stripe

General Application

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

Company or organization name

Thermodynamic Geoengineering

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

Nanaimo, British Columbia, Canada

Name of person filling out this application

Jim Baird

Email address of person filling out this application

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Brief company or organization description

Converts global warming to work, sequesters CO_2 by cooling the surface.

1. Overall CDR solution (All criteria)

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

Artificial downwelling of surface waters has been recognized as a theoretical engineering intervention to cool the surface and enhance CO_2 solubility but moving heat as sensible heat in water is not the most efficacious way of accomplishing this goal.

The thermodynamic efficiency of Thermodynamic Geoengineering (TG), which uses a 1,000 meter heat pipe to move surface heat as the latent heat of evaporation of a low-boiling-point working fluid like ammonia tops out at 1-(277/(303+5) or 10%. In practice it is closer to 7.6 percent according to the experimental psychist Melvin Prueitt of Los Alamos Labs in his US patent filing 20070289303A1. The major improvement of this design over the typical 3 percent efficiency of conventional ocean thermal energy conversion (OTEC) is the loss of half as much heat in the evaporators and condensers when both are contiguous to the water servicing the heat exchangers and the fact that a 1,000 meter long column of ammonia gains 5 degrees Celsius at the bottom of the column due to the influence of gravity.

The Nature paper Quantification of ocean heat uptake from changes in atmospheric O_2 and CO_2 composition by Resplandy et al. shows that between 1991 and 2016 the change in ocean heat content was $1.29 \pm 0.79 \times 10^{22}$ Joules per year, which equates to 409 terawatts. Converted at an efficiency of 7.6 percent equals 31 terawatts, 2.2 times the annual global consumption of fossil fuels.

This paper quantified ocean heat uptake on the basis of oxygen and carbon dioxide content. The cooler the ocean the less gas is vented to the atmosphere. The paper Negative-CO_2-emissions ocean thermal energy conversion (NEOTEC) shows for each gigawatt of continuous electric power generated over one year with NEOTEC roughly 13 GW of surface ocean heat would be directly removed to deep water which has ramification for cost.

Gay-Lussac's and Charles' Laws say that pressure and volume of a gas are directly proportional to absolute temperature. Instead of the closed container or pistons they used in their experiments, we have the atmosphere/ocean interface through which CO_2 moves depending on the change of the temperature at the surface.

Theoretically Direct Air Capture can return to the surface to preindustrial temperatures but the American Physical Society estimated the cost of this at between $600 and $1000 a tonne, whereas some claim they can get this down to $100 dollars. But these are highly energy intensive endeavours which deployed at scale could require as much as 25% of the global supply of energy by 2100.

All other CDR schemes are energy intensive (zero sum), produce waste heat, and are costly. Whereas TG, sequesters atmospheric CO_2, produces energy, and depletes the heat of global warming with no added cost for CDR.

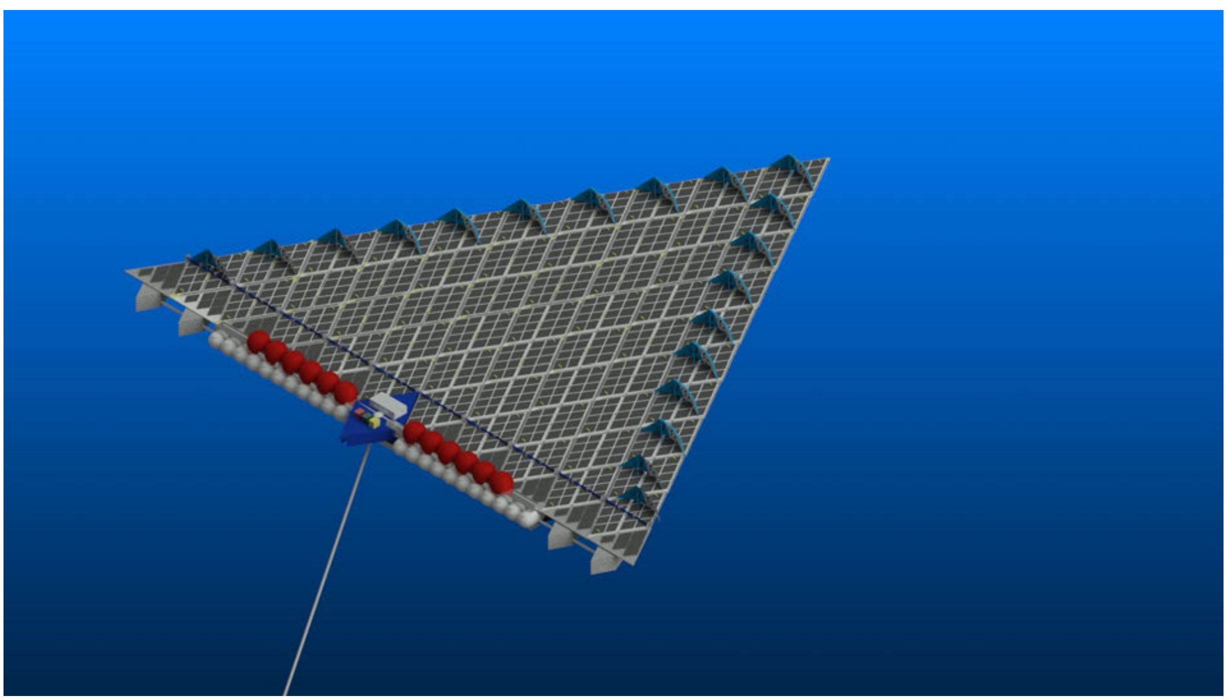
Energy produced at the tropical surface is a quadratic function of the change in temperature between the surface and deep water which is universally at about 4 degrees Celsius at a depth of 1,000 meters. Since this ΔT is impaired in the winter, TG plants are heat grazers that move with the seasons to convert heat at the highest surface temperatures available.

Operating and maintaining an offshore power plant in seawater, and transmitting the power to land, dealing with storms and other mishaps are serious challenges. But the petroleum industry has been operating in deep water in decades. The mass of TG plants makes them stable in rough water, which is less problematic in the Intertropical Convergence Zone where cyclones don't form and where the best conditions for producing OTEC power are abundant.

The exponential depletion of the heat of warming by converting it to work that is required on land is an extraction of heat from the ocean and a significant benefit for a planet experiencing the exponential growth of waste heat from the processes by which energy is used.

Boiling a low-point working fluid not only allows the heat of global warming to be convert to work, the pressure of the vapor moves the heat into the depths at a speed close to that of sound from whence 92.4 percent of the heat returns at rate of 1 cm/day to the bottom of the mixed layer and 1 meter/day through the mixed layer. In 226 years, the unconverted heat is back at the surface where it is recycled to work 12 more times until after about 3,000 all the heat of warming has been converted and the waste of those conversions has been safely dissipated into space.

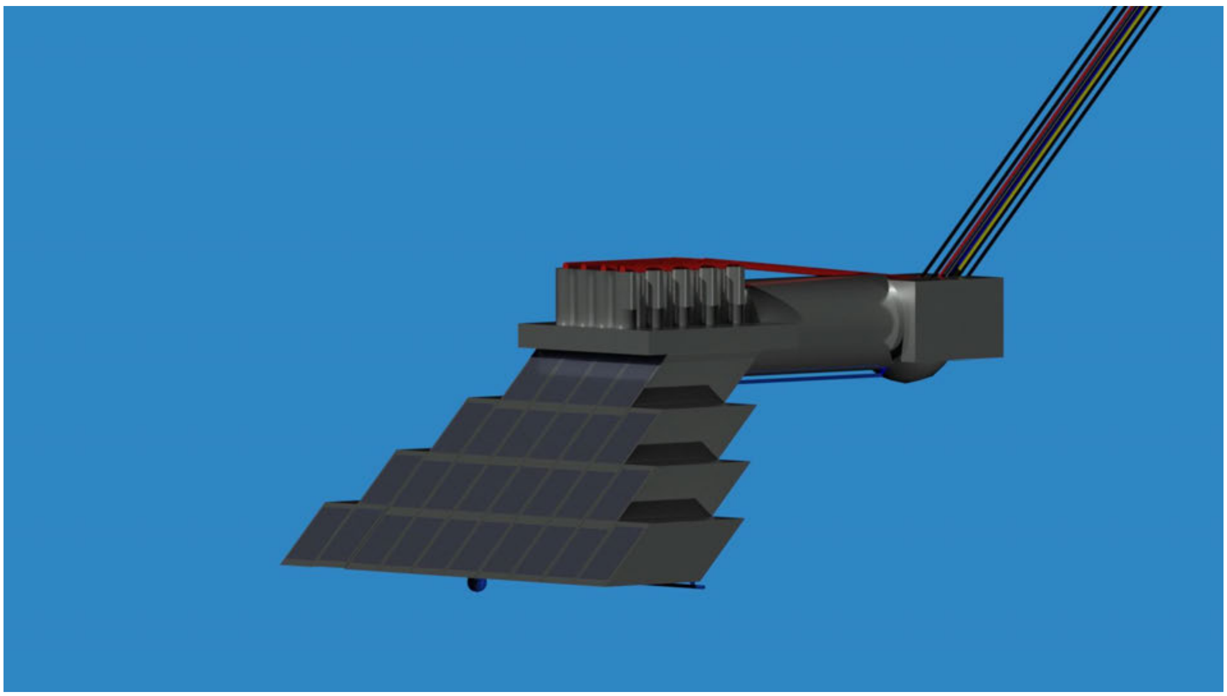
The essence of the TG system is the heat exchangers that convert ocean water to the latent heat of evaporation and the latent heat of condensation. Water flows through an array of pipes. The impetus for the movement of water through the pipes is derived from wave accumulators on the underside of an energy island, horizontal windmills when the island is proceeding into the wind, solar panels, and spinnakers when the island is proceeding downwind on the Trade Winds.



The island can be configured for hydrogen production. A 1 gigawatt plant can produce 130,000 tonnes of hydrogen a year. The hydrogen is stored in tanks that can be offloaded to awaiting tankers.

Or the island can be configured as a platform for the smelting of aluminum and steel, the production of cement, or any value added product that depends on constant, sustainable, energy for a cost savings of about 22 percent. A 1gigawatt (GW) plant provides 234000 sq meters of ocean front property for these endeavours. It can be configured with the turbines and hydrogen production on the surface or in deep water.

The bottom section of the 1-GW plant consists of an array of 52 condensers, a pump to return a condensed working fluid vapor back to the surface, and the turbines and generators in the deep water configuration.



Hydrogen and oxygen and or chlorine are produced in the electrolyzers. The hydrogen and oxygen and or chlorine and the working fluid are returned to the surface. The oxygen/chlorine is dispersed in front of the evaporators to prevent biofouling. A total of 31,000 1-GW plants can convert the existing heat of global warming to work at a cost of $.02 per kWh in a hydrogen configuration or $.016 as a straight electricity generator and produce 3,770,000,000 tonnes of hydrogen a year.

For each gigawatt of continuous electric power generated each year NEOTEC avoids 1.1×10^6 tonnes of CO2 emissions/yr), and consumes and stores (as dissolved mineral bicarbonate) approximately 5×10^6 tonnes CO2/yr.

To return CO2 levels we would have to reduce (416ppm-280pm) = 136 * 7.81 gigatonnes of CO2 = 1062*2 = 2024 gigatonnes, (It is necessaru.to remove 2 ppm CO2 to attain a net 1 ppm drop in air CO2).

This tonnage has been built up since about 1780 so 241 years. Therefore, we would have to remove 8.39 * 241/226 = 8.95 gigatonnes of CO2 a year to return to preindustrial conditions levels if we could start the drawdown overnight.

Since 1780 surface temperatures have risen 1.2 degrees Celsius. To remove 8.95 gigatonnes CO2 a year the temperature would decline by .005 Celsius in accordance with Gay-Lussac's Law.

The average annual profit per 1 GW plant for each tonne of CO2 transferred from the atmosphere into the ocean is $273.56 * 31000 plants = $8,480,360 a year * 226 years = $1,916,595,0000

In the alternative with the Project Vesta Project, “total costs are in the range of €20–40 per tonne of CO2 sequestered (or $27.84 to $55.68). At an average cost of $41.76 per tonne it would cost $88,698,240,000,000 to return pre industrial levels compared to the profit of $1.9 billion over 226 years with TG.

The average annual price for these plants is $4.6 trillion compared to the $5.3 trillion a year the IMF has estimated is the annual subsidy for fossil fuel subsidies, therefore, TG is essentially too cheap to meter?

With TG, CO2 levels would start to rise again once the sequestered heat and CO2 resurface but to counteract this both are sent back immediately to deep water to produce more energy.

Neither surface temperatures nor CO2 levels ever rise above today's levels once the buildout starts and are back at pre industrial levels within 3,000 years.

There is no foreseeable reason for halting a process that provides energy as well as climate respite, but if such a situation were to arise, Rajagopalan and Nihous in their paper, An Assessment of Global Ocean Thermal Energy Conversion Resources With a High-Resolution Ocean General Circulation Model acknowledge, “When turning off the prescribed OTEC sources and sinks in the model, the environment is shown to relax to its pre-OTEC condition. The time scales for both reverse and direct processes are similar.”

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.)*

I am the inventor of Thermodynamic Geoengineering and the rights holder of Canadian patent application 2,958,456, 2017/02/21, Method and Apparatus for Load Balancing Trapped Solar Energy.

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

The UN Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) report High Level Review of a Wide Range of Proposed Marine Geoengineering Techniques acknowledges that thermodynamic geoengineering, would cool the ocean's surface and could reduce warming associated with climate change but claims it would be temporary, regionally heterogeneous and presents the type of termination risks usually associated with solar geoengineering approaches.

In support of this claim, they cite a paper Atmospheric consequence of disruption of the ocean thermocline that is a work of science fiction.

The authors modeled global warming after 60 years of ocean mixing at an upwelling rate of 60 cubic meters per second which is physically impossible.

Conventional OTEC is temporary because it moves surface heat only to a depth of between 70 and 100 meters.

At 3 percent efficiency, 409 terawatts of global warming heat can be converted to about 12 TW TW, 85 percent of the current global demand for fossil fuels but the diffusion rate of heat in this mixed layer is 1 meter/day so the heat is back at the surface in about 3 months so there is no global warming respite.

What little respite conventional OTEC provides, is regionally heterogeneous because at an upwelling intensity of 20 meters a year, which the paper An Assessment of Global Ocean Thermal Energy Conversion Resources With a High-Resolution Ocean General Circulation Model equates to a power level of 30 terawatts, in 1,000 years the tropical surface would be cooled by as much as 4 degrees Celsius, offset by a commensurate and equal warming in the Arctic and off the fertile fishing grounds off the west coast of South America.

TG is for 3,000 years, cools the surface uniformly and there is no reason for it to be terminated .

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

- https://patents.google.com/patent/CA2958456A1/en?oq=CA2%2c958%2c456
- https://patents.google.com/patent/US20110036919A1/en
- https://patents.google.com/patent/US20100251789

- https://www.freepatentsonline.com/y2012/0234006.html
- https://patents.google.com/patent/US5022788A/en
- https://patents.google.com/patent/US20100105975A1/en

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.*	The CDR plants will operate for 3,000 years.
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.*	Carbon removal commences with the production of the first MW of energy.
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*	The 3311 gigatonnes are removed over the course of 226 years or 14.6 gigatonnes a year and then are recycled over the course of 3,000 years. Each of the first 226 years, .7 gigatonnes are sequestered naturally through photosynthesis, mineralization and absorption into the ocean (once sequestered this CO2 can't be double booked).

out-years, but this depends on unknowns re our mineralization kinetics".	
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.*	3,000 years as assured by the Laws of Gas Properties

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

The minimum viable size is 100 MW which would sequester 5×10^5 tonnes CO2/yr. The upper bound is 31 TW which sequesters 9.4 gigatonnes/yr.

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.)*

From, [Negative-CO_2-emissions ocean thermal energy conversion], "it is possible to convert the electrolytic production of H2 to a strongly CO2-emissions-negative process by using non-fossil energy and addition of base minerals to the acidic anolyte of a saline water electrolysis cell. An example of such an electrochemical reaction is:

$$4H_2O + Mg_2SiO_{4(s)} + V_{dc}\ Þ\ 2H_{2(g)} + O_{2(g)} + 2Mg^{2+} + 4OH^- + SiO_{2(s)} \text{ (reaction 1)}$$

followed by:

$$4CO_{2(g)} + 2Mg^{2+} + 4OH^-\ Þ\ Mg^{2+} + 4HCO_3^- . \text{ (reaction 2)}$$

The net reaction then is:

$$4CO_{2(g)} + 4H_2O + Mg_2SiO_{4(s)} + V_{dc}\ Þ$$
$$2H_{2(g)} + O_{2(g)} + 2Mg^{2+} + 4HCO_3^- + SiO_{2(s)} \text{ (reaction 3)}$$

where the change in Gibbs free energy ($\Delta G°$)= +236.8 kJ/mol H_2. Note that the preceding minimum work is actually less than that that required to just split water:

$$2H_2O + V_{dc}\ Þ\ 2H_{2(g)} + O_{2(g)},\ \Delta G° = +237.1 \text{ kJ/mol } H_2. \text{ (reaction 4)}$$

At a power level of 31 TW, however, the total 2124 gigatonnes of CO2 would be removed in 14 years at significant cost and the CO2 currently sequestered in the ocean would then have a wide open path to the atmosphere.

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?

In a 2012 paper Sydney Levitus et al. estimated if all the ocean heat accumulated between 1955-2010 to a depth of 2000 meters was immediately released into the atmosphere, the temperature of the atmosphere to a height of 10 kilometres would be warmed 36 degrees Celsius. It estimated the ocean heat accumulation was 240 zeta joules for the 56 years studied, which equates to 136 terawatts a year which is seven and a half times as much energy as is consumed globally each year. The Resplandy paper however, in 2020, found that the oceans were accumulating 12.9 zettajoules of heat at that time which equates to 409 TW a year. In which case instead of the potential release of 36 degrees into the atmosphere we could be looking at closer to an atmospheric warming potential of 102 degrees Celsius. And the only thing preventing this is the greenhouse layer.

The depletion of this layer therefore needs to progress slowly.

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.)*

The Laws of Gas Properties ensures the permanence of this carbon sequestration.

A black like Earth is an object that radiates energy corresponding to its temperature. The Stefan–Boltzmann constant is the constant of proportionality in the Stefan–Boltzmann law: that says the total intensity radiated over all wavelengths increases as the temperature increases. For a decrease of 1.2 degrees Celsius this is the equivalent of a radiative forcing of about 6.6 watts/m2. But over the course of 226 this forcing would be only .02 watts/m2 and would only kick in after the heat moved into the ocean broached the surface. In the interim the ocean would warm up by .005 degrees each year as the atmosphere cools by the same amount. And this warming would occur in the ocean that has 271.84 times the mass and greater heat capacity than the atmosphere. After 226 years the atmospheric temperature would remain constant as would its CO2 content as long the only heat being added to the atmosphere was the waste heat from the next cycle of work produced from the residual heat of global warming. Any CO2 that would result from this miniscule warming would be absorbed by photosynthesis, mineralization or the ocean.

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	3,311,000,000.000 tonnes

embodied/lifecycle emissions or permanence, we will ask you to subtract this later	
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	[36,666,000,000](#) tonnes annually.

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)*

The cooling of the surface by 1.2 degrees Celsius over the course of 226 years sequesters 3,311,000,000,000 tonnes. 3,311,000,000,000 tonnes/226 years = 14,650,000,000 tonnes/year. For a single 1-GW plant this would be 472,580 tonnes

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).

Nil. But a prototype of between 10 and 100 MW could be completed in about 3 years.

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

The foundation for the assumptions are basic scientific principles, including the Laws of Thermodynamics and the Gas Laws.

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.

- *https://www.climatecolab.org/contests/2015/geoengineering-workspace/c/proposal/1315102*
- *https://www.barnesandnoble.com/w/thermodynamic-geoengineering-jim-baird/1136125613*
- *https://hb.diva-portal.org/smash/get/diva2:884062/FULLTEXT01 - The Lessons of Nature and Heat Pipe OTEC, pp 130-146.*
- *http://gwmitigation.com/Thermodynamics.htm*
- *http://gwmitigation.com/1GWEnergyIsland.htm*

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	The commitment is to the removal of 3,311,000,000,000 tonnes by 2285, which is 12,569,811 tonnes annually.
Gross project emissions	Zero
Emissions / removal ratio	0/12,569,811
Net carbon removal	12,569,811 tonnes annually.

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.

												Cycle						
						1	2	3	4	5	6	7	8	9	10	11	12	13
		2021		2024	2050	2059	2285	2511	2737	2963	3189	3415	3641	3867	4093	4319	4545	4771
					Max temp													
					Max CO2													
		R&D		Accumulation								Depletion						
			Annual Increase															
Degrees C	Surface Temp	1.2	0.018	1.20	1.72	1.59	1.46	1.32	1.19	1.06	0.93	0.79	0.66	0.53	0.40	0.26	0.13	0.00
Atmosphere																		
Gigatonnes	CO2	2124	37.1	2235	3311	-3311		0	0	0	0	0	0	0	0	0	0	0
Mixed Layer																		
Deep Ocean to 1000 meters						3311	3035	2759	2483	2207	1931	1655	1379	1103	827	551	275	0
Terawatts	Ocean Heat	409	14	423	818	755	692	629	566	503	440	378	315	252	189	126	63	0

The plan is to complete a comprehensive LCA as possible with an outside consultant, but this LCA is our best estimate and model as of today.

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?

As of today 2124 gigatonnes have been added to the atmosphere since 1780 and the surface temperature has risen 1.2 degrees Celsius. By the time we can turn this around, 30 years from now, we will have added an additional 1187 gigatonnes and .32 degrees. At that time we will be able to start depleting both with TG infrastructure that is built with zero emissions energy and zero emissions materials.

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.

It will take time to build out the infrastructure necessary to enable the heat of global warming to be converted to useful work and in the process drawdown the accumulated CO2 load in the atmosphere down to the preindustrial level. During the next 3 years of R&D and for the 52 years thereafter the infrastructure will grow exponentially at a rate 2.5 times annual, maxing out in 2050 at about 818 terawatts. In the last decade of the accumulation phase growth will wind down as the exponentially growing number of Thermodynamic Geoengineering plants begin to pull heat and CO2 out of the atmosphere and by 2059 the growth of heat and CO2 will become depletion of 7.6% over the next 13 cycles of 226 years. Seventy percent of these plants will be straight electricity platforms on which the raw materials necessary to construct the plants, along with the rest of the infrastructure required globally, are built with zero emissions renewable energy and zero emissions materials, and the other 30 percent will be hydrogen generators that can, in part, provide the zero emission fuel necessary to bring the build materials to the build sites.

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

The values and formulas for the LCA are available here: *Stripe flow chart.xlsx*

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

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

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

Details are available here: TGCDR.xlsx   1GigStats.xlsx

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

Year	Units deployed (#)	Unit cost ($/unit)	Unit gross capacity (tCO_2/unit)	Notes
2021	Nil			*<50 words*
2020	Nil			*<50 words*
2019	Nil			*<50 words*
...				

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

Deployment costs and concept are a work in progress but have been reduced 60 percent in the past 6 months as a consequence of a new platform design.

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

# of units	Unit gross capacity (tCO_2/unit)
31,000	405.5tCO2/unit

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?

The estimate is a profit of **$273.56 per ton.**

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."

Units	Total $/Unit	$/Year	Total Annual	Rev 31TW	Rev per Unit	Profit Per Unit	Tons/Year	Per Ton
9300	$ 5,002,270,742	$ 166,742,358	$ 1,550,703,930,020	$ 8,611,111,111,111	$ 277,777,778	$ 111,035,420	472580	$ 234.96
21700	$ 3,907,522,443	$ 130,250,748	$ 2,826,441,234,059	$ 8,611,111,111,111	$ 277,777,778	$ 147,527,030	472580	$ 312.17
31000	**$ 4,454,896,593**	$ 148,496,553	$ 2,188,572,582,040	$ 8,611,111,111,111		$ 129,281,225		**$ 273.56**

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	2021	Hire, CEO, Marine Architect, Mechanical Eng. Manufacturing Eng.,Thermodynamics Grad, and Software Eng.	Q2 2021 - Q4 2021	6 salaries average $75K/year * 6 months average =$225K
2	2021	Founder Salary 8 months	Q2 2021	$40,000
3	2021	Marketing (1), Technicians (2), Admin (1)	Q2-Q4 2021	4 - $50K/year *6 months average = $150K Total $415K Proof T4 Summary Total estimated cost 2021-Q1 2023 Appendix.xlsx

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

Milestone #	Anticipated total gross capacity prior to achieving milestone (ranges are acceptable)	Anticipated total gross capacity after achieving milestone (ranges are acceptable)	If those numbers are different, why? (100 words)
1	*N/A*	*N/A*	Production will not begin before Q1 2024 - Total burnup prior to production is $90 million. Cost of the first 100MW plant is $400M.

			31TWIslands.xlsx
2			*<100 words*
3			*<100 words*

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

Milestone #	Anticipated cost/ton prior to achieving milestone (ranges are acceptable)	Anticipated cost/ton after achieving milestone (ranges are acceptable)	If those numbers are different, why? (100 words)
1	Total cost prior to sequestering the first tonne of CO_2 is $500 million which at a total sequestration tonnage of 3,311,000,000,000 is $ 0.000151/tonne		*<100 words*
2			*<100 words*
3			*<100 words*

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

Elon Musk, considering he is an exponent of Archimedes' First Principles, I would ask him, why since global warming is a thermodynamic problem, why does he think batteries are the answer?

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

Spread the word.

7. Public Engagement and Environmental Justice (Criteria #7)

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

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

The following questions are for us to help us gain an understanding of your public engagement strategy. There are no right or wrong answers, and we recognize that, for early projects, this work may not yet exist or may be quite nascent.

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

1. The financial sector as represented by Mark Carney, who in a BBC interview claimed there is a global pot of $170tn of private capital " looking for disclosure" with respect to global warming.
2. Bill Gates, who in his book "How To Avoid A Climate Disaster", shows that wind and solar are the easy part of climate change. The hard part is the 70 percent necessary to make steel, cement etc., and his Breakthrough Energy.
3. Tom Murphy, professor of Physics, University of California, San Diego, in his presentation Growth has an Expiration Date and in his blog Do the Math, that shows how the Earth's physical resources—particularly energy—are limited by exponential growth. (TG offers exponential depletion of the trapped energy in the system)

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

In-house, publications with Greg Rau, UofC Santa Cruz, the University of Borås, various others, collaboration with carbondioxideremoval@googlegroups.com, Linkedin, Facebook and YouTube.

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

I have learned that the public, confronted by the cost of climate change, balk at that cost. They love a bargain, which is what TG provides because it eliminates the environmental cost of doing business associated with burning fossil fuels, provides twice the energy with a replacement technology that costs less and eliminates legacy emissions at no additional cost. As a consequence of these engagements I have made modifications to the technology that increase the energy savings while maximizing the environmental benefits.

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

> There are further changes contemplated, which are proprietary until such time as the intellectual property rights have been secured.

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

> The UN's GESAMP proposed concerns that were unfounded.
>
> Wil Burns of The Institute for Carbon Removal Law and Policy, American University, Washington DC, addressed the environmental justice concerns in a Rutger seminar and in the google CDR group where he said, "decarbonization is the most critical component of addressing climate change. . . Virtually no one in the climate community would "PREFER complicated, high-tech, faraway gadgets instead." (emphasis added) Rather, many of us acknowledge that we will NEED carbon removal approaches at large-scale to help avoid passing critical climatic thresholds, or to address overshoot."
>
> In the humble opinion of the applicant, the exigency of a solution to the existential threat to humanity proposed by global warming, makes the legal niceties moot. Particularly when those niceties are more philosophical than real.

11. Legal and Regulatory Compliance (Criteria #7)

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

> Wil Burns is a LinkedIn connection and a member like the applicant of the CarbonDioxideRemoval@googlegroups.com. The London Dumping Convention is not pertinent because no material is being dumped into the ocean. The heat already exists there and is simply relocated with TG. The London Protocol passed a protocol in 2013 that contemplated marine geoengineering activities but only iron fertilization is currently covered. Geoengineering could be contemplated in the future but the protocol requires 33 countries to accept the amendment for it to come into force, and to date only 5 countries have accepted and major players like the United States aren't parties to the protocol.
>
> The human condition will ultimately hold sway in the opinion of the applicant.

b. What permits or other forms of formal permission do you require, if any? Please clearly differentiate between what you have already obtained, what you are currently in the process of obtaining, and what you know you'll need to obtain in the future but have not yet begun the process to do so.

To the best of the applicant's knowledge none are required.

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

These platforms will primarily be operated beyond the exclusive economic zone, prescribed by the 1982 United Nations Convention on the Law of the Sea, of sovereign states having special rights regarding the exploration and use of marine resources, including energy production from water and wind. As a consequence, any intellectual property rights with respect to the technology might not be enforceable.

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)	12,569,811 tonnes annually.
Delivery window (at what point should Stripe consider your contract complete?)	Next 3,000 years
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.*	$40.00/metric tonne CO_2, $1.76 less than the average. Project Vesta Project cost.

Application Supplement: Ocean

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

Physical Footprint (Criteria #1)

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

The geography of the area of deployment is within the Intertropical Convergence Zone beyond the continental shelf of the adjacent nations. In the tropics where life in the ocean is the least abundant and has been described as a desert.

2. Please describe your physical footprint in detail. Consider surface area, depth, expected interaction with ocean currents and upwelling/downwelling processes, etc.
    a. If you've also filled out the Biomass supplement and fully articulated these details there, simply write N/A.

Thirty-one thousand 1-GW TG plants cover an ocean surface of 234000 sq meters (0.234 sq kilometers) each for a total surface of 7,254 sq kilometers. Which is .002 percent of the ocean's total surface of 361.9 million square kilometers. The impact in upwelling/downwelling processes is minimal because TG doesn't move water vertically except for by diffusion, which is 1cm/day in the depths. Ocean heat is moved as the latent heat of the working fluid not as the sensible heat of water. Water only moves horizontally through the heat exchanges at the surface and at 1,000 meters. The greatest concern with ocean currents is with the relationship between Atlantic meridional overturning circulation slowdown and global surface warming, which it is argued here will likely continue to slightly reduce the effect of the general warming due to increasing greenhouse gas concentrations. The reasoning is, cooling of the surface in cold climes cools the deep ocean, indirectly warming the surface, thus less sinking implies less surface warming and has a cooling effect. In warm climes as is the case with TG, the opposite is true. Sinking heat decreases greenhouse gas concentrations and produces a cooling effect.

3. Imagine, hypothetically, that you've scaled up and are sequestering 100Mt of CO_2/yr. Please project your footprint at that scale, considering the same attributes you did above (we recognize this has significant uncertainty, feel free to provide ranges and a brief description).
    a. If you've also filled out the Biomass supplement and fully articulated these details there, simply write N/A.

As argued above, life in the tropical ocean is the least abundant. As has been demonstrated here, however, warmer waters from climate change will leave fish shrinking, gasping for air. The net effect of cooling the surface by 1.2 degrees is the average warming to a depth of 1,000 meters of .00012 degrees and more oxygen for fish. And this cooling has ramifications for sea level rise as well, because the thermal coefficient of expansion of sea water is half at 1,000 meters is it at the tropical surface.

Potential to Scale (Criteria #2 and #3)

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

Operating and maintaining an offshore power plant in seawater, and transmitting the power to land, dealing with storms and other mishaps are serious challenges. But the petroleum industry has been operating in deep water in decades. The mass of TG plants makes them stable in rough water, which is less problematic in the Intertropical Convergence Zone where cyclones don't form and where the best conditions for producing OTEC power are abundant.

Externalities and Ecosystem Impacts (Criteria #7)

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

Eutrophication is prevented by increasing oxygen content at a cooler surface. As was demonstrated here, electrochemically generating H_2 consumes CO_2, converting carbon to a common form of ocean alkalinity. The addition to the ocean of which would provide high-capacity carbon storage, while also helping counter the chemical and biological effects of ocean acidification.

The trade off for this acid neutralization is the cost of electrochemical electrolysis, mining, processing and delivery of the minerals, compared to straight electrolysis, which doesn't provide a pH benefit.

As noted above, we might also regret drawing down atmospheric greenhouse gas concentrations too rapidly with a rapid release of ocean heat.