Silicate

Carbon Removal Purchase Application

General Application

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

Company or organization name

Silicate

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

Ireland

Name of person filling out this application

Maurice Bryson, Professor Frank McDermott

Email address of person filling out this application

[redacted]

Brief company or organization description

Carbon mineralisation through silicate and hydroxide weathering

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.

Introduction
We mineralise carbon by using the geochemical reactivity of an alkaline construction product,

returned concrete, to sequester shallow-soil carbon dioxide (CO_2) as soluble groundwater bicarbonate that will ultimately precipitate solid calcium carbonate (limestone) in the ocean (Figure 1). To sequester CO_2, we take returned concrete, process it to agricultural lime specifications, transport it to farms, and spread it on agricultural land (Figure 2). The material takes ~1 year to fully weather, depending on grain size. Based on an annual wastage of 400 million-1,000 million tonnes (2-5% of the 20 billion tonnes of concrete produced globally each year), and the unit gross capacity value (rate of sequestration per tonne of material applied) as demonstrated and validated by our field trial data, we expect to be able to reach megatonne/year (Mt/y) scale before 2034, and gigatonne/year (Gt/y) by 2040. Moreover, unlike previously investigated mafic (basalt) and ultramafic (olivine) materials for accelerated weathering that generally require energy- and carbon-intensive mining, grinding and long-distance transport operations, returned concrete is a waste product that requires minimal crushing after post-return solidification at concrete plants to achieve high measured specific surface areas (~10m2/g). It is also far more reactive (orders of magnitude faster carbonation reaction) than these alternative weathering materials, and does not contain potentially toxic heavy metals such as nickel (Ni) and chromium (Cr), making it usable in arable, food-producing soils.

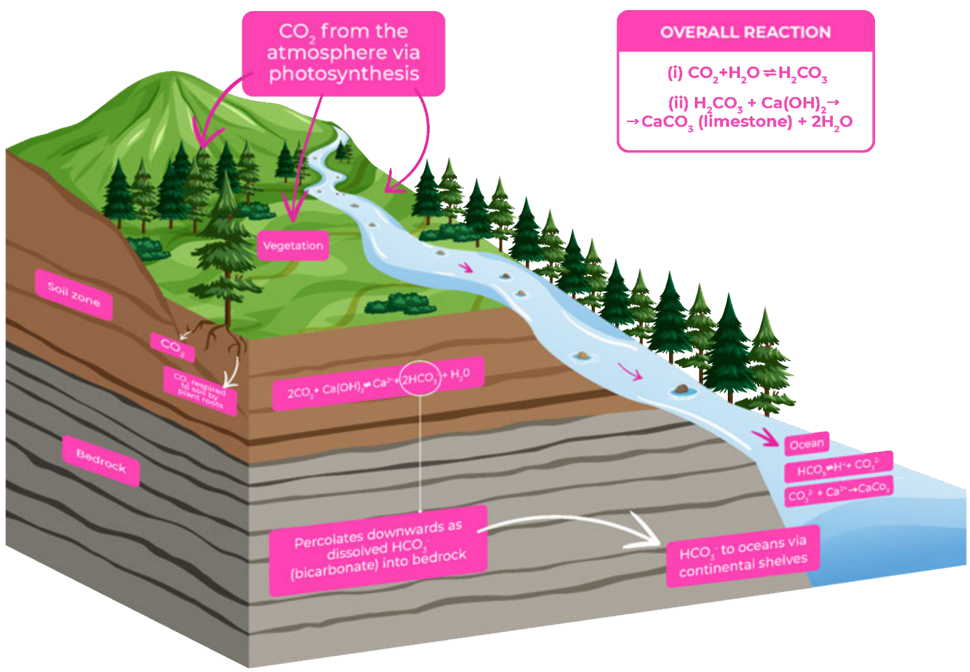

Figure 1: Mineralisation of carbon through weathering silicate and hydroxide minerals contained in returned concrete, and associated flow of bicarbonate percolating from the application site to aquifers and eventually to the ocean

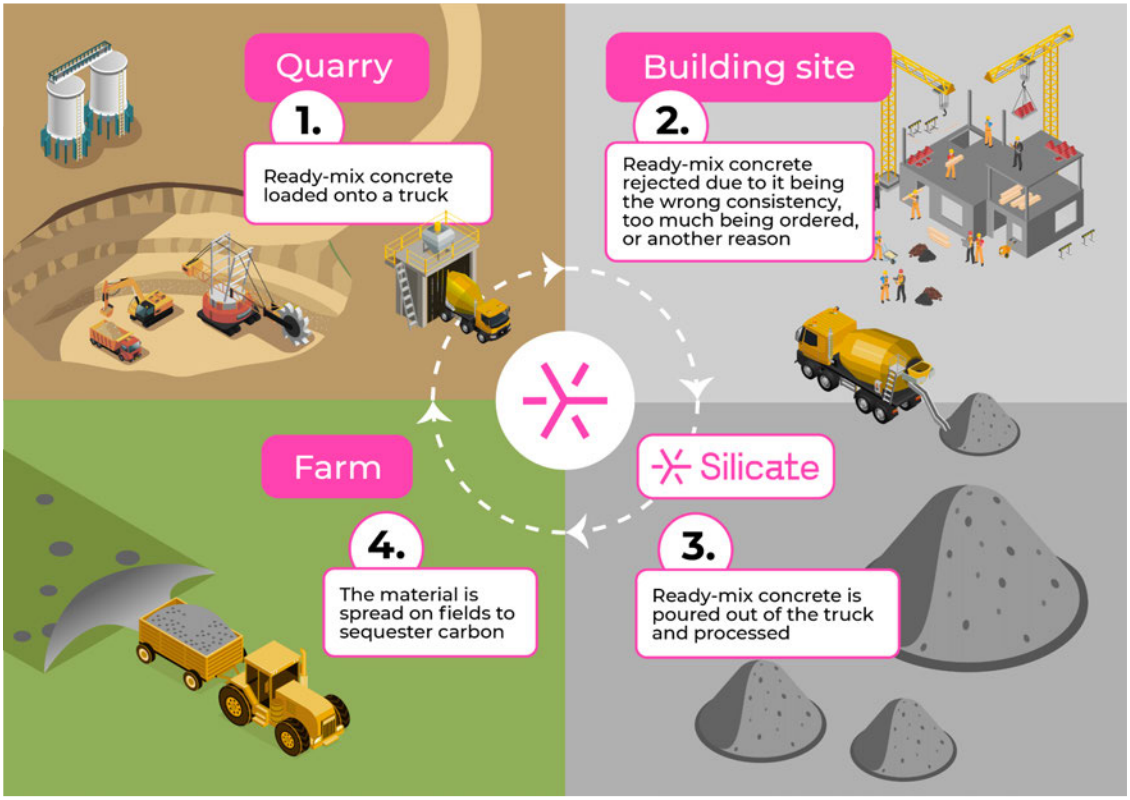

Figure 2: Process overview for using returned concrete as a carbon-removal vehicle

Technical explanation

Soil gases are characterised by high partial pressures of CO_2 (typically 5,000-10,000 ppmv) derived via soil organic matter decomposition and plant-root respiration. Because this CO_2, and the carbonic acid (H_2CO_3) produced from its reaction with downward percolating soil water, can be considered as atmospheric CO_2 (e.g., Spence and Tellmer, 2005), reactions that consume this carbonic acid are effectively sinks for atmospheric CO_2, thus forming the basis for enhanced weathering approaches that utilise alkaline materials (Renforth, 2019). The captured carbon will be stored as dissolved bicarbonate in sub-soils, underlying bedrock and aquifers before being ultimately transported to the oceans, where it has a residence time of c. 100,000 years (Figure 1). Some of this bicarbonate will precipitate as calcium carbonate in deep aquifers and in the oceans, where it will be stored permanently as limestone. The stoichiometry of hydroxide and silicate mineral weathering reactions at the heart of Silicate's approach implies that two moles of atmospheric CO_2 are removed for every mole of CO_2 released back to the atmosphere (on geological timescales) when limestone is eventually precipitated. On 100,000 year timescales, our sequestered carbon will be stored as dissolved bicarbonate, before eventual precipitation as a solid carbonate in the oceans.

Field-trial pilot study

In our first pilot study, which was carried out from June 2021 to April 2022, processed returned concrete (PRC) was added to the upper 15cm of a one-hectare trial arable field in the south east of Ireland at a rate of 10 tonnes/hectare. (An additional field trial was started in February 2022 covering 4 hectares of grassland at a rate of 4.5t/ha. Data for this field trial are still pending.) From the first pilot study, soil-water solutions were extracted for analysis using suction-cup lysimeters at monthly intervals from the amended and adjacent non-amended control sites to determine the geochemical impact of returned concrete on soil waters (alkalinity increase) and to calculate weathering and therefore CO_2 uptake rates via carbonic acid neutralisation. Relative to adjacent control sites, concrete-amended sites exhibited significant increases in soil-water pH (by 0.2 to 0.5 pH units) and bicarbonate alkalinity (c. 2 to 4 mmol/L), a two- to three-fold increase in electrical conductivity (total ion load) and similar increases in soil-water Ca^{2+}, reflecting the weathering of portlandite and calcium silicate hydrates (CSH) in the concrete. Field experiments are ongoing to assess the long-term effects of the returned concrete amendment on soil-water chemistry, soil pH and nutrient status. No increases in detrimental heavy metals (e.g., Ni, Cr), often associated with the use of olivine-bearing mafic and ultramafic materials as soil amendments have been detected. Weathering is attributable entirely to carbonic acid neutralization, with no evidence for weathering by strong acids (a 2:1 molar ratio of bicarbonate to divalent metal cations is observed in the soil water samples).

First commercial-scale pilot
In August and September 2022, we will spread PRC on ~250 hectares of arable agricultural land in the south east of Ireland to sequester ~500tCO_2. This event will be our first commercial-scale pilot. A geochemical model to compute the CO_2 sequestration potential of the material using readily measurable parameters to assist with our monitoring, reporting and verification processes will be constructed as we monitor these fields over 2022 and 2023 - the material takes approximately one year to fully weather. Lab-based pot experiments will also be run in advance of, and concurrent to, the commercial-scale pilot to help optimise PRC grain-size characteristics and amendment rates.

Proposal for Stripe - second commercial-scale pilot
In March 2023 and again in August and September 2023, we will begin scaling our commercial-scale operations to 3,000tCO_2/year. We propose to sell Stripe 2,000 of these tonnes, for delivery in 2024.

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.)*

Silicate is a climate solutions company. We take surplus-to-requirements concrete from concrete producers, process it to our desired specifications, and work with landowners and agricultural contractors to spread it on fields. The carbon removed by this process is monitored by Silicate using robust scientific monitoring methods, including soil water sampling and soil-to-air CO_2 gas fluxes using collar and flux chamber methods, as well as through a geochemical model that we are building to compute the CO_2 sequestration potential of PRC as a function of soil type, soil nitric acid content, and soil pH. The carbon removal credits created by this process, net of the CO_2 emissions incurred, are generated, and Silicate then sells these directly to corporate purchasers.

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

Our process, though relatively simple, has many moving parts that require alignment in order to scale the company to its gigatonne carbon removal goal by 2040. Part of this challenge comes from our rapid growth aspirations. Understanding how regulations could impact our business model and foreseeing the difficulties that could emerge as we grow our operations are two key challenges we are working to address now, and which can be summarised under two risk categories: regulatory and operational.

1. **Regulatory risk:** The regulations on waste and liming products in Europe are currently very prescriptive, and could potentially hinder the expansion of carbon dioxide removal (CDR) in Europe. Though these regulations are not currently constraining our ability to scale, they are equally not set up to accelerate our growth. As the regulations were not drafted with the use of alkaline waste materials for carbon removal in mind, we would hope to see policymakers redraft the EU Fertiliser Products Regulation and the Waste Framework Directive (2008/98/EC) to better enable Europe to capitalise on the carbon removal opportunities alkaline waste materials provide. We would also like to see a greater focus on policy alignment across all levels of government. We see ambitious goals on carbon removal at European level potentially being hindered by non-aligned objectives at the local level, which, in our view, pose a risk to the speedy rollout of CDR in Europe.
2. **Operational risk:** Given the relatively large land area requirements, a potential constraint in achieving Gt/y scale is sourcing an adequate supply of land. Targeting larger landowners, to reduce the number of individual contracts needed to scale to Gt/y carbon removal, will be one way of mitigating this risk. A second mitigating factor is our business model: offering a significant pecuniary incentive to landowners to partner with us should facilitate the accrual of land.
3. **Operational risk:** A third potential risk is supply of material. Though there is an abundance of material already in stockpiles and a recurring supply chain, changes to government regulations on the re-use of construction waste or the constituents of concrete, such as reducing the reliance on portland cement, may constrain the scaling of our sequestration process. Though these are certainly risks, given the sheer quantity of surplus concrete produced each year (400-1000 million tonnes), the nascent position of alternative cement options, and the difficulty in reusing concrete in buildings due to safety concerns because of the higher heterogeneity, porosity and lower strength compared to natural aggregates, we do not foresee these risks as terminal. These two operational risks, supply of land, and supply of material are the two primary risks that could limit growth; however, we believe both are sufficiently addressable to enable Gt/y scale to be achieved.

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

- Pending: EP 22162570.0

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?

We (Professor Frank McDermott and Maurice Bryson) are the first people, we believe, to scientifically test the potential of PRC as a carbon sequestration solution in the field, and will be presenting our research at the 2022 General Assembly of the European Geosciences Union in May.

Professor McDermott has >30 years' experience in high- and low-temperature geochemistry and igneous petrology, publications on a range of topics including igneous petrology, paleoclimatology, U-series dating for paleoanthropology, groundwater geochemistry, silicate weathering and links between climate change and wind/solar energy resources, as well as approximately 150 peer reviewed publications with >13,350 citations. Maurice has worked on some of the world's largest farms across the UK and Australia, and, prior to launching Silicate, worked in sustainable finance in London. Maurice holds an MSc in carbon finance from the University of Edinburgh Business School and a BSc in marine biology from the University of St Andrews.

We also have Dr Grace Andrews, who led the Leverhulme Institute's work on basalt weathering, and Dr Matthew Brander, a world authority on carbon accounting, on our scientific advisory panel. Collectively, we are a small (but growing), impactful team with science-led, large-scale carbon removal as our core mission. Our combined skillset, advanced research into this novel frontier CDR solution, and already robust market position (partnering with one of the largest construction materials companies in the world), give us a clear advantage in building this solution. Equally, we are looking to recruit people with experience in policymaking and scaling hard-tech businesses, as these are the key areas we feel could enhance Silicate's likelihood of reaching its gigatonne goal by 2040.

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.*	March 2023; August-September 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*	March 2023-September 2024

mineralization). Over what timeframe will carbon removal occur? *E.g. Jun 2022 - Jun 2023 OR 100 years.*	
Distribution of that carbon removal over time *For the time frame described above, please detail how you anticipate your carbon removal capacity will be distributed. E.g. "50% in year one, 25% each year thereafter" or "Evenly distributed over the whole time frame". We're asking here specifically about the physical carbon removal process here, NOT the "Project duration". Indicate any uncertainties, eg "We anticipate a steady decline in annualized carbon removal from year one into the out-years, but this depends on unknowns re our mineralization kinetics".*	100% in year 1
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.*	We expect 95% of the CO_2 captured to be durably sequestered. It is estimated that the carbon will be stored as dissolved bicarbonate for timescales ranging from several millennia to 100,000 years in the dissolved state, before eventual precipitation as a solid carbonate in the oceans.

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

Overall, we estimate that <10% (estimated here as 5%) of the sequestered CO_2 will be released back into the atmosphere on <100 year timescales, given the lowland nature of our existing and planned field sites and the evidence that enhanced bicarbonate in our soil waters is stabilised and balanced by cations such as calcium and magnesium. Nonetheless, small potential losses of CO_2 to the atmosphere via dagassing have been factored into our carbon-budget and carbon removal calculations (Figure 3, flux 11). Once bicarbonate is formed, we expect the carbon removed to be stored as bicarbonate for millennia to 100,000 years, before eventually precipitating as carbonate in the oceans.

c. Have you measured this durability directly, if so, how? Otherwise, if you're relying on the literature, please cite data that justifies your claim. *(E.g. We rely on findings from Paper_1* *and Paper_2 to estimate permanence of mineralization, and here are the reasons why these findings apply to our system. OR We have evidence from this pilot project we ran that biomass sinks to D ocean depth. If biomass reaches these depths, here's what we assume happens based on Paper_1 and Paper_2.)*

We anticipate that a very large fraction (>90%) of the sequestered CO_2 will remain sequestered in deep groundwater beneath the amended sites for longer than 100 years. Our soil-water geochemical data (pH, alkalinity, dissolved calcium) refer to waters sampled by permeable suction cup lysimeters placed at a depth of 30cm in the soil, indicating important downward transport of the weathering products through the soil profile. We have not observed any lateral runoff of rainfall into adjacent streams or rivers during the study period because our soil amendment has been and will be applied to low elevation agricultural lands (not mountainous uplands). As a result, the bulk of the bicarbonate produced by weathering of the PRC will be stored in shallow and then deep groundwater for several hundred years before eventual slow release to sluggish low elevation, low gradient drainage systems that are characterised by laminar flow and low rates of CO_2 degassing and/or release into the marine environment through deep groundwater flow through the continental shelves. Once the dissolved inorganic carbon (as bicarbonate) is transferred to the oceans it will remain sequestered for the order of 100,000 years, given the known residence time of c. 83,000 years for bicarbonate in the oceans (Berner and Berner, 1987).

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?

Some re-emission of the sequestered CO_2 could result on long timescales (>100,000 years) if a fraction of our observed enhanced bicarbonate is produced not by weathering of silicates (e.g., CSH) or oxides (e.g., portlandite), but rather by carbonate rocks in the aggregate of some concretes. This arises because when limestone is precipitated in the oceans, one mole of CO_2 is released for every mole of calcium carbonate (limestone) produced, but this will not occur on timescales shorter than the residence time of bicarbonate in the oceans (c. 80,000 years) and so is not a major concern on the timescale of relevance to this proposal.

Another potential but manageable risk is that in some soils, weathering might be driven not by carbonic acid (the neutralisation of which sequesters soil and therefore atmospheric CO_2), but rather by strong acids such as nitric and sulphuric acid as a result of a history of excessive nitrogenous fertiliser use or atmospheric sulphate deposition. These strong acids could impact the efficacy of the material because strong acids could dominate the weathering reactions relative to the carbon-sequestering carbonic acid neutralising reactions that are required to capture CO_2. These geochemical parameters will be measured as part of Silicate's ongoing monitoring and verification activities, but the data available from our field study so far indicates that carbonic acid neutralisation (and therefore CO_2 capture) is clearly the dominant process.

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.)*

As there is no formal carbon credit standard developed for enhanced weathering of PRC, we will adopt our own MRV process. This process will begin with scientific sampling of our test sites using a mixture of methods already employed on our 1 tonne/year-scale project, and additionally measuring CO_2 fluxes using soil chambers. We will have our results reviewed through a peer review process, and reported to stakeholders. We expect the material to weather completely over a one-year period, so we will monitor the fields applied for the full duration of the project. In time, we would like our verification process to be formalised in a standard, and so we will work with other companies in carbon dioxide removal to create a carbon accounting standard for enhanced weathering of PRC. A geochemical model to compute the CO_2 sequestration potential of PRC in different arable soil types, taking into account the effects of variables such as soil pH, moisture, temperature, nutrient (NPK) and lime status, and calcium carbonate stone content is being constructed during 2022, based on our lab-based mesoscale pot experiments and data already accrued from our field trials.

A third party will conduct the carbon accounting of our carbon-removal credits according to ISO 14062-2 2019 and/or The Greenhouse Gas Protocol for Project Accounting standards.

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	~2052tCO_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	~960tCO_2

production	

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

Based on our work to date, we are highly confident in our material's ability to sequester carbon at the 0.1/year unit gross capacity value. Given the stoichiometry of the material, and multiple efficiency improvements available to us, we expect to increase the unit gross capacity value to 0.2565tCO_2 in time. From our work to date, we expect the bulk of the material to weather rapidly (weeks) and a smaller proportion of larger grain sizes to weather more slowly (months), but that the full sequestration potential of the material will be realised within 12 months of application as demonstrated in our field results.

Assuming a like-for-like application rate of PRC to ground limestone, and using an IPCC emission factor of 0.12tCO_2/t limestone applied, we estimate that there would be ~960tCO_2 avoided by using PRC instead of ground limestone to amend soil pH for this 2,000 tCO_2/y proposal.

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).

500tCO_2/y in 2022, increasing to 3,000tCO_2/y in 2023, which is the year we propose to generate carbon removal credits for Stripe.

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.)*

The key component of our demonstration is the unit gross capacity value (ratio of mass of sequestered CO_2/mass of amendment material applied) because it determines the overall technical and economic feasibility of our approach. Methods for the calculation of the unit gross capacity value and its associated uncertainties based on alkalinity (dissolved bicarbonate) increases, divalent metal exports and enhanced soil-leachable Ca are described here. The unit gross capacity was estimated using three independent methods, all of which yielded similar results. First, increased soil water alkalinity, measured by acid titration was used to estimate the rate of soil CO_2 capture and drawdown into the groundwater by combining data for the enhanced bicarbonate ion concentration (relative to the control sites) with the downward flux of water through the soil into the underlying sub-soils and rocks (using the effective, evapotranspiration-corrected rainfall data from a nearby meteorological station). Second, CO_2 drawdown was estimated using the known stoichiometry of the likely weathering reactions involving the portlandite and CSH. The latter reactions predict a 2:1 molar ratio of carbon (as HCO_3^-) to calcium, as observed in the soil water samples. Finally, the enhanced level of loosely bound calcium, released during the weathering reactions whilst consuming soil CO_2 was used to estimate the extent of weathering of the soil amendments. This demonstrated component is critical to the performance of our proposed 2,000 tonne/year carbon dioxide removal project, because it forms the fundamental basis of our carbon removal and storage solution. Having shown its effectiveness at the 1 tonne/year scale, we now want to scale and optimise its efficiency to begin increasing our carbon removal capacity to commercial levels.

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.

- https://www.silicatecarbon.com/
- https://meetingorganizer.copernicus.org/EGU22/session/43538; see 'An investigation of crushed returned concrete (CRC) as a soil amendment for atmospheric CO_2 removal' - abstract #5
- References

  - Berner E. K. and Berner R. A. (1987) The Global Water Cycle: Geochemistry and Environment. Prentice-Hall.
  - Hogan, B., McDermott, F. & Schmidt, O. (2019) Release of plant-available silicon from various silicon-rich amendments into soil solutions and leachates. J. Soils & Seds. 19, 1272-1295.
  - Renforth, P 2019, The negative emission potential of alkaline materials, Nature Communications, vol. 10, 1401.
  - International Energy Agency, 2021, Global cement demand for building construction, 2000-2020, and in the Net Zero Scenario, 2025-2030.
  - West, T 2005, The contribution of agricultural lime to carbon dioxide emissions in the United States, Agriculture Ecosystems & Environment, vol. 108, 145-154.

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	~2052tCO_2 (including degassing CO_2 estimate)
Gross project emissions	~30tCO_2e
Emissions / removal ratio	0.0146
Net carbon removal	~2022tCO_2

b. Provide a carbon balance or "process flow" diagram for your carbon removal solution, visualizing the numbers above in table 4(a). Please include all carbon flows and sources of energy, feedstocks, and emissions, with numbers wherever possible *(E.g. see the generic diagram below from the [CDR Primer](), [Charm's application]() from 2020 for a simple example, or [CarbonCure's]() for a more complex example).* If you've had a third-party LCA performed, please link to it.

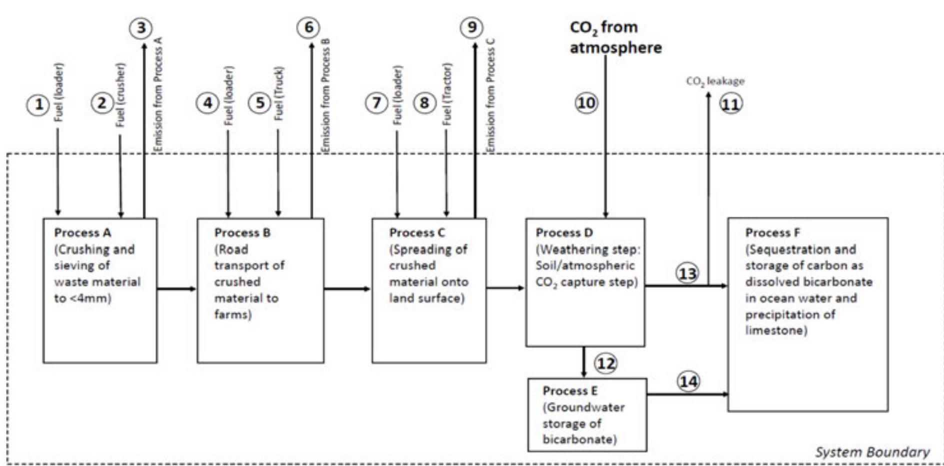

Figure 3: Process flow diagram for using returned concrete as a carbon-removal vehicle

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?

Diesel to fuel our crusher/mill, loaders, trucks and tractors is the main emissions source. Details of the amount of fuel estimated per stage of our process are summarised below, as well as the estimated re-release of CO_2 into the atmosphere due to environmental conditions (flux 11).

Table 1: Greenhouse gas emissions at each stage of process of this 2,000 tCO_2/y proposal

Flux #	tCO_2e emitted
3	2.22
6	22.5
9	5.9
11	108

As our feedstock is a waste product from the construction sector, the emissions associated with the manufacturing of the concrete are not in the boundary of our lifecycle assessment (LCA). We do not include the greenhouse gas emissions attributed to the production phase of the concrete in our carbon accounting, as the material was not created for Silicate's use. We are merely utilising a waste product of the construction sector. This PRC is considered a waste material, with no additional energy or fuel costs incurred with its use in our approach apart from the milling, transport and spreading activities accounted for in our carbon accounting calculations.

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.

Data such as fuel consumption for machinery were taken from the machinery manufacturers. Emissions factors were taken from DEFRA. The estimate for re-release of CO_2 was a best estimate by Prof. McDermott.

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)*

Tonnes of PRC

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	60	N/A	TBD	PRC was recently applied to 5 hectares in south east Ireland. The data are still to be determined
2021	10	N/A	0.1tCO_2/unit	This was our initial field trial in south east Ireland
2020	N/A	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.)*

During our field trials, our unit costs have remained stable, as the purchase, transport and application costs of PRC have been minimal. However, in order to optimise the unit gross capacity, we expect to incur higher unit costs, as further processing of material will be required. The additional milling steps, for example, will, we expect, increase the unit cost but will also boost the unit gross capacity. In time, we hope to decrease these unit costs again through further optimisation of the unit gross capacity of the material. We have a number of strands of research underway to assess the potential efficiencies that could be achieved that would increase the unit gross capacity and therefore decrease the unit costs.

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)
8,000	0.2565tCO_2/unit (our target unit gross capacity)

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?

USD280/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.

Our costs are primarily a function of the uncertainty around unit gross capacity. Should we achieve our target optimisation, we expect our costs to fall to ~USD180/tCO_2 over time. However, given our current unit gross capacity, we need to factor in the requirement for additional material, among other things, to achieve the target net sequestration volumes. The cost covers OPEX and a portion of CAPEX.

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.

• Megatonne: USD120/tCO_2 • Gigatonne: USD80/tCO_2

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

Our costs are driven, chiefly, by the volume of material needed to sequester a given volume of CO_2. If we can optimise our material to have a better unit gross capacity, we dramatically lower our processing, transport and spreading costs. We also reduce the area of land required to sequester a given volume of CO_2. As such, we are working on a number of strands of research to enhance the unit gross capacity of our material. We are also working to streamline our carbon accounting verification system, by investing heavily in detailed mesoscale experiments that will help us to create a geochemical model to credibly assess sequestration rates. Lowering our OPEX through these two methods will, we feel, dramatically lower our costs.

A final area we feel will allow us to breach the USD100/tCO_2 mark is the use of construction and demolition waste. Waste legislation currently limits the potential of demolished concrete to be used as a soil pH amendment. Should this legislative position change, we expect to be able to cover the costs of processing and spreading through the revenue earned by collecting demolished concrete, which would, potentially, enable us to dramatically lower our carbon price.

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.

In a worst case scenario, we would expect our carbon price to be maintained at the USD280/tCO_2 mark. However, we expect to make significant efficiency improvements from our first commercial-scale pilot onwards, so would expect this figure to fall over the coming years.

f. List and describe **up to three** key upcoming milestones, with the latest no further than Q2 2023, that you'll need to achieve in order to scale up the capacity of your approach.

Milestone #	Milestone description	Why is this milestone important to your ability to scale? (200 words)	Target for achievement (eg Q4 2021)	How could we verify that you've achieved this milestone?

1	Spread PRC on ~250 hectares of arable agricultural land in the south east of Ireland to sequester ~500tCO_2	This will be the first commercial-scale pilot. We hope to improve our unit gross capacity by taking the learnings from our initial field trials and applying them to this project. If we can demonstrate that the process works at this scale, we believe scaling beyond this part of Ireland and beyond Ireland will be more easily achieved	Spread PRC on ~250 hectares of arable agricultural land in south east Ireland with MRV ongoing from time of application until one year later	We will provide application data and photographic evidence
2	Continue detailed meso-scale pot and lab experiments to gather robust data on the performance of PRC under different scenarios	In order to truly understand the full geochemical efficacy of the material under different scenarios of nutrients and soil type, for example, we will run controlled meso-scale pot experiments. These experiments will greatly assist our understanding of PRC and how best to optimise its unit gross capacity	Complete this first iteration (>170 individual pots)	We will provide data to demonstrate that it was achieved as well as photographic evidence
3	Develop a first iteration of our geochemical model based on data from our initial field trials, first commercial-scale pilot, and our meso-scale and lab-based	Completing the MRV for our project will become increasingly challenging as the area of the project increases. Being able to confidently model the amount of carbon durably sequestered while accounting for the	Initial version of tool is functional	We will provide data to illustrate the tool's capability

	experiments	many variables that could impact the rate of carbonation will, we believe, be a vital tool to assist with scaling		

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	~200tCO_2/y	350-500tCO_2/y	Prior to completing milestone #1, the PRC unit gross capacity will not be optimised beyond the figure we calculated in our initial field trial. However, we anticipate this figure increasing after milestone #1 is complete
2	~200tCO_2/y	350-500tCO_2/y	Prior to achieving milestone #2, the PRC unit gross capacity will not be optimised beyond the figure we calculated in our initial field trial. We believe that after achieving milestone #2 that we will be able to increase the total gross capacity of the project by improving the unit gross capacity of PRC
3	50-150tCO_2/y	>500tCO_2/y	Due to limitations on equipment and manpower, performing detailed scientific analyses on soil water chemistry and soil-to-air CO_2 gas fluxes would prove difficult at any scale larger than 50-150tCO_2/y. On

			achieving milestone #3, we expect to be able to increase our land application area in order to be able to sequester >500tCO_2/y

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	USD280/tCO_2	USD250-280/tCO_2	N/A
2	USD280/tCO_2	USD250-280/tCO_2	N/A
3	USD280/tCO_2	USD250-280/tCO_2	N/A

h. If you could ask one person in the world to do one thing to most enable your project to achieve its ultimate potential, who would you ask and what would you ask them to do?

We would ask the President of the European Union Commission, Ursula von der Leyen, to shape CDR policy from a bottom-up, rather than a top-down, perspective. The Fit for 55 package under the European Green Deal sets out the target of reducing the bloc's net greenhouse gas emissions by at least 55% by 2030. CDR will invariably play a part in meeting this target, as exemplified by the certification of carbon removals initiative. We would contend that for CDR to work in Europe, there must be buy-in at the local level where it will be implemented. For DAC and geological storage to work, for example, local permits would be required. The same is potentially true for using alkaline waste materials for enhanced weathering. Developing a robust and comprehensive approach to CDR in Europe that incorporates local government at an early stage will, in our view, be key to enabling our project - and other CDR projects in Europe - to achieve their ultimate potential.

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

Working in partnership with Silicate and other CDR teams to create a verification standard for enhanced weathering that is robust and inspires confidence in the veracity of our carbon removal credits would be a boon to our project. Equally, guidance on local regulations and permitting in areas Stripe is familiar with - the US, for example - would be a notable help in our effort to grow our operations beyond Ireland.

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 2,000 tCO_2/y proposal will be implemented in Co. Wexford, Ireland. The key external stakeholders are the local communities in the rural areas where we spread our material. The area is a relatively wealthy part of Ireland, where the primary sectors of employment are agriculture, retail and construction. The area is within the commuter belt of Dublin, meaning that many local residents would commute to Dublin to work. <1% of the population would be below the poverty line. To date, as our application rates have been so-far limited to a number of field trials, engagement with the local communities, beyond the farmers directly involved, has been limited. However, the technology involved (land-spreading of alkaline material on arable land) is familiar to the community as lime addition to fields is a widespread land management activity in the area.

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

We will be holding information sessions at a number of agricultural events this year, where we will discuss our process and hear from communities their views on our work. We hope to grow our work through building momentum and interest among the communities where we operate. Community participation, including being contracted by Silicate to spread the material, is, therefore, vital to our success.

c. If applicable, what have you learned from these engagements? What modifications have you already made to your project based on this feedback, if any?

N/A

d. Going forward, do you have changes planned that you have not yet implemented? How do you anticipate that your processes for (a) and (b) will change as you execute on the work described in this application?

We have considered the potential health impacts of dust inhalation while our material is being spread. We will spread our material on still days, so as to limit dust clouds. Equally, the project sites will be located in relatively uninhabited areas, therefore limiting this potential public health risk. We are not aware of any historical patterns of exposure to environmental hazards in these areas.

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?

Land competition is something we see as a real concern for nature-based CDR. Our material and process, fortunately, do not preclude the use of land for agricultural/forestry production, so will not compete with other land use demands. We see this aspect as a vitally important element of our process - by not competing for finite arable land, our CDR work does not lead to unintended consequences of crop price dynamics, or increased CO_2 emissions elsewhere (see Searchinger et al., 2008 for reference).

Our project is built on community buy-in. Without landowners willing to let us apply material to their land, we would be unable to deliver our novel carbon removal solution. That is why maintaining strong and dynamic links with the communities where we operate has been, and will continue to be, a core aspect of what we do at Silicate.

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

At Silicate, we strive to create a just and equitable carbon removal solution. Community support will be pivotal to our successful removal of carbon. Through our work, we see the potential to change our social system, specifically in how we produce food and also the production systems that until now have been entrenched. An agricultural system that is premised on negative externalities is, in our view, unsustainable. We believe that by challenging the paradigm of conventional agriculture, we can foster a more balanced and equitable agricultural system. Enabling agriculture to play a meaningful role in CDR through our soil pH amendment material could, we think, be a catalyst for this shift.

9. Legal and Regulatory Compliance (Criteria #7)

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

We have liaised with the Irish Environmental Protection Agency, and were also provided a legal opinion by Mairead Smith BL on the application of waste controls to PRC.

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 been advised by our counsel that PRC is considered a product under the applicable waste legislation. As such, we are permitted to continue to use the material outside of waste legislation controls. EU waste law is primarily implemented in Ireland in the Waste Management Act 1996-2011 (and Regulations), this is the framework legislation for most waste management in Ireland. It encompasses many European Directives, not least of which the Waste Framework Directive 2008/98/EC.

The EU Fertiliser Products Regulation Product Function Category (PFC) 2 covers Liming Materials. This category states a number of requirements that the product must meet (e.g., contaminant limit values, specifications for neutralising value and grain size etc). Our material falls within the acceptable range for all prescribed limits.

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

N/A

d. In what areas are you uncertain about the legal or regulatory frameworks you'll need to comply with? This could include anything from local governance to international treaties. For some types of projects, we recognize that clear regulatory guidance may not yet exist.

We have been advised by the EPA that we must satisfy both ourselves and the local county council where the material will be spread that the material is a product, not a waste. Our counsel has advised that the material is a product, and discussions are arranged with the relevant councils to seek their input, and we expect an outcome during Q2 2022.

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)

N/A

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*	2000tCO_2 (2022tCO_2 less a buffer of 22tCO_2)
Delivery window *at what point should Stripe consider your contract complete?*	March-September 2024
Price (\$/metric tonne CO_2) ***Note on currencies:*** *while we welcome applicants from anywhere in the world, our purchases will be executed exclusively in USD (\$). If your prices are typically denominated in another currency, please convert that to USD and let us know here.*	USD280/tCO_2

Application Supplement: Surface Mineralization

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

Source Material and Physical Footprint (Criteria #1 and #8)

1. What source material are you using, and how do you procure it?

We use surplus-to-requirements concrete from the construction sector. We source this material from concrete producers, process it to agricultural lime specifications, transport it to farms, and spread it on agricultural land. Twenty billion tonnes of concrete are produced globally per year. Approximately 2-5% of this annual concrete production is returned to mixing plants undelivered (400-1,000 million tonnes) to be landfilled or sold as low-value fill. We estimate that Ireland produces 300,000 tonnes of returned concrete per year (2.5% of 12

million tonnes concrete produced; ICF 2019). This recurring supply is in addition to existing stockpiles of returned concrete, which is currently not used as a carbon removal solution.

2. Describe the ecological impacts of obtaining your source material. Is there an existing industry that co-produces the minerals required?

PRC is a repurposed product from the construction sector. No additional ecological impacts arise during its production beyond the minor carbon dioxide emissions associated with processing prior to landspreading. Synthetic minerals such as portlandite and calcium silicates in PRC are thermodynamically unstable in the presence of soil carbonic acid and weather to produce stable bicarbonate and calcium ions. The ecological impact on groundwaters and soils is minimal and the pH shift is beneficial for acidic soils. In essence, waters of medium hardness are produced and soil pH is not increased to harmful levels when Silicate's recommended application rates are followed.

3. Do you process that source mineral in any way (e.g. grinding to increase surface area)? What inputs does this processing require (e.g. water, energy)? You should have already included their associated carbon intensities in your LCA in Section 6.)

We process the source material by milling, not so much to increase specific surface area which is already relatively high (c. 10m2/g), but rather to meet the specifications set out by regulations for agricultural lime (e.g., >70% by mass with a grain size < 1mm). This processing is also necessary to ensure even spreading of the material on the land surface using existing agricultural infrastructure and machinery (e.g., lime spreaders). No water is required, the material will be dry-milled by our supplier. We estimate in our LCA that the processing of returned concrete to specification for this 2,000CO_2/y proposal would cause 2.2tCO_2e to be emitted.

4. Please fill out the table below regarding your project's physical footprint. If you don't know (e.g. you procure your source material from a mining company who doesn't communicate their physical footprint), indicate that in the square.

	Land area (km^2) in 2021	**Competing/existing project area use (if applicable)**
Source material mining	N/A	N/A
Source material processing	N/A (material is waste product from the construction sector)	Low-value fill, recycled concrete, de-aggregated concrete,

		stockpiled for further, undetermined, use
Deployment	For this 2,000tCO_2 proposal, we would expect to deploy the material on 1,000 hectares of arable land	Use of PRC as a liming agent does not preclude the use of that land for agricultural production. There is no competing project area use, and the existing project area use is compatible with our proposal

1. Imagine, hypothetically, that you've scaled up and are sequestering 100Mt of CO_2/yr. Please project your footprint at that scale (we recognize this has significant uncertainty, feel free to provide ranges and a brief description).

	Projected # of km^2 enabling 100Mt/yr	**Projected competing project area use (if applicable)**
Source material mining	N/A	N/A
Source material processing	N/A (material is waste product from the construction sector)	Low-value fill, recycled concrete, de-aggregated concrete, stockpiled for further, undetermined, use
Deployment	For this 100MtCO_2 proposal, we would expect to deploy the material on 50 million hectares of arable land. Though this number represents about 1% of agricultural land globally, we anticipate being able to achieve significant efficiencies across our process that could lower the land use requirements, over time. These efficiencies could come from the unit gross capacity, which would potentially permit an increase in the sequestration of carbon per unit area, or from the amount of material applied to each hectare, as certain areas of land, such as bogs, certain forests, or degraded agricultural land, could permit a higher	Use of PRC as a liming agent does not preclude the use of that land for agricultural production. There is no competing project area use, and the existing project area use is compatible with our proposal

	application rate, which would therefore lower the land use requirements of the 100MtCO_2/y scale project	

5. If you weren't proceeding with this project, what's the alternative use(s) of your source material? What factors would determine this outcome? *(E.g. Alternative uses for olivine include X & Y. It's not clear how X & Y would compete for the olivine we use. OR Olivine would not have been mined but for our project.)*

> Engineering codes preclude the reincorporation of PRC as aggregate in new concrete in many jurisdictions. These regulations, as well as other factors, such as the difficulty in reusing concrete in buildings due to safety concerns because of the higher heterogeneity, porosity and lower strength compared to natural aggregates, result in wide-scale availability of this highly weatherable alkaline material that is often landfilled or sold as a low-value construction fill.

Measurement and Verification (Criteria #4 and #5)

6. We are aware that the current state of the field may include unknowns about the kinetics of your material. Describe how these unknowns create uncertainties regarding your carbon removal and material, and what you wish you knew.

> Unknowns include how weathering kinetics are influenced by: (A.) soil-type characteristics and (B.) application rates/methods.
>
> A. Unknowns related to soil-type include the influence of: pre-existing soil pH, organic and carbonate content, nutrient status, variable incorporation depth in the soil profile. Our data indicate soil pH increases of about 0.5 pH units for weakly acidic soils (6.0), given a 10t/ha application. In our field trial, strong acid weathering was not important, but this will have to be checked for other sites that may have been farmed more intensively in the past (higher nitrate loadings). The possible effect of the material on the generation of other GHGs such as N_2O in high-nitrate soils also needs investigation.
>
> B. Unknowns related to application rates and methods include, for example, the relative efficacy of once-off heavy applications versus periodic lower applications. The effect of depth of incorporation in the soil profile is also potentially important because it is likely to be most efficacious when incorporated at depths corresponding to highest soil CO_2 partial pressures, in turn related to plant rooting depths. Multivariate analyses, based on data from pot and field trials will be used to construct algorithms to optimise application rates/methods.

7. If your materials are deployed extensively, what measurement approaches will be used to monitor weathering rates across different environments? What modeling approaches will be used, and what data do these models require?

First, soil water chemistry (monthly using soil-water suction samplers) will be used to quantify the geochemical responses (dissolved bicarbonate, calcium and magnesium) in amended vs. unamended plots. Model-based soil water fluxes (evapotranspiration-corrected rainfall) will be used to compute downward fluxes of captured carbon (as cation-balanced bicarbonate). These will be supplemented by measurements of leachable calcium, coupled with a weathering stoichiometry model to compute mineral (e.g., portlandite) weathering rates.

Second, soil-to air CO_2 gas fluxes will be measured monthly using soil flux-chambers.

The water-derived fluxes will serve as input parameters for our geochemical model while the soil-gas flux data will be used for model validation.

Human and Ecosystem Impacts, Toxicity Risk (Criteria #7)

8. What are the estimated environmental release rates of heavy metals (e.g. Cr, Ni, Pb, Hg)? Dust aerosol hazards? P loading to streams? How will this be monitored?

Based on the known geochemistry of the PRC material, coupled with our existing data for shallow soil waters (monthly monitoring of soil waters at 8 sites since July 2021), we do not anticipate detectable releases of heavy metals. Our data for soil waters at amended sites show that Ni and Cr, commonly associated with olivine weathering are below detection ICP-MS detection limits (<1ppb). Similarly, dissolved aluminium levels are exceedingly low (<1ppb in soil waters). Phosphorus levels in soil waters from amended sites are below the c. 0.1ppm detection limit of the ion-chromatography system used to monitor dissolved anions and is likely to be taken up by crop plants. Similarly, dissolved fluoride levels in the soil waters are low (<0.7ppm). Sulphate levels, presumably from gypsum dissolution are moderately elevated in some soil waters (up to 40ppm), but are not considered problematic because sulphate is a required nutrient element for plants.

9. If minerals are deployed in farmland, what are the estimated effects on crop yields, what's this estimation based on, and how will actual effects be monitored?

PRC will have beneficial effects on crop health and growth at recommended application rates. Major element analysis of PRC indicates 17.3 wt% silica, 43.4 wt% CaO, 1.46 wt% MgO, 0.4 wt% K_2O and trace phosphorus (0.05 wt% P_2O_5). Silicon in PRC is hosted by relatively soluble calcium silicates which should release bioavailable silica in soil waters, known to strengthen cereal plants. Nutrient elements such as potassium (K) and trace phosphorus (P) are important. Crop yields on amended vs. unamended plots will be monitored in collaboration with landowners using GPS-enabled yield monitors on combine harvesters.

10. How will you monitor potential impacts on organisms in your deployment environment? (E.g. Health of humans working in agricultural contexts, health of intertidal species, etc. depending on the context of deployment)

PRC contains no harmful minerals. When processed to meet the specifications for agricultural lime (70% <1mm) it can be spread on the land surface with the usual precautions observed by agricultural workers. The health of macro- and micro-fauna in the amended soils will be monitored by comparing populations (e.g., earthworm counts) in adjacent treated and untreated plots. Microbial health will be monitored through standard DNA- and RNA-based approaches to monitor changes in microbial populations in treated versus untreated plots. Results from field trials do not indicate any obvious detrimental effects, but the microbial work has yet to commence.

11. If you detect negative impacts, at what point would you choose to abort the project and how?

Based on field trials in 2021/22, and very low heavy metal loading, negative impacts are not anticipated. We are confident that the gross values demonstrated up to now can be improved significantly through optimisation of weathering rates. This will include the development of algorithms to tune application rates according to soil type (e.g., soil pH, organic content etc). We do not anticipate any circumstances in which the project would be aborted; instead the methodology will be tuned as necessary to achieve the desired results, based on geochemical and ecological data from ongoing experiments, geochemical modeling and algorithm development.