General Application

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

Company or organization name

Noya, Inc.

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

San Francisco, CA

Name of person filling out this application

Josh Santos

Email address of person filling out this application

-

Brief company or organization description

Retrofitting existing equipment to perform distributed direct air capture (DAC)

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.

<1500 words

Noya is radically reducing both the upfront capital costs and the installation time required to perform direct air carbon capture. We're doing this by retrofitting existing pieces of industrial equipment like cooling towers and turning them into CO_2 capture machines.

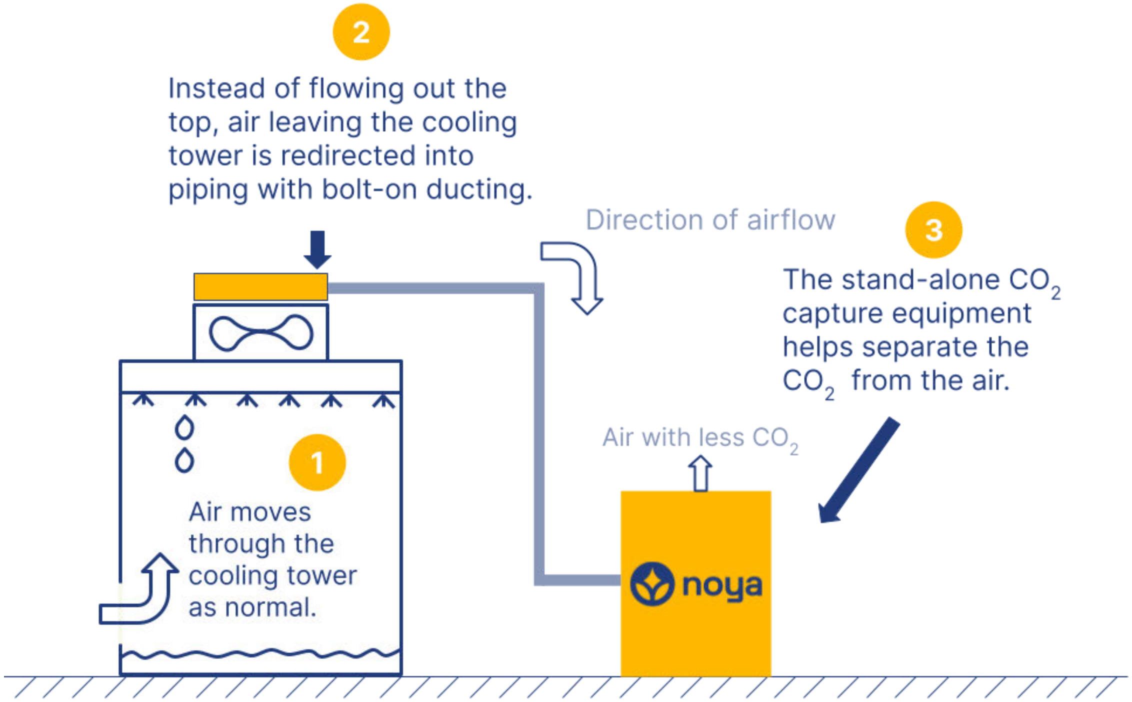
Under normal operation, cooling towers are large pieces of equipment used to dissipate heat from a moving stream of water. They do this with three main components:

1. **Large fans** that pull ambient atmospheric air through the cooling tower
2. **A spraying system** that sprays water down the inside of the cooling tower
3. **An air-liquid contact area**, usually either a packing material or a shell-in-tube system, that has a high surface area for the moving streams of air and water to come into contact with each other

Over the course of our development, we've designed two different versions of our process to perform DAC using cooling towers. Our first process takes advantage of the fact that cooling towers push air and water into contact with each other. In this process, we add an equimolar blend of hydroxides and amino acids directly into the water stream that cooling towers are already using. When pushed into contact with ambient air, the CO_2 in that air dissolves into the water and then reacts with this blend to form either aqueous carbonate or aqueous carbamate species. We then take the CO_2-rich water stream and run it through a stripping operation where we use heat to reverse the capture reaction and regenerate the captured CO_2. Because of the specific chemistry we use and the high surface area for air-water contact inside of the cooling tower, this process is highly selective and efficient for DAC. We've scaled this technology from a backyard prototype through a lab-scale and small industrial prototype to our first commercial pilot installation at a facility in the SF Bay Area capable of producing a max capacity of ~0.4t of CO_2 per day.

Despite being efficient and selective, aqueous sorbents result in large energy penalties associated with latent and sensible heat during regeneration. Our benchtop optimization efforts halved regeneration heat duty requirements, and at industrial facilities with large amounts of high-quality waste heat available, we have a path towards deploying this technology to provide extremely cheap DAC (<$100). To perform low-cost DAC with cooling towers that do not have a significant heat load available, we have developed a second approach that uses a solid sorbent instead of an aqueous solvent for cheaper, lower-energy regeneration.

In our second process, a duct redirects a cooling tower's exhausted moist air to a standalone combined capture and regeneration unit. During the capture step, this unit takes in moist air from a cooling tower and moves it through our sorbent (described below). CO_2 in the moving stream of air gets captured via chemisorption by the sorbent, and the rest of the air gets released out of the top of the unit. After the sorbent saturates, the regeneration step begins. In this step, the unit is sealed and put under a slight vacuum. We use radiative heating elements to add heat into the pellets, reversing the capture reaction and allowing pure CO_2 to be produced. During this regeneration process, the sorbent is also regenerated, allowing it to be used again for future capture cycles.



We selected our sorbent because it has many characteristics that shine within the unique conditions of our process. The specific material is listed in our patent-pending process, and it consists of two subcomponents: a porous “backbone” that acts as the structure of the sorbent, and a CO_2-reactive molecule embedded within the backbone that’s responsible for the CO_2 chemisorption. Sorbent components are cheap, readily-available and Earth-abundant materials The sorbent support is one of the most robust materials currently used in industrial catalysis. When taken with the fact that our early benchtop testing has not yet yielded a mechanism of irreversible deactivation, we are confident in a long lifetime of our sorbent. Our sorbent does not suffer from water-induced deactivation. There are many characteristics of our sorbent that give us confidence in its ability to perform well in a direct air capture process, but there are still many questions to answer and potential optimization points as we continue in our development.

At this point, we are at the earliest stages of design verification. We recently completed construction of the proof-of-concept for the second version of our process. This proof-of-concept uses a 6 ton cooling tower and will be capable of producing a max of ~20 tons CO_2 / year. This installation will be based at our office in San Francisco and will serve two main purposes: create a process performance baseline to identify / test the highest-priority cost reduction levers and inform the design of a process capable of producing 1,000 tons CO_2 / year.

The first step is to develop a strong performance baseline for the proof-of-concept we have constructed. This work is happening as we type, and our goal is to collect empirical numbers for heat duty, working capacity, adsorption / regeneration cycle times, and CO_2 production capacity. The empirical numbers we obtain will inform an updated version of our cost and carbon estimates and confirm the highest-priority cost reduction levers we have available to us.

In addition to helping us build a knowledge baseline, this proof-of-concept installation will be used to inform the design of a larger process — one that's capable of capturing ~1,000 tons CO_2/year. This installation, which will be built in Q4 of 2022, will either be located at our facility in San Francisco or on a commercial office tower in San Francisco's Financial District. This tower is one of the 100+ locations that have signed an LOI to join our waitlist for having our process installed once the technology is ready to deploy. As we approach deployment, our costs will get closer to our process's long-term lowest costs of $73-81 / t$CO_2$ captured and removed. This early carbon removal purchase from Stripe will help us accelerate the development work needed to unlock lower costs and deploy onto the 2M cooling towers across the US with a total capture potential of 10 Gt CO_2 / yr.

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.)*

Noya is a Direct Air Capture company. We retrofit existing cooling towers owned by our Partners with equipment we own to capture CO_2, all while not impacting the core tower functionality. We will sell this CO_2 to Concrete Producer (TBD) to sequester in fresh concrete via mineralization.

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

1) **The risk of reducing cooling tower performance due to a reduction in airflow.** We are addressing this with the design of the ducts that redirect the air from the cooling tower and the design of our contactors. Our goal is to reduce the potential back pressure of air as it moves through the tower. At worst, a secondary blower will be implemented to keep the flow of air through the cooling tower at acceptable levels.

2) **Uncertainty with sorbent lifetime.** Estimating catalyst or sorbent lifetime with confidence is a difficult technical process. Our solid sorbent has high mechanical strength and attrition resistance, and composition studies have not demonstrated a process of irreversible deactivation of the sorbent active sites. The sorbent lifecycle shows a small impact on the carbon intensity of the process (0.015 tCO_2 emitted/tCO_2 captured at 50,000 cycles vs. 0.008 tCO_2 emitted/tCO_2 captured at 100,000 cycles), but has a large effect on the production cost of CO_2.We haven't yet quantified the overall lifetime of our sorbent in our specific process, but this gives us confidence that our sorbent will last for a long time. We're currently at the earliest stages of the testing required to validate this timing.

3) **Uncertainty with how mass-producible and modular our process can become.** Cooling towers come in all shapes and sizes, and it will be a challenge to build a set of solutions that can easily be manufactured and scaled to fit these pieces of equipment. We envision developing our process in two parts: 1) the air-sorbent contactor and everything downstream

from it and 2) the components that integrate the cooling tower's fan exhaust with our equipment (including ducting, piping, etc). Our goal is to design part 1 to be a modular unit that can be duplicated to match a site's specific CO_2 capture potential. For part 2, we will have a suite of solutions to choose from that match the different cooling tower sizes that are in use today.

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

Our first patent is pending; it was filed on 06/30/2021 with application number 63/227,743. It is not publicly viewable 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.*	1/1/2022 - 12/31/2023
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.*	1/1/2022 - 12/31/2023
Distribution of that carbon removal over time *For the time frame described above, please*	1% in 2022, 99% in 2023

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".	
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.*	As the CO_2 will be mineralized as calcium carbonate (stable and abundant in nature), we anticipate durability ranging from 1,000 years on the low end to millenia or geologic timescales on the upper end.

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

Our durability claims are based on the geologic record, empirical claims from companies focused on concrete mineralization, including CarbonCure and CarbonBuilt, and from literature that investigates the timeline for durability with mineralized CO_2.

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.)*

<200 words

We have seen claims in previously accepted Stripe applications for CarbonCure and CarbonBuilt, and we've also seen findings in a few different pieces of academic literature [1, 2] that confirm this long-term duration of storage. Carbonate mineralization is a well-understood chemical process and carbon pathway, and we will take advantage of that for long-term carbon storage.

Supporting literature:

CarbonCure's Stripe application: link

CarbonBuilt's Stripe application: link

1: *"A Guide to CO_2 Sequestration".* Lackner, K. Science, 2003.
https://doi.org/10.1126/science.1079033

2: "*Chemical fixation of CO2 in carbonates: Routes to valuable products and long-term storage.*" Zevenhoven et al. Catalysis Today, 2006.
https://doi.org/10.1016/j.cattod.2006.02.020

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?

<200 words

The risks of using carbon mineralization are minimal. The process is straightforward, and the amount of physical risks this sequestration pathway brings with it are small.

Since the CO_2 we sequester is stored inside of concrete during concrete's setting process, there isn't a large opportunity to introduce socioeconomic risks due to misuse or mismanagement of storage of the mineralized product itself. On the front end of the process, there will need to be care taken around how the CO_2 is stored on-site prior to mineralization to ensure the pressurized storage containers are handled appropriately.

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.)*

<200 words

The exact method of quantification of storage within concrete will depend on the specific process our partners use. Generally, we will want to collect data on the amount of CO_2 flowing into and out of the mineralization process using flow meters and concentration sensors. This will give us an accurate read of how much CO_2 is being mineralized.

The long-term permanence of carbonate minerals are well understood in the literature, and we'll plan on doing a closer bi-annual monitoring of random samples of our mineralized product to ensure it matches what is expected in literature.

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	1000 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	We are currently in communication with a few concrete manufacturers who take in CO_2 as a feed to achieve higher strength concrete. Assuming the embodied emissions of these providers is the same as CarbonCure numbers from their 2020 application: *The ratio of emissions produced per tonne of carbon removal is 0.0032 or 0.32%.* *For every 1 tonne of carbon utilized, about 850 kg is mineralized while 150 kg of CO_2 is emitted (15% process emission). Production data has shown that each tonne of CO_2 utilized has achieved an estimated 45.3 tonnes of net CO_2 reductions (inclusive of the mineralized, avoided and emitted CO_2). Thus, for an emission of 150 kg there is 45,300 kg of benefit for a ratio of 0.0032.*

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)*

The carbon removal figure listed above is calculated based on CO_2 capture at a scaled up

version of our solid sorbent process.

Our proof-of-concept process is retrofitted onto a cooling tower that provides 6 tons of cooling and moves 2000 CFM of air. Based on calculations using the model linked in 3(d) below, we know that this cooling tower moves 65 kg of CO_2 per day. We estimate our proof-of-concept will be able to capture between 30-60% of the CO_2 that flows through it (based on benchtop capture efficiency yields), resulting in 19.5-39 kg of gross CO_2 capture per day, which will be stored and removed.

Based on these assumptions, we know the scaled-up version of the process that is able to capture 1,000 tons of CO_2 / year will have to move between 140,000-280,000 CFM of air through it. There are many cooling towers that are made in this operating range, such as the models AT 27-4K36 and AT 214-4K18 by Evapco.

We will design the scaled-up version of the process to produce 1,000 tons of CO_2 per year, and the proof-of-concept we're working on now will help us get closer to understanding how big our equipment will need to be.

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).

Our total capacity to capture CO_2 as of today is ~7 tons / year from our solid sorbent proof-of-concept. For sequestration, we will partner with a concrete mineralization partner to sequester our annual capacity.

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.)*

<200 words

Foundational model: for a given cooling tower, maximum CO_2 capture capacity is directly proportional to the amount of air that flows through the tower and is calculated using the following model. Link: CO_2 production estimation model

Foundational assumptions: In our baseline measurements so far, we've established the sorbent's baseline working capacity as 0.76 mol/kg. We have thermodynamically-calculated its heat duty to be 7.4 kJ/g CO_2 and are in the process of empirically measuring this number with the proof-of-concept that we completed on the day this application was submitted. For this application, we will double the calculated heat duty number to 15 kJ/g CO_2 in our cost and carbon calculations to account for heat losses and other inefficiencies, though we believe this number is too conservative for what we'll find in reality. We assume adsorption and desorption rates of 30 minutes. We assume a sorbent will be capable of reaching 50,000 cycles. More discussion on these assumptions listed below in the DAC supplement.

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

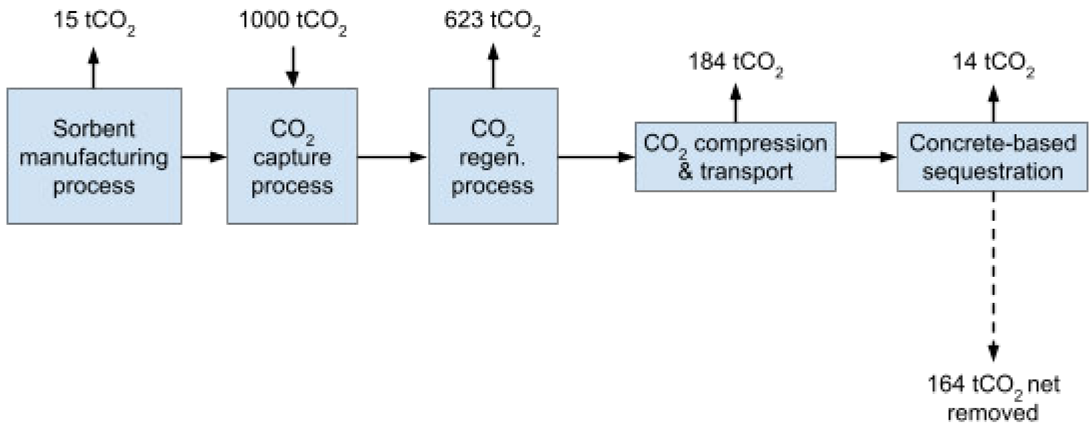
4. Net Capacity / Life Cycle Analysis (Criteria #6 and Criteria #8)

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	1000 tCO_2
Gross project emissions	Fossil grid: 836 tCO_2 Decarbonized grid: 317 tCO_2
Emissions / removal ratio	Fossil grid: 0.84 Decarbonized grid: 0.32
Net carbon removal	Fossil grid: 164 tCO_2 Decarbonized grid: 683 tCO_2

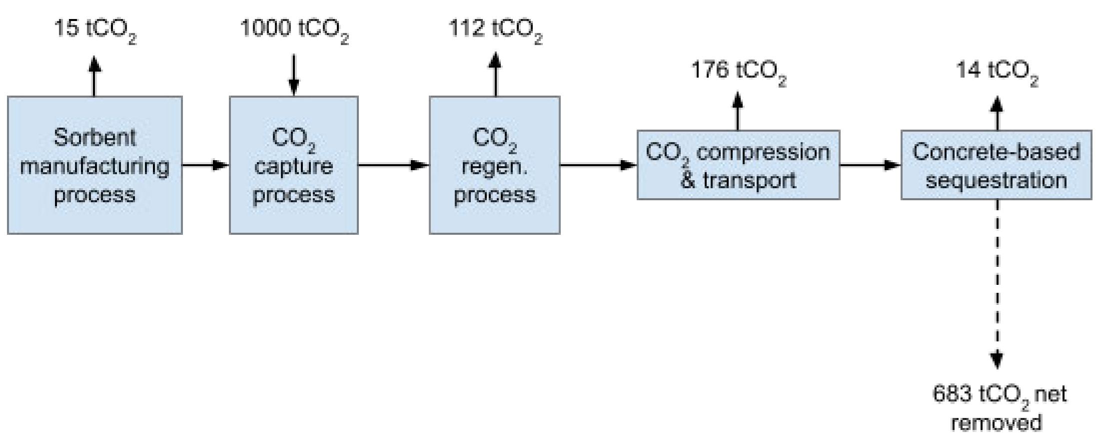
b. Provide a carbon balance or "process flow" diagram for your carbon removal solution, visualizing the numbers above in table 4(a). Please include all carbon flows and sources of energy, feedstocks, and emissions, with numbers wherever possible *(E.g. see the generic diagram below from the CDR Primer, 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.

A block diagram highlighting carbon flows can be found below. The primary inputs into the system are the CO_2 capture sorbent and moist air coming from the cooling tower's exhaust fans. The primary output is sequestered CO_2.



The biggest LCA considerations here are carbon impacts from the sorbent, energy consumption, and transport methods. The above numbers assume a sorbent lifetime of 50,000 cycles, energy consumption for regeneration and compression of 15 MJ/kg CO_2 and 0.24 MJ/kg CO_2 respectively, transportation distance of 10 miles, and emissions related with the concrete-based sequestration process of 0.02 kg emitted / kg sequestered. The above emissions ratio assumes grid electricity at the mix listed on PG&E's website [here](). We include this mix here to highlight the fact that even on a grid that's not yet fully decarbonized, with trucks still running on diesel, our process is still carbon-negative.

Our plan is to power our process using decarbonized energy for the same scenario described above, and our numbers improve dramatically: our emissions ratio decreases from 0.99 to 0.34:



The biggest component of our emissions here is now the diesel that our trucks use to move CO_2 around, accounting for 168 tons of emissions in the above scenario. Since our process is located within 50 miles to the concrete plants we will be sequestering at, our transport needs are perfect for electrified trucking. We do not yet know what the lifecycle reduction we can expect from electrifying trucking, but we do expect a near-elimination of the current footprint.

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?

This evaluation includes emissions directly from the process (Scope 1) and emissions related to sorbent production, energy production, compression, transportation, and sequestration (Scope 2). We also account for emissions due to equipment manufacturing (Scope 3).

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.

Lifecycle calculations are performed using OpenLCA, an open-source program for calculating LCAs. Some of our data is pulled from the US Federal LCACommons, which has life cycle inventories available for many types of compounds, electricity mixes, and transportation processes. Other pieces of data come from the NEEDS (New Energy Externalities Developments for Sustainability) database available for download on OpenLCA's website. We will directly measure these numbers as we test our proof-of-concept to validate our model.

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)*

We count units of deployment in "number of cooling towers" we have deployed onto.

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	~$400,000	140t/unit/yr	Aqueous solvent approach deployed on pilot facility
2020	0	N/A	N/A	N/A
2019	0	N/A	N/A	N/A
…				

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.)*

<50 words Our costs are falling because we're switching from a process with high regen costs (aqueous solvent-based capture, aka our V1) to one with lower regen costs and sorbent (our solid sorbent approach). As we scale up from our proof-of-concept to first pilot of V2, costs will fall even more.

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	1000 tCO_2/unit/year

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?

$1,523 / t CO_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.

>100 words

The above cost calculations include cost estimates for the following components:

- Ducting to connect cooling tower to air-sorbent contactor
- Air-sorbent contactor equipment, including heaters and vacuum pump
- Cost of the sorbent amortized over its assumed lifetime
- Equipment maintenance and labor cost estimates
- Compression, transport, and storage costs
- Conservative energy cost estimates of $0.24/kWh

These cost estimates do not include the following:

- Ongoing research and development costs

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	Achieve target unit costs for CO_2 capture sorbent	Our sorbent is one of the largest components of our costs and one of the elements with the biggest delta between the	Q1 2022	We will provide a report on our findings that includes experimental procedures and

		best-case and the worst-case. As such, it should be one of the first risks we burn-down. If our sorbent requires frequent replacing, our process will suffer because (a) we will need to frequently cough up new capital to pay for the material and (b) we will need to cover the additional operations costs to cover a human going on-site to replace it. Our sorbent needs to be robust and effective over its entire lifetime, and this testing will help us to understand how long we can expect it to last, what failure modes it may have, and how we may be able to regenerate failed sorbent to save costs and extend its effective lifetime.		results.
2	Achieve no greater than a 5% reduction in cooling tower performance with our equipment installations.	Our process relies on the use of other people's equipment. We will not scale to the 2M cooling towers in the US if we are not able to consistently and seamlessly integrate with the existing equipment as it is. A cooling tower's airflow is a critical part of ensuring the	Q2 2022	We will provide a demonstration that compares a cooling tower operating normally and with our equipment installed and shows the cooling performance is within an acceptable range.

		tower can provide the level of cooling needed to support its industrial process. For our process to be scalable, we will need to ensure that our equipment is designed and integrated in such a way that pressure drop and drag forces are minimized on the stream of air we are performing carbon capture with. There is a “brute force” backup plan we have in case we are not able to achieve target performance with duct design alone, but it requires adding additional energy costs into the system and would preferably be avoided.		
3	*<100 words* Achieve target CO_2 adsorption and desorption rates in and out of the air-sorbent contactor.	*<200 words* After ensuring the sorbent works effectively and robustly, we will turn our attention to minimizing our equipment’s levelized cost per tCO_2. We’ll do this by maximizing its CO_2 production capabilities over a given unit of time. The main bottleneck to maximizing CO_2 production is the rate at which the	Q3 2022	*<100 words* We will provide a demonstration of our process producing CO_2 that matches the target adsorption / desorption rates (and maybe even serve some Noya-carbonated water, too).

		sorbent captures and releases CO_2 — the faster it does either, the faster it can move on to the next part of the cycle and the more CO_2 it can produce. This milestone, when combined with milestones 1 and 2, allow us to build the process that will produce the CO_2 needed to fulfill a purchase order from Stripe.		

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	*Should match 3(c)* 7 tCO_2	7 tCO_2	N/A
2	7 tCO_2	7 tCO_2	N/A
3	7 tCO_2	7 tCO_2	These two numbers aren't different, but the completion of these milestones allow us to lock-in the design of the 1000 ton/year plant that will fulfill any purchase order from Stripe.

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	$1,523	$1,400-1,350	Achieving our target sorbent lifetime and costs will allow us to reach a new price tier in that one move alone. This essentially amortizes the cost of the sorbent across more CO_2, making it cheaper per ton removed.
2	$1,400-1,350	$1,400-1,350	<100 words
3	$1,400-1,350	$1,200-1,100	Optimization of the adsorption and desorption rates lead to optimization on the cycle time we are running and a better utilization equipment and energy input, leading to better capex and opex numbers.

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?

I would ask David Gottfried, Founder of the US Green Building Council, to support adding on-site direct air capture to the criteria that can be used to support a building in becoming LEED-certified.

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

<50 words

Evangelize our mission to climate job-seekers and policy makers, support future carbon removal purchases from other companies, and provide a platform for amplifying our roadblocks and where we need operational support.

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?

<100 words

Given our unique approach of retrofitting existing equipment in the built environment, we have a lot of different stakeholders that need to be identified:

- Building/property owners and their tenants
- Policy makers on the local, state, and federal level
- Carbon removal purchasers, typically corporates
- Other business entities, like suppliers, transportation partners, sequestration partners, academic and research labs, and investors

These stakeholders are geographically based in a wide variety of places, and we have identified and engaged with them ourselves by thinking through where our process interfaces/could interface with other groups and organizations and being proactive with outreach. Additionally, we've engaged with NGOs like Carbon180 to provide feedback on different initiatives to help move the industry forward.

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 engaged these stakeholders mostly through in-house engagement and external consultants. We are looking to onboard independent advisors over the next few months.

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?

Many of the changes we've made to our project so far have been made directly from feedback we've gotten from our stakeholders. A few key call-outs are:

- Changing to ducting the air from a cooling towers exhaust, as opposed to our initial plan of installing our equipment directly on top of the tower
- Changing the business model to reward our cooling tower partners with carbon removal credits instead of direct payments

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?

> As we get further into execution, we will increase the focus on engaging with our stakeholders to ensure we collect feedback on our process and share our learnings along the way. We will build a team responsible for stakeholder engagement, with an emphasis on local communities and policy makers. This team will ensure we are building our process in a way that meets the needs of all stakeholders generally, but specifically the needs of all of our neighbors. Like our carbon capture process, this team will be distributed, with people on the ground within each geography we grow into.

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

> Rather than any specific environmental justice concerns, we have a very unique environmental justice opportunity we can take advantage of. The largest cooling towers are usually found on sites that are the most responsible for CO_2 emissions and the sites that are most damaging to neighboring communities. We can use the equipment found at that facility to help mitigate the impacts that facility has on these frontline communities and provide employment opportunities to this community to ensure the economic growth that comes from the work we do is funneled back into the communities most impacted by this problem.

11. Legal and Regulatory Compliance (Criteria #7)

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

> For our cooling tower projects, we cover the CapEx of installation and any increase in OpEx due to our process.
>
> We've been advised that our approach could be structured with cooling tower owners like a lease agreement, where we're paying to "rent" the space where our equipment is installed in the form of shared revenue or possibly a share of credits generated for those parties more interested in credits than cash.

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.

> Our approach requires permits for the installation work we do to retrofit existing buildings. These are building permits typically offered by city building departments (e.g. for future work

in the city of San Francisco, these would be issued by the SF Department of Building Inspection). For anything we build on our own space, we will not need these types of permits, so we won't have to worry about the long wait times usually associated with permitting. For our first commercial installation on a building in SF, we will need permits and have not started the work to obtain these yet.

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.

Our main legal or regulatory uncertainties involve the sequestration component of our program. While there are experts we can and will lean on to help us here, it's unclear to us what delays or cost increases may stem from unanticipated complications here. Additionally, in some states, cooling towers are more closely regulated than in others, so we will need to ensure we understand the ways in which those local regulations are written and work to include their requirements into our designs.

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)	683
Delivery window (at what point should Stripe consider your contract complete?)	1/1/2022 - 12/31/2023

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.*	$1,822 / t

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	Land Footprint (km^2)
2021	2.3×10^{-5}
2022	2.3×10^{-5}
2023	7.9×10^{-5}

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	0.011
2022	0.011
2023	11

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

1. What sorbent or solvent are you using?

Our initial selection for the solid sorbent is a porous supported alkali with an active material embedded inside of it. The specific materials we're using are listed in our proprietary IP.

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

0.082 g CO_2 per g solid sorbent per cycle

Note: this number was collected using a very different geometry than the proof-of-concept we are now testing with, so we expect to get a much better number with the testing that is currently ongoing.

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

0.034 g CO_2 per g solid sorbent per cycle

Note: this number was collected using a very different geometry than the proof-of-concept we are now testing with, so we expect to get a much better number with the testing that is currently ongoing.

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)

For our solid sorbent approach, the support and active were sourced from suppliers while the sorbent was synthesized in-house. As this solution scales, we will scale-up sorbent production with an external partner to ensure we can scale quickly and easily, and in the long-term we will vertically-integrate sorbent production within the company.

Our sorbent production requires mining, chemical processing and transport to produce the feedstock we need. We have included all associated carbon intensities in the LCA.

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

We cycle the sorbent by switching between capture mode, where air flows through the system, and regeneration mode, where the system is sealed, the module is placed under a vacuum, and we apply heat to regenerate the captured CO_2. We are assuming a regeneration heat duty of 15 MJ/kg of CO_2 as explained in question 3(d). This will be a key optimization lever for us in the future because there are many ways we can reduce this energy requirement with the process we're developing, including using on-site heat integration opportunities and changing the sorbent's pore sizes and volumes.

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)

At the beginning, our project will run off of grid electricity. This mix assumes 0.25 kg CO_2 emitted / kWh of electricity, with data taken directly from PG&E. As we scale onto larger pieces of equipment located at either bigger buildings or large industrial sites, we will decarbonize our energy consumption using renewables and a cleaner grid.

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)*

Rather than consuming resources, our solid sorbent approach helps our partners cut costs. When the stream of air from the cooling tower goes through our sorbent, humidity gets captured alongside CO_2. During regeneration, this water is liberated, and we can add it back into the tower to cut utility costs.

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

N/A

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

This is a detail that will be locked-in and optimized with our proof-of-concept. As one data point, this reference (Veselovskaya et al., Int'l Journal of Greenhouse Gas Control, 2013) uses a sorbent that is similar to ours, and the authors report an adsorption time of 6 hours and a regeneration time of 20 minutes. We know we can modulate the cycle time of the sorbent by adding/removing sorbent mass within the contactor, and there's a potential trade-off between this cycle time and sorbent replacement frequency (the less sorbent you have, the faster it saturates, but the more you may have to replace due to more cycles). We will find the right optimal balance between these two variables for the process we are developing.

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

> With our solid sorbent, we haven't observed a direct degradation method yet, and this is something we are working to better understand. We've seen literature data that suggests the sorbent sees minimal performance reduction after 50 cycles (link).
>
> There may be a deactivation method that involves the material mechanically falling part, but this is unlikely because part of the reason we selected this sorbent is because it provides a high working capacity with high durability due to the mechanical strength of the materials. Our temperatures are not high enough to chemically decompose our materials, so this is not something we need to worry about. Since the air coming into our process is going to be freshly scrubbed of organic materials due to the air-water contact that happens within the cooling tower, we also do not expect organic fouling or char to take place on the surface of the sorbent. Nothing lasts forever, however, so we are going to conduct a deeper-dive into sorbent robustness as one of the key three milestones we listed above to find our failure points.

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

> In the paper referenced in question 10 above, adsorption performance is empirically measured over 30 cycles, and no decrease in performance seems to be observed. The authors also report high crystalline stability for over 80 cycles. In practice, we will aim to run the sorbent for much longer than that, and we will get a better sense for the sorbent lifetime as one of the key milestones we listed above.

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.

> At end of life, the sorbent can be recycled and reconstituted into new starting materials. This type of “recycling” process can be done with our specific alkali support using a few different types of processes, and we will choose the one that best allows for our material to be easily reconstituted into another blend of fresh carbon capture 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.

> *<200 words*
>
> Our system is differentiated from other systems in a few key ways.

First, our system has capital costs that are up to an order of magnitude lower than other approaches. We keep the capex low by retrofitting existing pieces of equipment that are already in the ground and operating at sites that have already been developed with existing infrastructure, utilities, etc. This also comes with the benefit of minimizing the amount of land we use since our process lives in the free space inside of commercial sites, requiring no new land to be dedicated to DAC.

Besides the low upfront capital costs, we also are differentiated because we can deploy our system in a matter of months rather than years. This allows us to commission many installations across many sites in parallel to each other, enabling a much faster cycle time for iteration, learning, and cost reductions to occur.

Finally, since we are installing our process onto cooling towers, there exists a heat source of some sort that needs to be cooled, otherwise the cooling tower wouldn't be there! We can take advantage of these sources of heat and integrate them into our process to keep our generation cost low and enable our partner's process to run more efficiently.

Application Supplement: CO_2 Utilization

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

Feedstock (Criteria #6 and #8)

1. How do you source your CO_2, and from whom?

<100 words
We source CO_2 from the atmosphere and will partner with a concrete company TBD to sequester via mineralization.

2. What are alternate uses for this CO_2 stream?

<100 words
If we were not sequestering this CO_2 into concrete, we would pursue research efforts into sequestering CO_2 into the ocean and into underground storage wells.

3. Do you have a pathway towards sourcing atmospheric CO_2 so as to achieve carbon removal? *(e.g. Future coupling of process to direct air capture)*

<100 words
This is the plan - the CO_2 we use for this process will always be atmospheric.

Utilization Methods (Criteria #4 and #5)

4. How does your solution use and store CO_2? What is the gross CO_2 utilization rate? *(E.g. CO_2 is mineralized in Material at a rate of X tCO_2 (gross) / t storage material).*

<100 words
We will partner with companies who inject CO_2 into concrete to convert CaO into $CaCO_3$, resulting in long term CO_2 sequestration as the concrete sets, trapping the $CaCO_3$ inside. The specific gross utilization rate will depend on the exact company we move forward with, but we've spoken with companies who have utilization ratios that range from 0.003-0.02 ton emitted:tons removed.

5. What happens to the storage material (e.g. concrete), and how does that impact its embodied carbon storage over time? How do you know?

<100 words
The concrete that will hold our CO_2 will be used the same way that conventional concrete is used: to build new construction projects. And since carbonates are stable for tens of thousands of years, this will ensure that the carbon stored in these molecules will stay out of the atmosphere for a long time to come.

See references in question 2(c) in general application above.

6. How do you ensure that the carbon benefits you are claiming through a CO_2 utilization process are not double counted? *(E.g. If sourcing CO_2 from a DAC system, or selling your product to a user interested in reducing their carbon footprint, who claims the carbon removal benefits and how could an independent auditor validate no double counting?)*

<200 words
Part of the agreement we will have with our concrete partner is that we will be given the carbon credits that come from the storage, which we will then take to offer to Stripe and other corporate removal purchasers.