stripe

Parallel Carbon – Carbon Removal Purchase Application

General Application

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

Company or organization name

Parallel Carbon Limited

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

Ingatestone, United Kingdom

Name of person filling out this application

Ryan Anderson, Aránzazu Carmona Orbezo

Email address of person filling out this application

[redacted]

Brief company or organization description

Low cost, renewable direct air capture via mineralization and electrochemistry

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.

Overview

Parallel Carbon is developing the world's most affordable direct air capture (DAC) process, relying only on wind, sunshine, and abundant minerals. We combine a nascent version of DAC based on passive, ambient mineral carbonation paired with an electrochemical process. By leveraging well-developed supply chains with low capital costs our process will rapidly scale, providing CO_2 for durable storage and creating high-quality CDR credits. The technology is compatible with intermittent renewable power, avoids (or reduces) demand for fossil fuel extraction, and reduces the cost of achieving net-zero. The product aligns with the climate imperative – emission reduction and removal, in parallel.

High-quality CDR

Generating effective carbon removal credits is critical to DAC's value proposition. Fortunately, DAC is well-positioned to measurably and verifiably supply CO_2 for permanent storage. Parallel Carbon stands out as the most affordable DAC process, best positioned for integration with low-cost, intermittent renewable electricity.

Physical footprint

Direct land use for Parallel Carbon's DAC process is 20–30Ha per 1.0MtCO_2/yr capacity. Because we utilize a passive CO_2 capture process, average local wind speeds affect natural convection and CO_2 diffusion within/through our contactors.

Indirect land use from renewable solar PV and on-shore wind power assets is significantly larger. At the 1.0GtCO_2/yr scale, renewable power demand could exceed the land area of Rhode Island. Amending our power consumption with off-shore wind or nuclear power could reduce the land intensity.

Capacity

Parallel Carbon's process produces CO_2 from air for CDR, but is an incomplete CDR technology without durable CO_2 storage. Parallel Carbon's DAC process is scalable to meet demand in the thousand to million tCO_2/yr range and can be deployed practically anywhere with clean power, so CO_2 storage capacity is the key limiting factor to achieving >0.5GtCO_2/yr by 2040.

A recent paper [Renforth] describes the CO_2 sequestration potentials of highly alkaline materials, by-products and wastes. From this work, it is estimated these sinks could provide 2.2–3.0GtCO_2/yr by 2040 through mineral carbonation. Our DAC process offers unique synergies with mineral carbonation operations, so we believe we can cost-effectively utilize a large fraction of these materials for measurable, verifiable, additional, and durable CDR.

Global reservoirs for underground CO_2 storage are estimated to be capable of storing 1000s of gigatonnes, but 2020 operational injection capacity was limited to 0.04$GtCO_2$/yr with another 0.04 in advanced development. If injection continues to grow at its historic CAGR (~10%), only 0.25$GtCO_2$/yr may be expected by 2040. However, we believe climate action will increase demand and accelerate growth and achieve a gigaton (or more) of storage capacity by 2040.

We do not expect physical capacity barriers to prevent Parallel Carbon from achieving >0.5$GtCO_2$/yr CDR in 2040.

Cost

Parallel Carbon expects to produce CO_2 at <$100/t by 2030 with costs continuing to fall thereafter.

The electrolyzer technology we've developed leverages existing and expanding supply chains and the associated cost benefits. Electrolyzers lend themselves to mass-manufacture and rapid cost reductions and have exhibited learning rates (18–20%) similar to solar PV (21.5%).

Our mineral sorbent is created from limestone – a globally ubiquitous, inexpensive surface mineral with gigaton scale supply and local availability. Our air contactor support structure is designed to use the cheapest materials and trivial construction. The remaining processing equipment is commonly available for industrial operations, available at any scale, and benefits from excellent economies of scale.

Parallel Carbon has designed our DAC process to minimize capex. We expect our first megaton-scale facility to achieve <$300/$tCO_2$/yr capacity costs, last 20 years or more, and require minimal fixed operating and maintenance costs.

Our technology's energy demand is 1.7MWh/tCO_2 today and we expect that to fall below 1.5MWh/tCO_2 through ongoing R&D. Parallel Carbon is afforded the ability to operate on intermittent renewable power because our process is based on electrochemical reactions. This is critical because intermittent renewable power is low-cost. However, very few regions of the world provide wind and solar conditions capable of supplying low-cost power >70% of annual hours (i.e. co-located solar and wind with 4 hour energy storage in batteries). Fortunately, our low capacity cost enables cost-effective amortization without requiring 24/7 carbon-free energy. **We expect to achieve our <$100/$tCO_2$ cost target with <70% utilization rates.**

Combining low-cost renewables with our rock-bottom cost capex, we believe our DAC process could achieve costs significantly under $75/$tCO_2$ for future megaton facilities. Parallel Carbon's success creates an incredibly competitive CDR pathway and ensures net-zero (and net-negative) GHG goals are economically viable.

Durability

Parallel Carbon prioritizes mineralization opportunities for CO_2 storage. Mineralized CO_2 will form carbonate rocks, predominantly calcium carbonate. Carbonate rocks are incredibly stable at earth's surface. No intervention or management is required to maintain stability or to prevent CO_2 release.

Our focus on mineralization carries over into underground CO_2 injection opportunities. As long as in-situ mineralization sites rapidly develop, we assume they offer an advantage over saline aquifers (etc.) by providing greater long-term certainty, reduced risk of re-emission, and less leakage monitoring.

Verifiability

Measuring CO_2 captured and durably sequestered from the air is physically verifiable based on mass balancing and gas flow rate monitoring.

Additionality

Direct air capture projects derive value from carbon removal and would not be financed or operated otherwise.

Public engagement and legal compliance

Parallel Carbon will only engage in responsible CO_2 management. Given the project-based nature of building DAC facilities, we intend to actively engage with local communities to determine and mitigate risks. We will intentionally limit/prevent/eliminate known negative externalities and intend to remediate or rectify emergent negative externalities that may arise.

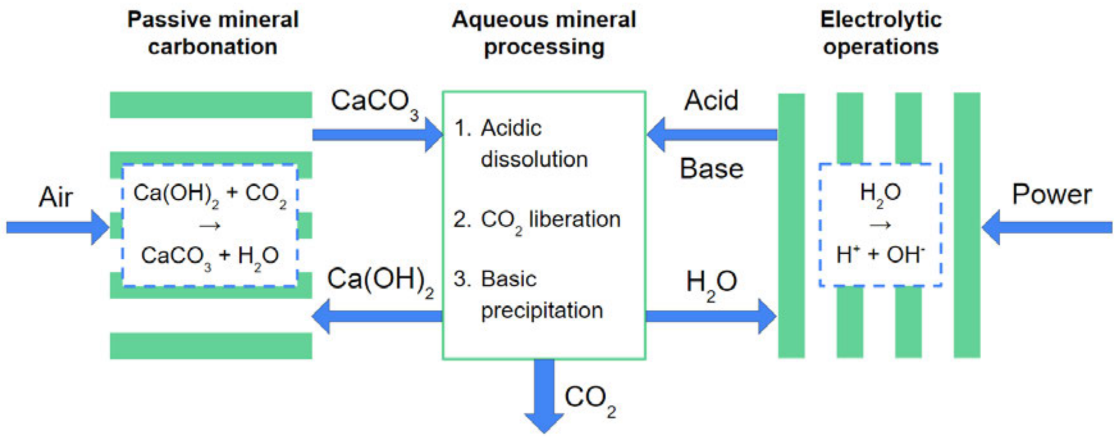
Net-negative lifecycle

Parallel Carbon's emissions primarily come from the LCA-related effects of renewable power consumption. Proper power purchasing is paramount to Parallel's process. Our pilot operations will run on 100% renewable energy (using RECs initially as a half-measure). At the demonstration stage we will sign virtual power purchase agreements and tailor our power consumption to match renewable power availability. As we deploy larger projects we will secure on-site and/or behind-the-meter power purchase agreements with dedicated renewables.

We expect our pilot facility to emit approximately 0.03 tCO_2e per 1.0 tCO_2 captured on a Scope 1 and 2 basis depending on the renewable power mix.

The Technology

Parallel Carbon's DAC process is based on calcium hydroxide mineral looping with aqueous processing facilitated by electrolysis. We liberate CO_2 from carbonates and regenerate our hydroxide capture medium using aqueous, acid-base reactions. The pure CO_2 stream is optionally compressed and transported, but can be directly stored in alkaline earth byproducts and wastes.



Semi-wet $Ca(OH)_2$ particle granules capture CO_2 through ambient carbonation in the presence of an electrolyte to create solid $CaCO_3$. Upon carbonation, the $CaCO_3$ is dissolved in low-pH solution to liberate CO_2, then the calcium ions precipitate $Ca(OH)_2$ particles in high-pH solution. The solution is clarified, the slurry is extruded to form $Ca(OH)_2$ granules. Fresh $Ca(OH)_2$ is loaded into trays and racked. Thin granule layers passively carbonate over hours/days. Fully-reacted $CaCO_3$ is recovered and the cycle loops.

The acids and bases are produced by electrolysis which creates H_2 byproducts. We use the H_2 onsite to generate power, reducing our external energy demand. For some CO_2 storage opportunities we use the H_2 to displace fossil fuels used for process heat, effectively combining emissions reduction with carbon removal.

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.)*

Parallel Carbon creates integrated DAC solutions. Our projects will generate CO_2 for partners with durable storage capabilities, creating high-quality CDR credits which we sell. We are progressing process integration discussions with multiple CO_2 offtakers who create durable carbonate building materials which ensures >1,000 year storage.

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

Parallel Carbon's hydroxide looping DAC process is the first of its kind and faces technology commercialization, electrocatalyst development, and CO_2 offtake risks.

1. All sub-processes exist individually for commercial applications, use existing materials and processes, but have yet to be combined for a similar commercial application. Aside from continued development and optimization of each sub-process, total process integration represents engineering, cost, and development timeline risks.

2. Using our current electrolyzer design, we would expect to use about 250 tonnes of Platinum once deployed at the $0.5GtCO_2$/yr scale. The current Platinum market uses only 210 tonnes of Platinum per year. We expect to innovate on electrode materials over the coming years, likely reducing or replacing Platinum as an electrocatalyst altogether. However, if we fail, our deployment rate could eventually be limited if Platinum production/supply doesn't grow.

3. Stripe's pre-purchase of credits from our pilot facility catalyzes development and reduces financing risks. Long-term CDR pre-purchase agreements will likely enable debt financing to reduce the cost of DAC. However, long-term CDR agreements require long-term CO_2 offtake agreements. Outside of Oil & Gas companies, few entities exist today who can durably store CO_2 at the megaton scale. If CO_2 storage opportunities are too slow to scale, there is risk that DAC deployment will become bottlenecked.

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

- Our pending patent (application number 63/305,113) is not yet public.

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?

The Parallel Carbon team is currently just two passionate PhDs, combining their expertise in a unique way to solve the world's most important problem. The DAC process pairs mineral carbonation, electrochemistry, and aqueous particle processing. Our team has deep understanding and years of experimental mastery in these fields.

Ryan Anderson brings the mineral carbonation and particle synthesis expertise. He got a PhD studying sustainable cement production with an emphasis on mineral carbonation and applied geochemistry. He has been working on carbon capture, use, and storage for nearly a decade, starting in the labs that spawned Solidia Technologies. In grad school, he created a novel method to measure the rate minerals react with CO_2 and developed a process to produce carbon-neutral concrete. After his PhD, he spent a couple of years as the in-house expert on carbon capture, use, and storage for BloombergNEF, where he was immersed in sustainable manufacturing, circular economy, and all-things decarbonization economics.

Aranzazu [“Aranza”] Carmona Orbezo brings the electrochemistry and flowing particle suspension expertise. She got a PhD working on capacitive desalination, which consists of removing salts from seawater using flowing charged particles that also store energy. She became the UK’s leading expert on the technology and even has a dimensionless number – the Carmona Orbezo number – which correlates flowing, charged particle diffusion with the Stokes-Einstein equation. Previously, she worked in regulatory affairs for DuPont to protect public health by ensuring pesticides were safe and efficacious throughout Mexico, Central America, and the Caribbean. At 19, she led manufacturing for her first startup which commercialized personal care products.

The team is urgently looking to recruit a process/chemical engineer to help us scale up and accelerate commercialization.

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.*	April 2023 – March 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 mineralization). Over what timeframe will carbon removal occur?* *E.g. Jun 2022 - Jun 2023 OR 100 years.*	April 2023 – March 2025
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".*	~30% in 2023 ~50% in 2024 ~20% in 2025
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

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

Extremely likely that CO_2 will be durably stored for well over 100–1,000 years

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.)*

Parallel Carbon prioritizes CO_2 mineralization and underground injection for storage,

but we have not measured the durability directly.

Ex-situ mineralization in construction materials is subject to infrastructure turnover, but is frequently crushed and recycled at its end-of-life to be used in future infrastructure projects until eventually landfilled [McCord]. Other ex-situ mineralization options accelerate the carbonation process to form limestone which is stable in Earth's surface conditions, as evidenced by widespread deposits of natural limestone [NASEM].

In-situ mineralization can convert CO_2 to carbonates in years and significantly increase storage security to geologic timescales [Snæbjörnsdóttir]. Injecting CO_2 into underground structural or solubility traps is also acceptable, but introduces risk of leakage. For well-regulated injection reservoirs, the most probable outcome is 0.2–0.9% leakage over 1,000 years [Alcalde].

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?

Mineralizing CO_2 to create carbonate solids unequivocally maximizes storage durability.

Carbonate decomposition, and CO_2 re-emission, may occur during thermal recycling (>900°C) at the end of carbonate building material product life, but this is incredibly rare (usually only for cement production supply chain feasibility research). Since cement kilns tend to be located near a quarry with large reserves of high-quality raw material, transporting poor-quality construction/demolition waste from a work-site to a cement plant is rarely economical. As cement kilns present the greatest risk to re-emission, it is virtually certain that more than 99% of sequestered CO_2 will remain sequestered for >100 years and it's very likely that 100% of CO_2 will remain sequestered for >1000 years.

The major challenge for long-term sequestration in carbonate building materials is monitoring and verification as products proliferate and advance through their useful life. However, it would not be unreasonable to intermittently check that infrastructure projects containing materials used for CDR have not been demolished. If demolition has occurred, local permitting offices could help determine if the wastes were disposed/recycled.

For storage via underground CO_2 injection, Parallel Carbon will coordinate with offtakers to ensure long-term monitoring and leakage remediation is contractually

required. For poorly-regulated injection reservoirs, the most probable outcome is 8% leakage over 1,000 years [Alcalde].

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.)*

DAC CO_2 provided to our sequestration partner will be quantified with gas measurement tools (volume/mass flow rate meters). Partners will measure CO_2 uptake in building materials and quantify carbonate formation. We will assume the carbonate building materials will not be exposed to high temperatures or strong acids over their useful product life, and will be recycled and eventually landfilled thereafter, permanently storing the CO_2 for >1,000 years.

3. Gross Capacity (Criteria #2)

a. Please fill out the table below. **All tonnage should be described in metric tonnes here and throughout the application.**

	Offer to Stripe (metric tonnes CO_2) over the timeline detailed in the table in 2(a)
Gross carbon removal Do not subtract for embodied/lifecycle emissions or permanence, we will ask you to subtract this later	231 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	64 tCO_2

b. Show your work for 3(a). How did you calculate these numbers? If you have significant uncertainties in your capacity, what drives those? *(E.g. This specific species sequesters X tCO_2/t biomass. Each deployment of our solution grows on average Y t biomass. We assume Z% of the biomass is sequestered permanently. We are offering two deployments to Stripe. X*Y*Z*2 = 350 tCO_2 = Gross removal. OR Each tower of our mineralization reactor captures between X and Y tons CO_2/yr, all of which we have the capacity to inject. However, the range between X and Y is large, because we have significant uncertainty in how our reactors will perform under various environmental conditions)*

Our pilot DAC test facility will have the capacity to remove 250 tCO_2/yr from the air, but we intend to operate predominantly when renewable power is available. This may lead to only ~45% utilization rate resulting in ~225 tCO_2/yr removed over 2 years.

A TBD sequestration partner will store 100% of this DAC CO_2 in building materials. Integrating our hydrogen byproduct into sequestration operations (or nearby industry) reduces fossil fuel demand. We will displace roughly 1202 MMBtu (LVH) of heat (52.9kgCO_2/MMBtu if natural gas) and directly avoid 64 tCO_2.

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).

Two lab-scale DAC setups: <4tCO_2/yr capture rate, <1tCO_2/yr sequestered.

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.)*

Parallel Carbon's technology is still a prototype system and operates at the lab-scale.

Our CO_2 production capacity is proportional to our power consumed to generate acids and bases. We've calculated the energy consumption of our electrolysis process (power = voltage*current and energy = power*time) and measured the carbonation rate of our mineral sorbent through thermogravimetry.

We calculate our energy requirements at 1.7 MWh/tCO_2 for our process (accounting

for 50% energy recovery of our byproduct hydrogen). Our sorbent uptakes $0.25gCO_2/gSorbent$ in under 1 day, but we are still improving this rate.

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.

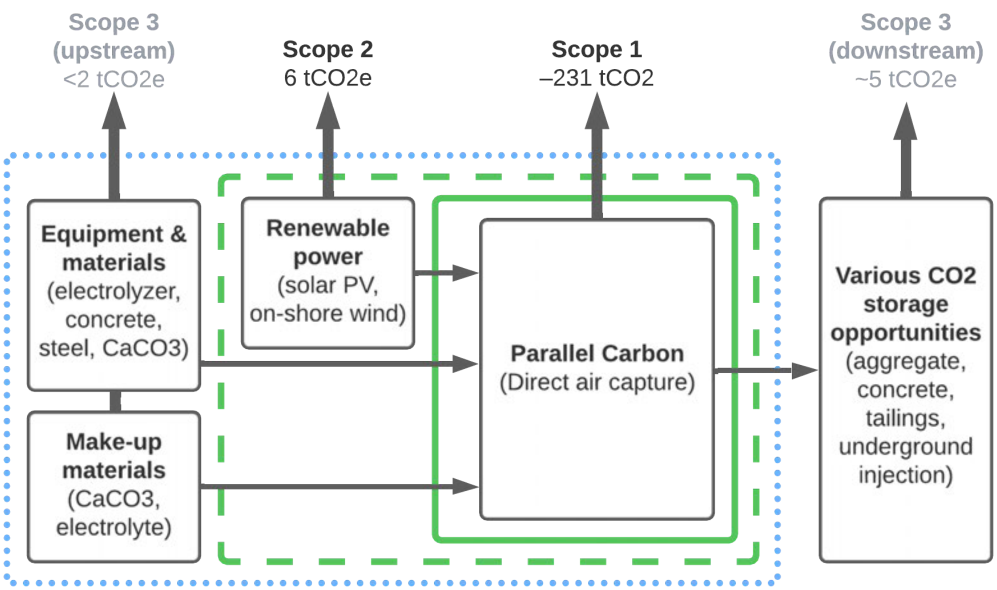
• Verified information from third party

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	231 tCO_2
Gross project emissions	6 tCO_2
Emissions / removal ratio	0.026
Net carbon removal	225 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.



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?

Scope 1 and 2 emissions are our assumed boundaries for DAC carbon accounting (green in part B). We consider upstream Scope 3 emissions for DAC decision-making, extending a 'soft' boundary (blue in part B).

Downstream Scope 3 emissions are considered when generating CDR credits, but will vary by CO_2 offtaker. Parallel Carbon sees opportunity to integrate our process into CO_2 storage opportunities which can reduce the downstream Scope 3 emissions. However, integration effects vary widely. We currently exclude downstream Scope 3 emissions from our DAC carbon accounting, but we will account for this upon CDR credit generation.

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](#).

Parallel Carbon's DAC process removes legacy emissions from the atmosphere. The direct, Scope 1 emissions are -1.0tCO_2e/tCO_2 – a negative emissions technology.

Scope 2, or indirect emissions from purchased energy, depend on the TBD location of our project. The wind-to-solar power ratio will slightly affect our emission intensity. On a life cycle basis, on-shore wind [NREL] and solar PV [NREL] contribute 0.013 and 0.043 tCO_2e/MWh respectively. We assume 75% wind power and 25% solar power for operations, resulting in $0.021tCO_2e/MWh$ and $0.03tCO_2e/tCO_2$ for our process.

Upstream Scope 3 values reported above have been solely modeled and obtained from life cycle databases [GHGProtocol]. We include all equipment, construction materials, make-up materials, and assume a 10-year project life for this DAC pilot project. The result is ~$0.008tCO_2e/tCO_2$.

Downstream Scope 3 cannot be calculated with certainty until we have established a CO_2 offtaker. Potential offtakers in Stripe's applications portfolio tend to have emission-to-removal ratios near $0.02tCO_2e/tCO_2$ (which we have assumed in part B).

These values were calculated from a $5{,}000tCO_2/yr$ DAC demonstration project we've designed, then scaled down for the $230tCO_2/yr$ pilot.

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 modules' capacity depends on power consumption. Electrolytic acid and base production is currently limited to non-commercial power sources. The maximum capacity is calculated from our acid production rate.

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	2	$645	2	Employing a larger, commercial electrolyzer
2021	2	$930	0.1	Small, custom, 3D printed electrolyzer
2020	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.*)

Capacity costs are falling as we innovate and develop our process at the lab scale. We've hit our efficiency milestones and are ready for larger-scale testing. We anticipate costs will continue falling with economies of scale.

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	231 tCO_2/yr/unit

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?

>$1,000/tCO_2$

b. Help us understand, in broad strokes, what's included vs excluded in the cost in 6(a) above. We don't need a breakdown of each, but rather an understanding of what's "in" versus "out." Consider describing your CAPEX/OPEX blend, non-levelized CAPEX costs, assumptions around energy costs, etc.

We expect our costs to remain above $1,000/tCO_2$ until we reach demonstration scale. Current costs include the electrolyzer, power supply, pumps, particle regeneration equipment (glassware), mineral stacks, electricity and consumables. The cost excludes materials lost for thermogravimetric analysis, energy recovery equipment, some pumps, blowers, (optionally compressors), and other material handling equipment.

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.

Our current cost targets:

- >$1,000/tCO_2$ – R&D Pilot, 2023 (~200tCO_2/yr capacity)
- $400/tCO_2$ – 1st Demonstration, 2024 (~4,000tCO_2/yr capacity)
- $100/tCO_2$ – Commercial, 2030 (1.0$MtCO_2$/yr capacity)
- <$75/tCO_2$ – Global deployment, 2040 (1.0$GtCO_2$/yr cumulative capacity)

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)

Electrolyzers

A substantial fraction of our capex today, we expect electrolyzer costs to fall roughly 75% by the end of the decade [IRENA]. Global interest in green hydrogen is increasing electrolyzer manufacturing economies of scale and deployment is driving learning-by-doing. Moreover, we are exploring alternative electrocatalyst chemistries and electrolyzer architectures to further accelerate cost reductions and improve manufacturability.

Carbon-free energy availability

Levelized costs of well-sited solar PV and wind power projects continue to fall, with <$30/MWh possible today. However, availability for co-located wind and solar projects with energy storage rarely exceeds 70% of annual hours. Increasing availability (e.g. with more battery capacity) increases electricity costs. We aim to operate with 70% uptime to access low-cost, renewable power. Powering DAC with dedicated, behind-the-meter renewables could limit our power costs to <$40–50/t$CO_2$ for well-sited projects. As renewable power and energy storage costs continue to fall over the coming decades, we believe 80–85% uptime at under $30/MWh may become possible, improving our capex amortization.

Economies of scale

Parallel Carbon's electrolysis and carbonation sub-processes are modular, so cost declines are largely tied to manufacturing scale. The aqueous particle processing operations use tanks and vessels, so individual project economies of scale have significant impact.

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.

I thought you said $100 per ton

Parallel Carbon sees many pathways for our process to achieve <$100/t$CO_2$ DAC. However, if built today, our direct air capture process would cost $220/t$CO_2$ [calculated] at the 1.0MtCO_2/yr scale. For this scenario, capital costs assumes 2020 electrolyzer prices and first of a kind cost of capital. Operating costs assume an average $45/MWh for renewable power available 70% of annual hours. The calculated costs represent a "bad case scenario" and ignores further improvement to our process, reaction rates, and energy consumption.

From bad to worse

Power purchasing is a critical cost-sensitivity metric for our process. Let's say we can only power our "base case scenario" DAC process at grid prices, \$70/MWh, and that only 50% of annual hours are decarbonized. Higher energy prices and poor amortization increase our DAC cost to \$300/tCO_2 creating a "worst case scenario".

(Ir)responsible DAC

Proper care must be taken to account for DAC's Scope 2 emissions lest the worst case scenario worsens further.

If our electric DAC process creates new demand for grid power, new renewable power supply should be added to the grid to backfill the increased load. Otherwise, new load from DAC may require a dispatchable marginal power source, likely supplied by unabated fossil fuel combustion. Attributing these marginal emissions to DAC would dramatically affect the LCA-adjusted cost. For instance, if Parallel Carbon uses 1.7MWh/tCO_2 and the marginal power source emits 0.45tCO_2e/MWh, the DAC emission-to-removal ratio increases from 0.03 to 0.76. This exacerbates our "worst case scenario" increasing costs to \$1,238/tCO_2. While the LCA doesn't cause DAC to become a net-emitter, it effectively ruins the economic viability for use in CDR.

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?	Target for achievement (eg Q4 2021)	How could we verify that you've achieved this milestone?
1	Switch from batch to continuous processing and integrate aqueous processing flows with electrolytic operations	Batch processes may not accurately represent heat flow or reaction kinetics expected in our continuous process. This milestone will allow us to properly evaluate particle dissolution and	Q4 2022	Experimental reports, data, pictures, video, site visits.

		regeneration characteristics, overcome unknown engineering hurdles, and define process controls to maximize $Ca(OH)_2$ reactivity. Integration will also allow us to evaluate electrode fouling/degradation and optimize system design and operational conditions.		
2	Establish storage agreement with durable CO_2 offtaker and secure necessary rights	Providing CDR credits to Stripe for our pilot facility requires a CO_2 offtake partner capable of durable storage. Alongside establishing an agreement, we will secure rights regarding construction permits, local operational permits, utilities, power purchase agreements, etc.	Q4 2022	Signed paperwork
3	Deploy pilot to deliver CO_2 while testing ~1 tpd solid materials handling for carbonation	Operating near the ton-per-day scale is critical to test our solids handling processes and gather real-world	Q2 2023	Steel in the ground, CO_2 production

	process	application. This includes feasibility tests for intermittent operations, air quality monitoring, CO_2 delivery issues, and value engineering. Overcoming unknown hurdles at this stage unlocks future cost-reductions and reduces the risk of project scale-up.		

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?
1	2–4tCO_2/yr	20–40tCO_2/yr	Additional processing volume for continuous system, additional electrolyzer capacity, and increased power consumption.
2	20–40tCO_2/yr	20–40tCO_2/yr	
3	20–40tCO_2/yr	200–250tCO_2/yr	Integrated pilot scale system delivering CO_2 with related processing volume and solids handling capabilities

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	$>\$1,000/\text{tCO}_2$	$>\$1,000/\text{tCO}_2$	*<100 words*
2	$>\$1,000/\text{tCO}_2$	$>\$1,000/\text{tCO}_2$	*<100 words*
3	$>\$1,000/\text{tCO}_2$	$>\$1,000/\text{tCO}_2$	*<100 words*

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?

I'd ask the person reading this to 1) tell us how you think you could help us accelerate commercialization, 2) send us your resume (1-page, PDF, jobs@parallelcarbon.com) and 3) let your friends/colleagues know we will be building a diverse, multidisciplinary team and will soon need their help also.

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

Stripe could create a physical CDR cluster by sponsoring/funding a CO_2 offtaker (e.g. an aggregate producer, injection site, etc.) that can be home to multiple DAC demonstrations. Shared equipment, knowledge, permits, etc. could eliminate many hurdles and catalyze early-stage commercialization.

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 primary external stakeholders are CDR credit buyers, CO_2 offtake partners, renewable energy providers, local lawmakers and communities, investors, equipment vendors, climate policy advocates, and government agencies.
>
> Business-related stakeholders come from many countries and represent the international commitment to fight climate change by catalyzing scalable CDR development. Regulatory and political stakeholders are at the national, state, and local levels.
>
> Although we have not chosen a CO_2 offtake partner (so have not finalized deployment plans), we will include local communities in our planning to maintain transparency and ensure we positively impact the region.

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.*

> Engagement with CDR credit buyers and CO_2 offtakers is critical for preparing pre-purchase pacts, establishing procurement prices, and integrating Parallel's operations with partners' production processes. These conversations are ongoing.
>
> We haven't engaged with local stakeholders but, the moment the final location of the pilot plant is defined, we will reach out to consultants and advisors that will guide us on how to approach the different groups and communities that could be impacted. We intend to utilize independent consultants to perform Environmental Impact Assessments as needed.

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?

> Since some CO_2 offtakers can use our hydrogen to replace on-site fossil fuel combustion, process integration discussions allowed us to eliminate a fuel cell from our equipment list. Not only does this significantly reduce our capital costs and project

CO_2 emissions, it reduces local air pollution positively impacting the nearby communities.

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 gain certainty about our deployment location, we want to begin engaging local stakeholders including communities and regulatory bodies. We are exposing powders to the air. It's highly likely we will need to implement control measures to prevent dusting which could negatively impact the local area. Quantifying material loss and measuring air quality will be critical to 1) satisfying local health and safety requirements, 2) designing mitigation measures, and 3) ensuring employee and community health are unaffected.

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?

We strive to ensure meaningful involvement of all community members and regional lawmakers in the development, implementation, and operation of our DAC facilities. Our main consideration is preventing local dust pollution, and we are prepared to redesign our air contactor to ensure safety if needed.

Our commercial scale DAC process is currently designed with communities in mind. We expect to employ a substantial workforce instead of automating-away certain operations. These jobs are a small fraction of the DAC costs, so we decided creating job opportunities to benefit local communities was more valuable than the associated cost savings.

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

Our CDR solution can be deployed practically anywhere, so we want local communities to fully accept our presence. Projects will provide well-paying jobs for skilled and unskilled labor. We will be part of regulatory efforts and community outreach in order to benefit local communities, especially majority-minority and less affluent communities.

Sustainability and waste remediation is central to the project's value; therefore, our operations will strive to lead by example. The project's operations are designed to have minimal impact on the surrounding environment and communities. Every effort will be taken to limit the project's effect on human health and the local environment. For potential dust pollution prevention, measures include water sprayers, louvered walls to slow/stop airflow as needed, or fully controlled airflow with cyclonic dust separators, etc.

The project's aqueous processes employ chemicals in a closed-loop that will not contaminate the environment barring an operational incident. Emergency plans for such incidents will be developed before deployment. Risk management and regular inspection will reduce the likelihood of leaks and accidents thereby minimizing or eliminating negative impacts to human health and the environmental.

9. Legal and Regulatory Compliance (Criteria #7)

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

We have not yet received legal advice regarding deployment. To our knowledge, our DAC process will comply with UK and US regulations regarding health and safety. The feedstocks used in our process don't require any special handling, special permits, and are part of major interstate and international supply chains.

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 have not yet begun the permitting process. We are not aware of domestic permits/forms/permissions to perform DAC, but expect land use and air permits will be required for operations. Depending on our CO_2 offtaker, our CDR solution will potentially require a Class VI permit for an underground injection well.

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?

To our knowledge, there is no international regulatory framework for DAC. We have not yet engaged with these legal regimes.

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.

To our knowledge, local land use permits may be our only requirement at the pilot scale, but we are investigating the need for an air permit as well. Depending on our CO_2 offtake partner, existing site permits may already cover our process. For larger deployments, an air permit and other requirements are likely, especially regarding the production and use of our hydrogen byproduct. We are still unsure of the regulatory and legal frameworks required to comply with international sale of CDR credits via Internationally Transferred Mitigation Outcomes (ITMOs) from Article 6.2 of the Paris Agreement.

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 have not received tax credits from government compliance programs, and do not intend to during Stripe's purchase window.

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*	*Should match the last row in table 4(a), "Net carbon removal"* 225tCO_2

Delivery window *at what point should Stripe consider your contract complete?*	*Should match the first row in table 2(a), "Project duration"* April 2023 – March 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.*	*This is the price per ton of your offer to us for the tonnage described above. Please quote us a price and describe any difference between this and the costs described in (6).* \$1,111/tCO_2

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	0 km^2
2022	0.000006 km^2
2023	0.0001 km^2

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 m^3
2022	0.01 m^3
2023	4.7 m^3

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

1. What sorbent or solvent are you using?

Mixture of calcium hydroxide ($Ca(OH)_2$), water, electrolyte

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

0.25 gCO_2 / g sorbent – maximum for pure $Ca(OH)_2$ to $CaCO_3$ is $0.35gCO_2/gCa(OH)_2$

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

0.25 g CO_2 / g sorbent

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)

> $Ca(OH)_2$ is obtained from $CaCO_3$, which is currently purchased from Amazon.
>
> As our solution scales, this material will be sourced from local providers, obtained from nearby mines.

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

> Semi-wet $Ca(OH)_2$ particle granules capture CO_2 through ambient carbonation in the presence of an electrolyte to create solid $CaCO_3$. Upon carbonation, the $CaCO_3$ is dissolved in acid to liberate CO_2, then $Ca(OH)_2$ is regenerated in base. Fresh $Ca(OH)_2$ is loaded into trays, stacked on racks and exposed to air. Thin granule layers passively carbonate. Fully-reacted $CaCO_3$ is recovered and the cycle loops.
>
> The acids and bases are produced by electrolysis which creates a H_2 byproduct. This process consumes 1.7 MWh/tonne of CO_2 assuming 50% of the energy in H_2 is recovered.

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)

> We use renewable wind and solar energy. On a life cycle basis, on-shore wind and solar PV contribute 0.013 and 0.043 tCO_2e/MWh respectively. We assume 75% wind power and 25% solar power for operations, resulting in $0.03tCO_2e/tCO_2$ for our process.

Our pilot operations will run on 100% renewable energy (using RECs), likely around \$70/MWh. At the demonstration stage we will sign virtual power purchase agreements and tailor our power consumption to match renewable power availability, potentially at \$60/MWh. As we deploy larger projects we will secure on-site and/or behind-the-meter power purchase agreements with dedicated renewables, ideally under \$30/MWh by 2030.

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)*

Water - Recycled during the process. Some lost to ambient evaporation and in the electrolysis process. Oxidizing H_2 in a closed loop (fuel cell) will decrease water demand. \$1-2/m^3.

Electrolyte for electrolysis. Recycled during the entire process, only small losses expected and treated as wastewater. \$350-450/t.

Electrodes and electrocatalysts - Our electrolyser components are expected to have limited degradation, and less degradation than traditional electrolyzers. We expect them to last at least 5–10 years. Replacement costs are included in fixed O&M. Materials of construction can include stainless steel, titanium, and small amounts of platinum group metals, but we plan to limit/replace Pt.

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

Water - 0.28 m^3 per cycle

Electrolyte - 0.005 kg per cycle

Electrodes - <0.0001 kg Pt, 0.02 kg Ti, 0.03 kg Stainless Steel per cycle if not recycled.

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

One cycle per day

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

Sorbent does not degrade because we use an aqueous regeneration process. Some can be lost during cycling because of dusting and accumulation in regeneration processes.

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

During an entire year, we expect we will need to replace <10 kg of sorbent.

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.

Due to the CO_2-reactive nature of $Ca(OH)_2$, our sorbent will be in $CaCO_3$-form (essentially limestone) at its end-of-life. We plan to recycle the limestone in ways that fight climate change including, but not limited to using it to displace clinker in cement (e.g. Portland-limestone cements) and to reduce ocean acidification.

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

Supply chains and scalability

Rapidly scaling DAC requires unconstrained supply chains. Parallel Carbon uses 1) ubiquitously available limestone as the feedstock for our sorbent and 2) commercially available electrolyzers for desorption/regeneration. By tapping into existing supply chains, we avoid chicken and egg manufacturing conundrums plaguing DAC with solid sorbents [Izikowitz]. Using limestone to supply alkaline earth cations for our sorbent avoids reliance on alkali salts used in liquid sorbents (e.g. KOH, NaOH). Electrolysis of alkali salts produces chlorine which has a limited market size, potentially constraining deployment [Chatterjee].

Integration with low-cost renewable power

Breaking carbonate bonds (liberating CO_2 from $CaCO_3$) requires acid or heat. High-temperature calcination requires thermal stability to ensure consistent particle reactivity and process control. Parallel Carbon uses a low-temperature acid to dissolve carbonates. This better positions Parallel to take advantage of low-cost, intermittent renewable power.

Other electric DAC technologies may offer lower energy intensity than Parallel Carbon; however, they are burdened by more expensive equipment. To successfully amortize their projects, they rely on 24/7 carbon-free electricity. Dispatchable low-carbon electricity typically costs 2–4x more than variable renewable power [Lazard].

Parallel Carbon's rock-bottom capacity cost allows us to offer the world's most affordable direct air capture process relying only on wind, sunshine, and abundant minerals.