Ocean-Based

APPLICATION FOR STRIPE 2020 NEGATIVE EMISSIONS PURCHASE

Section 1: Project Info and Core Approach

1. Project name

All-Natural Biogeochemical CO_2 Sequestration In Deep Ocean

2. Project description. ***Max 10 words***

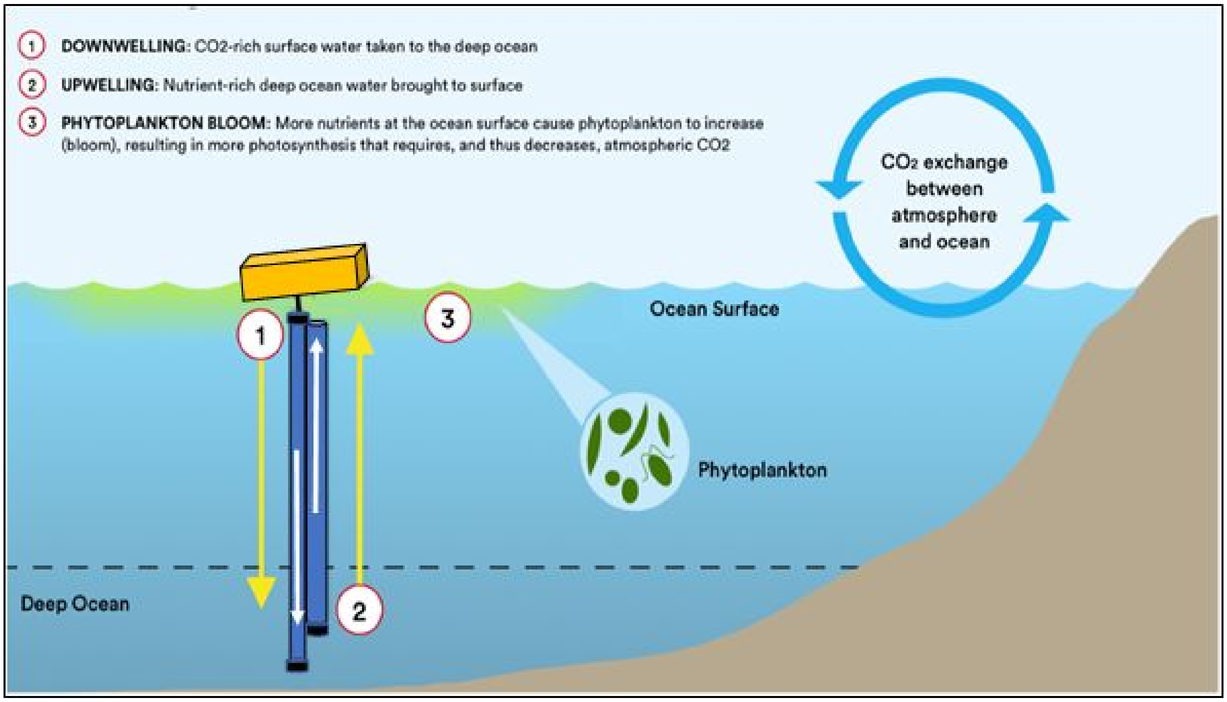
Leveraging biogeochemistry, our wave-powered upwelling/downwelling technology achieves long-term CO_2 sequestration.

3. Please describe your negative emissions solution in detail, making sure to cover the following points:
   a) Provide a technical explanation of the project, including demonstrations of success so far (preferably including data), and future development plans. Try to be as specific as possible: all relevant site locations (e.g. geographic regions), scale, timeline, etc. Feel free to include figures/diagrams if helpful. Be sure to discuss your key assumptions and constraints.
   b) If your primary role is to enable other underlying project(s) (e.g. you are a project coordinator or monitoring service), describe both the core underlying technology/approach with project-specific details (site locations, scale, timeline, etc.), and describe the function provided by your company/organization with respect to the underlying technology/approach.
   c) Please include or link to supplemental data and relevant references.

Max 1,500 words *(feel free to include figures)*

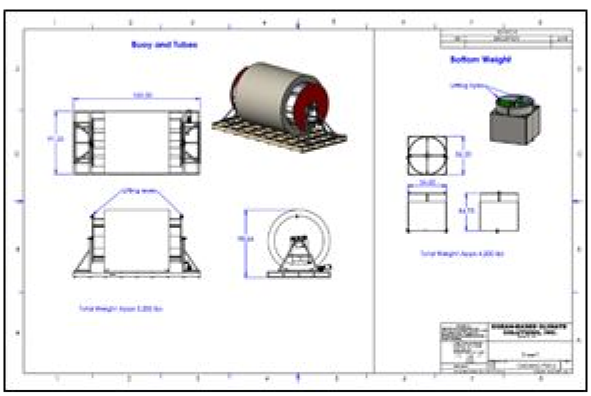
Technology Description

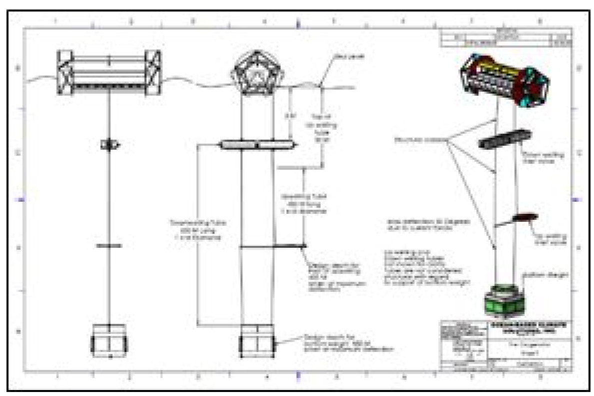
Powered by ocean wave-energy, each pump [1] upwells seawater from 500-m, triggering phytoplankton blooms, absorbing dissolved CO_2. This CO_2-enriched water is concurrently downwelled below 600-m, sequestered for millennia.



Pump Design.

The pump comprises cylindrical buoy with internal releasable downwelling one-way valve, 600m downwelling fabric tube, 500m upwelling tube, upwelling one-way valve, and counterweight. In transit the fabric tubes are spooled-onto the buoy separate from counterweight.





To deploy, the free end of tube connects to counterweight, off-lifted onto ocean. The counterweight sinks, unspooling the tubes. When fully unspooled, the downwelling valve releases from inside the buoy. This triggers rotation of floats so the buoy becomes raft-shaped to efficiently ride up and down passing waves. This automated deployment feature improves efficiency and reduces boat time, enabling large-scale deployments in the open ocean.

We built a prototype in December 2018 and demonstrated this feature off California.

Since inception in 2005, for various configurations of upwelling/downwelling pumps, we've conducted over 100 days of ocean tests in Bermuda, TX, CA, OR, HA, Peru, and Newfoundland; six weeks of wave tank testing at Plymouth Univ (UK) and Texas A&M; and been awarded a dozen grants from Oregon Wave Energy Trust, Sandia National Laboratories, Los Alamos National Laboratories, and Technology Strategy Board (UK).

Pump Distribution, Density, Perturbation Ratio, and Safety/Durability Strategy.

To minimize adverse side effects, our safety strategy is to induce **small changes** (~8%/year) **over large areas** (millions of square kilometers), **far from land** (beyond the 200nm EEZ's), **for long time periods** (decades). Given the five-year life expectancy of each pump, and recovery capability, adverse side effects are overcome by terminating the program either slowly (pumps stop working/recovered) or quickly (pumps removed, region-by-region).

We propose deploying two pumps per square kilometer, giving an annual cumulative "perturbed" seawater volume of 8% (up/down combined volume divided by the volume of one km^3).

Our pump is designed so the buoy submerges in waves over 3m height, reducing forces imposed by higher waves. Biofouling will accrue more on the steel/foam surface parts but less on the slick and flexible fabric tube extending into the dark ocean depths. We plan on-site biofouling maintenance.

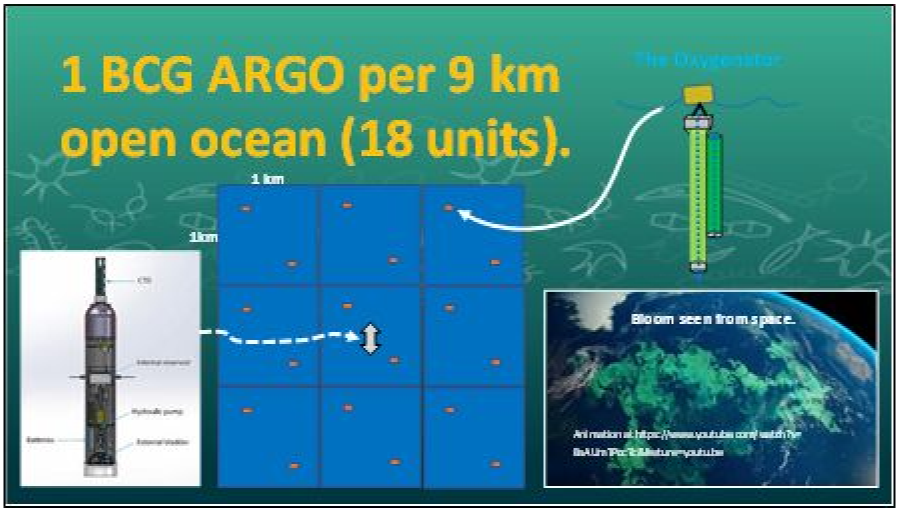
The component most likely to fail is the tube, which can be replaced periodically. Overall, we estimate a pump life of five years and refurbishment cost of 50%.

CO2 Sequestration Data Acquisition and Verification.

Estimated annual CO_2 sequestration is 139.4 tons per pump.

Our measurement strategy is to deploy one drifting biogeochemical (BGC) ARGO robotic float for every 18 pumps.

stripe



Programmed to descend 2,000m then resurface, each BGC- ARGO collects verification data which is uplinked via satellite to the France data center operated by CLS. Their US subsidiary, Woods Hole Group Inc. is supporting our submission to STRIPE.

For the two pumps to be funded by STRIPE in 2020, temperature sensors will be used to verify the upwelling and downwelling volumes and determine net CO_2 sequestered according to known ocean biogeochemical attributes.

More details on the BGC-ARGO at https://biogeochemical-argo.org/.

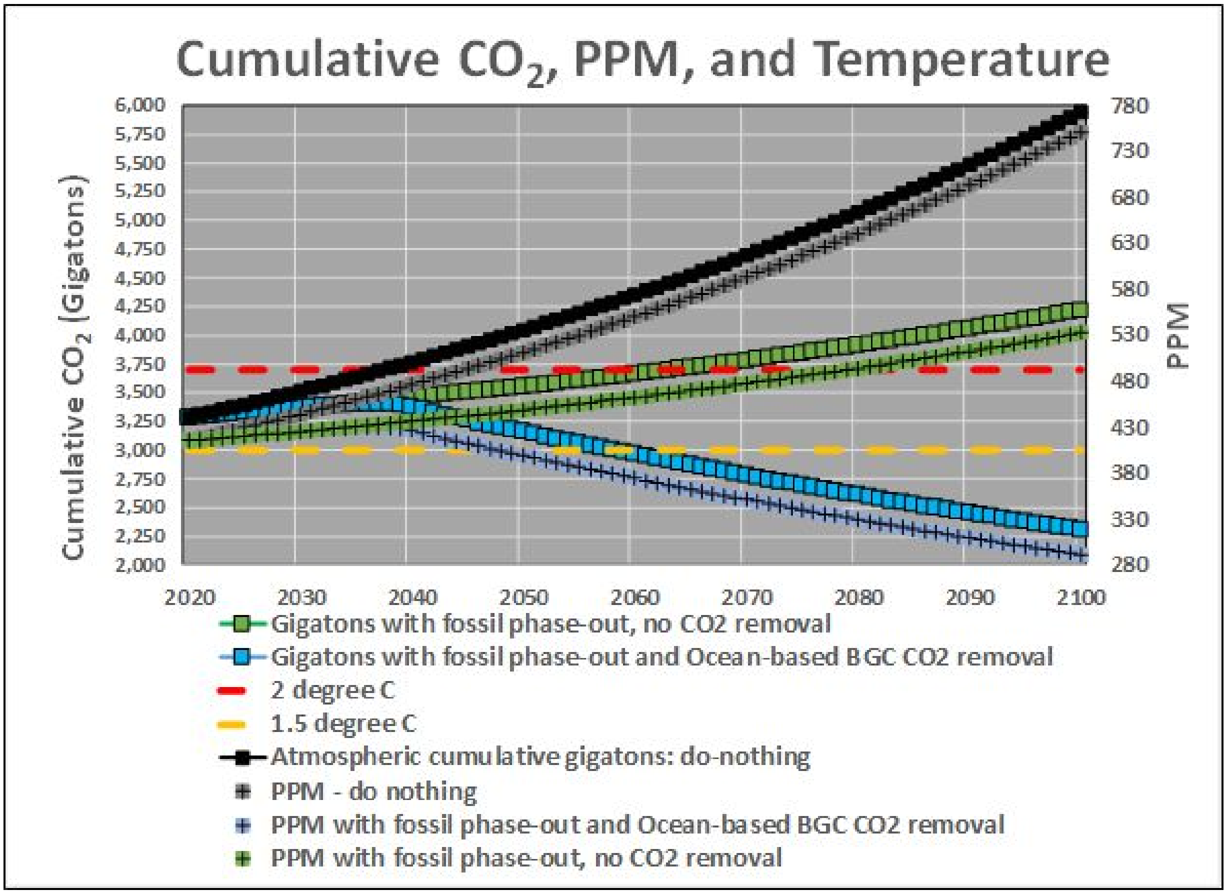
Geographic Locations and Numbers of Pumps.

Geographic locations will be the "ocean deserts" – low nutrient surface waters between 45 degrees N-S in the Pacific, Atlantic, and Indian Oceans. The total ocean area (beyond the 200nm territorial EEZ's) is estimated at 200 million square kilometers – providing space for up to 400 million pumps when fully populated.

The initial site to be funded by STRIPE is either offshore California, or Hawaii (pending COVID-19 issues).

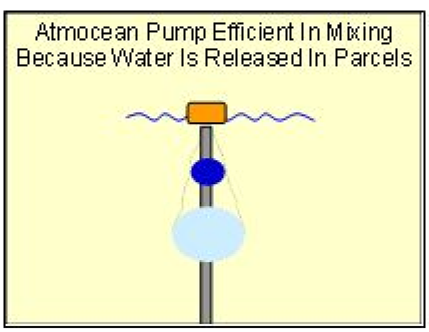
Long-term Impact on Cumulative Gigatons CO_2, PPM, and Temperature Rise.

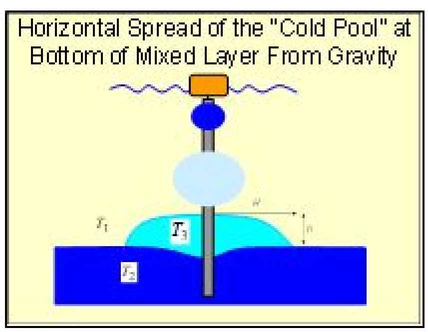
Our technology can sequester nearly 1,900 gigatons, which together with fossil fuel phase-out can return earth to pre-industrial CO_2 of 280 PPM by 2100.



Upwelling modeling, testing, data, and efficiency.

Mathematical analysis [2] by Professor Isaac Ginis from the University of Rhode Island Graduate School of Oceanography in 2008 concluded:





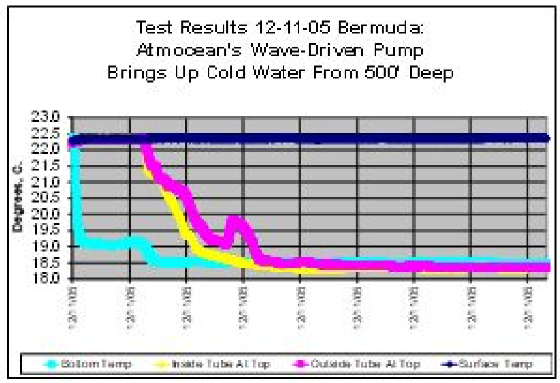
1) When more-dense deep cold water parcels are pumped into the warmer surface layer, they sink and mix becoming neutrally-buoyant, “piling-up” on top of the thermocline.

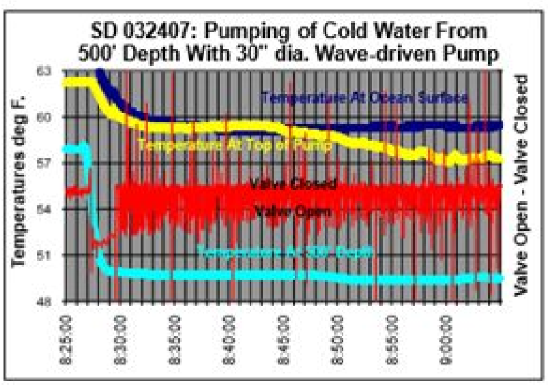
2) Variations in wave height/period deliver variable flows – mimicking natural ocean

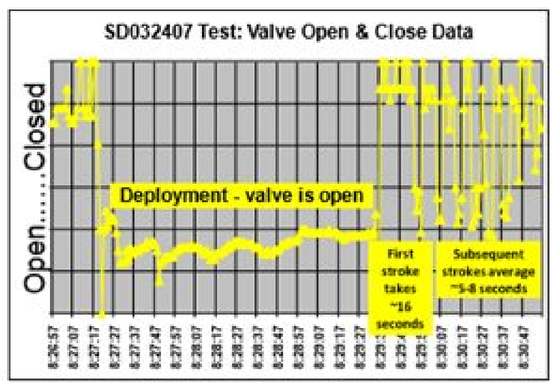
upwelling processes.

These conclusions indicate the nutrient-enriched deeper water will accumulate above the thermocline in the sunlit zone, achieving critical nutrient ratios needed to trigger and maintain a bloom.

We documented wave-powered upwelling from 500 feet depth in Bermuda in 2005, followed by our 2007 test off San Diego obtaining data showing one-way valve open-close cycles combined with temperature data, which gives a flow rate of 4.8 m^3 per minute.







Comparing wave-driven upwelling flow rate to theoretical gives upwelling pump efficiency of 73.3%. For downwelling, gravity-driven sinking of the heavy bottom weight gives estimated efficiency of 94.9%.

Analysis of data from National Data Buoy Center (www.ndbc.noaa.gov) wave heights and wave periods from their buoy #51001 located 100nm north of Oahu Hawaii allows calculation of nominal annual pumped volumes. In the Atlantic, we use NDBC data from #41049, 300nm SSE of Bermuda. To estimate both upwelling and downwelling volumes, we cutoff waves over

3m height and disregard pumped volume from waves under 0.5m. Pacific waves deliver about 10% more than Atlantic waves.

	Nominal Pumped Volume (m^3) Data Buoy 51001 - Hawaii					
	2016	2017	2018	Average	Efficiency	Annual Volume
Upwelling	24,428,009	23,055,034	24,283,096	23,922,046	73.3%	17,545,907
Downwelling	24,428,009	23,055,034	24,283,096	23,922,046	94.9%	22,707,561

Applying these estimated upwelling and downwelling volumes to nutrient stoichiometries at depth determines CO_2 sequestration (see below).

Downwelling Mechanics and Efficiencies.

In 2017-18, we coordinated computational fluid dynamics downwelling studies by Sandia National Laboratories [3] which found density of downwelled surface water inside a tube became equal to external water density at ~300m depth, due to greater density (by cooling) of the downwelled water combined with its unchanged surface salinity-density.

The mixing model is seen here for outflow at 1,000m depth:

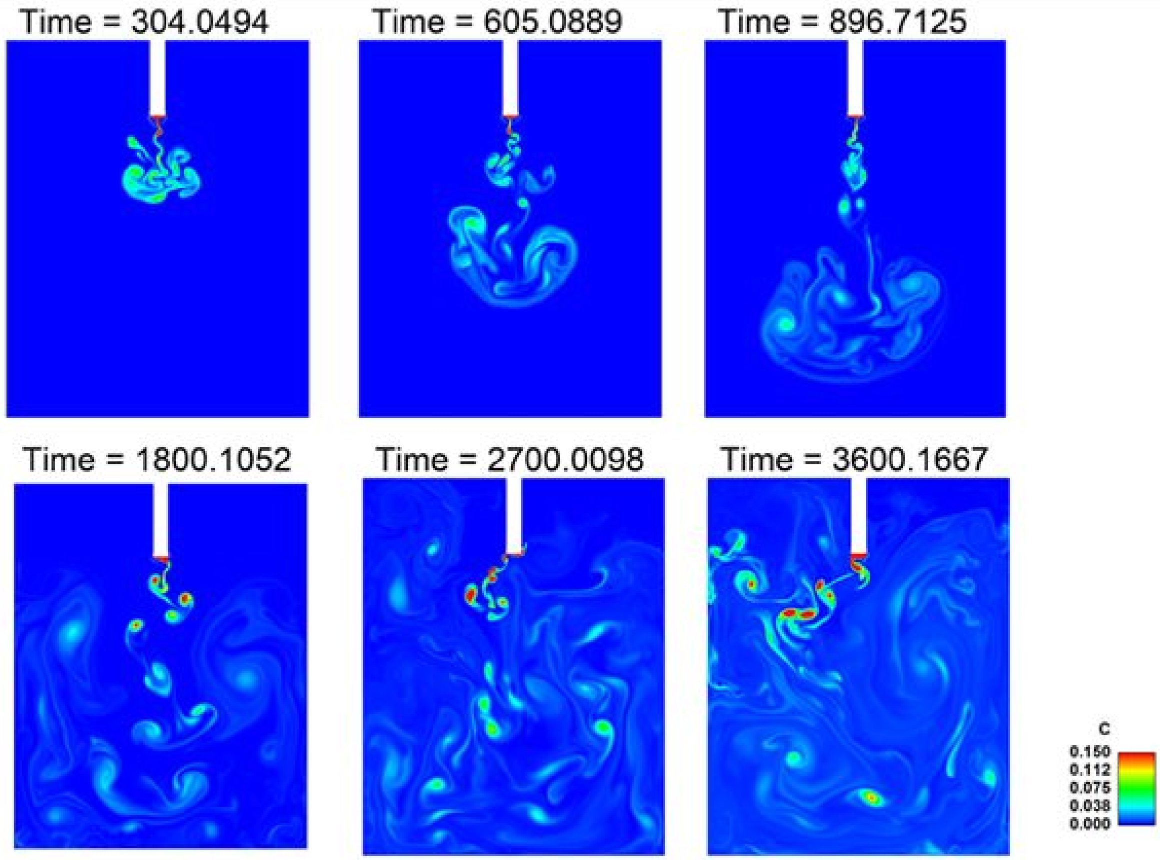


Figure 1. Buoyantly driven convective dissolution in a 60 x 75 ft tank. The concentration scale is reduced to enhance visibility. Time is depicted in seconds.

Nutrient Conversion and Net Carbon Sequestration Due To Upwelling

Net C export via a dual bloom was hypothesized by University of Hawaii Professor David Karl et.al. in their iconic 2008 paper "Nitrogen fixation-enhanced carbon sequestration in low-nitrate, low-chlorophyll seascapes" [5]. Table 1 provides estimated volumes sequestered per m^{-3} upwelled, for depth-measured nutrient concentrations:

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)			Excess nutrient concentration[a]			Total P excess plus r-P (µM)	Total N_2 fixation[b] (µM)	Net C sequestered (mmol C m^{-3} upwelled)[c]
	DIC	NO_3^-	PO_4^{3-}	DIC (µM)	P (µM)	DIC:P (mol:mol)			
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)

Dissolved Organic Carbon.

In 2010 Dennis Hansell et.al. published "Dissolved Organic Matter In The Ocean - A Controversy Stimulates New Insights" [6] suggesting vast ocean reservoirs of dissolved organic carbon (DOC), previously not well characterized, with levels of ~80 mmol/m^{-3} found in the upper ocean.

Their abstract reads "Containing as much carbon as the atmosphere, marine dissolved organic matter is one of Earth's major carbon reservoirs. With invigoration of scientific inquiries into the global carbon cycle, our ignorance of its role in ocean biogeochemistry became untenable. Rapid mobilization of relevant research two decades ago required the community to overcome early false leads, but subsequent progress in examining the global dynamics of this material has been steady. Continuous improvements in analytical skill coupled with global ocean hydrographic survey opportunities resulted in the generation of thousands of measurements throughout the major ocean basins. Here, observations and model results provide new insights into the large-scale variability of dissolved organic carbon, its contribution to the biological pump, and its deep ocean sinks."

Their Figure 2 provides estimated quantity of DOC sequestered via downwelling: 80 umol/kg at surface vs 40 umol/kg at 500m (net of 40 umol/kg).

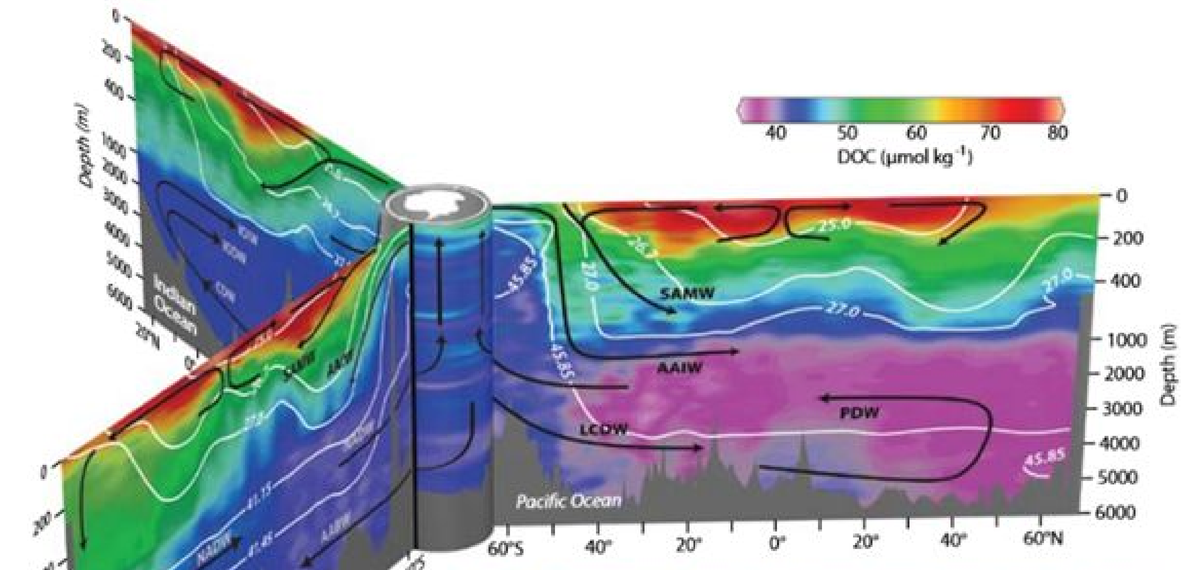
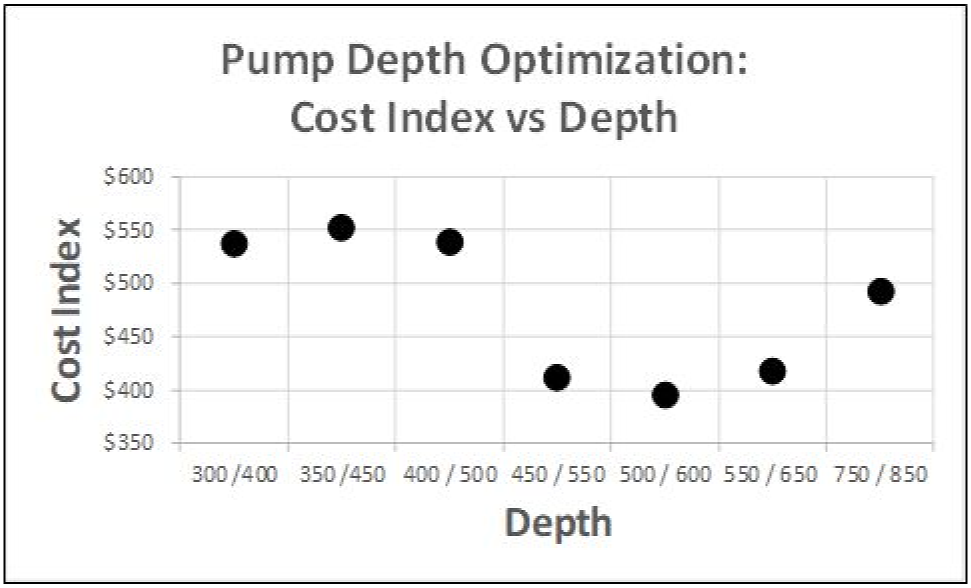


Figure 2. Distributions of DOC (µmol kg^{-1}) in the central Atlantic, central Pacific, and eastern Indian oceans on CLIVAR lines A16, P16, and I8/I9, respectively, with water from all lines connected via the Antarctic circumpolar currents (line locations shown in Figure 1). Arrows depict water mass renewal and circulation; white lines indicate isopycnal surfaces employed in Figure 3. Note DOC export in the North Atlantic with NADW formation, then DOC loss during deep circulation to the South Atlantic. In the Pacific, there is a northward invasion of relatively DOC-enriched circumpolar deep water along the bottom (LCDW), slow removal of DOC into the far North Pacific, and return flow of DOC-impoverished water to the south at mid depths (PDW). NADW = North Atlantic Deep Water. SAMW = Subantarctic Mode Water. LCDW = Lower Circumpolar Deep Water. PDW = Pacific Deep Water. CDW = Circumpolar Deep Water. IODW = Indian Ocean Deep Water. IOIW = Indian Ocean Intermediate Water. AAIW = Antarctic Intermediate Water. All DOC samples were analyzed by high-temperature combustion along with systematic use of shared reference materials.

Optimization; Projected Net CO_2 Sequestered For Different Pumping Depths.

Combining Karl and Hansell with our estimated annual pumped volumes and converting C to CO_2, we calculate net sequestration at different depths, and index this to tube cost – determining that upwelling from 500m and downwelling to 600m is optimum.



Direction/depth (m)	Net C sequestered		Efficiency-adjusted annual pumped volume (m^3)	Downwelling depth-volume adjustment factor		C sequestered ($mmol/m^{-3}$)	Upwelling CO2 sequestered tons/yr	Downwelling CO2 sequestered tons/year	Up and down combined CO2 sequestered tons/year
	Amount (mmol C per m^{-3})	Source		Percentage applied to downwelling volume	Source				
Downwelling									
300	40	Hansell Fig 2	22,707,561	100%	Sandia study	10.90	-	40.0	40.0
Upwelling / (downwell depth)									
200 / 300	2.0	Karl Table 1	17,545,907	90%	Author estimate based on Sandia study	0.38	1.4	36.0	37.4
250 / 350	15.7	Karl Table 1	17,545,907	95%		3.14	11.5	38.0	49.5
300 /400	32.7	Karl Table 1	17,545,907	100%		6.89	25.2	40.0	65.2
350 /450	41.2	Karl Table 1	17,545,907	101%		8.76	32.1	40.4	72.5
400 / 500	54.5	Karl Table 1	17,545,907	102%		11.70	42.9	40.8	83.7
450 / 550	101.1	Karl Table 1	17,545,907	103%		21.93	80.4	41.2	121.6
500 / 600	121.8	Karl Table 1	17,545,907	104%		26.67	97.8	41.6	139.4
550 / 650	125.7	Karl Table 1	17,545,907	105%		27.80	101.9	42.0	143.9
750 / 850	141.5	Karl Table 1	17,545,907	109%		32.47	119.07	43.6	162.6

Microbial Carbon Pump and Redfield Ratio.

In 2015 Jiao et.al. published “Microbial production of recalcitrant dissolved organic matter: long-term carbon storage in the global ocean” [7], outlining the role of the microbial carbon pump which converts DOC into long-lived recalcitrant DOC - radiocarbon dated at over 5,000 years.

The abstract reads “The biological pump is a process whereby CO_2 in the upper ocean is fixed by primary producers and transported to the deep ocean as sinking biogenic particles or as dissolved organic matter. The fate of most of this exported material is remineralization to CO_2, which accumulates in deep waters until it is eventually ventilated again at the sea surface. However, a proportion of the fixed carbon is not mineralized but is instead stored for millennia as recalcitrant dissolved organic matter. The processes and mechanisms involved in the generation of this large carbon reservoir are poorly understood. Here, we propose the microbial carbon pump as a conceptual framework to address this important, multifaceted biogeochemical problem."

The paper hypothesizes a dramatic increase in the ratio of C:N:P from the conventional Redfield Ratio of 106:16:1 to recalcitrant DOM ratio of 3,511:202:1 (FYI "Redfield ratio or Redfield stoichiometry is the consistent atomic ratio of carbon, nitrogen and phosphorus found in marine phytoplankton and throughout the deep oceans" Wikipedia).

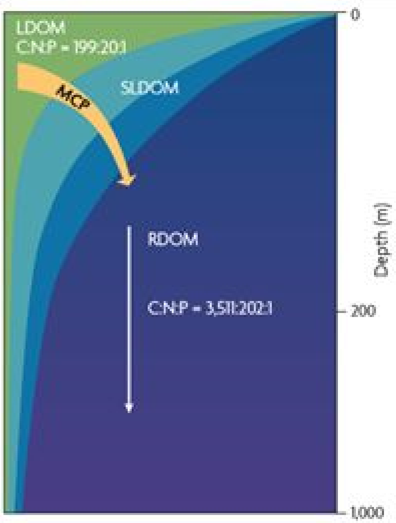


Figure 2 | **The effects of the microbial carbon pump.** Successive transformation of labile dissolved organic matter (LDOM) and semi-labile DOM (SLDOM) through the microbial carbon pump (MCP) results in the accumulation of recalcitrant DOM (RDOM) and an increase in the carbon to nitrogen and carbon to phosphorus ratios in RDOM, thus storing carbon in the ocean.

Conclusion.

Wave-powered upwelling/downwelling pumps leverage known ocean biogeochemistry, with potential to sequester massive tons CO_2 in the deep ocean at long term cost under $5 per ton.

Section 2: 2020 Net-Negative Sequestration Volume

See Stripe Purchase Criteria 1: The project has volume available for purchase in 2020.

4. Based on the above, please estimate the **total net-negative sequestration volume** of your project (and/or the underlying technology) in 2020, in tons of CO2. (Note: We're looking for the net negative amount

sequestered here, net lifecycle emissions. In Section 3; you'll discuss your lifecycle and why this number is what it is).

693 tons

5. Please estimate how many of those tons are still available for purchase in 2020 (i.e. how many tons not yet committed). This may or may not be the same as the number above.

693 tons

6. (Optional) Provide any other detail or explanation on the above numbers if it'd be helpful. ***Max 100 words.***

We use accrual-based accounting, with the net tons booked as sequestered upon deployment, at the start of the projected technology life of five years.

Section 3: Life Cycle Analysis

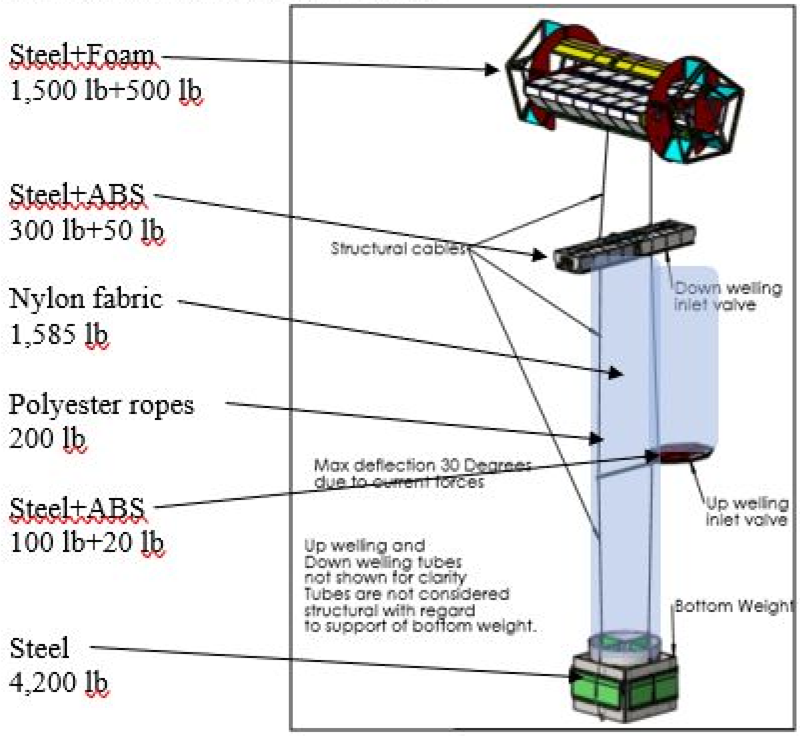
See Stripe Purchase Criteria 2: The project has a carbon negative complete lifecycle (including energy use, etc).

7. Provide a life cycle analysis of your negative emissions solution demonstrating its carbon negativity, as complete as possible given limited space, and making sure to cover the following points:

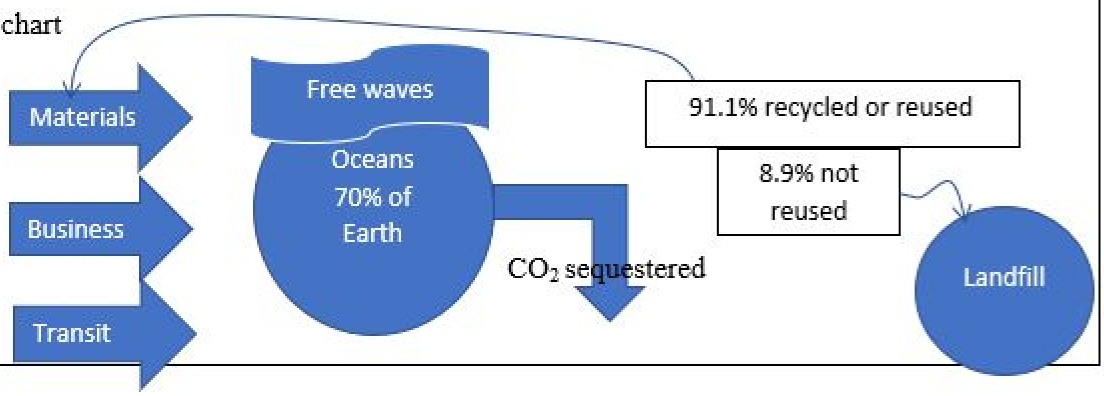
a) Include a flow sheet diagram of direct ingoing and outgoing flows (GHG, energy, materials, etc) that bear on the LCA.
b) Please be explicit about the boundary conditions of your LCA, and implications of those boundaries on your life cycle. Let us know why the conditions you've set are appropriate to analyze your project.
c) Make sure to identify assumptions, limitations, constraints, or factors that relate to ingoing and outgoing flows, citing values and sources (for example: land and resource scarcity, limitations on a required chemical, energy requirements). Also identify key sources of uncertainty in determining these values.
d) If your solution results in non-CO2 GHG emissions, please be sure to separately specify that (e.g. in units of GWP 20 or 100 years, ideally both).
e) For solutions that rely on modular components (for example: incoming energy flows or outgoing CO2 streams), feel free to cite values associated with those interfaces instead of fully explaining those components. For these values, please identify the upstream and downstream life cycle emissions of the component.
f) Explain how you would approach a more comprehensive LCA by citing references and underlying data needed for the analysis.

Max 1,000 words *(feel free to include figures or link to an external PDF)*

Component materials weight in air:



Flow chart



Materials weights and CO_2 footprint per pump.

Materials	Weight	CO_2 per ton of material	% virgin	Reycled/ reused at 5 yrs?	Total new tons CO_2	Basis

Steel	6,100 lbs 2.77 t	1.46	12%	Yes	0.485 t	1.46 tons CO_2 per ton steel 88% of steel is recycled.
ABS	70 lbs	Minimal	n/a	Yes, n/a	n/a	Minimal
Foam	800 lbs .363 t	Consumes rather than emits CO_2	100%	Yes	n/a	**"Carbon dioxide (CO_2) as sustainable feedstock for polyurethane production"** Green Chemistry 16(4) · March 2014 DOI: 10.1039/C3GC41788C
Nylon	1585 lbs 0.72 t 6,258 m^2	0.068 kg CO_2 per m^2 nylon 6,6.	100%	No	0.426 t	See [8] for details.
Polyethylene (PE) rope	200 lbs .091 t	Allow 200% ratio of CO_2 to PE	100%	Yes	0.181 t	
Total	3.944 t				1.092 t	

Transit CO_2 footprint

Mode	Units calculated	g CO_2 per km per TEU	Trip distance	Transit CO_2 per pump	Basis
Ocean	1 per 20' TEU	53.4 g per km per TEU	1,000 km round trip	.0534 t	2014 global ocean fleet-wide average 53.4 grams CO_2 emissions per TEU carried per kilometer traveled.
Land (intermodal)	2 (7.14t) per 40' container	22g per ton-mile 65g per ton-mile	1,000 km (620 miles) 1-way 2/3 rail 1/3 truck	.033 t .047 t	EPA: rail 22g/ton-mile truck 65g/ton-mile
Total				.1334 t	

Business (management and factory) CO_2 footprint

Input	Units	Quantity	CO_2 per man-hour	Business operations CO_2 footprint	Notes

US all-in CO_2 emissions per man-hour	Man-hours	Factory 113.4 Management (10%) = 11.3	0.01974 0.01974	2.24 t 0.22 t	US CO_2 emissions in 2019 ~6 Gt / US labor force 160m / 1,900 hours/year = 0.01974 t CO_2 per man-hour.
Total				2.46 t	

Summary per pump

Source	CO_2 footprint
Materials	1.0920 t
Transit	0.1334 t
Business	2.4600 t
Operating energy from ocean waves	No CO_2!
Total	3.6854 t

Further information requested.

a. Boundary conditions

Per pump as described herein.

b. Assumptions, limitations, constraints, or factors

Pump operating life is 5 years with 50% material reused/refurbished. Assumes steel net footprint accounts for 88% recycled. If 100% new steel is assumed, the materials CO_2 footprint increases by 3.5592 t (total CO_2 per pump is then 7.2446 t).

Pump factories within 1000km of port. Land shipping 2/3 rail, 1/3 truck.

Deployment 500km offshore

Ocean vessels capacity 8 pumps per trip.

c. Uncertainty

Accounting for steel LCA (100% virgin, or 12% virgin/88% recycled?) At 100% virgin, our total footprint increases by 3.56 t.

d. (Not applicable)

e. Non-CO_2 GHG emissions

For a discussion of nylon, see [8].

f. How to approach a more comprehensive LCA

Need actual transit values for each factory and deployment location, and transit mode CO2 emissions.

8. Based on the above, for your project, what is the ratio of emissions produced as any part of your project life cycle to CO2 removal from the atmosphere? For true negative emissions solutions, we'd expect this ratio to be less than 1.

Assuming 5-year life, the footprint per pump is 3.6854 tons and the sequestration is (5 x 139.4 = 697 tons), giving a ratio of 0.00529 (0.53%).

Section 4: Permanence and Durability

See Stripe Purchase Criteria 3: The project provides durable, long-term storage of carbon.

9. Provide an upper and lower bound on the likely durability / permanence of sequestered carbon provided by your project, in years:

According to Jiao et.al., ocean biogeochemical sequestration has been radiocarbon dated at over 5,000 years. We offer this as the upper bound. For lower bound, some of the particulate organic carbon from phytoplankton will be remineralized and could outgas, reducing our net impact. Also, the deeper ocean contains higher levels of dissolved CO_2 *which when upwelled could outgas, reducing our net impact. Over time (years to decades) we believe these deductions will not greatly impact our net biogeochemical sequestration.*

Professor Andreas Oschlies addresses some of these issues in his contribution in paragraph 13, below.

To avoid misinterpretation, we wish to define these terms.

"Durability" to us means the amount of sequestered CO_2 *that remains as* CO_2*, rather than converts or elicits another GHG which then changes heat absorption by the atmosphere. This is expressed as a percentage.*

"Permanence" to us means the time, in years, that the sequestered CO_2 *accumulates in storage – thus includes both a time component and a volume component. Preferably the time component extends many human generations.*

"Sequestered carbon" to us means residual CO_2 *emissions in the atmosphere that are "durably" and "permanently" removed.*

For permanence, time is in years and volume is cumulative, not one-time tons (a ton emitted today makes warming worse almost forever; similarly, a ton removed today reduces warming almost forever). What matters are the tons sequestered multiplied by the time that CO_2 *is removed from the atmosphere.*

10. Please provide a justification for your estimates, and describe sources of uncertainty related to: the form of storage, effects of environmental or climatic variability, difficulty in monitoring or quantification, etc. Specifically, discuss the risks to permanence for your project, the estimated severity/frequency of those risks (e.g. 10% of the acres of forest in this forest type are burned by fire over a 100 year period), and the time-horizon of permanence given those risks.
Max 500 words

Projected Net CO_2 Sequestered For Different Pumping Depths.

As indicated above, upwelling from 500m and downwelling to 600m is optimum. Our estimated net CO_2 sequestered derives from the Karl, Hansell, and Jiao papers cited above:

sequestration is (5 x 139.4 = 697 tons) minus lifecycle net emissions of 3.6854 tons, for a net

CO_2 sequestration of 693.3 tons over five years, on average 138.7 tons per pump/year.

Sources of uncertainty relating to:

a. Form of storage: very certain; natural.

b. Permanence of storage: 5,000 years is semi-permanent in geologic time frame but very permanent in human lifespan time frame.

c. Effects of environmental/climate variability: warming will continue but our pumps cool the upper ocean, mitigating this concern. As cumulative CO_2 comes down post 2050, our solution may be slightly less effective as air/water pCO_2 is dampened.

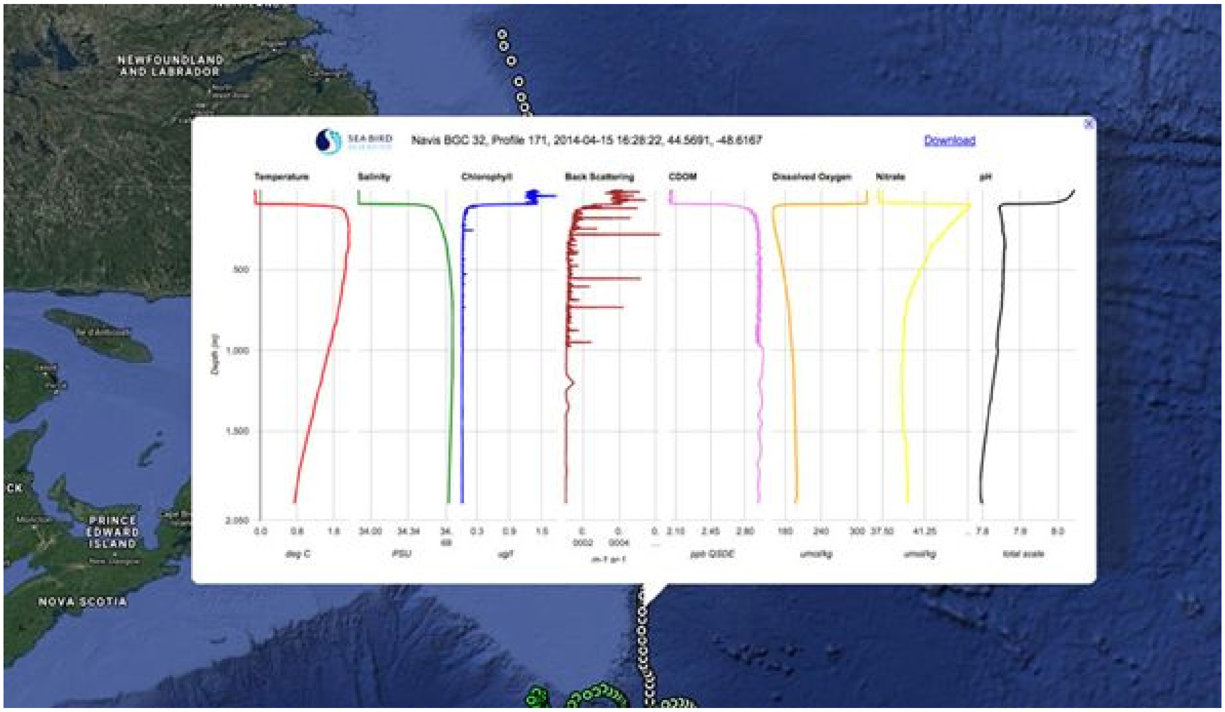
Difficulty in monitoring: recent and future improvements to the biogeochemical ARGO units will substantially address these challenges.

Section 5: Verification and Accounting

See Stripe Purchase Criteria 4: The project uses scientifically rigorous and transparent methods to verify that they're storing the carbon that they claim, over the period of time they claim to.

11. Provide detailed plans for how you will measure, report, and verify the negative emissions you are offering. Describe key sources of uncertainty associated with your monitoring, and how you plan to overcome them.
Max 500 words

Measuring ocean biogeochemistry is rapidly evolving with the introduction of BGC ARGO floats – as seen in this data set from 2014:



(source:
https://www.seabird.com/eBooks/Profiling-Floats-Explained-Sea-Bird-Scientific?gclid=CjwKCAjwsMzzBRACEiwAx4lLGyul3Fs-skvIHcD-EO-bB78qvtf2yxFTAXcQT--0hB5CqBdK_Jp0TBoCTNwQAvD_BwE).

A recent comprehensive review of BGC-ARGO is found at [9] https://www.frontiersin.org/articles/10.3389/fmars.2019.00502/full.

Ian Walsh
Senior Oceanographer
Sea-Bird Scientific
Philomath, Oregon, USA

...kindly provides the following details:

"The NAVIS BGC floats include a sensor package that measures the bulk properties of the most significant oceanic carbon pools that will be affected by the enhanced vertical exchange of water across the thermocline from the pumping technology.

Temperature, salinity and pressure yield the density field and will be used to generate a mixing model of the pumping effect on vertical transport of the quasi conservative heat and salt budgets. This constrains the entire system.

The carbon dynamic response to the vertical exchange is measured by the rest of the sensors.

The chlorophyll fluorescence and backscattering sensors measure the particle load of particulate organic carbon (backscattering) and the viable phytoplankton (chlorophyll). The FDOM fluorometer measures the concentration of the fluorescent fraction of the dissolved organic matter pool. The pH sensor measures one component of the pCO_2 equilibrium and with the backscattering and FDOM sensors monitors net transfers of carbon between the dissolved and particulate pools through autotrophic and heterotrophic activity. The dissolved oxygen sensor constrains net community production of fixed carbon and the impact of gas exchange kinetics on pCO_2. Finally, the nitrate concentration measurement monitors the effectiveness of the exchange of nutrient rich deep water with nutrient depleted surface water through the pumping process and therefore the net increase in autotrophic carbon production potential achieved by the pumps.

The floats will be deployed in a near field/far field manner with one float within the pumping volume and the other deployed outside the pumping volume. The float mission profiles (park depth, profile interval, the rate and ratio between deep and shallow profiles) will be adjusted during the initial trial period and subsequently during roll out to optimize modeling of the effect of the pumps.

As the system scales, a network effect of increasing data from the floats relative to the governing scales across time and space will decrease the carbon flux measurement uncertainty between any pair of near and far field floats, resulting in a measurement system that asymptotically approaches a fixed structural relationship between the pumping and the net sequestration of carbon."

12. Explain your precise claim to ownership of the negative emissions that you are offering. In particular, explain your ownership claim: 1) in cases in which your solution indirectly enables the direct negative emissions technology and 2) when, based on the LCA above, your solution relies on an additional upstream or downstream activity before resulting in negative emissions. Please address the notion of "double counting" if applicable to your project, and how you'll prevent it.
Max 200 words

On behalf of our corporate sponsors, we will own and control the pumps and the biogeochemical ARGO robotic floats which send continuous data regarding the tons of CO_2 sequestered to the data center in France. As is their policy, this data will be available to the public. The data is thus owned by us and publicly available.

Regarding double counting, our data will be cumulative, therefore the calculation of periodic tons sequestered is [cumulative value at end of period, minus cumulative value at start of period].

Also regarding double counting, under our business model “Stock For Carbon” we contract directly with corporations who sponsor the number of pumps needed for them to achieve net-zero or net-negative CO_2 footprint by an agreed end date.

These tons sequestered are not tradeable, rather are directly contracted between us and the corporate client, without intermediaries, brokers, or commission agencies. This eliminates double counting. By avoiding offset trading, commissions and fees are eliminated.

Our solution does not rely on any upstream or downstream activity.

Section 6: Potential Risks

This section aims to capture Stripe Purchase Criteria 5: The project is globally responsible, considering possible risks and negative externalities.

13. Describe any risks or externalities, any uncertainties associated with them, and how you plan to mitigate them. Consider economic externalities, regulatory constraints, environmental risk, social and political risk. For example: does your project rely on a banned or regulated chemical/process/product? What’s the social attitude towards your project in the region(s) it’s deployed, and what’s the risk of negative public opinion or regulatory reaction?
Max 300 words

Regarding environmental risk, Professor Andreas Oschlies writes:

“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.”

[Andreas Oschlies is Professor of Marine Biogeochemical Modelling at GEOMAR and the University of Kiel, Germany. He leads the Collaborative Research Centre "Climate-Biogeochemistry Interactions in the Tropical Ocean" and the Priority Program

“Climate Engineering: Risks, Challenges, Opportunities”.] As to economic externalities, if we restore a stable climate by 2100, this benefit far outweighs all conceivable costs. Regarding regulatory reaction, we believe this will be neutral to positive, as we are not adding any substance to the oceans, and our pumps mimic natural ocean processes and outcomes. When properly communicated in the context of global climate risk, we suggest social response will be positive. Risks/externalities can be mitigated by anticipatory rather than reactive (post-event) communications.

Section 7: Potential to Scale

This section aims to capture Stripe Purchase Criteria 6: The project has the potential to scale to high net-negative volume and low cost (subject to the other criteria).

14. Help us understand how the cost and net-negative volume of your solution will change over time. Note that we aren’t looking for perfect estimates. Instead, we’re trying to understand what the long-term potential is and what the general cost curve to get there looks like. (Note: by “cost” here we mean the amount Stripe or any other customer would pay for your solution):

	Today	In ~5 years	In ~20 years
Est. Cost per net-negative ton (in $) Initial pump cost $175k, margin 25%, STRIPE price is $233k. We propose two pumps ($466k) are deployed for this 2020 effort. The 5-year net CO_2 sequestered = 693.3 t per pump, total for 2 pumps of 1,386.6 t. Cost per ton = $336.07 over five-year period.	$336.07	$75.01	$42.50

When fully scaled-up over the project lifetime 2020 to 2100, applying annual discount rate of 5% to total cost and cumulative CO_2 sequestered, the present value cost per ton is $3.91.			
Est. Net-negative volume (in tons of CO2)	1,387 t	9.1 mil. t	75.8 Gigatons

15. What are the drivers of cost? Which aspects of your costs could come down over the next 5 years, and by how much? Do you think your eventual scale potential is limited by cost or by volume? Why? Refer to any relevant constraints from question #7, like land or materials scarcity, and specify the boundary conditions for which you consider those constraints.

Max 300 words

-Fabric cost per linear meter. Nylon ($2/meter) is less expensive but requires a $4,000 structural rope top to bottom. Dyneema® ripstop fabric ($10/meter) is expensive but may be strong enough to serve as tube fabric and as the structure, saving that cost and simplifying the assembly process.

-Labor rates are less key: the savings comparing $65/hour shop rate per labor hour, vs. $5 shop rate per labor hour, is about $7,000 per pump.

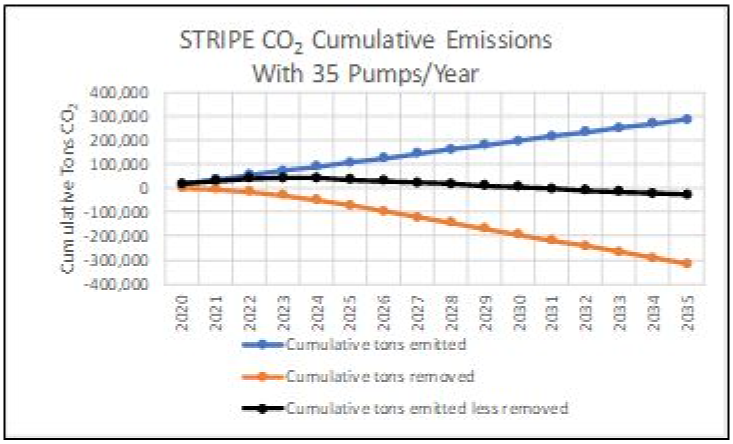
-Boat capacity and availability are important due to high cost per hour of offshore operations. More units deployed per trip, brings down the cost per unit. We have a customized deployment vessel designed and ready to produce, which will overcome these issues.

Volume production will help reduce costs (we estimate learning curve savings at 53%, based on 2021 selling price of $125,000 vs $59,000 in 2026, after inflation, assuming initial factory production quantity of 1,000 per year).

Our scale potential will be a function of our Stock For Carbon marketing success, gaining corporate sponsors to become net-negative CO_2. Under this plan, they pay in stock not cash so negative CO_2 emissions are essentially free to the corporation. Shareholders are diluted but higher ESG ratings increase stock price, gaining them better ROI.

By sponsoring just 35 pumps per year (3.5% of one factory's annual output), STRIPE eliminates its 18,000 annual tons CO2 (288,000 cumulative tons assuming constant future emissions), becoming cumulatively net negative CO_2 by 2035.

If paid in cash, the cumulative cost is $60.6 million. Based on STRIPE's 2019 venture investors' valuation of $35 billion, the S4C cost is 0.03% equity at 2035, without allowing for expected much higher valuation (which correspondingly will reduce our percentage equity under S4C).



Section 8: Only for projects with significant land usage

See Stripe's Purchase Criteria 2: The project has a net cooling effect on the climate (e.g. carbon negative complete life cycle, albedo impact, etc.) ***This section is only for projects with significant land usage requirements: Forest, Soil, and BECCS/Biochar/Biomass sequestration projects.***

16. Location: Please provide baseline information about the geographic location(s) of your project; and link shapefile(s) of project area(s).
Max 100 words

17. Land ownership: Please describe the current (and historical as relevant) land ownership and management for the area(s) provided in (16). If your project is not the landowner, describe your relationship to the landowner.
Max 150 words

18. Land use: For forest projects, please provide details on forest composition as well as forest age and basal crop area/density. For soil projects, please provide details on land use and crop type (if agricultural), soil organic

carbon baselines, and regenerative methodology. For BECCS, biochar, or wooden building materials projects, please provide details on biomass crop type and methodology as applicable.
Max 500 words

19. Net effect on climate: Please discuss the non-CO2 impacts of your project that may not be covered in your LCA, such as your impact on albedo.
Max 150 words

Section 9: Other

20. What one thing would allow you to supercharge your project's progress? This could be anything (offtakes/guaranteed annual demand, policy, press, etc.).
Max 100 words

We need STRIPE Inc to subscribe to our Stock For Carbon (S4C) business model, thereby validating the concept and enabling us to double new corporate subscribers each year (+1 in 2021, +2 in 2022, +4 in 2023, +8 in 2024, etc.).

Relative to market size and penetration, by 2035 we need 500 subscribing corporations (out of 30,000 corporations on the top 10 stock markets - 1.66% market share) to achieve our 1,900 Gt CO2 sequestration target by 2100.

"Supercharging" starts with a detailed discussion of our S4C proposal with STRIPE executives.

21. (Optional) Is there anything else we should know about your project?
Max 500 words

A significant amount of our production and deployment will occur in low-income communities both US and overseas, thus creating jobs and income for those most in need.

Our pumps offer numerous side benefits to the ocean ecosystem: cool the upper ocean, re-oxygenate the mid-ocean, restore and enhance the food web to benefit fisheries, seabirds, marine mammals, and more.

Everything is "off-the-shelf", thus can be implemented immediately and scale-up quickly.

Production requires just semi-skilled factory labor, and widely available marine operations skills.

Notes and references

[1] International patent pending PCT/US2019/046292.

[2] Professor Isaac Ginis – University of Rhode Island Graduate School of Oceanography -

unpublished report ""Investigation Of The Possibility Of Limiting Hurricane Intensity By Locally Reducing The Upper Ocean Heat Content Using Wave-Driven Deep-Ocean Pumps", 2008.

[3] Sandia National Laboratories unpublished report "Model-based Assessment of 'Down-welling' Carbon Relocation Concepts", 2019.

[5] Karl, David M., Ricardo M. Letelier, "Nitrogen fixation-enhanced carbon sequestration in low nitrate, low chlorophyll seascapes" MEPS 364:257-268 (2008) https://doi.org/10.3354/meps07547

[6] Hansell, Dennis A., CA Carlson, DJ Repeta, R Schlitzer "Dissolved organic matter in the ocean: A controversy stimulates new insights" Oceanography, 2009.

[7] Jiao, Nianzhi, Gerhard J. Herndl, Dennis A. Hansell, Ronald Benner, Gerhard Kattner, Steven W. Wilhelm, David L. Kirchman, Markus G. Weinbauer, Tingwei Luo, Feng Chen and Farooq Azam "Microbial production of recalcitrant dissolved organic matter: long-term carbon storage in the global ocean" Nature Reviews | Microbiology Volume 8 | August 2010 doi:10.1038/nrmicro2386

[8] https://oecotextiles.wordpress.com/2012/06/05/nylon-6-and-nylon-66/

[9] Bittig HC, Maurer TL, Plant JN, Schmechtig C, Wong APS, Claustre H, Trull TW, Udaya Bhaskar TVS, Boss E, Dall'Olmo G, Organelli E, Poteau A, Johnson KS, Hanstein C, Leymarie E, Le Reste S, Riser SC, Rupan AR, Taillandier V, Thierry V and Xing X (2019) A BGC-Argo Guide: Planning, Deployment, Data Handling and Usage. Front. Mar. Sci. 6:502. doi: 10.3389/fmars.2019.00502.

Section 10: Submission details

*This section **will not** be made public.*

22. Please insert below the name and title of the person submitting this application on behalf of your company (or, if you are submitting this application on your own behalf, your own details). By submitting this application, you confirm that you have read and accept the Project Overview (available HERE), as well as the further conditions set out below. As a reminder, all submitted applications will be made public upon Stripe's announcement. *Once you've read and completed this section, submit your application by March 20th by clicking the blue "Share" button in the upper right, and share the document with **nets-review-2020@stripe.com**.*

Name of company or person submitting this application

[redacted]

[redacted]

Name and title of person submitting this application (may be same as above)

[redacted]

Date on which application is submitted

[redacted]

We intend to make the selection process as informal as possible. However, we do expect that (a) the content of your application is, to the best of your knowledge, complete and correct; (b) you do not include any content in your application that breaches any third party's rights, or discloses any third party's confidential information; (c) you understand that we will publicly publish your application, in full, at the conclusion of the selection process. You also understand that Stripe is not obliged to explain how it decided to fund the projects that are ultimately funded, and - although extremely unlikely - it is possible that Stripe may decide to not proceed, or only partially proceed, with the negative emissions purchase project. Finally, if you are selected as a recipient for funding, Stripe will not be under any obligation to provide you with funding until such time as you and Stripe sign a formal written agreement containing the funding commitment.