stripe

44.01 Carbon Removal Purchase Application

General Application

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

Company or organization name

Protostar Group Ltd ("44.01")

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

United Kingdom

Name of person filling out this application

Talal Hasan, Karan Khimji

Email address of person filling out this application

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Brief company or organization description

Permanent and Secure CO2 Storage via Mineralization in Peridotite

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.

Our Approach

44.01 provides CO2 storage through accelerated in-situ CO2 mineralization in mantle peridotites, taking advantage of peridotite's large mineralization potential. Mantle peridotites are primarily composed of the mineral olivine that spontaneously reacts with air and fluids containing CO2 to form inert carbonate minerals which are stable for millions of years. Apart from the peridotite alteration mineral brucite and the relatively rare mineral wollastonite, at temperatures exceeding ~50°C the fastest mineral carbonation rates known are for the mineral olivine. High solubilities and rapid reaction rates for carbon mineralization in olivine and other minerals in mantle peridotite are due, in part, to the fact that they are far from CO2, H2O, and O2 exchange equilibrium with air and surface waters. Thus mantle peridotite massifs like that observed in Oman and the UAE constitute an immense reservoir of chemical potential energy which can be harnessed for solid storage of CO2 via in-situ CO2 mineralization (Kelemen et al., 2011, 2019, 2020; National Academies of Science, Engineering, and Medicine, 2019).

Extensive CO2 mineralization has been observed in the mantle peridotites in Oman (Fig.1), California, Italy, and other locations (Barnes and O'Neil, 1969; Neal and Stanger 1985; Bruni et al., 2002, Chavagnac et al., 2013; Kelemen and Matter, 2008).

Figure 1. Photographs of carbonate veins in Oman (Source: 44.01).

Normally found several kilometers beneath the Earth's oceans, peridotite appears on the surface in Oman and the UAE. This area has the largest and best exposed peridotite massif in the world (Fig. 2). The natural carbonation rate in the Oman ophiolite is on the order of 1,000 tCO2/km3/yr (Kelemen et al., 2011). Olivine-rich peridotite has high uptake capacity. Peridotite commonly contains 45 to 55 wt% MgO and a few wt% CaO, thus every ton of pure olivine is capable of mineralizing 500-600 kg of CO_2. In comparison, typical basalt contains 6 to 8 wt%

MgO and 9-11 wt% CaO and can mineralize 140-170 kg of CO_2 per ton of basalt. This ~3x multiple enables greater economies of scale. These factors indicate that the Oman-UAE ophiolite is one of the most optimal locations for CO2 storage on the planet. Moreover, assuming the reactivity of peridotite with CO2 and the global availability of peridotite reservoirs, the theoretical mineralization potential of peridotites globally has been estimated to be of 10^5-10^8 GtCO2 (Kelemen et al., 2019).

Figure 2. Peridotite formations in Oman and the UAE (Source: The New York Times, 2018).

44.01 accelerates the natural rate of CO2 mineralization in peridotite by injecting CO2 fully dissolved in water into hydraulically isolated and permeable peridotite aquifers using injection boreholes. Depending on the location of injection sites, groundwater, grey water, saline groundwater, or seawater can be used to fully dissolve the CO_2. Gaseous CO_2 is less dense than formation waters, providing a driving force for CO_2 to escape to the surface via fractures and abandoned wells. By dissolving the CO_2 into water prior to storage in the subsurface and keeping the partial pressure of CO_2 in solution below the hydrostatic pressure within the storage reservoir, we eradicate this buoyancy, initially storing the CO_2 by solubility trapping. The injected CO_2-saturated fluid is of low pH (<3.0) and thus reacts with the peridotite, mobilizing base metal cations (Mg, Ca) and thereby neutralizing the acidity. Once the acidity is neutralized and the reservoir fluids reach oversaturation with respect to Ca and Mg carbonates, carbonate minerals precipitate (Kelemen et al. 2011). A comprehensive monitoring program using monitoring boreholes and geochemical (inert and reactive tracers) techniques will be developed to quantify and verify mineralization.

Our Pilot Project:

44.01 is currently conducting the world's first pilot project of CO2 injection and accelerated in-situ mineralization in mantle peridotite (Fig. 3). We hypothesize that near complete mineralization of a specific mass of CO_2 in peridotite will occur within 1 year of injection. 44.01 has the relevant permits in Oman to conduct this pilot, which will serve as a proof-of-concept for accelerated in-situ mineralization of CO2 in peridotite and will enable 44.01 to build commercial-scale sites.

Figure 3. 44.01 pilot site in Oman.

Our Demonstration Project:

44.01 is preparing to build a demonstration-scale CO2 storage via mineralization project.

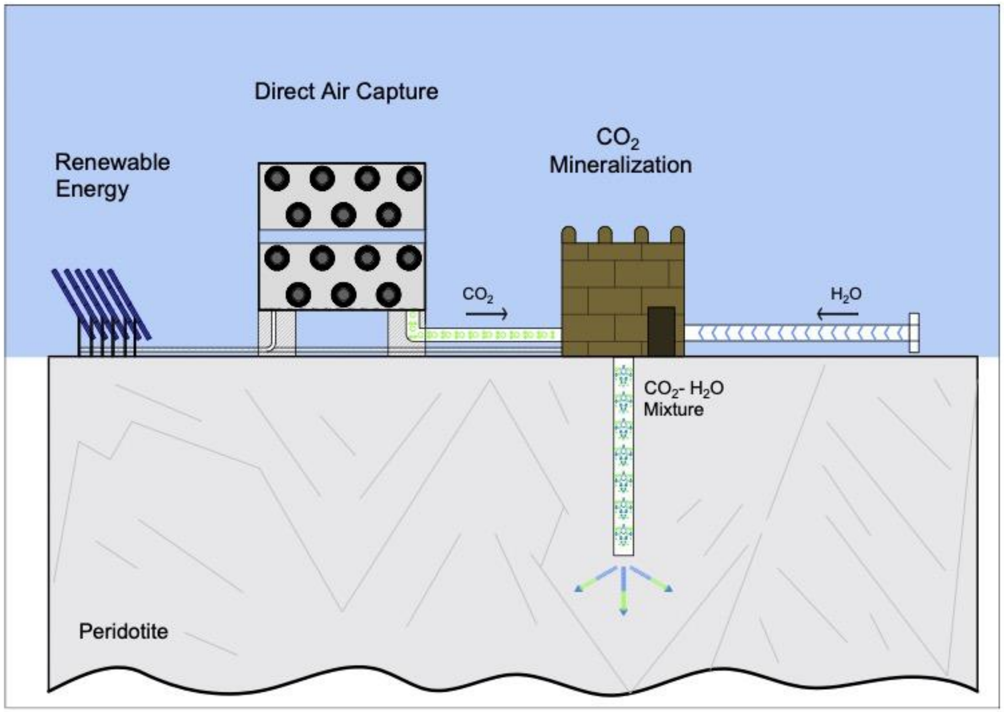


Figure 4. 44.01 mineralization project.

We aim to have two demonstration-scale injection boreholes and associated infrastructure complete and ready for mineralization by February 2023. We expect to start injecting at a rate of 3 tCO_2/day per borehole, equivalent to a total 2,190 tCO_2/year. Injection rates are inherently site-specific. As we observe the results of this demonstration, we will scale by increasing injection rates and developing additional injection sites.

Our main objective is to demonstrate feasible, secure, permanent, and scalable CO2 storage via accelerated in-situ CO2 mineralization in peridotite to kick-start industrial-scale integrated carbon capture and storage via in-situ mineralization. We are in active discussions with multiple DAC companies to host DAC units at our sites. We currently have an established partnership with Climeworks. Until we have DAC units operating on our site, we will also welcome CO2 from local point-source emitters to enable us to scale.

Our Mineralization as a Service Model:

44.01 will offer a Mineralization-as-a-Service (MaaS) model (Fig. 4) wherein 44.01 will provide all onsite infrastructure required for the receipt and management of CO_2 from DAC units, including calibration of the received CO_2 (e.g., purity, state) to ensure parameters required for our process. 44.01 will provide onsite resources for hosting DAC units, including renewable energy (solar PV, solar thermal, biofuel), land, piping, and monitoring. We will effectively offer a "plug-and-play" model, enabling DAC companies to outsource resource requirements and storage infrastructure to us while simultaneously enabling us to spread our costs across multiple DAC customers. Our open-source service model empowers DAC companies to focus on DAC innovation and scale while we take care of the CO_2 storage component, eliminating a significant resource drain for DAC and delivering a more efficient approach to building scalable carbon removal. We will charge DAC companies a MaaS fee per tCO_2 stored which will encompass all the above items.

Stripe's purchase will effectively enable us to offer the purchased CO_2 MaaS capacity for free to DAC companies, an immediate reduction in the total cost of carbon removal via DAC + Mineralization.

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.)*

44.01 provides permanent and secure CO2 storage via in-situ mineralization in peridotite. We receive CO2 from DAC companies and point-source emitters and inject it underground in peridotite. We also provide onsite resources including renewable energy, land, piping, and monitoring. We charge a per tCO2 MaaS fee for all the above.

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

The most important risk we face is sourcing significant amounts of CO_2 to scale our mineralization process, particularly from DAC sources. DAC currently has high capture costs, long construction lead times, and low capture quantities per unit (the largest operating unit today is Climeworks' Orca at 4,000 tCO_2/year). We are optimistic that DAC will innovate and scale, and we intend to empower DAC companies to do so on our sites by providing (1) permanent and secure CO_2 sinks and removing the burden of CO_2 storage infrastructure, (2) onsite resources to drive down costs of DAC, particularly cheap renewable energy, and (3) feasible CO_2 storage by operating an open-source CO_2 storage platform, sourcing CO_2 from multiple DAC companies and point-source emitters, to benefit from economies of scale and drive down mineralization costs.

Another risk is securing sites from relevant landowners. We are currently in negotiations for sites in Oman and the UAE which are progressing positively and have raised strategic local capital to support us, though inherent political risk remains.

The most technical risk we expect to encounter is the clogging of pore space and rock expansion from injection. We expect to mitigate this through mineralization-driven fracturing, the idea that volume changes associated with carbonate and hydrous mineral precipitation

cause local stresses that fracture rocks and open existing cracks, maintaining or enhancing permeability and reactive surface area. A similar concept is discussed in Rudge et al., 2010; Kelemen and Hirth 2012; Evans et al., 2020. Geological examples of fully carbonated peridotite (listvenites, e.g., Falk & Kelemen, 2015), in which every Mg and Ca atom has combined with CO_2 to form solid carbonate minerals, indicate that this is achievable.

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

We have two patents pending for our process. These have not been published yet.

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.*	February 2023 – February 2024
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.*	During the project duration
Distribution of that carbon removal over time *For the time frame described above, please*	We anticipate increasing our rate of injection from 3 to 5

<table>
<tr>
<td>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”.</td>
<td>tCO_2/day/borehole uniformly during project duration, thus carbon removal distribution will be:
<table>
<tr><td>Injection rate 2 wells (tCO2/day)</td><td>Days</td><td>Total tCO2 injected</td><td>Distribution</td></tr>
<tr><td>6</td><td>110</td><td>660</td><td>22%</td></tr>
<tr><td>8</td><td>115</td><td>920</td><td>31%</td></tr>
<tr><td>10</td><td>140</td><td>11,400</td><td>47%</td></tr>
<tr><td>Total</td><td>365</td><td>2,980</td><td></td></tr>
</table>
If initial observations are favorable, we can increase injection rates more quickly and distribution will adapt accordingly.</td>
</tr>
<tr>
<td>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.</td>
<td>10,000s to millions of years (geological timescales).</td>
</tr>
</table>

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

44.01 immobilizes CO2 as inert carbonate minerals (e.g. calcium carbonate and magnesium carbonate). Such minerals are abundant in nature (e.g. limestone, coral reefs, White Cliffs of Dover) and are known to be thermodynamically stable for millennia.

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.)*

We have not measured this durability directly, however there is extensive evidence in the geological record of the stability of carbonates in nature over millions of years, thus in situ

mineralization of CO_2 in peridotite is essentially permanent. References to durability of geological storage via mineralization in peridotite are available in [Matter and Kelemen, 2009] and [Kelemen et al., 2019].

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?

During our mineralization process, we immobilize CO_2 as inert carbonate minerals which are stable on geologic timescales. Thus by definition the risk of CO_2 re-release is nonexistent over the long-term. However, as mineralization occurs over an expected ~1 year duration, there may be minor leakage risks during the mineralization phase. We minimize this risk by using solubility trapping within the peridotite reservoir. By injecting CO_2 dissolved in water and keeping the partial pressure of CO_2 in solution below the reservoirs' hydrostatic pressure, we eradicate CO_2 buoyancy until the CO_2 is fully mineralized.

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.)*

A comprehensive monitoring program using monitoring boreholes hydraulically connected to the injection boreholes will be developed to quantify and verify mineralization. This technique allows CO_2 mass balance to be quantified and mineralization to be verified ([Matter et al., 2016]).

Newly drilled monitoring boreholes will be fully characterized using state-of-the-art borehole geophysical and hydrogeological methods. In-situ CO_2 mineralization will be monitored and verified applying novel tracing techniques, involving non-reactive (e.g., dye tracer) and reactive tracers (stable carbon isotopes) in addition to geophysical monitoring techniques (hydrophones and seismometers). Monitoring using non-reactive and reactive tracers will involve retrieving fluid samples from the monitoring boreholes using submersible pumps for subsequent analysis. Furthermore, hydrochemical sensors will be installed in the monitoring boreholes for continuously monitoring pH, dissolved CO_2, electrical conductivity, temperature, and alkalinity. The physical and geochemical monitoring data will be used to demonstrate verifiable accelerated in-situ CO_2 mineralization.

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	2,980 tCO_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	N/A

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 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)*

Our estimate is based on an estimated average injection rate per borehole of approximately 4 tCO_2/day/borehole over the project duration of 1 year, as illustrated in the table below..

The main uncertainty is our rate of CO_2 injection over the project duration. We will start injecting at a rate of 3 tCO_2/day/borehole and aim to increase to 5 tCO_2/day/borehole. We aim to increase the injection rate over the project duration,however the rate of increase is a function of observations within the subsurface environment. If observations are favorable, we can increase injection rates more quickly and inject a greater amount of tCO_2 over the project duration at a cheaper cost per tCO_2 (we can amortize our costs over greater tCO_2 injected over the project duration).

Injection rate 2 boreholes (tCO_2/day)	Days	Total tCO_2 injected	Distribution
6	110	660	22%
8	115	920	31%
10	140	1,400	47%
Total	**365**	**2,980**	

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).

We recently completed a pilot project during which we injected CO_2/H_2O fluid mixture at a rate of 37 $kgCO_2$/day to test the safety and permanence of our process. We demonstrated an injection rate equivalent to 1.6 tCO_2/day at our pilot borehole.

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.)*

We recently completed the injection phase of our pilot. The aim of our pilot was to serve as a proof of concept, thus we started with a conservative amount of CO_2. We estimate we can increase injection rates to 3 tCO_2/day/borehole by Q4 2022. These projections are based on learnings from our pilot related to concentration of CO_2 dissolved within the injected fluid mixture and the study of dissolution rates and in situ cation release rates which provided information about mineral trapping within the peridotite aquifer. We are currently monitoring the dynamic progression of the mineralization reaction which will enable us to further refine the basis for scaling up.

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.

In situ mineralization in peridotite is discussed in the following papers:

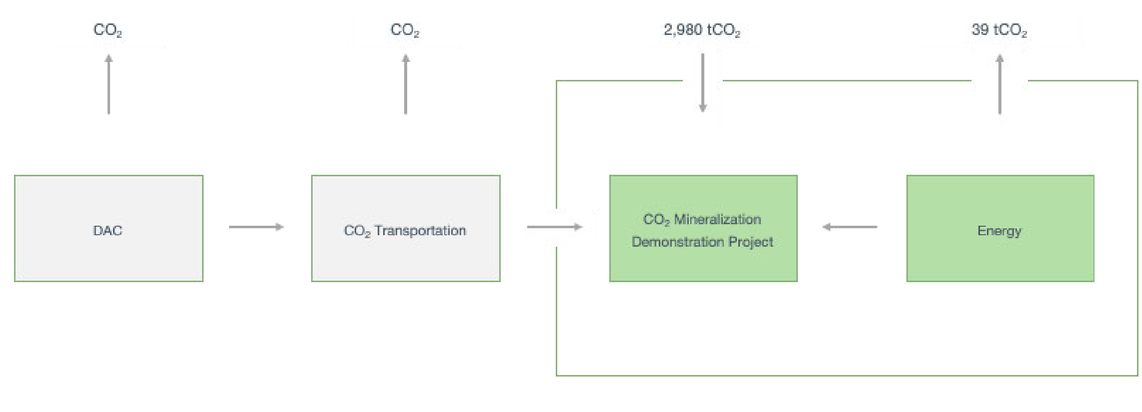
- Kelemen and Matter, 2008
- Matter and Kelemen, 2009
- Kelemen et al., 2011
- Kelemen et al., 2019
- Kelemen et. al, 2020

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	2,980 tCO_2
Gross project emissions	39 tCO_2
Emissions / removal ratio	0.013
Net carbon removal	2,941 tCO_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?

As we purely offer mineralization services, our LCA focus is solely on storage via mineralization, from CO_2 receipt until CO_2 mineralization. The only emission-source for our process is electricity which will be sourced from solar PV and biodiesel.

We cater our mineralization service to multiple DAC companies, each with unique capture technologies and transportation requirements and accordingly unique carbon balances. For each DAC we host, we will calculate a cradle-to-grave carbon balance combining the DAC system boundary to our storage system boundary.

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

The numbers provided here are the output of our internal analysis and are based on a thermodynamic and fluid transport model required for sequestration. They are supported by a currently ongoing independent 3rd party LCA evaluation of our pilot.

The energy required to inject and pressurize the fluid is the only source of emissions for our mineralization process. Assuming a 70% efficiency of converting electrical energy into mechanical work we calculated the electrical energy needed as 186 kWh/ tCO_2 sequestered.

Electricity will be sourced from a solar/biodiesel hybrid energy system from which we assumed an annual average of 50%/50% coverage from electricity sourced from biodiesel and solar PV. Solar PV emissions intensity is assumed at 25 gCO_2/kWh (National Academies of Science, Engineering, and Medicine, 2019). Biodiesel (UCOME) emissions intensity is assumed at 437gCO_2/l (sourced from Omani biodiesel producer WAKUD).

The result is an emissions/ removal ratio of 0.013.

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.)

N/A

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)*

Main unit is # of injection boreholes. When combined with injection rate (tCO_2/day), we can define total injection capacity (tCO_2/day).

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	1	> $1,000/$tCO_2$	13.5 tCO_2/ borehole/ year	Pilot project (1 injection well)

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 have been stable as we have just completed our first project (pilot). We expect our costs to decrease with our upcoming demonstration project, mainly driven by operational learnings from the pilot, an improved understanding of third-party equipment and service provider landscape (e.g. drilling contractors), and economies of scale from a larger deployment.

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)
2	1,490 tCO_2/unit/year (gross capacity will increase in following years as we increase injection rates)

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?

> $1,000/$tCO_2$

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." Consider describing your CAPEX/OPEX blend, assumptions around energy costs, etc.

Our cost includes (1) operating expenditures of our injection site (labor, electricity, supplies) amortized over the site's annual injection capacity in tCO_2/yr and (2) capital expenditures for the development and construction of the site (borehole works, site infrastructure, injection and monitoring equipment etc.) amortized over the site's total estimated injection capacity over an estimated 20-year expected lifetime.

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	Identify, secure and characterize a suitable mineralization site for demonstration-scale mineralization (range of 3,000->15,000 tCO_2/year mineralization capacity)	Our process is highly site specific as subsurface characteristics differ greatly and determine key drivers of our process including injection depth, water source and injection rate. Identifying an ideal site for our first demonstration-scale project is crucial to increasing injection rates and driving down costs.	Q1 2022	We can provide evidence of a use of land rights contract executed with the relevant landowner and video evidence of the site.
2	Contracting with a DAC partner to deliver our first commercial-scale DAC unit onsite	We need a source of CO_2 for our mineralization process. Securing a commercial-scale DAC unit onsite will provide the required CO_2 for mineralization, enabling complete carbon removal.	Q2 2022	We can provide proof of a contractual partnership with a DAC company.
3	FEED study for the demonstration-scale injection facility	Constructing the site requires site characterization	Q2 2022	We can provide data related to our FEED study

	(2 injection boreholes)	(Milestone 1) and a FEED to understand engineering and site development requirements for injection. This will enable us to source equipment and secure third-party services to develop our site.		and evidence of site construction.

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	13.5 tCO_2/year	13.5 tCO_2/year	N/A
2	13.5 tCO_2/year	13.5 tCO_2/year	N/A
3	13.5 tCO_2/year	3,000 to >15,000 tCO_2/year	We will be developing a demonstration-scale facility with 2 injection boreholes capable of mineralizing > 3 tCO_2/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	> $1,000/ tCO_2	> $1,000/ tCO_2	N/A

2	> $1,000/ tCO_2	> $1,000/ tCO_2	N/A
3	> $1,000/ tCO_2	$170/ tCO_2	We will be in a position to operate a demonstration-scale facility with 2 injection boreholes capable of mineralizing >3 tCO_2/day at full capacity.

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?

We would ask Michael S. Regan, Administrator of the United States Environmental Protection Agency, to classify injection wells for CO_2 storage via mineralization within the federal UIC Class VI (Wells used for Geologic Sequestration of CO_2) definition. This will enable us to build sinks in the United States, to qualify for the generation of carbon credits within federal (45Q) and state (e.g. LCFS) thereby proving a long-term commercial model, and to set the stage for global expansion.

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

(1) connect us with DAC companies and other carbon capture solutions to whom we can provide CO_2 storage via mineralization, (2) set a high bar for high quality carbon removal by supporting us, and (3) help us get CO_2 mineralization defined within CO_2 storage legislation at the US federal and state levels.

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?

> Our key stakeholders are (1) our customers – DAC companies and other companies and industries capturing CO_2 from various processes, (2) government and regulatory agencies to ensure access to suitable sites and obtaining relevant permits, (3) environmental agencies to ensure our process is independently verified as permanent and safe, and (4) the public to ensure public acceptance through active transparency and awareness engagement. These are stakeholders in Oman, the UAE, and the US which are directly involved with or enable the development of our process or groups with which we actively engage with to address concerns and maintain full transparency about our work.

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 actively engage these stakeholders in-house as well as through external consultants. In Oman, we attend events and public forums hosted by local environmental groups in an effort to engage the public. We have been invited as part of the Omani delegation to COP26 and are advising policy makers and government entities on their decarbonization strategies.

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?

> We are constantly adapting our process to the specifications of CO_2 suppliers, particularly DAC companies who have specific requirements to operate units onsite. One major outcome of our engagement with governments is identifying suitable injection sites. Finally, the most crucial result of our engagement is the recognition that we are a key influencer in the region in communicating urgent action needed to tackle climate change. We have a responsibility to engage, inform and raise awareness, and we have actively been doing so.

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 aim to explore variations in fluid mixtures for our injection process, including using different water types (seawater, treated water) and variations in CO_2 purity. This will enable us quicker scalability by targeting a wider range of potential injection sites and by welcoming a broader range of DAC solutions and other CO_2 sources.

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

The main environmental justice benefit of our mineralization process is the effective elimination of the inherent possibility of CO_2 leakage due to the buoyancy effect of supercritical CO_2 used in traditional CO_2 storage in depleted onshore hydrocarbon reservoirs or saline aquifers. This removes a key concern in long-term responsibility and accountability for the monitoring and verification of traditional storage reservoirs. Also, the resources required for our process is closely aligned with the declining oil and gas sector, thus we are able to capture and repurpose these jobs and skills with low switching costs.

11. Legal and Regulatory Compliance (Criteria #7)

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

We have received formal approval and required permits associated with our process and actively engage with the relevant government ministries to assure compliance with local regulations.

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

We have all the required permits for our process at our current pilot site in Oman. We will require access and operating permits at any new sites we identify for our process, however this will be relatively straightforward given we have the same permits for our current site. As we expand to other global locations, we will require local permits. We are already in the process of obtaining permitting in the UAE and are actively engaging with relevant stakeholders in the US (CARB, DOE) to navigate federal and state permitting processes (e.g. EPA UIC Class VI permit).

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.

We are navigating the process of obtaining permitting in the US for future projects. Currently, injection wells for CO_2 storage via mineralization is not defined under UIC Class VI.

d. Does the project from which you are offering carbon removal receive credits from any government compliance programs? If so, which one(s)? (50 words)

No

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)	2,941 tCO_2
Delivery window (at what point should Stripe consider your contract complete?)	February 2024
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.*	$170/ tCO_2

Application Supplement: Geologic Injection

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

Feedstock and Use Case (Criteria #6 and 8)

1. What are you injecting? Gas? Supercritical gas? An aqueous solution? What compounds other than C exist in your injected material?

We are injecting an aqueous solution of CO_2 and H_2O.

2. Do you facilitate enhanced oil recovery (EOR), either in this deployment or elsewhere in your operations? If so, please briefly describe. Answering Yes will not disqualify you.

> No, we do not facilitate EOR. We offer an option that results in longer-term, more secure, and verifiable CO_2 storage for DAC and point-source applications.

Throughput and Monitoring (Criteria #2, #4 and #5)

3. Describe the geologic setting to be used for your project. What is the trapping mechanism, and what infrastructure is required to facilitate carbon storage? How will you monitor that your permanence matches what you described in Section 2 of the General Application?

> We inject an aqueous solution of CO_2 and H2O in peridotite aquifers. Mantle peridotites are primarily composed of the mineral olivine that spontaneously reacts with air and fluids containing CO_2, mineralizing the CO_2 as stable carbonate minerals. By dissolving the CO_2 into water prior to storage in the subsurface and keeping the partial pressure of CO_2 in solution below the hydrostatic pressure within the storage reservoir, we eradicate the buoyancy associated with gaseous and supercritical CO_2, initially storing the CO_2 by solubility trapping. The injected CO_2-saturated fluid is of low pH (<3.0) and thus reacts with the peridotite, mobilizing base metal cations (Mg, Ca) and thereby neutralizing the acidity. Once the acidity has been neutralized and the reservoir fluids are reaching oversaturation with respect to Ca & Mg carbonates, carbonate minerals will precipitate.
>
> A comprehensive monitoring program using monitoring boreholes hydraulically connected to the injection boreholes will be developed to quantify and verify mineralization. This technique allows CO_2 mass balance to be quantified and mineralization to be verified (Matter et al., 2016).
>
> In-situ CO_2 mineralization will be monitored and verified applying novel tracing techniques, involving non-reactive (e.g., dye tracer) and reactive tracers (stable carbon isotopes) in addition to geophysical monitoring techniques (hydrophones and seismometers). Monitoring using non-reactive and reactive tracers will involve retrieving fluid samples from the monitoring boreholes using submersible pumps for subsequent analysis. Furthermore, hydrochemical sensors will be installed in the monitoring boreholes for continuously monitoring pH, dissolved CO2, electrical conductivity, temperature, and alkalinity. The physical and geochemical monitoring data will be used to demonstrate verifiable accelerated in-situ CO2 mineralization.

4. For projects in the United States, for which UIC well class is a permit being sought (e.g. Class II, Class VI, etc.)?

> N/A

5. At what rate will you be injecting your feedstock?

3 to 5 tCO_2/day/borehole

Environmental Hazards (Criteria #7)

6. What are the primary environmental threats associated with this injection project, what specific actions or innovations will you implement to mitigate those threats, and how will they be monitored moving forward?

The primary environmental threats are (1) CO_2 mineralization causing physical damage to the subsurface environment and (2) CO_2 mineralization causing chemical damage to the subsurface environment.

The main action to mitigate these risks is rigorous monitoring and verification of reservoir pressure via seismic network and of groundwater quality before, during and after CO_2 injection. Monitoring using non-reactive and reactive tracers will involve retrieving fluid samples from the monitoring boreholes using submersible pumps for subsequent analysis. Hydrochemical sensors will be installed in the monitoring boreholes for continuously monitoring pH, dissolved CO_2, electrical conductivity, temperature, and alkalinity.

We are starting at the low injection rate of 3 tCO_2/day/borehole to better understand mineralization kinetics and will only increase rates once we can confirm these risks are not apparent through the monitoring methods described above.

7. What are the key uncertainties to using and scaling this injection method?

The main uncertainty is impact of CO_2-H_2O mixture injection at scale on formation porosity causing clogging of pore space and rock expansion. We anticipate mineral carbonation will occur far-field from the CO_2 injectors, thereby avoiding clogging of the available pore space near the injectors. However, formation clogging remains a risk to scalability due to limiting fracture access within the peridotite aquifer.

We aim to investigate the idea of mineralization-driven fracturing to mitigate this uncertainty. Volume changes associated with carbonate and hydrous mineral precipitation cause local stresses that fracture rocks and open existing cracks, maintaining or enhancing permeability and reactive surface area. A similar concept is discussed in Rudge et al., 2010; Kelemen and Hirth 2012; Evans et al., 2020.