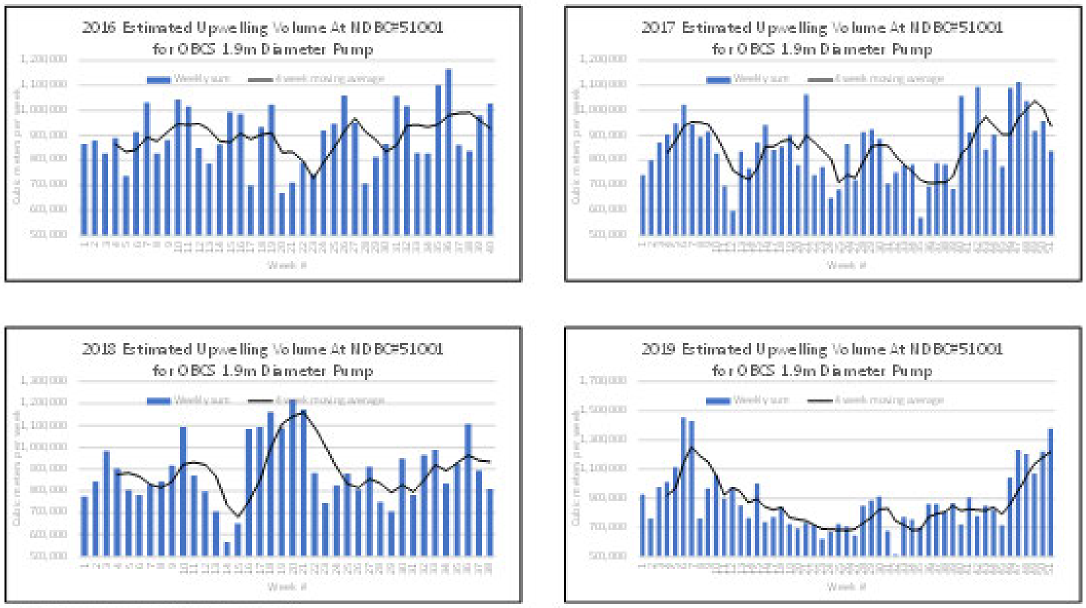


Figure 6. Winter bloom in North Pacific (Xing et al., 2020) demonstrating interactions of mesoscale atmospheric forcing on the upper water column resulting in export flux events.



X-axis – please note missing data is not accounted for.

Figure 7. Weekly upwelling volumes at NDBC #51001 2016-2019-demonstrating sufficient wave action during all time periods to produce meaningful volumes.

Cost.

The total project cost is budgeted at $3,593,750 which includes two preliminary verification tests this summer; full instrumentation on all ten pumps plus two BGC-ARGO's (one inside the array and one as reference outside the array); and the high-speed custom workboat needed for deployment and monitoring.

The selling price for future arrays of twenty pumps will be as low as $825,000, plus the BGC-ARGO at $150,000 (one per 20 pumps). Powered entirely by wave energy, the pump operating cost is zero.

If 20 pumps are deployed in 2022 and operate to 2050, the estimated cost per ton removed is $18.09.

Permanence:

In the North Pacific the mean ocean age is over 1,000 years, thus qualifying our outcomes from this region as “permanent” according to the Stripe criteria.

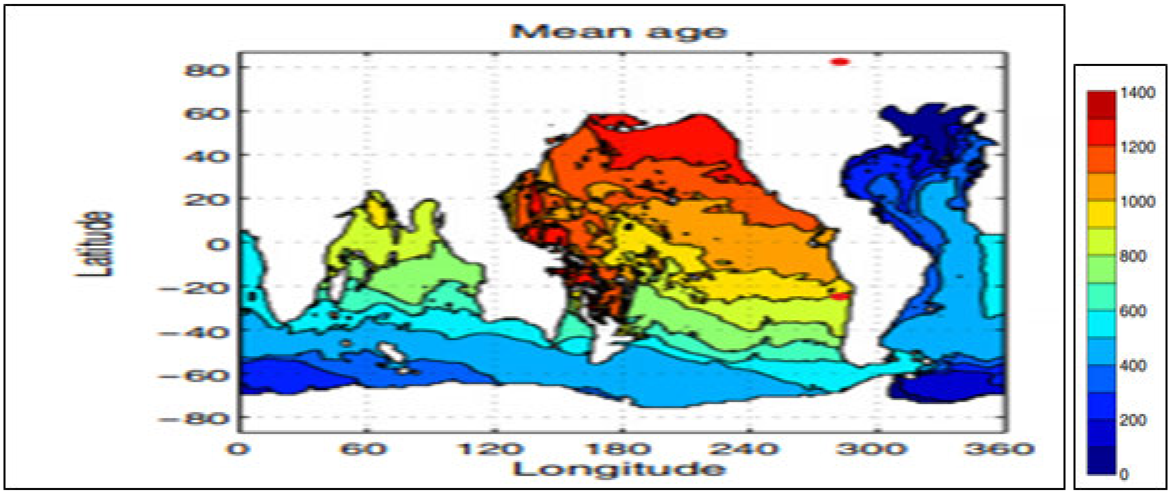


Figure 8. Mean age of oceans. From “Ventilation of the deep ocean constrained with tracer observations and implications for radiocarbon estimates of ideal mean age.” S. Khatiwala F. Primeau M. Holzer Earth and Planetary Science Letters 325–326 (2012) 116–125.

Verifiability

Net production driven by the upwelling pumps will be measured by integrating the particulate organic carbon measured by the backscattering sensors on a pair of robotic profiling floats within
the pump patch and outside of the patch. The robotic floats are similar to the floats used in the ARGO program, and will be equipped with the sensor set as used in the BIO-ARGO program. This will allow for detailed monitoring of the physical and major biogeochemical parameters of
the water column within the pump footprint and the outside baseline water column. The pumps

will be programmed for daily cycling and profiling mission parameters can be modified to keep the floats moving with the pumps.

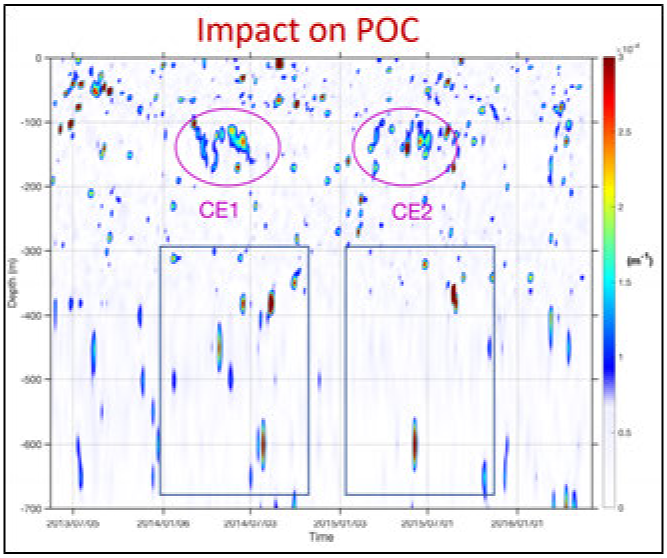


Figure 9. Biogeochemical ARGO's measuring sinking POC from North Pacific wintertime phytoplankton blooms, by Dr. Fei Chai.

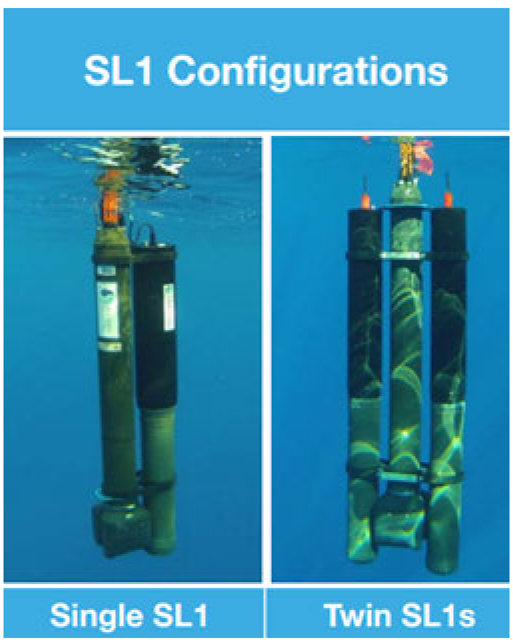


Figure 10. ARGO with SeaTrek powerpack

By programming the floats to dive and resurface once per day rather than once per five or ten days, much higher resolution data is obtained which captures many more productivity events triggered by the nutrients delivered to the sunlit upper ocean by our upwelling pumps.

A commercially available strap-on powerpack from SeaTrek operating on the ocean thermal energy principle, provides near-infinite power for the BGC ARGO floats. This enables daily operating cycles essentially forever.

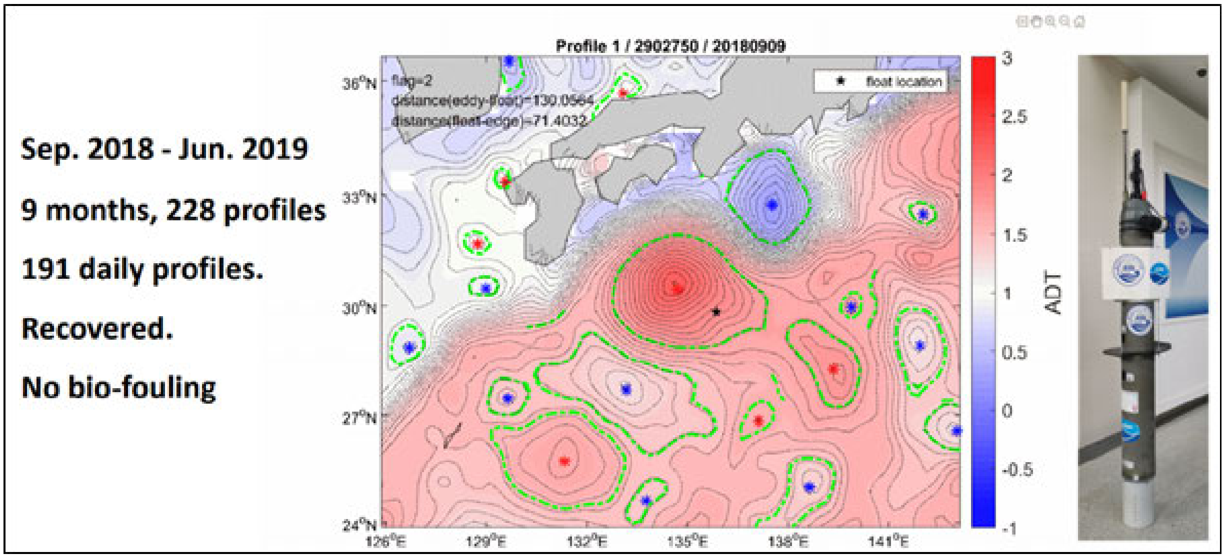


Figure 11. BGC-ARGO coherence within gyre (courtesy Dr. Fei Chai).

Quality and Safety

Since our technology is not adding any foreign substance to open ocean waters, we comply with UN Law of The Sea and The London Protocol.

Tons CO2 Sequestered per Array of Ten Pumps.

Based on Table 1 in Karl-Letelier 2008 paper each pump will sequester 251.5 tons CO2 per year attributable to the excess phosphate. In addition, preliminary data from testing in the western NPSG suggest iron upwelled from 500m may increase diatom production with up to 20% additional net CO2 export. For now, our projections will include only the more-established value from Karl-Letelier.

The pump one-time CO_2 footprint is 8.5 tons. Below is the projected cumulative net CO2 tons sequestered for this initial ten pump array:

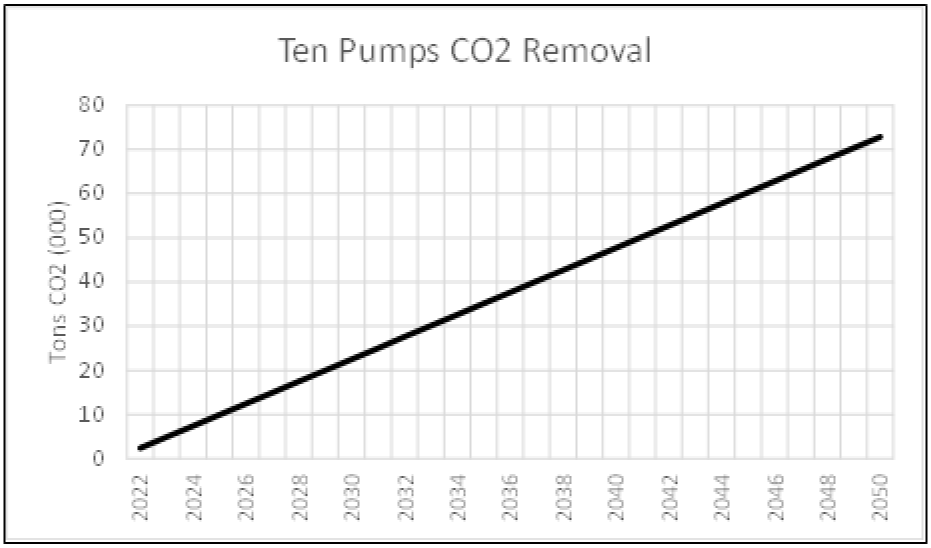


Figure 12. Estimated net CO_2 sequestration for 10 pumps deployed 2022.

Scaleup.

Deploying 110,000 pumps in 2022 will remove over 500,000,000 tons CO2 by 2040. However, this instantaneous deployment is impractical and unwise. A staged increase year-by-year is our approach (available on request).

Timeline and Budget.

With approval and funding by April 30, 2021, we can proceed on the following schedule.

	2021								2022										
Cost description	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Per unit	Qty	Total Budget
Non-recurring engineering*																	$ 50,000	1	$ 50,000
50m verification test*																	$ 75,000	1	$ 75,000
500m verification test*																	$ 250,000	1	$ 250,000
Engineering interns*																	$ 10,000	1	$ 10,000
Tube fabrication																	$ 32,500	10	$ 325,000
Hardware fabrication																	$ 48,500	10	$ 485,000
Final assembly																	Included		$ -
On-pump instruments																	$ 75,000	10	$ 750,000
BGC ARGO acquisition																	$ 150,000	2	$ 300,000
Vessel acquisition*																	$ 750,000	1	$ 750,000
Shipment to Hawaii																	$ 50,000	1	$ 50,000
Deployment & monitoring																	$ 75,000	1	$ 75,000
ARGO data																	$ 5,000	1	$ 5,000
Indirect																		15%	$ 468,750
Total Budget																			$ 3,593,750
* Non-recurring cost																			

Table 5. Timeline and budget to produce and deploy 10 pumps.

Participants.

- Woods Hole Group/CLS-France, exclusive instrumentation partner.
- Seabird Electronics, supplier of NAVIS biogeochemical ARGO robotic floats.
- SeaTrek – developer of power supply attached to BGC ARGO's enabling unlimited measurement cycles.
- Reytek Corporation - produces hardware; final assembly; shipping; advises deployment.
- Ballotta Marine – produces high-speed workboats.

Our consulting science and engineering advisors include:

- Professor Fei Chai, University of Maine.
- Dr. Ian Walsh. Formerly Seabird Scientific Director of Science/Senior Oceanographer.
- Professor Ulf Riebesell – German Marine Research Institute-Kiel (GEOMAR).
- Professor Andreas Oschlies – German Marine Research Institute-Kiel (GEOMAR).
- Bob Hamilton, PE, President Woods Hole Group.

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

I am the primary inventor of the upwelling pump; founder/CEO of Ocean-based Climate Solutions, Inc. (founded 2018), and parent company Atmocean, Inc. (2005). Key actors include Woods Hole Group (instrumentation); CLS-France (ARGO data); Seabird Electronics (BGC-ARGO's), and SeaTrek (BGC ARGO perpetual power supply).

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

300 Societal rejection of ocean CDR due to outdated or incorrect information or political beliefs. Corporate customer decisions against ocean CDR based on incorrect assumptions, lack of knowledge, or failure to acknowledge the much higher risk from their excess CO2 under business-as-usual. Scientific reviewers' reliance on outdated, incorrect, or obsolete papers, data, and information.

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

PCT/US2019/046292

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.*	10 2021-2050
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 Our goal is from 2022 to 2050 (and perhaps longer).

Distribution of that carbon removal over time *For the time frame described above, please detail how you anticipate your carbon removal capacity will be distributed. E.g. "50% in year one, 25% each year thereafter" or "Evenly distributed over the whole time frame". We're asking here specifically about the physical carbon removal process here, NOT the "Project duration". Indicate any uncertainties, eg "We anticipate a steady decline in annualized carbon removal from year one into the out-years, but this depends on unknowns re our mineralization kinetics".*	50 Our tons removed are proportional to number of pumps and available wave energy each time period. Given that phytoplankton biomass doubling time is 24 hours, and nutrients are delivered to the sunlit upper ocean on every wave (10 to 14 seconds typical period), our time scale for removal is continuous.
Durability *Over what duration you can assure durable carbon storage for this offer (e.g, these rocks, this kelp, this injection site)? E.g. 1000 years.*	10 Should exceed 1,000 years (Dr. Stephanie Hensor from NASEM webinar Q&A)

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

No lower bound; upper bound 5,000 years

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.)*

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As implementation of ocean CDR via upwelling is a new field of activity we rely on the data and analysis by David Karl and Ricardo Letelier.

Also we look to the paper cited by Dr. Stephanie Henson – https://escholarship.org/uc/item/8jq8c83r.

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?

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Some exported CO_2 is remineralized and over time may reappear above the thermocline. Since our pumps operate 24/7/365, upwelling of nutrients is continuous therefore the CO_2 making its way to the surface layer is reprocessed biologically and re-sequestered.

The socioeconomic risks cited as examples do not apply.

Until recently there was uncertainty on how to measure and validate net CO_2 export, but this has now been answered by daily sampling using the biogeochemical ARGO robotic floats as discovered by Dr. Fei Chai, in accordance with the procedures set forth by Dr. Ian Walsh.

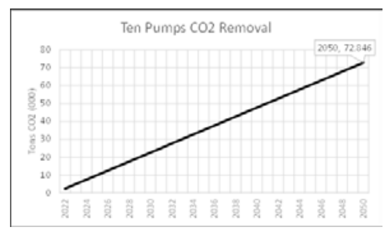
e. How will you quantify the actual permanence/durability of the carbon sequestered by your project? If direct measurement is difficult or impossible, how will you rely on models or assumptions, and how will you validate those assumptions? *(E.g. monitoring of injection sites, tracking biomass state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

200

We can now directly measure both quantity and depth profile using the BGC ARGO's as further explained by Dr. Ian Walsh and Dr. Fei Chai.

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	Each pump is projected to remove 251.5 tons CO2 per year. With ten pumps operating 2022-2050, the cumulative removal is seen below:  Figure 12. Estimated net CO_2 sequestration for 10 pumps deployed 2022.
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	None

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)*

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Upwelling depth (m)	Net C sequestered (u-mol C per m^{-3})	Source data	Annual pumped volume (m^3)	C sequestered (mmol/m^{-3})	Iron upwelling impact on net sequestered C	Convert C to CO2 tons/yr
200	2.0	Karl Table 1	45,121,253	0.54	100%	2.0
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400	54.5	Karl Table 1	45,121,253	30.10	100%	110.4
450	101.1	Karl Table 1	45,121,253	56.38	100%	206.7
500	121.8	Karl Table 1	45,121,253	68.59	100%	251.5
550	125.7	Karl Table 1	45,121,253	71.49	100%	262.1
750	141.5	Karl Table 1	45,121,253	83.51	100%	306.2

Figure 15. Calculation of Tons CO2 Sequestered Per Pump Per Year.

	2021	2022	2023	2024	2025	2026	2027	2028
Total production	-	10	-	-	-	-	-	-
Oxygenators operating	-	10	10	10	10	10	10	10
Production footprint CO2 tonnes/unit (000)	-	(0.09)	-	-	-	-	-	-
Gross CO2 sequestered in year (000)	-	2.51	2.51	2.51	2.51	2.51	2.51	2.51
Net annual co2 sequestered in year (000)	-	2.43	2.51	2.51	2.51	2.51	2.51	2.51
Cumulative CO_2 sequestered (000)	-	2.43	4.94	7.46	10.0	12.5	15.0	17.5

Figure 16. Actual calculation of tons sequestered 2022-2028

2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
-	-	-	-	-	-	-	-	-	-	-
10	10	10	10	10	10	10	10	10	10	10
-	-	-	-	-	-	-	-	-	-	-
2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
20.0	22.5	25.1	27.6	30.1	32.6	35.1	37.6	40.2	42.7	45.2

Figure 17. Actual calculation of tons sequestered 2029-2039

2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
-	-	-	-	-	-	-	-	-	-	-
10	10	10	10	10	10	10	10	10	10	10
-	-	-	-	-	-	-	-	-	-	-
2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
47.7	50.2	52.7	55.2	57.8	60.3	62.8	65.3	67.8	70.3	72.8

Figure 18. Actual calculation of tons sequestered 2040-2050.

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).

Zero.

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

Based on our testing going back to 2005, we know the flow rate for .75m diameter by 152m deep pumps. Friction is proportionally less for larger diameter pumps so we expect equal or better flow rate with our proposed 1.9m diameter by 500m depth design.

We use wave data from the National Data Buoy Center to estimate annual volume of upwelled water.

We use the calculated values of net C export for 500m depth upwelling, from Karl-Letelier Table 1 which are based on measured nutrients and ratios at Station ALOHA.

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.

5 links

- www.ocean-based.com.
- Corporate history narrative can be seen at https://youtu.be/dBB3dbL8FU0
- Our business projections narrative can be seen at https://youtu.be/7ThY9IcqDqo

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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.

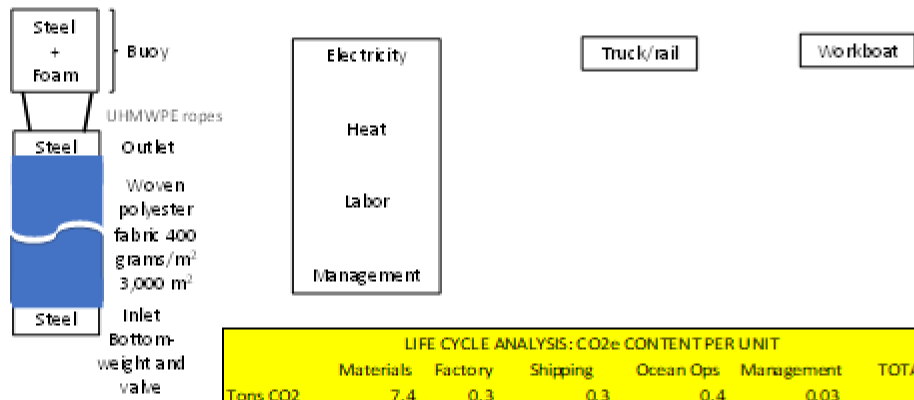
	Offer to Stripe (metric tonnes CO_2)
Gross carbon removal	251.5 tonnes per year per pump
Gross project emissions	8.5 tonnes per pump produced and deployed (full lifecycle).
Emissions / removal ratio	.034

Net carbon removal	243 tonnes per pump in first year then 251.5 tonnes per pump each year thereafter for life of the pump (which could be 80 years if properly maintained/refurbished). Total 20,111.5 tons CO2 removed over this lifetime per pump.

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.

Life Cycle Analysis Block Diagram

Components	Manufacturing/Assembly/Mgmnt	Land Transport	Marine Transport
7.4 t	0.3 t + 0.3 t	0.3 t	0.4t



LIFE CYCLE ANALYSIS: CO2e CONTENT PER UNIT						
	Materials	Factory	Shipping	Ocean Ops	Management	TOTAL
Tons CO2	7.4	0.3	0.3	0.4	0.03	8.5
Percent	87.0%	4.0%	3.9%	4.8%	0.4%	100%

Detailed calculations next slides

Component	description	quantity	units
Steel	annual steel production	1,869,900,000	metric tons
	CO2 emissions per ton	1.90	tonnes CO2 per tonne steel
	annual global co2 emissions from st	3,552,810,000	tons CO2 from steel
	2019 global CO2 emissions	33,000,000,000	tons CO2
	ratio	10.8%	percent
	product	1.90	tons Co2 per ton of steel
	percent steel recycled	86%	percent
	product	**0.27**	effective tons CO2 per ton steel
Oxygenator steel bottomweight	OBCS steel used per unit	2.60	metric tons
Oxygenator buoy & valves	OBCS steel used per unit	1.23	metric tons
	Total steel per Oxygenator	3.83	metric tons
	Total steel effective CO2 emissions p	**1.02**	tons CO2
Polyurethane foam	high estimate, kg CO2 per kg foam	2.86	https://www.researchgate.net/p
	buoy foam displacement	4.5	m^3
	weight of foam	1.44	tonnes
	CO2 emitted from foam, per unit (gr	4.1	tonnes
	percent recycled end of life	90%	https://www.letsrecycle.com/ne
	effective CO2 emissions per unit	**0.41**	tons CO2
POLYESTER FABRIC	kg co2 per sq meter woven coated f	1.77	kg/m^2
	length	500	m
	up and down	1	tubes
	plies per unit	2	plies
	width	3	m
	sq meter per device	3,000	sq m
	total fabric weight per unit	5,310	kg CO2 per unit
	CO2e	**5.3**	tonnes CO2 per unit
Subtotal materials emissions	**CO2 emissions of materials used**	**6.74**	**tonnes CO2 per unit**
Accessories (light, satlink, ARGO	10%	**0.67**	**tonnes CO2 per unit**
Total per pump		**7.41**	**tonnes CO2 per unit**

Land Shipping	rail emissions per ton-mile	40	g CO2 per ton-km
	weight of one unit	6.32	tonnes per unit
	distance	1,300	km ABQ - Long Beach CA
	tonnes CO2 per unit	**0.33**	**tonnes CO2 per unit**
Ocean shipping emissions	Diesel Fuel CO2 intensity kg CO2/gal	10.18	ABB v1 12/9/20
	Gallons per year	234563	ABB v1 12/9/20
	Annual trips	590	ABB v1 12/9/20
	kg CO2 per trip	4,047	
	Pumps deployed per trip	10	
	Tons CO2 to deploy one pump	**0.40**	

Factory operations-hardware	factory electricity per year	140,000	From Reytek general manager, an
	factory nat gas per year	1,130	From Reytek general manager, an
	NM kwh emissions factor	6.08E-04	web search
	factory electricity emissions per year	**85.12**	product
	1130 ccf in liters-atmos	11,766,230	http://www.kylesconverter.com,
	emissions factor	**1.44E-05**	web search
	heating emissions per year	**169.4**	product
	Total elec and heating emissions	254.55	tons CO2 per year
Factory operations-tube	Tube energy emissions	84.00	tons CO2 per year
	Total factory operations	338.56	tons CO2 per year
	annual production	1,000	units per year
Total elec and heating emissions per unit		**0.34**	tons CO2 per unit produced
General management	office, road and some air travel	**0.034**	tons CO2 per unit produced
GRAND TOTAL		**8.52**	tonnes CO2 per unit

We use 3.83 tons steel per pump and we assess its CO2 content of 1.9 tons CO2 per ton steel at 14% - as 86% of steel is recycled according to https://steelsustainability.org/recycling.

The 1.9 tons comes from a variety of sources, including:
https://www.iea.org/articles/global-co2-emissions-in-2019 and
https://www.worldsteel.org/en/dam/jcr:c3acc5fd-e3c2-458c-a2cc-8c4880b9334c/Steel%2527s+contribution+to+a+low+carbon+future.pdf .

We assess the polyester fabric at 5.1 tons CO2 content based on value of 1.77 kg CO2 per square meter, provided by the fabric producer, and 3,000 square meters per pump.

The high estimate for kg CO2 per kg foam is 2.86, from
https://www.researchgate.net/publication/262008540_Life_cycle_assessment_of_polyols_for_polyurethane_production_using_CO_2_as_feedstock_Insights_from_an_industrial_case_study

Similar to steel, we assess the polyurethane foam used in the buoy at 10% - as 90% is recycled according to
https://www.letsrecycle.com/news/latest-news/polyurethane-foam-and-the-environment/

With 4.5 cubic meters of foam at a density of 320kg//m^3, we estimate 4.1 tons CO2 before recycling, and 0.41 tons after recycling.

Total identified materials have a CO_2 content of 6.74 tons per pump. We then add 10% for accessories such as navigation light, GPS, and onboard as well as prorata remote (ARGO) instrumentation, giving 7.41 tons CO_2 content per pump.

For land rail shipping we use 40 g CO_2 per ton-km, (from Table 3: Published Emission Factors for Rail Freight Movement (gCO_2/tonne-km) in https://www.ecta.com/resources/Documents/Best%20Practices%20Guidelines/guideline_for_measuring_and_managing_co2.pdf) and with 6.32 tons weight per pump, and 1,300 km distance Albuquerque NM to Long Beach CA equals 0.33 tons CO_2 per pump for land rail shipping.

For ocean operations we use diesel fuel intensity of 10.18 kg CO_2 per gallon provided to us by ABB. As well they provided fuel consumption for our high speed workboat at 234,563 gallons per year. ABB's calculation assumed 800nm trip distance at 6 kts with 590 trips per year. With payload of 10 pumps per trip, the CO_2 emissions are 4.05 tons per pump.

Factory operations electricity (140,000 kwh) and natural gas (1,130 ccf) data come from our production partner Reytek in Albuquerque. Taking NM kwh and gas emissions factors and allowing 15 workers for hardware and 5 workers for tube assembly yields 0.34 tons CO_2 per pump based on 1,000 pumps per year annual rate. We add 10% for office and for local travel.

The grand total of all identified CO_2 emissions per pump after allowing for recycling rates is thus 12.16 tons. As the pumps operate on ocean waves once deployed, there are no ongoing CO_2 emissions. Repair, replacement, and refurbishment is conducted by our boats already at sea, with those emissions accounted for in the ocean operations budget.

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

100

All components are included, as well as indirect emissions from transportation, business management, etc. We take credit (deduct) for recycled inputs, particularly steel which has a global recycle rate of 86% (for each 100 tonnes consumed, 14 tonnes is new production).

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

200

The values used are best available data from independent sources as shown in full detail above.

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

Same answer

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.)

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

50

One upwelling pump, 1.9m diameter by 500m depth.

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	0	n/a	n/a	50 n/a
2020	0	n/a	n/a	n/a
2019	0	n/a	n/a	n/a
2005-2018	30+ for short duration testing	various	n/a	50 Nearly all our ocean trials have been restricted to single-daytime for budgetary reasons (overnight requiring remote tracking).

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 Pump costs constant. Estimated tons CO2 sequestered per pump/year increased - better estimates from scientists. Marine operations costs per pump declined. Transit costs have remained constant. Labor costs have remained constant. Management costs have remained constant.

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).

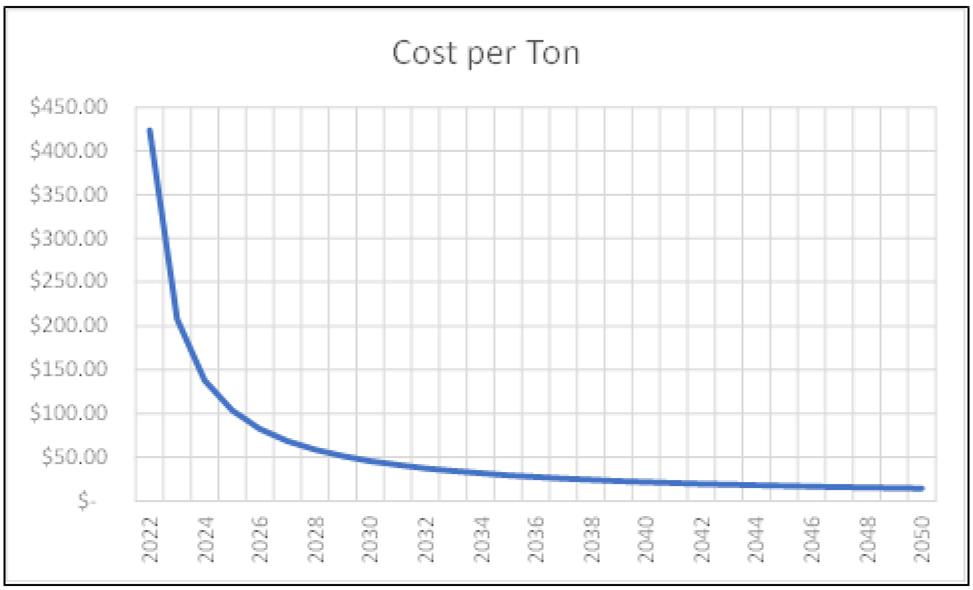
# of units	Unit gross capacity (tCO_2/unit)
10	251.5 tonnes

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?

$423



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 Baseline direct cost per pump FOB port learning curve cost saving inflation rate Cost before RR&R or communications Repair, replace, refurbish (RR&R) sinking fund 5yr Data comm cost per Argo (1 per 20) Adjusted cost per Oxygenator Shipping/loading, staff travel & onsite Total cost per Oxygenator Gross profit margin

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 1 day seatrial	200 Verify several engineering elements, fabrication techniques, and processes	August 2021	100 Participate by visiting our production facility in Albuquerque, as well come out on the boat (Morro Bay likely location) - 1 day event.

2	Long term seatrial	Verify long-term data acquisition, upwelling performance, and pump durability	September 2021 - April 2022 or longer	Participate by visiting our production facility in Albuquerque (the pump in #1 will be reconfigured from 50m depth to 500m depth); come out on the boat (CA or HA location); we will include you as recipient of uplinked data and analysis from Woods Hole Group.
3	Produce first high-speed deployment workboat	Obtaining a suitable marine workboat is required to conduct low-cost (and low CO_2 emissions) deployment of pumps. This also allows us to scale each factory to produce 1,000 pumps per year.	November 2021-April 2022	Visit boat factory in Lima Peru. Come out on shakedown run.

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	Verify upwelling flow rate which directly scales to annual net CO_2 removed. Current flow rate for 0.75m diameter x 152 m deep pump is .078 m^3/s.	Scaled by larger diameter pump, should be about 6.5 times greater, in range of 0.47 m^3/s.	100 Larger diameter = less friction = greater flow rate.

2	1 day duration	180 days or longer duration	100 Demonstrate long-term pumping and ocean response to nutrients
3	A few pump deployments per year	1,000 or more pump deployments per year	100 High speed efficient deployment vessel becomes available

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	n/a	n/a	100 Engineering verification, not intended to remove CO2 given 1 day duration.
2	n/a	$423	100 This trial will verify pump durability and performance over 6 months or longer and will be instrumented to measure CO2 removal.

3	Deployment cost in excess of $50,000; high CO2 emitting vessel reduces the net CO2 sequestered per pump..	Deployment cost of $5,000 per deployed pump with low vessel CO2 emissions per pump.	100 By acquiring this efficient workboat we will substantially reduce the cost to deploy our pumps far offshore, as well reduce CO2 emissions from marine operations..

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 Jeff Bezos. Select us to remove Amazon's emissions (past, present and future); and pay in stock (our Stock For Carbon funding mechanism allows public companies to become net negative at zero cash cost). Other public-listed companies follow by adopting this breakthrough zero-cash-cost net-negative CO2 funding mechanism.

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

50 Introduce us to other companies closely following Stripe's effort so we can implement similar projects with them.

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.

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

100 We have stayed low on the radar screen until now and thus had limited interaction with stakeholders. Going forward, we will seek out those which may be most critical (think, Greenpeace!) or most impacted - whether real or imagined (think, Maersk).

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

100 Not applicable (yet).

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

100 Not applicable (yet).

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

100
Relative to this document: our pump design including component selection is locked, subject to minor tweaks. Our factory locations will be determined based on suitable labor force, proximity to ports (or rail transit if inland), and distance to ocean deployment sites. The deployment locations will be determined based on consultation with our science and engineering advisory team, including Woods Hole Group Inc. however this could include input from stakeholders.

As to public engagement, we intend to form an Upwelling Impact Study Board (UISB) comprised of leading independent experts in the field of ocean CDR, to guide our forward efforts.

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

100
We expect to produce our pumps in port cities worldwide, providing good-paying jobs for thousands. This economic benefit will assist gaining justice for those societal members most impacted by climate change. This same benefit will accrue from our boat-building and marine operations activities.

In addition, in our submission to Microsoft last September, we proposed creating a Sea-level Rise Adaptation Fund funded from a significant percentage of our profits. This fund would directly support persons in front-line communities most impacted by sealevel rise, providing grants for relocation, retraining, etc. We will be happy to revisit this with Stripe if selected.

11. Legal and Regulatory Compliance (Criteria #7)

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

100
We have not paid for any legal opinions but have had informal emails and/or conversations with UN Law of the Sea experts, including Wil Burns and Holly Buck.

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.

100
Deploying open ocean upwelling pumps is exempt from provisions of UN Law of the Sea and London Convention -no substance added to seawater (not “dumping”).

If a relevant and fair opinion issued that all objects put in the open ocean (on purpose – such as our pumps; or inadvertently, such as 40’ cargo containers, ARGO’s whose batteries have died, or lost fishing gear) must have a permit, we will comply.

We will be transparent with our project plans, including data derived from our pumps and BGC ARGO devices (which by themselves will provide immense data to the ocean science community).

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

100
The UN Law of the Sea and London Convention governing use of the ocean commons (US not signatories) are ambivalent as to our technology.

As a practical matter, it makes no sense for those treaties to be silent about discarded/lost fishing gear, the 15,000 dead ARGO’s now littering the seafloor, or containerships losing thousands of 40 foot containers overboard each winter, while seeking to impose strict control over our device whose components are inert in seawater, mimics natural biological outcomes, and has a beneficial impact on the ocean ecosystem.

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)	72,845
Delivery window (at what point should Stripe consider your contract complete?)	2022-2050
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.*	Total budget $3,593,750 / 72,845 tons = $49.33 per ton

Application Supplement: Ocean

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

Physical Footprint (Criteria #1)

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

200
Our pumps will be deployed free-drifting in the open ocean beyond any country's 200nm EEZ. We will ascertain local gyres from satellites and seek these locations which will take advantage of the work by Prof. Fei Chai who found that BGC ARGO's deployed in these gyres remain in the gyre for many months/years, if the BGC ARGO dives and resurfaces every 24 hours (whereas a standard 5 or 10-day down/up cycle causes the BGC ARGO to be ejected from the gyre).

As to shipping, we can avoid the most-used routes. In the event our pumps drift into a lane, the tiny footprint of our very slow-moving buoy vs the enormous footprint of the fast-moving ship produces a bow wake that pushes the buoy away.

Relative other human activity, there may be some commercial fishing boats and very few recreational boats in the open oceans where our pumps are deployed, with low risk of interaction.

Fish and marine mammals will be attracted to each pump given its higher productivity and food supply - a substantial co-benefit.

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

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

200

Each buoy on the ocean surface measures about 2.5m by 4.5m. Hanging beneath the buoy is a rectangular box (upwelling water outlet) 0.9m by 3.9m. The 1.9m diameter fabric tube extends 500 m vertically from this box to the 2.6 ton bottom weight/valve which measures 1.85m diameter. To avoid choking the upward flow, there is a fabric funnel at the top of the tube which matches the tube cross-sectional area to the cross-sectional area of the upwelling outlet.

The mass of the bottom weight was modeled by Sandia National Laboratories with the model inputs being: 500m tube maximum deflection of +/- 30 degrees when subjected to typical currents.

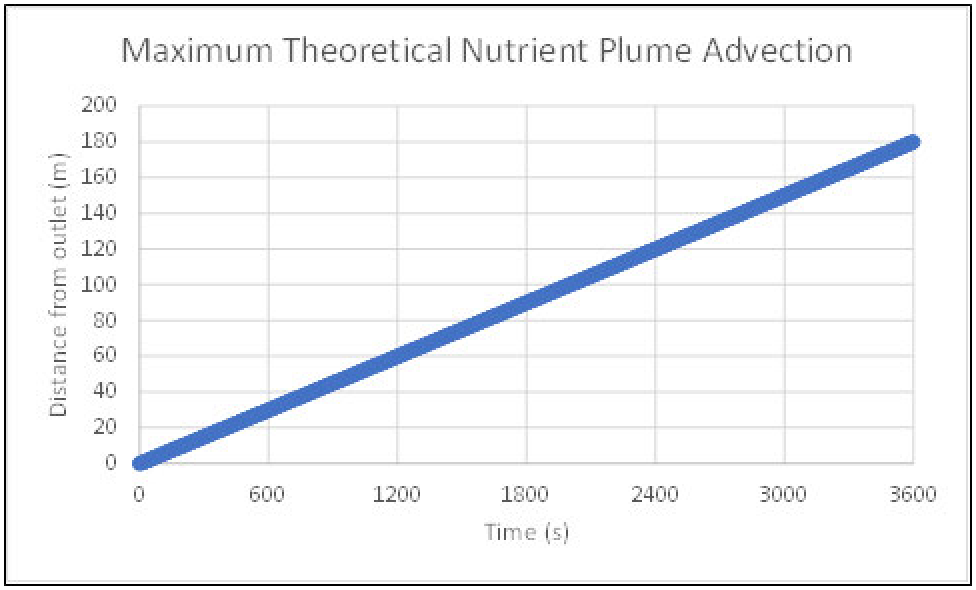
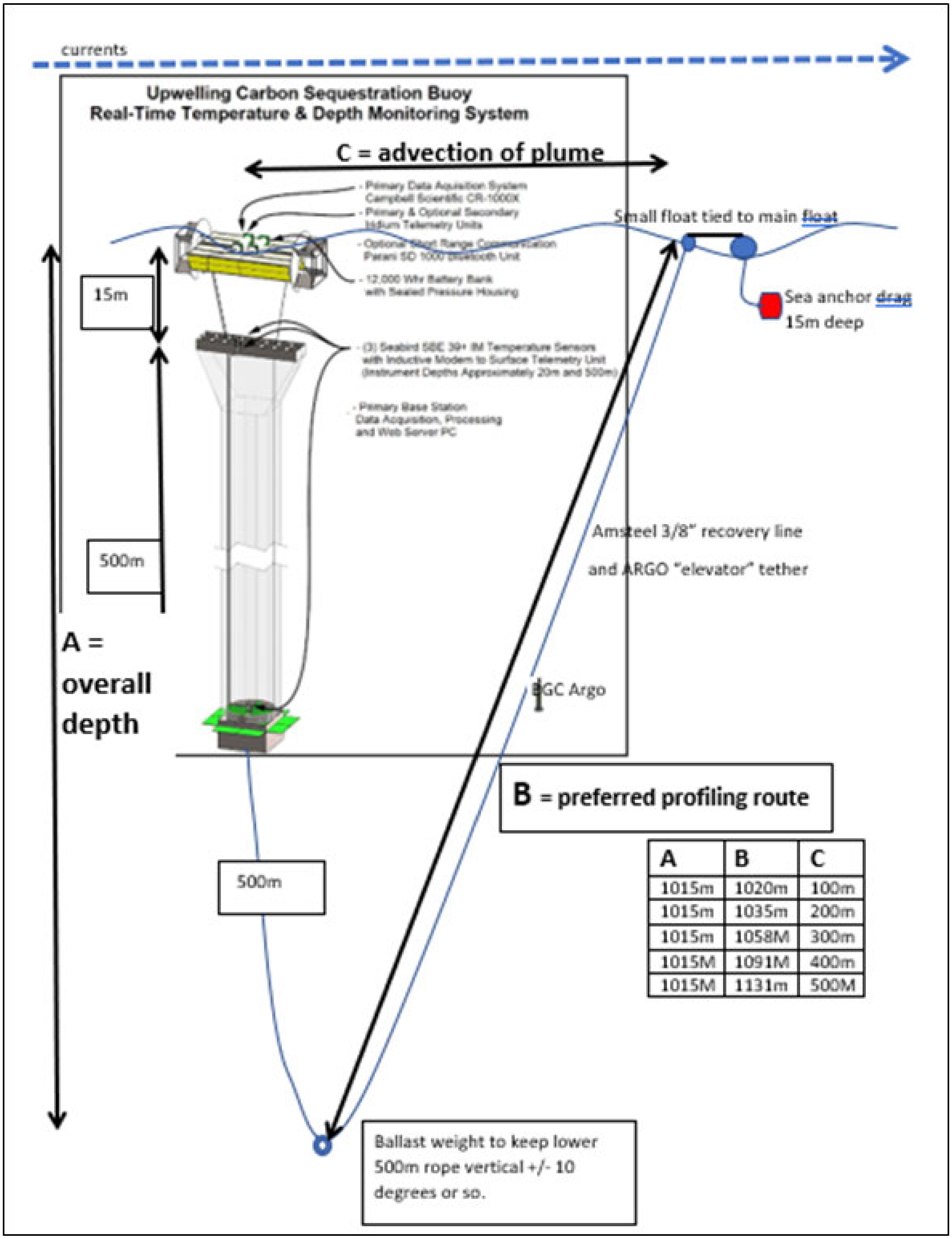


Figure 1. Theoretical plume advection.

To optimize the BGC ARGO profiling relative to upwelled plume of nutrients and resulting phytoplankton, we are reviewing if a down-current tether rope can be used similar to the following sketch.



A	B	C
1015m	1020m	100m
1015m	1035m	200m
1015m	1058M	300m
1015M	1091M	400m
1015M	1131m	500M

Figure 2. Tethering sketch for BGC ARGO.

Our upwelling occurs wave-by-wave, roughly on ten-second intervals. Therefore, the biological response also occurs wave-by-wave.

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).

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

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At two pumps per square km and further assuming 251.5 tons sequestered per pump/year and a 1-time CO2 footprint of 8.5 tons, we will need 110,000 pumps installed to reach annual net CO2 sequestered of 100 million tons within three years, covering an ocean area of 235 kilometers square. This is about 0.028% of the North Pacific Subtropical gyre which encompasses 20 million square kilometers (https://en.wikipedia.org/wiki/North_Pacific_Gyre).

Potential to Scale (Criteria #2 and #3)

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?

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The major challenge - how to install a tube 1.9m diameter by 500m deep oriented vertically in the open ocean - - is solved by our use of rugged flexible fabric which is spooled onto the buoy and self-deploys and self-primes when the buoy and the heavy bottom weight are pushed off the boat. We first demonstrated this technique in a 2006 sea trial off Galveston TX and many times since.

We eliminate the cost and difficulty of moorings by using free-drifting pumps.

Our pump design provides for force-limiting: above about 3m wave heights the buoy submerges as its vertical velocity is less than the vertical velocity of the wave face.

Our 25 knot (top speed) catamaran workboat with capacity for 10 pumps each trip is the best solution - under full cost accounting, just $5,000 per pump deployed hundreds of miles offshore, and low CO2 emissions per pump deployed.

Measuring the CO2 in the ocean required ship-based sampling – difficult, extremely expensive, and unreliable due to the inherent lack of repeatability. But the BGC ARGO's operated at daily sampling interval accurately measure the exported CO2. With one BGC ARGO per 20 pumps provides very high resolution data.

Externalities and Ecosystem Impacts (Criteria #7)

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?

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Eutrophication and turbidity seldom in open ocean.

The BGC ARGO's provide data to quantify/monitor pH, other biogeochemistry.

On risk, Professor Andreas Oschlies GEOMAR says:

"There is essentially no environmental risk associated with small-scale field trials. For hypothetical large-scale deployment, local oxygenation of subsurface waters by translocation of surface waters and deeper waters will be accompanied with a translocation of nutrients and heat, likely leading to a cooling and enhanced biological productivity of surface waters. Enhanced productivity will eventually be followed by enhanced respiration and oxygen consumption that may to some extent offset the initial oxygen gain. Enhanced biological productivity will likely enhance the productivity of higher trophic levels including fish. There will be shifts in the ecosystem, the valuation of which is difficult, but with higher productivity in normally not over-productive waters, these will most likely be viewed positively. It cannot be ruled out that species of little commercial value or possibly even toxic algae may benefit more than others. Mechanisms of such ecological shifts are poorly understood and based on current knowledge there is little expectation that shifts will differ from natural shifts observed when moving from oligotrophic to more eutrophic conditions, such as usually found further onshore."