Carbon Removal Purchase Application General Application

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

Company or organization name

Seawater Mineralization LLC

Note (added by Stripe after application review): this project's name has changed to Seachange, Inc.

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

Los Angeles, CA, USA

Name of person filling out this application

Dante Simonetti

Email address of person filling out this application

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Brief company or organization description

We develop mineralization reactors for CO_2 removal with hydrogen co-production.

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.

   The basis of the proposed technology involves forcing the rapid precipitation, electrolytically, of solid carbonates by combining dissolved CO_2 with Ca^{2+} and Mg^{2+} species in an aqueous

(reaction) medium within electrolytic flow-reactors. CO_2 is solubilized in seawater to a level described by Henry's Law which establishes the ocean-atmosphere equilibrium vis-à-vis CO_2, and other gases. As such, seawater contains nearly 150 times more CO_2 than air per unit volume. The approach does not, therefore, require energy intensive CO_2 enrichment and simultaneously exploits the favorable thermodynamics of carbonate precipitation from alkaline solutions. The proposed technology thus, (a) minimizes process complexity and emphasizes modularity (i.e., by minimizing the number of discrete unit operations), and (b) emphasizes process intensification (PI) by renewable energy integration. With its ability to encompass diverse CO_2 concentrations, the proposed technology allows flexibility in achieving carbon management across diverse locations and settings without the need for complex logistics facilities (e.g., pipelines, compression stations, etc.) that are required for traditional carbon management solutions.

The basic premise involves the generation of acidity, alkalinity and hydrogen production - via electrolysis - while emphasizing processes that can be operated using renewable energy. While one prominent process of this nature is the chloralkali process[1,2], whose products can enable indirect ocean capture of CO_2 as either as a gas or a mineral via electrodialysis; the tremendous energy intensity of chloralkali processes, and/or the fouling of ion-exchange (or bipolar) membranes[3, 4] make such approaches impractical.[1, 5, 6] The proposed single-step carbon sequestration and storage (sCS^2) process is based on the electrochemical forcing (of carbonate mineral formation), but is unique in that it does not require membranes. Rather, it utilizes flow-through mesh-electrodes. Unlike the more common static architecture of electrolyzers, the process mimics flow-reactors to maximize yield, and facilitates upscaling and parallelization, which is more difficult to accomplish with electrodialysis systems.[3, 4] Lastly, while existing approaches have often sought to induce bulk pH-shifts of the entire fluid volume,[7-9] the proposed process generates elevated alkalinity, *in situ*, and in the vicinity of the mesh electrodes within small control volumes, wherein the driving force for precipitation is maximized, to promote energy efficiency and to ensure robust reaction control.

The ability of the sCS^2 technology to remove CO_2 has been demonstrated using a prototype flow ('Gen0') reactor. The influent seawater flows through the mesh cathode and reacts with the electrically generated alkalinity to produce mineral carbonate precipitates. Thereafter, the Mg^{2+}, Ca^{2+} and CO_2 depleted seawater mixes with the acidic anolyte before contacting rock particulates, i.e., of limestone, and silicates (d_{50} ~ 100-1000 µm), as a means to re-alkalize the effluent to influent levels prior to its discharge [N.B.: Granulation of these rocks to particle sizes in this size range is associated with an energy intensity of 0.2 MWh/tonne of rock, and approximately 2 tonnes of rock (e.g., limestone) to re-alkalize the effluent (~350 m^3 of water) that is discharged during mineralization of 1 tonne of CO_2]. Interestingly, our initial data shows that the effluent pH actually exhibits an increase compared to the influent, indicating the absence of CO_2 degassing and acidification, in general. At this time, a single-pass CO_2 removal extent of >30% was achieved with wide-spread formation of solid $CaCO_3$ on the cathode mesh. As such, the process accomplishes the following. First, by mineral (Mg,Ca) carbonate precipitation, the process removes dissolved CO_2 in seawater, thereby undersaturating it with respect to dissolved inorganic carbon (DIC). Second, upon its discharge, the alkalinized effluent reabsorbs CO_2 (from the atmosphere) to the limits established by Henry's Law for pH ~ 8.2. Taken together, this ensures: (i) DIC stabilization as mineral carbonates, and (ii) atmospheric CO_2 removal and stabilization in the form of dissolved bicarbonates.

The proposed process has the potential for implementation at a global scale and may be

capable of much higher rates of carbon mineralization and CO_2 removal than existing negative emissions technologies (NETs). Achieving global scale removal requires a sequence of scale-up steps in which the process is further de-risked and optimized, and this project will focus on this next step of scale-up/optimization of the prototype described above. Over the course of a 18-months project, technology specialists at Seawater Mineralization LLC will construct a Gen1 flow-through reactor that can achieve 1 tonne of CO_2 removal per day. We will accomplish this objective by evaluating mesh architectures at various sizes and process conditions over a three month period, followed by integrating these meshes into flow through reactors. These reactors will be tested at various process conditions over a 3-month period to determine the optimum conditions required for 1 tonne per day of CO_2 removal.

References:

[1] Jones, J. D. Removing Carbon Dioxide from Waste Streams through Co-Generation of Carbonate and/or Bicarbonate Minerals. US8741244B2, June 3, 2014.
[2] Constantz, B. R.; Youngs, A.; Holland, T. C. Co2-Sequestering Formed Building Materials. WO2010039903A1, April 8, 2010.
[3] Esposito, D. V. Membraneless Electrolyzers for Low-Cost Hydrogen Production in a Renewable Energy Future. Joule 2017, 1 (4), 651–658. https://doi.org/10.1016/j.joule.2017.07.003.
[4] Talabi, O. O.; Dorfi, A. E.; O'Neil, G. D.; Esposito, D. V. Membraneless Electrolyzers for the Simultaneous Production of Acid and Base. Chem. Commun. 2017, 53 (57), 8006–8009. https://doi.org/10.1039/C7CC02361H.
[5] Eisaman, M.; Parajuly, K.; Tuganov, A.; Eldershaw, C.; Chang, N.; A. Littau, K. CO 2 Extraction from Seawater Using Bipolar Membrane Electrodialysis. Energy & Environmental Science 2012, 5 (6), 7346–7352. https://doi.org/10.1039/C2EE03393C.
[6] de Lannoy, C.-F.; Eisaman, M. D.; Jose, A.; Karnitz, S. D.; DeVaul, R. W.; Hannun, K.; Rivest, J. L. B. Indirect Ocean Capture of Atmospheric CO2: Part I. Prototype of a Negative Emissions Technology. International Journal of Greenhouse Gas Control 2018, 70, 243–253. https://doi.org/10.1016/j.ijggc.2017.10.007.
[7] Lu, L.; Huang, Z.; Rau, G. H.; Ren, Z. J. Microbial Electrolytic Carbon Capture for Carbon Negative and Energy Positive Wastewater Treatment. Environ. Sci. Technol. 2015, 49 (13), 8193–8201. https://doi.org/10.1021/acs.est.5b00875.
[8] House, K. Z.; House, C. H.; Schrag, D. P.; Aziz, M. J. Electrochemical Acceleration of Chemical Weathering as an Energetically Feasible Approach to Mitigating Anthropogenic Climate Change. Environ. Sci. Technol. 2007, 41 (24), 8464–8470. https://doi.org/10.1021/es0701816.
[9] Rau, G. H.; Carroll, S. A.; Bourcier, W. L.; Singleton, M. J.; Smith, M. M.; Aines, R. D. Direct Electrolytic Dissolution of Silicate Minerals for Air CO2 Mitigation and Carbon-Negative H2 Production. PNAS 2013, 110 (25), 10095–10100. https://doi.org/10.1073/pnas.1222358110.

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.)*

Seawater Mineralization LLC is a technology development company. Our technology can be

implemented directly by either CO_2 emitters, water treatment entities (public or private) or by companies that seek to develop dedicated CO_2 sequestration projects.

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

1.) *Mis-match of mineralization and alkalization kinetics:* The technology relies on alkalinity generated by the mesh for promoting carbonate precipitation reactions. If alkalinity is generated faster than it is consumed, CO_2 removal yields will be lower than desired. This risk can be mitigated by developing rigorous reactor designs that match hydrodynamic residence times with alkalinity generation and precipitation reaction kinetics. In addition, sparging air within the reactor can ensure CO_2 saturation and thereby maximize removal rates.

2.) *Acidification of seawater:* The electrolytic reactor generates an acidified anolyte stream, which could lead to de-gassing of CO_2 from seawater if it were simply discharged into it. However, our current results indicate that mixing of the anolyte and catholyte at the reactor effluent neutralizes this acidity and prevents large changes in pH between reactor influent and effluent. An additional strategy to prevent discharge of acidified effluent is to re-alkalize the effluent by using it to dissolve alkaline geologic solids to adjust its pH ~ 8.2.

3.) *Adoption within innovation-resistant industries:* The industries that are the primary CO_2 emitters tend to be resistant to adoption of new or different technologies. We plan to mitigate this risk by constructing a reactor that closely resembles those already in use in industry (i.e., continuous flow tubular reactor/drum filter) and that consists of readily available components (i.e., standard electrode materials) and that's well-suited for integration with existing desalination operations as the first-market customer/adopter.

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

● Not applicable [A patent based on this work has been filed but is not publicly viewable yet: https://pubs.acs.org/doi/abs/10.1021/acssuschemeng.0c08561]

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*	We will construct the prototype reactor over 18 months.

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.	
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.*	12 months following the project and potentially up to 10 years (useful service life).
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".*	We expect the carbon removal to be evenly distributed over the whole operating time frame.
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.*	Essentially indefinite because of the stability of mineral carbonates and aqueous complexes (bicarbonates).

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

There is extensive evidence in the geologic record of the stability of (Ca,Mg)-carbonates in nature over millions of years, in spite of significant variations in both atmospheric CO_2 concentration and temperature. Such carbonates - particularly the anhydrous forms - are thermodynamically, and kinetically stable at ambient pressure, and over a broad range of

temperatures, and CO_2 concentrations. The CO_2 that is immobilized in such carbonates can only be removed by heating the material to ~800°C at atmospheric pressure.

    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.)*

The findings from the following papers support the mineral carbonate stability estimates in Table 2a. Our technology produces mineral carbonates of the same chemical composition as those occurring naturally in rock formations.

Pytkowicz, R. M. On the Carbonate Compensation Depth in the Pacific Ocean. Geochimica et Cosmochimica Acta **1970**, 34 (7), 836–839. https://doi.org/10.1016/0016-7037(70)90034-7

Feely, R. A.; Sabine, C. L.; Byrne, R. H.; Millero, F. J.; Dickson, A. G.; Wanninkhof, R.; Murata, A.; Miller, L. A.; Greeley, D. Decadal Changes in the Aragonite and Calcite Saturation State of the Pacific Ocean. Global Biogeochemical Cycles **2012**, 26 (3). https://doi.org/10.1029/2011GB004157.

Zevenhoven, R.; Eloneva, S.; Teir, S. Chemical Fixation of CO2 in Carbonates: Routes to Valuable Products and Long-Term Storage. Catalysis Today **2006**, *115* (1), 73–79. https://doi.org/10.1016/j.cattod.2006.02.020.

Teir, S.; Eloneva, S.; Fogleholm, C. J.; Zevenhoven, R.; Stability of calcium carbonate and magnesium carbonate in rainwater and nitric acid solutions. Energy Conversion and Management 2006, 47, 3059-3068. https://doi.org/10.1016/j.enconman.2006.03.021

    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?

Physical and socioeconomic durability risks are minimal because of the geological inertness and environmental benignness of the mineral carbonates.

    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.)*

Given the abundance of information and data on erosion rates of geological formations and the dissolution rates of mineral carbonates, it is reasonable to assume that models for geological erosion can be applied to quantify the durability of the mineral carbonates produced from our technology. In any event, we will examine the carbon content of mineralized carbonates, and bicarbonate contents of the effluent solutions (e.g., that mimic seawater) to assess permanence/durability by random sampling of captive samples over a period of 5 years.

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	365 tonnes CO_2
If applicable, additional avoided emissions e.g. for carbon mineralization in concrete production, removal would be the CO_2 utilized in concrete production and avoided emissions would be the emissions reductions associated with traditional concrete production	164 tonnes CO_2

b. Show your work for 3(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 tCO₂/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 tCO₂ = Gross removal. OR Each tower of our mineralization reactor captures between X and Y tons CO₂/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)*

Our prototype reactor will capture 1 tonne of CO_2 per day via direct reaction of carbonate ions with Ca and Mg ions in seawater, that is always equilibrated with CO_2 in air, to form stable mineral carbonates. $H_{2(g)}$ is a byproduct of the electrochemical reaction. 45 kg of H_2 are generated for every tonne of CO_2 mineralized. This $H_{2(g)}$ could displace 1.2 MWh of natural gas electricity (i.e., 60% conversion efficiency), yielding an additional 0.45 tonnes of CO_2 emissions avoidance. These numbers are then multiplied by 365 days.

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).

1.2 kg CO_2 per year

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.)*

Our current bench scale reactor has demonstrated CO_2 removal rates equivalent to ~5 kg CO_2 per year per square meter of mesh area. Because our reactor operates under similar hydrodynamics as a traditional plug-flow reactor, we can use standard reactor design and scale-up equations to establish the mesh areas and residence times needed for a reactor system that can sequester CO_2 at a rate of 1 tonne per day.

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.

- [Saline Water-Based Mineralization Pathway for Gigatonne-Scale CO2 Management](#)
- [Mineral Dissolution under Electric Stimulation | The Journal of Physical Chemistry C](#)

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	365 tonnes of CO_2
Gross project emissions	26 tonnes of CO_2
Emissions / removal ratio	0.07
Net carbon removal	339 tonnes of CO_2

b. Provide a carbon balance or "process flow" diagram for your carbon removal solution, visualizing the numbers above in table 4(a). Please include all carbon flows and sources of energy, feedstocks, and emissions, with numbers wherever possible *(E.g. see the generic diagram below from the CDR Primer, Charm's application from last year for a simple example, or CarbonCure's for a more complex example).* If you've had a third-party LCA performed, please link to it.
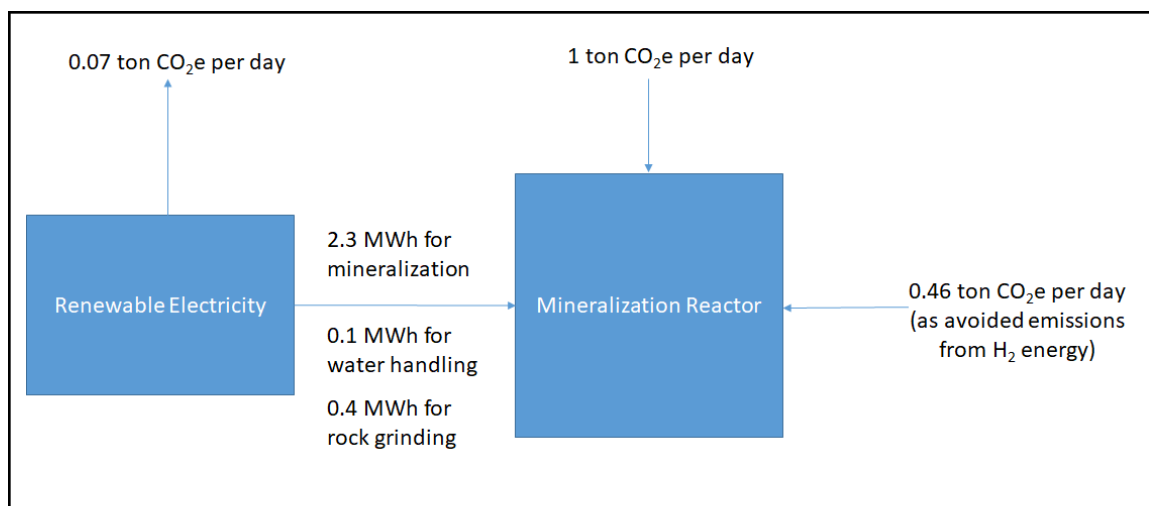
c. Please articulate and justify the boundary conditions you assumed above: why do your calculations and diagram include or exclude different components of your system?

The diagram above only includes the electrochemical reactor because the energy needed for water and solid carbonates handling accounts for less than 100 kWh per tonne of CO_2 removal (i.e., about 4% of the total 2.8 MWh per tonne of CO_2). Furthermore, the energy required for rock granulation, for realkalization, only accounts for 0.4 MWh per tonne of CO_2 mineralized (~15% of the total energy requirement). Therefore, it is sufficient and appropriate to only consider the electrolytic reactor as the principal process operation.

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.

> An energy balance based on current state-of-the-art electrolyzers shows that the energy intensity of our process is 2.8 MWh per tonne CO_2 removed. Assuming this energy is derived from solar (with a carbon intensity of 25 kg CO_2 per MWh), the process would emit 0.07 tonnes of CO_2 per every tonne mineralized. However, 45 kg of H_2 are generated for every tonne of CO_2 removed, and around 0.45 tonnes of CO_2 could also be avoided from the energy recovered from the H_2 co-product (assuming 60% combustion-to-electricity generation efficiency of hydrogen). This H_2 energy is not accounted for in Table 4(a) nor in the process flow diagram. Comprehensive analysis of the process is noted in:
> https://pubs.acs.org/doi/abs/10.1021/acssuschemeng.0c08561

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.)

> Following its fabrication, and during pilot operations, we will assess the actual power consumption of our reactor and the amount of H_2 that is present in the gaseous effluent.

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

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

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

> Our current unit of deployment is a bench-scale reactor module.

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
2022	1	500,000	1	We expect that this project will produce our first unit

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.)*

Our costs are based on the construction and development of our first (bench-scale) unit.

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)
1	365 tCO$_2$/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?

~$1370/ton CO$_2$ at the initial prototype scale considering the CapEx and OpEx needed.

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."

The cost is based on the estimated cost of construction, and operations cost for an electrochemical reactor module capable of 1 tonne of CO$_2$ removal per day.

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	ASPEN Simulation of entire sCS^2 process cycle including robust accounting of heat, mass and energy balances	The simulation will help establish the optimal process parameters, and associated energy intensity of a 1 tonne of CO_2 removal per day pilot-system	Q3 2021	Technical Report that describes the outcomes and learnings of the ASPEN simulations
2	System design of 1 tonne of CO_2 removal per day pilot-system including sizing and definition of "off-the-shelf" and bespoke components associated with all unit operations, utility connections, and piping and instrumentation diagrams (PID)	The system design will guide the fabrication including development of bid estimates of the pilot-system, and identify difficulties and opportunities associated with integration of unit operations and sensor systems (for assessing operating performance, and CO_2 removal)	Q4 2021	Technical Report that describes the system design, the sizing of components, and the system's expected performance
3	System fabrication and assessment of technoeconomics (TEA) and lifecycle (LCA) footprint of the "as fabricated" pilot system	The performance of the pilot system will be assessed during commissioning and operations to understand the implications of operating parameters and energy mix scenarios on	Q1 2023	Real-time operational data of the system during piloting

		net-CO$_2$ removal.		

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

Milestone #	Anticipated total gross capacity prior to achieving milestone (ranges are acceptable)	Anticipated total gross capacity after achieving milestone (ranges are acceptable)	If those numbers are different, why? (100 words)
1	1.2 kg CO$_2$ per year	1.2 kg CO$_2$ per year	
2	1.2 kg CO$_2$ per year	1 tonne CO$_2$ per day	This milestone is the core component of the project. Based on our current studies, constructing a larger reactor and optimizing its performance will lead directly to increasing the total gross capacity of the technology.
3	1 tonne CO$_2$ per day	1 tonne CO$_2$ per day	

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	$1370/ton CO$_2$	$1370/ton CO$_2$	
2	$1370/ton CO$_2$	$1370/ton CO$_2$	
3	$1370/ton CO$_2$	$1370/ton CO$_2$	

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?

> President Joseph Biden: To implement an economy-wide carbon tax.

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

> Stripe's support has two beneficial dimensions: first, it provides a pathway to upscale and de-risk the core technology which is needed to access cost reductions that come from 'learning while doing'. Second, the market signaling associated with purchasing of carbon credits indicates demand and desire from a counterparty that is interested in purchasing carbon credits offers evidence to the ecosystem (innovators, financial institutions, etc.) of the opportunities associated with carbon management. Both of these aspects are foundational to the creation of a low (zero)-carbon economy.

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?

> Access to real seawater will require us to partner with external stakeholders that are located near or have access to a source of seawater. In addition, external stakeholders may be existing desalination plants where our technology can integrate into existing infrastructure, further reducing costs.

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

> We have started preliminary discussions with such host-site stakeholders both in the U.S. and overseas who have expressed favorable sentiment to host upcoming sCS^2 pilot-system(s)

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?

NA

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?

We do not have any changes planned other than scale up.

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

There are concerns regarding ocean pH and de-gassing of CO_2. As mentioned previously and in the Ocean supplement, the re-alkalization of the reactor effluent can be readily accomplished via mixing of the anolyte and catholyte streams followed by rock dissolution (if needed).

11. Legal and Regulatory Compliance (Criteria #7)

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

Not applicable at the current stage of development. However, we have engaged regulators to understand the nature of permitting that would be needed to integrate our technology with desalination operations. These interactions have indicated that integration of our technology, particularly with desalination plants, would not require dramatic changes/alterations in the baseline permits already in place.

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.

Not applicable at the current stage of development.

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.

Not applicable at the current stage of development.

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)	365 tonnes (1.0 tonne per day)
Delivery window (at what point should Stripe consider your contract complete?)	We will construct the prototype reactor over the course of 18 months from Q4 2021 to Q1 2023
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.	$1370/ton CO_2

Pricing note (added by Stripe after application review): In our Spring21 purchase, we paid this project $1370/ton. The project provided the following context for their price:

"This price represents the partial cost to construct a first-of-a-kind (FOAK) process plant that can remove at least 365 tonnes of CO2 per year [1 tonne per day]. The performance of this plant will derisk future larger plants, enable reductions in construction costs, and allow removal of larger quantities of CO2 over longer lifetimes."

Application Supplement: Ocean

Physical Footprint (Criteria #1)

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

> Our technology is anticipated to be deployed near coastlines where water handling and solid redispersion costs are minimized. An alternative method of deployment would be to integrate our technology with a desalination plant or with existing offshore wind energy platforms.

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.

> The benefit of our technology is that its core consists of modular flow-reactors which can be integrated into existing water treatment plants that only require land space and do not interact directly with ocean currents.

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.

> Assuming the same energy intensity as described previously (2.8 MWh of solar energy per tonne CO_2) and a land footprint of 5 acres per MW of solar power, our process would require 159,817 acres of land at 100 Mt of CO_2 per year scale.

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?

> As mentioned above, our technology can exist near the ocean or it can be incorporated into offshore wind energy platforms. Integrating our technology into these plants would present a

engineering challenge. However, the extensive experience in constructing near shore desalination plants and offshore platforms reduces the engineering challenges and constraints.

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?

The removal of cations from seawater - in the course of DIC removal - if carried out without constraints would result in its acidification, and the de-gassing of CO_2; an obviously detrimental outcome that reduces the ability of seawater to sequester atmospheric CO_2. We remedy this issue by the dissolution of natural carbonates and silicates (e.g., limestone, and olivine) into the effluent stream prior to its discharge. Such dissolution which is facilitated by the acidity generated at the anode, and consequential acidity of the anolyte acts to re-alkalize the effluent stream, such that, prior to discharge it achieves an alkalinity equivalent to that at the process inlet (pH 8.2). These aspects related to "solution pH" are (and will be) rigorously monitored within the process via online pH sensors mounted upstream, downstream, and at the electrodes. Furthermore, the electrolytic forcing promoted within the process will result in the formation of polydisperse carbonate precipitates. While these precipitates will remain stable within, and be carried away into the ocean, given their small volume (generally, <<<0.5 vol. %), they are not expected to affect turbidity. In any event, to address these concerns, we will monitor turbidity of the influent and effluent streams to assess and ensure no changes manifest in either the water chemistry, or its optical properties over the course of CO_2 removal. We propose that such sampling, sensing and analysis is most effectively carried out within the sCS^2 process cycle as the assessment of these parameters in the ocean is challenging.