stripe

Holy Grail

Carbon Removal Purchase Application

Company or organization name

Holy Grail Inc

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

Mountain View, CA

Name of person filling out this application

Nuno Pereira, David Hicks, Adlai Katzenberg, Aigerim Begaliyeva

Email address of person filling out this application

[redacted]

Brief company or organization description

We use electrons to capture carbon dioxide from the atmosphere

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 and system schematics.

We build modular electrochemical carbon capture devices that can be stacked in small decentralized and large centralized direct air capture (DAC) plants with minimal deployment costs. The modules will be manufactured in automated assembly lines to ensure scalability and low cost. Our modules (Figure 1) run on electricity, operate at atmospheric pressure and temperature and do not require water or additional resources to capture carbon dioxide (CO_2).

We plan to deploy our own carbon capture plants and start by selling the service. In the next phase, we will sell the scrubbers for commercial applications, and in the last phase, we will enable individuals to contribute to the removal of the ~2.4 trillion tonnes of anthropogenic CO_2 in the atmosphere by installing a scrubber at home. The carbon credits that we are proposing to sell to Stripe will be fulfilled in our first 1 tCO_2/day plant that will start operations in H1 2024.

Figure 1. Functional prototype of a Holy Grail scrubber. 12x12x2in

We have developed a novel composite material that operates simultaneously as a scrubber and a compressor for CO_2. Unlike traditional compressors, it is highly selective towards CO_2. Our device currently operates at CO_2 selectivity higher than 800 over oxygen (O_2) and higher than 400 over nitrogen (N_2), compared to 20 over N_2 for state-of-the-art membrane separators at the same production rate (Han and Ho, 2021). There is limited reported data for CO_2 over O_2 selectivity, but a recent high-performing membrane reported by Jankowski et al achieved selectivity under 18.

Holy Grail's solution offers low footprint and storage costs as a result of a process that actively pressurizes CO_2, which differs from traditional gas separators, such as membrane separators. Our material contains an electrochemically active molecule that reversibly binds and releases CO_2 upon gaining and releasing an electron. The device consists of two main chambers, one where atmospheric air flows and CO_2 gets scrubbed, and the second where captured CO_2 is compressed.

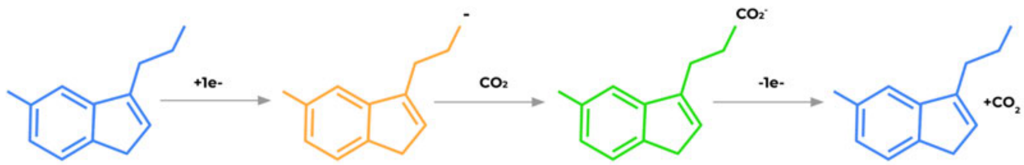

Figure 2. Schematic of the electrochemically-driven CO_2 separation/compression process.

As illustrated in Figure 2, a redox-active molecule (blue) is converted to a CO_2-binding species (orange) when it gains an electron at the cathode. This active species binds to a CO_2 molecule in atmospheric air to form a pair (green). In the anode, the molecule loses one electron and is converted back to the original non-CO_2-binding species (blue). This releases CO_2 in the storage chamber. The redox-active molecule that we use is confidential, and the molecular structure in the image is shown for illustration purposes.

In addition to being highly selective, modular, and able to compress CO_2, our device operates continuously at room temperature and does not contain any moving parts. These design considerations help minimize operating costs and make the modules suitable for large-scale manufacturing in automated lines. These characteristics will allow us to quickly ramp up production, reduce manufacturing/deployment CAPEX and OPEX, and reach gigaton/year scale faster. This modular approach makes our technology uniquely flexible for deployment from small, decentralized sites (i.e., at home or in-office) to megaton and gigaton DAC plants.

Our 5-year plan consists of 4 phases:

Phase 0: Research & Development
We have demonstrated devices that selectively bind and release CO_2. Our team has built a high-throughput testing pipeline that measures CO_2, O_2, and N_2 concentrations in 14 scrubbers 24/7 with a multi-channel potentiostat and a gas chromatograph. We currently have 192 possible material formulations in our library.

We have a two-pronged approach to improve CO_2 capture density and durability.

(1) High-throughput materials screening with a streamlined pipeline of:
synthesis → screening of 14 distinct formulations per day→ data collection → automated analysis. We measure in real-time the electrical performance (current, voltage) and CO_2 capture rate of 14 scrubbers with a variety of cost and performance metrics calculated automatically with an integrated techno-economic analysis and life cycle assessment. This allows us to quickly scan material combinations and identify top-performing formulations without manual calculations.

(2) Targeted research, leveraging our expertise in electrochemical engineering and materials science, we improve our understanding of the underlying physics in the device and materials system. We are rapidly characterizing and addressing limiting processes.

Phase 1: Carbon Credit Sales
We will sell carbon credits generated by DAC plants that we build and operate. The carbon credits that we are proposing to sell to Stripe will be fulfilled by our first 1 tCO_2/day plant that will start operating in H1 2024 in California. We will use this period to improve and scale manufacturing processes and to study and improve scrubber lifetime. In 2027, we intend to launch our first megaton plant and a gigaton plant in ~2030, both locations to be defined.

Phase 2: Scrubber Sales - Commercial
We will sell and lease scrubbers to companies that want to capture CO_2 emissions from their processes in-house. We will leverage the manufacturing and lifetime improvements made during Phase 1.

Phase 3: Scrubber Sales - Consumers
We will sell and lease scrubbers to give every individual an opportunity to capture their own CO_2 emissions and to contribute to the removal of the excess CO_2 in the atmosphere.

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.)*

We are a carbon capture technology developer, device manufacturer, and operator of future DAC plants. Permanent sequestration will be done with a partner to be defined.

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

- **Materials:** to achieve a meaningful impact, our devices will need to be manufactured at a 100 million to 10 billion scrubbers per year rate depending on the capacity per year of each device. Some materials are not yet available at this scale.

- **Durability**: We need to ensure that the devices are durable for up to 15-20 years to achieve our target $/ton capacity. Alternatively, or in combination, when we increase the CO_2 capture density we can achieve our target costs with less durability.

- **Scaling:** Manufacturing more than 100 million devices annually is not trivial and several challenges will need to be overcome to achieve that rate.

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

We have filed two provisional patents that are not publicly available yet.

e. Who's the team working on this? What's your team's unfair advantage in building this solution? What skills do you not yet have on the team today that you are most urgently looking to recruit?

Our team's unfair advantage in developing this technology is that we bring together a unique set of skills and experiences. Our background in electrochemistry, material science, chemistry, chemical engineering, design, mechanical engineering, manufacturing, probabilistic machine learning, active learning, and robotics brings a different approach to the carbon capture problem that is focused on working backwards from the ideal solution to the technology. Our experience in scaling carbon capture technologies and electrochemical engineering uniquely positions us to deliver on the promise of modular carbon capture at scale. We are hiring for several roles, see our job board here. We have all the skills needed to address our immediate challenges, and we are hiring candidates with similar or complementary skills to the ones we already have on the team.

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 2022 - Jun 2023. The end of this duration determines when Stripe will consider renewing our contract with you based on performance.*	January 2024 - January 2025
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*	January 2024 - January 2025

mineralization). Over what timeframe will carbon removal occur? *E.g. Jun 2022 - Jun 2023 OR 100 years.*	
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".*	Evenly distributed over the project duration
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.*	>1,000 years with mineralization or geologic storage

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

We intend to permanently sequester our carbon geologically, either in secure storage like a Class VI well or with a subsurface mineralization approach such as CarbFix.

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 permenence 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 are primarily focused on the capture problem, permanent sequestration will be achieved using a partner to be defined. Underground mineralization is one of the possible paths. It was reported by Matter et al., 2016 that 95% of injected CO_2 was mineralized within 2 years. According to a National Academy of Sciences Research Agenda, once the CO_2 is in mineral form the sequestration is expected to be permanent.

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?

The most significant durability risk in geological storage, although unlikely, is leakage. We will prioritize partners that provide combined storage and mineralization to reduce the likelihood of CO_2 release.

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.)*

We will work with permanent storage partners to ensure that the monitoring is to the satisfaction of both parties. We are interested in seismic monitoring and gravity monitoring as those methods have been shown reliable during the 20-year monitoring of the Sleipner CO_2 injection site, as reviewed by [Furre et al., 2017]().

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	309 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	N/A

emissions reductions associated with traditional concrete production	

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)*

We based our calculations on experimental data, our techno-economic analysis, and life cycle assessment. Within the scope of this offer, we are planning to run ~309 scrubbers and remove 309 tCO_2. Each scrubber has a 1 tCO_2/year capacity. We anticipate that the project's emissions will equal 14.7 tCO_2. As a result, the total net carbon removal will equal 294 tCO_2.

Scrubber durability is currently the most significant uncertainty and will take time to assess over the projected device lifetime (15-20 years). We are currently de-risking materials stability, which we expect to be the primary driver of device durability. We use methods like infrared spectroscopy, gas chromatography, and mass spectrometry to study the stability of the materials and have identified operating windows that produce no chemical degradation. We are still assessing environmental degradation.

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).

Less than 1 tCO_2/year. We have working prototypes and test rigs in two different scales.

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 projections are based on experimental data. We use empirical data (potentiostat + gas

chromatograph) to extrapolate to 1 tCO_2/year capacity and calculate the cost per tonne of CO_2 captured. Our techno-economic analysis is part of our data pipeline where the cost per tonne of CO_2 captured and other sub metrics like energy efficiency and CAPEX/OPEX ratio are calculated automatically for each formulation taking into account raw materials cost, footprint, manufacturing, assembly, CO_2 emissions, etc.

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.

N/A

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	309 tCO_2
Gross project emissions	14.7 tCO_2
Emissions / removal ratio	0.05
Net carbon removal	294 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 2020 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.

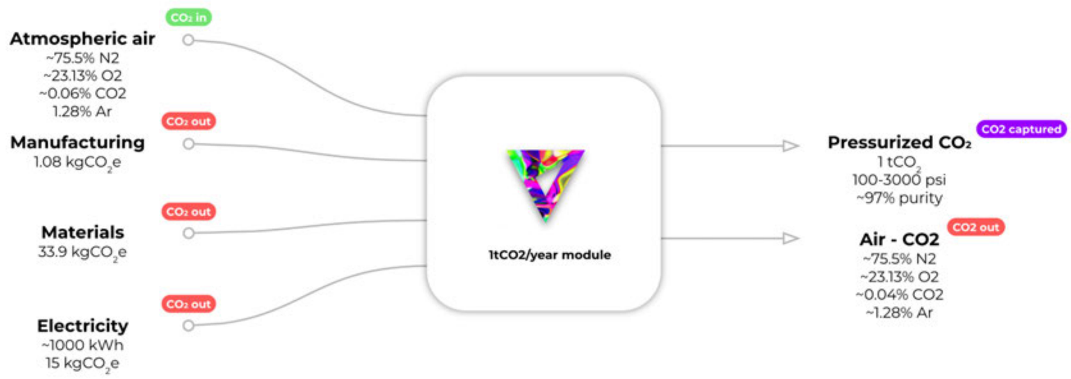

Figure 3. Holy Grail's process flow diagram

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?

We included emissions associated with the raw materials, manufacturing, assembly, overhead, and operation of the scrubbers.

We excluded emissions related to permanent storage.

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.

Our energy efficiency and capture rates are measured in our lab with a gas chromatograph. We gathered CO_2e data from public and commercial databases and performed a first-principles life cycle assessment of all materials that we used to calculate their CO_2 emissions.

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.

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 progress.)

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

Our unit of deployment is a 1 tCO_2/year module. These modules can be stacked to create the desired capacity of a plant.

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.

Year	Units deployed (#)	Unit cost ($/unit)	Unit gross capacity (tCO_2/unit)	Notes
2022	<1	$5,000-$50,000	1	It is a range because changing certain manufacturing variables generates different CAPEX/OPEX trade-offs
2021				*<50 words*
2020				*<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.*)

We are in our first cycle of development, costs will go down with manufacturing scaling and R&D.

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)
309	1 tCO_2/year

6. Cost and Milestones (Forward-looking) (Criteria #2 and #3)

We are open to purchasing high cost carbon removal today with the expectation the cost per ton will rapidly decline over time. We ask these questions to get a better understanding of your potential growth and the inflection points that shape your cost trajectory. There are no right or wrong answers, but we would prefer high and conservative estimates to low and optimistic. If we select you for purchase, we'll expect to work with you to understand your milestones and their verification in more depth. If you have any reservations sharing the information below in the public application format, please contact the Stripe team.

a. What is your cost per ton of CO_2 today?

More than $1,500/$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, non-levelized CAPEX costs, assumptions around energy costs, etc.

Included:

- CAPEX: raw materials, manufacturing, R&D, land, overhead
- OPEX: energy, airflow, overhead
- Energy cost at $0.05/kWh
- 8.7% capital recovery factor and 6% weighted average cost of capital

In our best performing formulation 20.86% is OPEX and 79.14% is CAPEX. This blend will change over time.The manufacturing cost breakdown of our scrubbers (Figure 4) will evolve with scale as we improve the units/hour rate and reduce the cost of the raw materials.

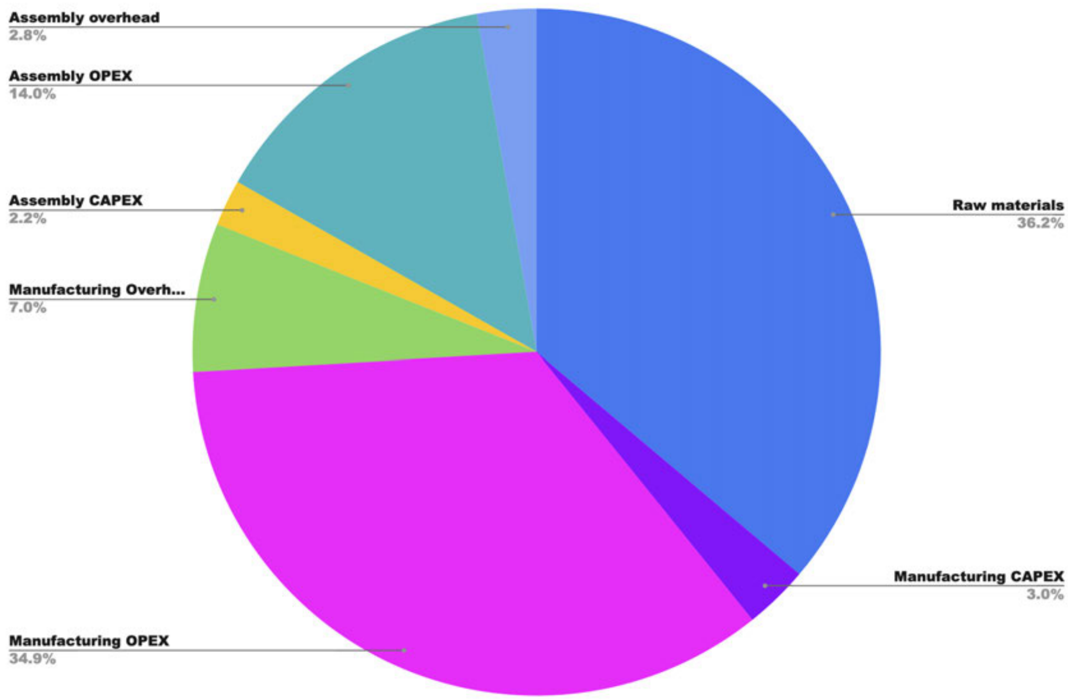

Figure 4. Manufacturing and assembly cost breakdown of scrubbers

Excluded: Permanent storage costs because the path is to be defined.

c. How do you expect your costs to decline over time? Specifically, what do you estimate your cost range will be as you reach megaton and then gigaton scale? We recognize that at this point, these are speculative and directional estimates, but we would like to understand the shape of your costs over time.

Megaton/year :~$100/tCO_2$

Gigaton/year: <$50/tCO_2$

d. Where are the primary areas you expect to be able to achieve cost declines? E.g., what are the primary assumptions and sensitivities driving your cost projection? What would need to be true for a long-term cost of <$100/ton to be achievable with your technology? (i.e., you are able to negotiate an x% reduction in CAPEX at scale and purchase renewable electricity at $y/kWh)

Megaton/year scale ($100/tCO_2$)

- Medium throughput manufacturing
- Materials scale-up to 100,000 tonnes/year (5x cost reduction)

- $0.04/kWh
- Production of 100,000 modules/year

Gigaton/year (<$50/t$CO_2$)

- High throughput manufacturing
- Materials scale-up to 100 million tonnes/year (10x cost reduction)
- $0.02/kWh
- Production of 200 million to 10 billion modules/year

The number of modules produced per year will depend on how fast we want/can scale to 1 GtCO_2/year, 10 Gt, and 100 Gt. If we wanted to achieve a 10 GtCO_2/year removal in one year we would need to manufacture 10 billion modules, depending on the capacity per module.

e. In a worst case scenario, what would your range of cost per ton be? We've been doing a lot of purchasing over the past few years and have started to see a few pieces that have tripped people up in achieving their projected cost reductions: owned vs leased land, renewable electricity cost, higher vendor equipment costs, deployment site adjustments, technical performance optimization, supporting plant infrastructure, construction overruns, etc. As a result, we'll likely push on the achievability of the cost declines you've identified to understand your assumptions and how you've considered ancillary costs. We would love to see your team kick the tires here, too.

If we couldn't improve the technology and had to rely fully on mass reduction, raw materials cost reduction, and manufacturing optimization, $500-$1,000/tCO_2 would be the range of our cost.

f. 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	Materials scale-up and ensuring durability	It will validate our cost projections at scale	Q4 2022	We will show you a scale-up plan and experimental data
2	1 tCO_2/year prototype module	A 1 tCO_2/year module shows theoretical scalability to MtCO_2/year	Q1 2023	We will send you experimental data of the 1 tCO2/year

		plants when we are able to manufacture at scale		prototype module
3	1 tCO_2/day plant	The 1 tCO_2/day plant proves scalability and reliability of the system and puts us in a good position to move to megaton/year and gigaton/year scales	Q2 2023	We will send you the plan of our 1 tCO_2/day plant

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	N/A
2	<0.1 tCO_2/year	1 tCO_2/year	We will build the first 1 tCO_2/year prototype during this milestone
3	1 tCO_2/year	1-10 tCO_2/year	The capacity might change after this milestone depending on how many 1 tCO_2/year modules we can build

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

Milestone #	Anticipated cost/ton prior to achieving milestone (ranges are acceptable)	Anticipated cost/ton after achieving milestone (ranges are acceptable)	If those numbers are different, why? (100 words)
1	N/A	N/A	N/A

2	>$1,500/tCO_2$	>$1,500/tCO_2$	
3	$700-1,500/tCO_2$	$700-1,500/tCO_2$	

h. 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 the president to appoint commissioners of the Nuclear Regulatory Commission to modernize nuclear power regulation. Energy will become a bottleneck for the carbon capture community. Even at 100 kJ/mol of CO_2 captured (~600 kWh/tCO_2) we cannot solely rely on solar and wind at the gigaton scale.

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

> Wholesale energy buying with Stripe climate companies, carbon removal education, and free transactions fees forever.

7. Public Engagement (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 mechanisms 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 and how your project is working to follow the White House Council on Environmental Quality's draft guidance on responsible CCU/S development. We recognize that, for early projects, this work may be quite nascent, but we are looking to understand your early approach.

a. Who have you identified as your external stakeholders, where are they located, and what process did you use to identify them? Please include discussion of the communities potentially engaging in or impacted by your project's deployment.

> Our external stakeholders are our investors, customers, regulators, materials suppliers, equipment suppliers, neighbor communities of our facilities, and the fauna and flora on the planet. Our process of identifying external stakeholders consists of mapping which parties influence and are influenced by our work.

We will deploy our first 1 tCO_2/year plant in our facility in California. From the information we gathered so far, this will require regular construction permits. We will involve the city council, residents, and all regulatory stakeholders when choosing our future megaton and gigaton sites to make sure the projects achieve their full potential with the smallest impact possible on the existing ecosystems.

We commit not to harm fauna and flora on all our sites, including the DAC plants and manufacturing facilities. We will own the full lifecycle of all materials that we use and will not dispose of any products in landfills. Everything that we ship from our factories will return when it needs to be refurbished or recycled.

We will design and manufacture products for durability and ease of repair, not short-term profit. We will build our company for the long term and cultivate business models that will help establish a better balance between humans and other species on the planet.

b. If applicable, how have you engaged with these stakeholders and communities? Has this work been performed in-house, with external consultants, or with independent advisors? If you do have any reports on public engagement that your team has prepared, please provide. *See Project Vesta's community engagement and governance approach as an example.*

We engage regularly with our investors, started engaging with customers recently, and did not engage with regulatory bodies yet.

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?

N/A

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 plan to engage with local communities on deciding future DAC sites.

8. Environmental Justice (Criteria #7)

a. What are the potential environmental justice considerations, if any, that you have identified associated with your project? Who are the key stakeholders?

Building modular devices that can be deployed in a decentralized way can potentially democratize carbon capture access to climate change affected communities that may not have the means to raise hundreds of millions of dollars to build DAC plants based on traditional technologies. We would like to contribute to a future where carbon capture is something that everyone can do, eventually even at home.

b. How do you intend to address any identified environmental justice concerns?

We intend to keep the technology accessible to everyone. To achieve this we will continually work on bringing the costs down.

9. Legal and Regulatory Compliance (Criteria #7)

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

We have not received any legal opinions yet and plan to address all compliance-related questions as they arise.

b. What domestic permits or other forms of formal permission do you require, if any, to engage in the research or deployment of your project? 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 do not anticipate the need for special permits to run our carbon capture modules or plants other than regular business licenses issued at the city, county, state, and federal levels. These permits include building and construction permits, land use, zoning clearance, etc. We initiated contact with the regulating agencies and departments and plan to obtain all necessary permits.

c. Is your solution potentially subject to regulation under any international legal regimes? If yes, please specify. Have you engaged with these regimes to date?

N/A

d. 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.

New regulations might emerge for running DAC plants. We will comply as they are rolled out.

e. Has your CDR project received tax credits from any government compliance programs to-date? Do you intend to receive any tax credits during the proposed delivery window for Stripe's purchase? If so, which one(s)? (50 words)

We did not receive any tax credits to-date, we might use 45Q in the future.

10. 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*	294 tCO_2
Delivery window *at what point should Stripe consider your contract complete?*	January 2024 - January 2025
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.*	$1,700/ton

Application Supplement: DAC

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

Note: these questions are with regards only to air capture: e.g. your air contactors, sorbents or solvents, etc. Separately, there exist Geologic Injection and CO_2 Utilization supplements. We anticipate that most companies filling out this DAC supplement should ALSO fill out one of those supplements to describe their use of the CO_2 stream that's an output of the capture system detailed here.

Physical Footprint (Criteria #1 and #2)

1. What is the physical land footprint of your project, and how do you anticipate this will change over the next few years? This should include your entire physical footprint, i.e., how much land is not available for other use because your project exists.

Year	Entire System Land Footprint (km^2)
2021	0.02
2022	0.01
2023	0.005

2. What is the volumetric footprint of your contactor? (How big is your physical machine compared to how much you're capturing?) and how do you anticipate this will change over the next few years? These numbers should be smaller than (1) above.

Year	Contactor Footprint (m^3)
2021	1.2 m^3/tCO_2/year
2022	0.825 m^3/tCO_2/year
2023	0.525 m^3/tCO_2/year

2. Capture Materials and Processes (Criteria #5, #7, and #8)

1. What sorbent or solvent are you using?

We do not use sorbents or solvents. We use a composite material that contains a redox-active molecule.

2. What is its absorption capacity? *(grams CO_2 per grams material/cycle)*

N/A

3. What is its desorption capacity? *(grams CO_2 per grams material/cycle)*

N/A

4. How do you source your sorbent or solvent? Discuss how this sourcing strategy might change as your solutions scales. Note any externalities associated with the sourcing or manufacture of it (hazardous wastes, mining, etc. You should have already included the associated carbon intensities in your LCA in Section 6)

All the materials that we use in our scrubbers are available at the scale that we need to reach gigaton/year and megaton/year rate, except for one. This material is currently available at a ~1,000 tonnes/year scale. With our current CO_2 capture density (amount of CO_2 captured per volume of scrubber), we can scale up to 12,000 tCO_2/year.

We expect to improve the CO_2 capture density by an order of magnitude in the next 12 months. This improvement represents a 120,000 tonnes capacity increase per year. At this manufacturing capacity, it would take us ~9 years to achieve megaton/year scale. Because of this, we are working on scaling this material to ~10-100M tonnes per year. At this raw material supply level, we would be able to add ~1 gigaton capacity per year.

We can go faster than this, if we manage to produce ~10 billion scrubbers per year, as a result, we would achieve 100 Gt/year in ~10 years. We want to achieve that milestone sooner than 10 years but we understand that making 10 billion modules per year will constitute a massive manufacturing challenge.

This material is also the most expensive in the manufacturing of our modules. Working with our suppliers, we are optimizing its synthesis route and manufacturing steps, and an order of magnitude cost improvement is likely. It is not yet defined if we will manufacture this material in-house, completely outsource the manufacturing, or establish a joint venture with some of our suppliers.

5. How do you cycle your sorbent/solvent? How much energy is required?

Our system runs continuously. Currently, it requires 500 to 5,000 kWh/tCO_2 depending on the formulation.

6. What is your proposed source of energy? What is its assumed carbon intensity? What is its assumed cost? How will this change over the duration of your project? (You should have already included the associated carbon intensities in your LCA in Section 6)

Our proposed source of energy is solar. The cost assumption is $0.05/kWh, which will decrease as we scale and get access to wholesale prices. We expect $0.02/kWh to be possible at the megaton and gigaton scales. We assume 15g CO_2e/kWh.

7. Besides energy, what other resources do you require in cycling (if any), e.g water, and what do they cost? Where and how are you sourcing these resources, and what happens to them after they pass through your system? (You should have already included the associated carbon intensities in your LCA in Section 6) *(100 words)*

No other inputs are required.

8. Per (7), how much of these resources do you need per cycle?

N/A

9. How often do you cycle your sorbent/solvent?

N/A

10. Does your sorbent or solvent degrade over time? Is degradation driven primarily by cycling, environmental conditions, or both?

N/A

11. In practical operation, how often do you need to replace your sorbent or solvent material, if at all?

Our materials should be cyclable throughout the device's lifetime without being replaced/replenished. In practice, we have verified no observable material loss by infrared spectroscopy. Our understanding of the material cyclability and lifetime will improve as we progress through research milestones.

12. Per (11), what happens to your sorbent/solvent at end-of-life? Please note if it is hazardous or requires some special disposal, and how you ensure end-of-life safety.

We collect the modules and refurbish them. The active material can be recycled and, therefore, we do not intend to dispose of any hazardous materials.

13. Several direct air technologies are currently being deployed around the world (e.g. Climeworks, which Stripe purchased from in 2020). Please discuss the merits and advantages of your system in comparison to existing systems.

- **Energy-efficient:** Uses only electricity and operates at atmospheric temperature and pressure.
- **Continuous operation:** A single device captures and pressurizes CO_2, eliminating the need for several steps common in other technologies.
- **No extra resources:** No consumables - all active materials are regenerated. Does not require water, natural gas, or other resources.
- **Mass-production:** It can be manufactured using processes that are already scaled to high throughput manufacturing lines.
- **Can be used in small DAC plants:** Does not require megaton scale to be cost-effective, we shift the scaling from building large custom DAC plants to manufacturing the modules in an assembly line. Once we achieve large-scale manufacturing the cost per tonne of CO_2 captured for a megaton/year plant and a module installed at home will be almost the same.