Frontier

Inplanet GmbH

Carbon Dioxide Removal Purchase Application

Fall 2022

General Application - Prepurchase

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

Company or organization name

Inplanet GmbH

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

Brazil (Piracicaba)/Germany (München)

Name(s) of primary point(s) of contact for this application

Felix Harteneck, Dr. Philipp Swoboda, Dr. Elisabete Trindade Pedrosa, Niklas Kluger

Brief company or organization description

We employ enhanced weathering in the tropics by connecting farmers, mines and the global carbon market with the goal to sequester 1 Gt of CO_2 and regenerate degraded tropical soils.

1. Project Overview[1]

a. Describe how the proposed technology removes CO_2 from the atmosphere, including as many details as possible. Discuss location(s) and scale. Please include figures and system schematics. Tell us why your system is best-in-class, and how you're differentiated from any other organization working on a similar technology. <1500 words

Enhanced weathering on highly weathered soils in the tropics
The weathering of silicate rocks naturally consumes CO_2, a process that regulates the global carbon cycle and the earth's climate (Source, Source). This regulation occurs due to the consumption of CO_2 during the dissolution of silicate rocks, a reaction that produces bicarbonate ions (HCO_3^-) and alkaline-earth-metal ions (e.g. Ca^{2+}, Mg^{2+}, Na^+). The bicarbonate ions are washed out into the rivers and

[1] We use "project" throughout this template, but note that term is not intended to denote a single facility The "project" being proposed to Frontier could include multiple facilities/locations or potentially all the CDR activities of your company

oceans, where they eventually accumulate as carbon rich sediment, remaining stable for thousands of years (Source). Naturally, silicate rock weathering is too slow to counteract the current CO_2 emission rates (Source). Enhanced weathering aims to accelerate this natural process by grinding the rocks and applying them onto soils, which exposes more surface area of the rocks to react faster (Source, Source, Source). Enhanced weathering is also taking advantage of the naturally higher CO_2 gradients in the soil.

At Inplanet, we focus on applying silicate rock powder on agri- and silvicultural land in regions where the potential for increased weathering rates is highest: the tropics. This practice can restore degraded soils, and has various ecological benefits for humans and wildlife. It guarantees future food security (Source, Source), and allows for impactful socio-economic capacity building (Source). Our solution connects farmers and mines with the global carbon market to accelerate the transition to a low carbon, nature based, and regenerative tropical agriculture.

Entry market and potential for tropical enhanced weathering
Our entry market is Brazil, a country that offers a vast mining infrastructure, access to clean renewable energy (Source), and optimal edaphoclimatic conditions for effective and fast weathering (Source). We estimate that by 2050, Brazil has a sequestration potential of 200-250Mt CO_2eq per year at a rock powder consumption of 1-1.5 Gt/year. In the long-term, we plan to apply our solution to all addressable agricultural areas in the tropics, unlocking a potential of 1-1.5 Gt CO_2eq/year (Source), with an estimated rock powder demand of 5-8 Gt/year.

Inplanet as pioneer and catalyst in the tropics
Brazil has a long history of research related to the use of rock powders in agriculture (Source). However, the market remains far behind its potential as incentives for mass adoption of rock powder fertilization (in Brazil usually referred to as *rochagem)* are missing. Until now, scientists have focused on agronomic benefits and almost no research has been conducted about its carbon sequestration potential. At Inplanet, we are tackling this knowledge gap and aim to create the missing incentives for its mass adoption by acting as the pioneers and catalysts for enhanced weathering carbon credits, initially in Brazil and later the global tropics.

Our efforts are focussed on understanding the particularities of tropical soils (low pH, silica depletion, low orgC content), interacting with a range of rock powders (basalt, kamafugite, serpentinite, phyllite), and weathering accelerators (fungi, bacteria, biochar and organic composts). We are developing the most comprehensive model for tropical enhanced weathering projects, considering not only the full project life cycle, rock powder type, soil conditions and climate, but also the type of crop and management system the rock powder is applied to. Thereby, we will predict and validate the weathering potential with high precision. All our calculations are cross checked with measurements from the field as well as high-tech field monitoring stations (FMS) in various university locations. We create a synergy between miners and farmers, adding value to mining materials otherwise considered as waste, and provide an alternative to expensive conventional fertilizers to farmers. Inplanet is developing software tools that allow for simple logistics prediction, a practical operations verification process, and an easy visualization of the financial advantages that farmers acquire after transitioning to rock powder fertilization (see Figure 1).

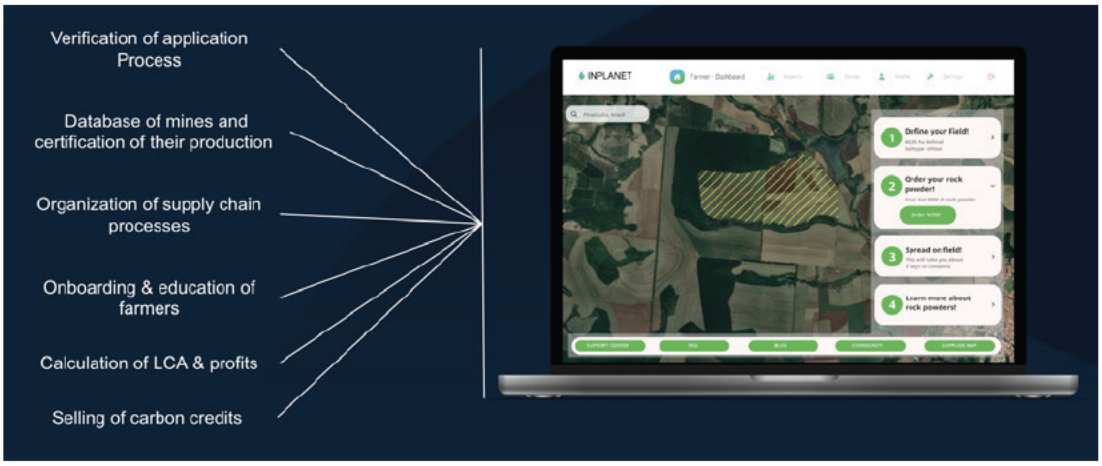

Fig. 1: Mockup of the Inplanet platform

Restoring pasture and removing carbon dioxide
About 170 million hectares of pastures in Brazil were considered degraded in 2017 (Source). Our project proposal presents an economically and environmentally viable case for regeneration and fertilization of these often neglected areas (Source). For the specific purpose, we want to apply 8000t of silicate rock powder on degraded pasture land. The targeted areas are located in the state of São Paulo within a radius of 25-50km around a mine in the municipality of [redacted]. Our primary MRV is performed using a high tech field monitoring station (FMS) developed in collaboration with experts at the Higher School of Agriculture "Luiz de Queiroz" of the University of São Paulo (ESALQ/USP) and at the School of Natural and Environmental Sciences in Newcastle University (UK).

Summary
Inplanet implements enhanced weathering in the tropics where climatic , soil and socio-economic conditions are particularly favorable. We offer the most comprehensive, full stack solution for project planning, implementation and verification through our software platform that connects farmers and mines with the local carbon market. Rigorous MRV is achieved by a combination of field-covering soil sampling with high-tech field monitoring stations. After having tapped the Brazilian market potential, we intend to expand our activities to the global topical belt to unlock a carbon removal potential of up to 1 Gt/year through the use of silicate rock powders in agriculture and silviculture.

b. What is the current technology readiness level (TRL)? Please include performance and stability data that you've already generated (including at what scale) to substantiate the status of your tech. <500 words

Our technology is TRL5 to TRL6. Compared to past studies looking at enhanced weathering (Source), advances have occurred regarding technology development and demonstration. Furthermore, we already have developed a series of subsystems including calculation of weathering curves, mapping of relevant mine networks and rock powder sources in Brazil, modeling of project economics, modeling of impact on farm level and building of an automated life cycle impact engine. These Subsystems have been applied to a range of pilot projects throughout Brazil, adding up to more than 100ha with more than 1000t of rock powder applied (see our project map). Our platform is currently under development with a beta version planned for Q3/2023.

We are collaborating with two of the leading agricultural universities in Brazil on the implementation of field monitoring stations, greenhouse experiments and lab trials with the goal to deliver precise data for the quantification of enhanced weathering under tropical field conditions. This globally unique partnership has been built since the beginning of 2022 among leading researchers including Antonio Azevedo, David Manning and Suzi Theodoro Huff. Moreover, we built a network of public and private entities who research rock powders in Brazil (Embrapa, [redacted], ABREFEN, Reminera, [redacted] etc.) with the goal to integrate the field data from various biomes and rock powder trials into our model. Through the quantity of data streams and a significant increase in pilot activities we expect a full calibration of our models within the next three to five years.

c. What are the key performance parameters that differentiate your technology (e.g. energy intensity, reaction kinetics, cycle time, volume per X, quality of Y output)? What is your current measured value and what value are you assuming in your nth-of-a-kind (NOAK) TEA?

Key performance parameter	**Current observed value (units)**	**Value assumed in NOAK TEA (units)**	**Why is it feasible to reach the NOAK value?**
Emissions of rock powder production	5,4 kgCO2eq/t	2,7 kgCO2eq/t	Improved rock comminution technology, increased availability of renewable energy, e.g. we observed various installations of solar power by mines themselves
Emissions of rock powder transport	0,0609 kgCO2eq/tkm	0,0409 kgCO2eq/tkm	Modernizing of the Brazilian transport sector, hydrogen powered vehicles in the long run may even lover that footprint further
Efficiency of rock powder distribution	10 t/h	25 t/h	Larger machinery available for rock powder spreading, improved efficiency of spreading operation
Weathering rate	Fully dependent on local climate and soil, no blends used	Improved through optimized blends e.g. with microorganisms, biochar, etc	Creating optimal blends to improve weathering rates is an ongoing field of research (Source, Source)
Reduction of synthetic farming chemicals (pesticides, chlorides, etc.)	0%	25-75%	The reduction of synthetic agrochemicals after rock powder application is a gradual process. Depending on the soil, climate and crop combination farmers observed a 25-75% reduction of conventional farming inputs while increasing yield.
Reduction of limestone	full substitution	full substitution	We fully substitute limestone through silicate rock powders today and in the future on all project areas. Through fast tropical weathering and greater application rates we can create the same effects in tropical soils (pH increase, Ca^{2+} provision).

			Silicate rock powders furthermore address widespread micronutrient deficiencies that are not remedied by limestone.
Yield increase	20-50%	20-50%	Yield increase in the indicated range has been observed in various studies and has been confirmed by many pioneering farmers we interviewed in Brazil.

d. Who are the key people at your company who will be working on this? What experience do they have with relevant technology and project development? What skills do you not yet have on the team today that you are most urgently looking to recruit? <300 words

Our core team is made up of **Felix Harteneck (CEO/Co-Founder)**, **Niklas Kluger (COO/Co-Founder)**, **Dr. Elisabete Trindade Pedrosa (Head of Science)** and **Dr. Philipp Swoboda (Research Lead)**.

Felix is a serial entrepreneur who already founded two software companies, one in agriculture and one in mobility. His skills in strategy and business development are outstanding and resulted in him winning a set of awards, inter alia, Project Morgenstadt (Fraunhofer Institute), Spark Award (Handelsblatt & McKinsey), IKT Innovativ Preis, and EXIST (both German Ministry of Economics and Energy). He has a valuable network of impact investors and was able to secure growth capital in the order of millions from renowned investors (e.g. Swarovski, Quandt, Getty). In 2019, the German Chancellor Angela Merkel visited his startup ParkHere to understand and discuss the needs of the startup ecosystem for sustainability in Europe.

Niklas is an environmental engineer with a master degree in natural resource management. He worked at INFARM in Berlin and helped scaling the urban farming operations from local to global. During the last years, Niklas has developed a profound knowledge of the reality of tropical agriculture in Brazil while working with several NGOs and farmers in the country. Before founding Inplanet, he received various scholarships (DAAD, Deutschlandstipendium) for his agricultural research in the northeast of Brazil. He speaks fluent Portuguese, and has the necessary network to quickly enter the Brazilian market for enhanced weathering.

Elisabete is our head of science with a profound understanding of the dissolution kinetics of minerals. She has been researching geochemical processes for more than 10 years and consequently developed ample knowledge of analytical methods (e.g., SEM, XRD, EMPA, AFM, ICP-OES) and modeling software like PhreeqC. She is one of the few researchers worldwide who have primary experience on ERW field experiments due to her participation in the Carbdown field trial from the Carbon Drawdown Initiative (Source).

Philipp has been researching rock powders and agricultural emissions for 8 years in collaboration with leading experts worldwide and has written the most comprehensive review on rock powders in agriculture currently available (Source). Due to his science communication skills (winner of various science slams) and his ability to maintain clarity while navigating through the ample topics related to enhanced weathering, he is leading the conceptualization and implementation of new scientific experiments with the goal to validate and calibrate our models.

Open Positions

We are looking for talent in Brazil to quickly reach the capacity to run Mt CO2seq. Operations and are currently growing our team in the areas modeling, product development and software engineering.

e. Are there other organizations you're partnering with on this project (or need to partner with in order to be successful)? If so, list who they are, what their role in the project is, and their level of commitment (e.g., confirmed project partner, discussing potential collaboration, yet to be approached, etc.).

Partner	Role in the Project	Level of Commitment
University of São Paulo/ESALQ & University of Brasília	MRV and Research Partnership	partnership agreement signed
Puro.Earth & Carbonfuture	Development and testing of methodologies for enhanced weathering	partnership agreement signed
[redacted]	[redacted]	[redacted]
Farmers within 100km radius from our mine in [redacted] SP	Farmers own degraded pasture that requires regeneration	approx. 80% of project area secured in LOIs

f. What is the total timeline of your proposal from start of development to end of CDR delivery? If you're building a facility that will be decommissioned, when will that happen? <30 words

The rock powder for this proposal will be applied in Q1 and Q2 2023. We defined an MRV period of 5 years for this project. We suggest that delivery will be 50% activity based (e.g. verified spreading) and 50% results based (e.g. sampling).

g. When will CDR occur (start and end dates)? If CDR does not occur uniformly over that time period, describe the distribution of CDR over time. Please include the academic publications, field trial data, or other materials you use to substantiate this distribution. <100 words

Over the next 10 years (Figure 2): The Carbon Removal potential is based on models from leading researchers (Source, Source). We extrapolated the weathering progression of Source, and assumed slightly higher dissolution rates due to our favorable tropical conditions. Actual weathering rates based on MRV will vary and lead to a different weathering curve. Through comprehensive biogeochemical measurements and climate observations we will adjust the modeled expectations to the actual verification. We will accumulate the residual potential after five years of MRV as the low removal percentages after 2028 do not justify the cost and effort for MRV anymore.

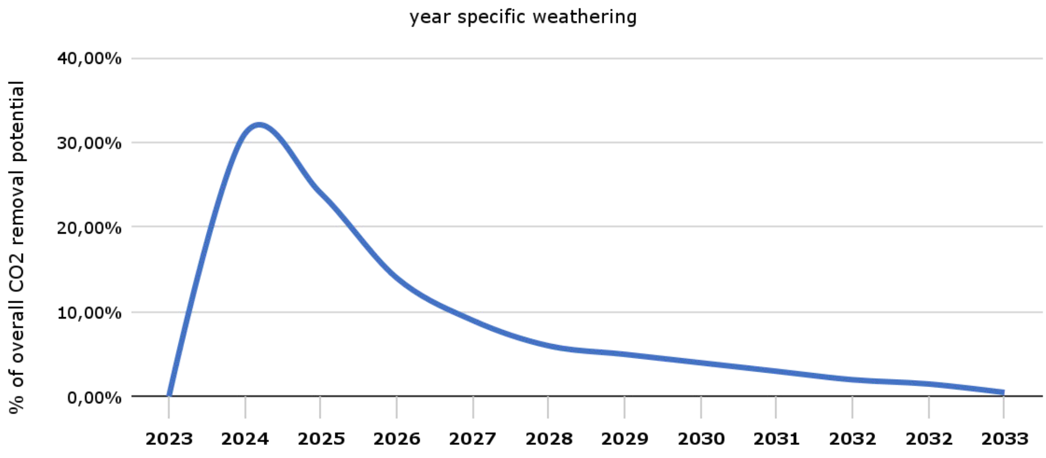

Figure 2: Expected CO2 removal in the first 10 years of the project (assuming complete mineral weathering until 2033).

h. Please estimate your gross CDR capacity over the coming years (your total capacity, not just for this proposal).

Year	Estimated gross CDR capacity (tonnes)
2023	20.000
2024	150.000
2025	350.000
2026	800.000
2027	1.500.000
2028	3.000.000
2029	6.000.000
2030	18.000.000

i. List and describe at least three key milestones for this project (including prior to when CDR starts), that are needed to achieve the amount of CDR over the proposed timeline.

	Milestone description	Target completion date (eg Q4 2024)
1	Onboard farmers with degraded pasture, oxisols in the municipality of [redacted] (approx. 80% committed already)	Q4 2022
2	Implement MRV field monitoring station at University of São Paulo	Q1 2023
3	Deliver 8000t of basalt rock powder to farmers and verify spreading	Q1/Q2 2023
4	Do MRV based on field monitoring station + yearly field sampling	yearly in Q1 until 2028

j. What is your IP strategy? Please link to relevant patents, pending or granted, that are available publicly (if applicable). <200 words

We have exclusive access to data and measurements from the first of its kind tropical field monitoring station at University of São Paulo, ESALQ. This allows us to gain a unique understanding about the weathering of basalt in South American oxisols. Additional field monitoring stations are planned in other locations throughout Brazil, each one representing a specific climate-soil-crop-rock powder nexus for a precise MRV. Tropical soils are inherently different from those found on the northern hemisphere and existing models will need to be adjusted for the tropics.

Part of our IP strategy includes long term farmer contracts to bind the farmer to a rock powder fertilization scheme, and simultaneously offer expert guidance for reducing the use of conventional chemical inputs. We are developing the right tools for farmers that bundle relevant information, allow for a lean project planning and verification process as well as access to our valuable network of mines.

We are already building a Brazilian (and later an intratropical) network of mines and quarries that can deliver the required rock powder amounts for our carbon sequestration goals. We want to close exclusive distribution partnerships to enable new revenue streams for mines with secure future demand.

k. How are you going to finance this project? <300 words

We have already closed a first investment round with leading Impact Investors, inter alia, Katapult VC from Norway. With our proposal we got approved after competing with 1900 applications and are now participating in their exclusive impact accelerator program. Moreover, we are supported by grants from the European Union through the first European CDR ClimAccelerator and MRV grants to our partner universities from the Grantham Foundation. Besides investments and grants we are also working with a number of sales platforms (e.g. Thallo) and customers that are interested in direct purchase of carbon removal from enhanced weathering projects in Brazil [redacted]

l. Do you have other CDR buyers for this project? If so, please describe the anticipated purchase volume and level of commitment (e.g., contract signed, in active discussions, to be approached, etc.). <200

This specific project proposal was exclusively made to the Frontier Climate Fund.

m. What other revenue streams are you expecting from this project (if applicable)? Include the source of revenue and anticipated amount. Examples could include tax credits and co-products. <200 words

Besides the revenue from carbon removal credits, there are no intended additional income streams for this project.

n. Identify risks for this project and how you will mitigate them. Include technical, project execution, ecosystem, financial, and any other risks.

Risk	**Mitigation Strategy**
Use of inappropriate rock powder	Exclusive application of rock powders that are certified according to the Brazilian laws 6.894, of 1980, and 12.890, of 2013, following the normative instruction no. 05 of 2016, issued by EMBRAPA and the Ministry of Agriculture (MAPA).
Availability of rock powder	Close a partnership with a mine that has sufficient stock of mining residue to produce required rock powder amount [redacted]
Availability of spreading equipment	Conducting pilot activities prior to this proposal and checking availability of spreaders in our target municipality. We time the spreading operations between soybean and corn harvest cycles to make use of a time with low competition for agricultural implements.
Disinterest of farmers to regenerate their pasture	Conducting interviews and hypothesis testing prior to project proposal plus signing letters of intent with interested farmers.
Uncertainty about the actual carbon removal rates in the field	Working with the most conservative approach possible, reducing the theoretical potential based on the full discount of all uncertainty factors and leakage.
Health risk from breathing fine rock powder particles	The mine in [redacted] does fulfill all environmental and health standards according to Brazilian law and is regularly inspected. Additionally, the rock powder is produced with 5-10% humidity, this way improving loss during handling and reducing the dust plume while spreading. Moreover, all our pastures are within a distance of 1km of urban centers.

2. Durability

a. Describe how your approach results in permanent CDR (> 1,000 years). Include citations to scientific/technical literature supporting your argument. What are the upper and lower bounds on your durability estimate? < 300 words

Once CO_2 is removed from the atmosphere, durability will depend on the fate of the weathering products. The products of weathering will be in the form of dissolved bicarbonate (HCO_3^-), and cations such as sodium (Na^+) and calcium (Ca^{2+}). Calcium tends to adsorb to soil particles, whilst Na^+ and HCO_3^- tend to be more mobile. In low CEC (cation exchange capacity) and low pH soils, mobile ions such as HCO_3^- tend to leach into groundwaters and then rivers, which is the case of our target soils (oxisols). **We expect that only about 5% of the HCO_3^- will be consumed by biogeochemical processes directly in the soil, while the remaining 95% will leach out to ground- and surface waters** (Source).

It is estimated that as much as 45% of the world's carbon transfer from terrestrial ecosystems is lost in streams and rivers, but all is accounted for from organic carbon sources. The durability of bicarbonates coming from weathering in rivers is unknown (Source). We know however, that dissolved inorganic carbon (DIC) loss via CO_2 degassing mostly occurs in very acidic (< 4.4) catchments, which rarely occur in nature. Additionally most naturally occurring river beds consist of silicate rock, which decreases the chances for further losses. **Thus, we assume that an inorganic leakage through degassing would be between 5-10%.**

Overall, we consider that as much as **90%** of the DIC produced by enhanced weathering could reach the oceans, where **durability is above 10.000 years** (Source).

b. What durability risks does your project face? Are there physical risks (e.g. leakage, decomposition and decay, damage, etc.)? Are there socioeconomic risks (e.g. mismanagement of storage, decision to consume or combust derived products, etc.)? What fundamental uncertainties exist about the underlying technological or biological process? <200 words

As mentioned above, when bicarbonates and the rest of dissolved inorganic carbon (DIC) reach surface waters (rivers and lakes), leakage through degassing of CO_2 can occur. This is inherent to the global carbon cycle and cannot be controlled. Nevertheless, it is estimated to be much lower than the expected sequestration (Source).

The greatest challenge is to understand the precise speed of the rock weathering in the soil. Although it is proven that silicate rock sequesters CO_2, site-specific weathering rates still have to be determined and verified by field measurements. Heat, water, microorganisms, fungi and plants (Source) can accelerate the weathering process, which we will quantify for various soil and rock powder combinations in the tropics.

A socioeconomic risk when scaling enhanced weathering to the Gt is the demand for rock powder based on the application rate per hectare. If applying 10t of basalt on all agricultural land in Brazil, this will require moving Gt of rock powder. The resulting pressure on transport infrastructure, road networks and truck availability will be enormous. We believe that some viable application amount

exists so that carbon sequestration can be maximal while the burden for the additional necessary infrastructure is minimal.

3. Gross Removal & Life Cycle Analysis (LCA)

a. How much GROSS CDR will occur over this project's timeline? All tonnage should be described in **metric tonnes** of CO_2 here and throughout the application. Tell us how you calculated this value (i.e., show your work). If you have uncertainties in the amount of gross CDR, tell us where they come from.

Gross tonnes of CDR over project lifetime	1128 tCO_2eq.
Describe how you calculated that value	We will distribute 8000t of basalt rock powder originating from a mine in [redacted] São Paulo state, Brazil with these chemical properties. The enhanced weathering potential (Epot) in tCO_2/t of rock powder was calculated according to (Source): $$E_{pot} = \frac{M_{CO_2}}{100} \cdot \left(\alpha \frac{CaO}{M_{CaO}} + \beta \frac{MgO}{M_{MgO}} + \varepsilon \frac{Na_2O}{M_{Na_2O}} + \theta \frac{K_2O}{M_{K_2O}} + \gamma \frac{SO_3}{M_{SO_3}} + \delta \frac{P_2O_5}{M_{P_2O_5}} \right) \cdot 10^3 \cdot \eta,$$ (Mx are molar masses, greek coefficients are relative contributions, and XOx are observed concentrations). η is the molar ratio of CO_2 to divalent cation sequestered during enhanced weathering, which stoichiometrically is 2 for most silicates. We apply a more conservative value of 1.5. Additionally, we discount another 32% from this potential due to uncertainties as discussed in the MRV section 4c., leading to a potential sequestration of 0,141 tCO_2eq/t basalt powder. (8000*0,141=1128)

b. How many tonnes of CO_2 have you captured and stored to date? If relevant to your technology (e.g., DAC), please list captured and stored tons separately.

Until now we have created a 140-200t CO2 removal potential for the next few years through the application of 1000t of different rock powders throughout Brazil (see our project map). Separating between capture and storage does not apply for enhanced weathering. Once the rock powder is spread, the point of no return is reached. From that moment on, capture and storage processes happen simultaneously and cannot be directly controlled. Weathering itself can be further enhanced, e.g. the use of different crops or blends, but this is not within the scope of this project because we will first and foremost focus on restoring degraded pasture land.

c. If applicable, list any avoided emissions that result from your project. For carbon mineralization in concrete production, for example, removal would be the CO_2 utilized in concrete production and avoided emissions would be the emissions reductions associated with traditional concrete production. Do not include this number in your gross or net CDR calculations; it's just to help us understand potential co-benefits of your approach.

The use of basaltic rock powder can substitute limestone for soil amelioration and can be used as partial substitute for chemical fertilizers (Source). Thereby, it can avoid emissions along the supply chain of these products and on field level. In addition, rock powder fertilization tends to improve soil organic carbon stabilization and increases the above ground biomass production (Source). We do not consider any of these co-benefits in our carbon balance as we are only interested in selling carbon removal that is part of the long carbon cycle (Source).

d. How many GROSS EMISSIONS will occur over the project lifetime? Divide that value by the gross CDR to get the emissions / removal ratio. Subtract it from the gross CDR to get the net CDR for this project.

Gross project emissions over the project timeline *(should correspond to the boundary conditions described below this table)*	107 $tCO_2eq.$
Emissions / removal ratio *(gross project emissions / gross CDR–must be less than one for net-negative CDR systems)*	0,105
Net CDR over the project timeline *(gross CDR - gross project emissions)*	1021 $tCO_2eq.$

e. Provide a process flow diagram (PFD) for your CDR solution, visualizing the project emissions numbers above. This diagram provides the basis for your life cycle analysis (LCA).

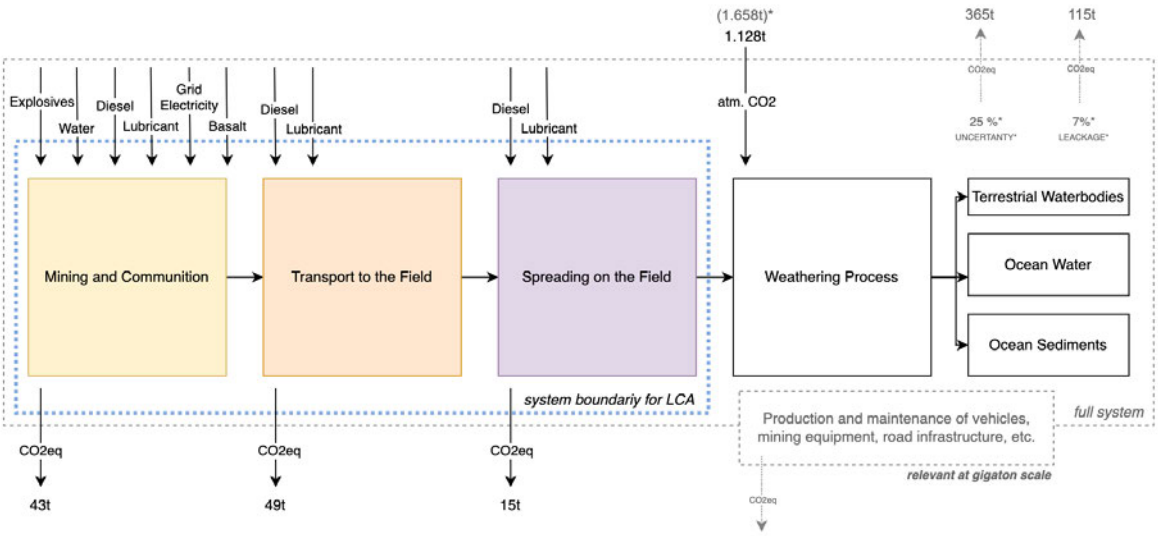

Fig. 3: Process flow diagram for LCA. To view a more detailed process flow see here.

f. Please articulate and justify the boundary conditions you assumed above: why do your calculations and diagram include or exclude different components of your system? <100 words

In our LCA we do focus on mining, transport and spreading as these are the key processes defining the negative climate impacts of enhanced weathering. We exclude the weathering and storage part as these mechanisms need different approaches to be modeled. We also want to avoid overengineering here. For each operation that will generate CDR related to this proposal we will realize a detailed ex-post LCA representing the actual project emissions.

Due to the low rock powder amounts we use for this project our LCA excludes emissions generated by mining equipment or vehicle production. However, we think that regarding these impacts it is relevant, especially when reaching scale and mines/quarries do aquire extra machinery to enhance rock powder storage, production and handling.

Our following LCA combines a combination of scientific literature and measurements based on our pilot activities throughout Brazil. We realized our Life Cycle Assessment in collaboration with the Impact Forecast Platform, including coaching sessions and validation of our assumptions and calculations.

g. Please justify all numbers used to assign emissions to each process step depicted 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.

Process Step	CO_2(eq) emissions over the project lifetime (metric tonnes)	Describe how you calculated that number. Include references where appropriate.
Mining and Crushing	43 tCO2eq.	For this calculation we used the results from (Source) who realized an impact assessment for enhanced weathering in São Paulo. As the conditions described in this article are very similar to the ones in our mine in [redacted] we find the numbers very applicable. We do not consider the extra effort that may apply through additional sieving or grinding of the rock because (1) the article presents one of the most pessimistic results for rock aggregates in scientific literature (5,4 kgCO_2eq/t of aggregate compared to 2.92 Source or 2.2 by Source) and (2) we are using secondary material that has already been mined for construction purposes and are highly conservative by considering the mining impact to this degree.
Transport to Field	49 tCO2eq.	We will work with 46t hauler trucks that carry our rock powder to the locally degraded pasture land. We assumed that all our fields are at a distance of 100km from the mine which is a conservative assumption as we will mainly work with farmers in the municipality where our mine is located. In our calculation we follow the indications for transport >33t with 0,0609 kgCO_2eq/tkm as suggested in the supplement by (Source).
Spreading in Field	15 tCO2eq.	Based on our pilot experiences we calculate with an application capacity of 10t per hour at a consumption of 6l/h (hydraulically controlled implement). The diesel Impact Forecast suggested applying 3,12 kgCO_2eq/l.

4. Measurement, Reporting, and Verification (MRV)

Section 3 above captures a project's lifecycle emissions, which is one of a number of MRV considerations. In this section, we are looking for additional details on your MRV approach, with a particular focus on the ongoing quantification of carbon removal outcomes and associated uncertainties.

a. Describe your ongoing approach to quantifying the CDR of your project, including methodology, what data is measured vs modeled, monitoring frequency, and key assumptions. If you plan to use an existing protocol, please link to it. Please see Charm's bio-oil sequestration protocol for reference, though note we do not expect proposals to have a protocol at this depth at the prepurchase stage. <300 words

> We focus our work on basalt powder applications on degraded pastures with oxisols in the humid subtropical climate of Sao Paulo state, Brazil. This factorial combination provides the highest weathering potential (Source), and the limited primary silicate stock in the soil enables clear ERW signals. We will monitor the sites using self-designed field monitoring stations (FMS). These will be

installed for a soil-crop-climate-rock powder (oxisol-pasture-humid/subtropical-basalt) setting representative for the field application sites.

Operationally feasible rock powder application loads are difficult to monitor due to the low signal-to-noise differences. Thus, the FMS includes a plot representative of the average load spread in the field (Ø 10t/ha) and additional plots with higher loads to create calibration curves for carbon sequestration values specific to the soil, climate and rock type used.

The FMS will collect solid, gas and liquid samples to continuously monitor all relevant parameters using state-of-the art technologies. The resultant data will be used to calibrate reactive transport models (Source, Source). In parallel, low budget easy to use sampling and measurement techniques will be tested in the field aiming at the economic use of these techniques by the farmers in the future.

The FMS is centered around a 3x3 m pit excavated into the soil profile with a 2 m depth (Figure 3). Soil water is collected weekly using rhizon-type and lysimeter-type samplers to analyze instantaneous soil chemistry and calculate leachate flux. The water samples will be analyzed for pH, EC, DIC, TA, inorganic species, nutrients, and DOC. DIC and pH are the most sensitive parameters and will be analyzed directly in the field. Soil samples will be collected annually at several depths and analyzed for mineralogy, particle size, bulk density, saturated hydraulic conductivity, soil water retention, infiltration rate and isotopic analysis.

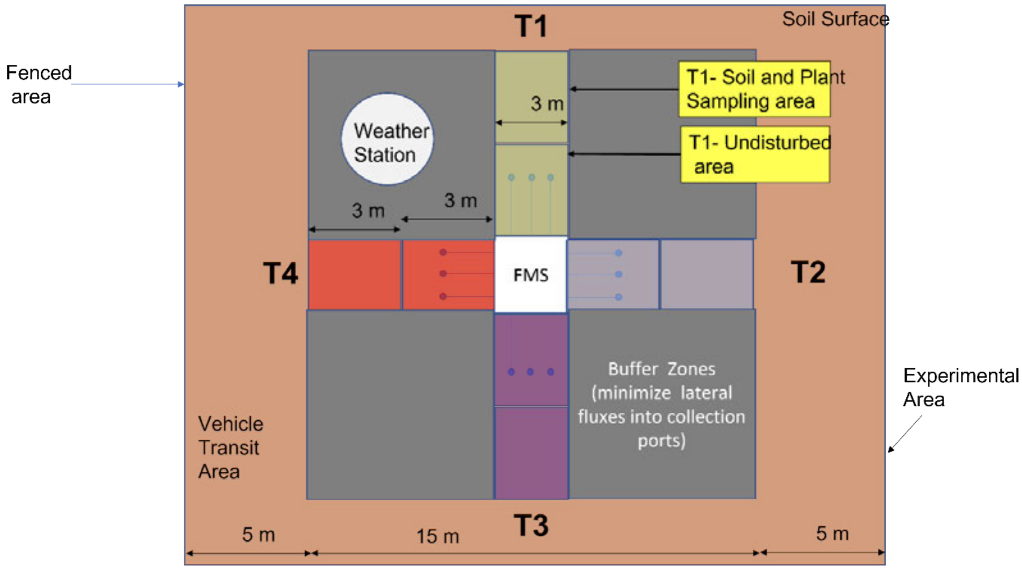

Fig. 4: Field Monitoring Station top view.

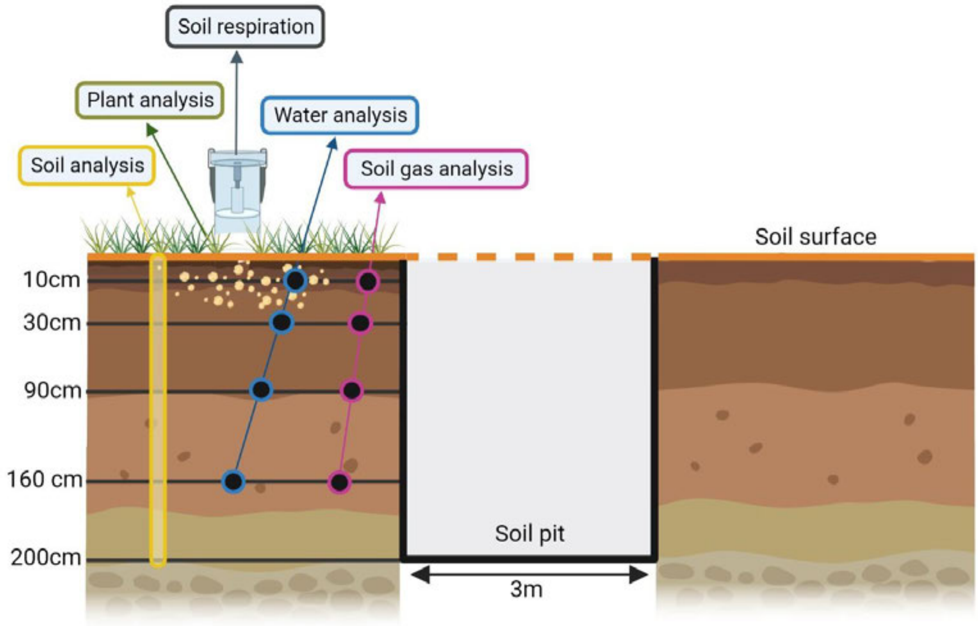

Fig. 5: Field monitoring station side view

b. How will you quantify the durability of the carbon sequestered by your project discussed in 2(b)? If direct measurement is difficult or impossible, how will you rely on models or assumptions, and how will you validate those assumptions? *(E.g. monitoring of injection sites, tracking biomass state and location, estimating decay rates, etc.)* <200 words

Once the sequestered dissolved inorganic carbon (DIC) reaches the ocean, it enters the long-term carbon cycle and the durability exceeds 10^4-10^5 years (Source). Potential efficiency losses of carbon drawdown can occur through three major routes: (1) rock powder stimulated microbial activity (Source), (2) carbonation, and (3) CO_2 emissions along riverine transport to the oceans (Source). We will validate these routes as follows:

(1) Potential losses through stimulated microbial activity (CO_2 ,NO_x and CH_4) will be monitored through gas flux meters installed on the soil surface.
(2) Although carbonation occurrences will be at a minimum in our setting, we will monitor calcium and magnesium carbonate accumulation through biannual soil sampling. Additionally, basalt dissolution will be quantified through mineralogical and isotopic analysis.
(3) Comprehensive direct measurements of potential DIC losses along riverine transport to the oceans is not feasible at this moment and can only be estimated using refined approaches such as the alkalinization carbon-capture efficiency (ACE) (Source). We will gather essential empirical parameters to validate such theoretical approaches, such as DIC speciation, soil pH gradients and overall cation/anion leachate flux.

c. This tool diagrams components that we anticipate should be measured or modeled to quantify CDR and durability outcomes, along with high-level characterizations of the uncertainty type and magnitude for each element. We are asking the net CDR volume to be discounted in order to account for uncertainty and reflect the actual net CDR as accurately as possible. Please complete the table below. Some notes:

- In the first column, list the quantification components from the Quantification Tool relevant to your project (e.g., risk of secondary mineral formation for enhanced weathering, uncertainty in the mass of kelp grown, variability in air-sea gas exchange efficiency for ocean alkalinity enhancement, etc.).
- In the second column, please discuss the magnitude of this uncertainty related to your project and what percentage of the net CDR should be discounted to appropriately reflect these uncertainties. Your estimates should be based on field measurements, modeling, or scientific literature. The magnitude for some of these factors relies on your operational choices (i.e., methodology, deployment site), while others stem from broader field questions, and in some cases, may not be well constrained. We are not looking for precise figures at this stage, but rather to understand how your project is thinking about these questions.
- See this post for details on Frontier's MRV approach and a sample uncertainty discount calculation and this Supplier Measurement & Verification Q&A document for additional guidance.

Quantification component Include each component from the Quantification Tool relevant to your project	**Discuss the uncertainty impact related to your project** Estimate the impact of this component as a percentage of net CDR Include assumptions and scientific references if possible
Mineral application	Uncertainty 2%. Dissolution rate constants might overestimate field kinetics (Source) but biological activity might increase kinetics (Source).
Mineral weathering	Uncertainty 22%. Mineral weathering will be at its almost highest potential since our project encompasses high temperature and high precipitation, highly weathered soils with a high proportion of sand (70%) that favor water percolation (Source). Low pH low cation saturated soils enhance dissolution and reduce secondary mineral formation. Formation of secondary minerals on the rock particles may delay weathering reaction.
Alkalinity loss	Suggestion for alternative of component description: The here provided description of alkalinity refers to the charge-balance definition of alkalinity, which differs from the definition by "acid-neutralization" measurement, known as total alkalinity (TA) by acid titration. In low pH conditions (<5.5) most of the dissolved carbonates will be in the form of molecular gas CO_2. The CO_2 in gas form will not be measured by acid neutralization. Thus, measured TA will not be representative of the total amount of carbonate species in the soil pore waters. This means that measured alkalinity (TA) can only be used as a proxy for ERW if the system is at pH > 6.4. We are focused on acid soils. Thus, using alkalinity as a proxy

	for ERW will hardly apply in our case. Moreover, the loss of cations by secondary reactions does not reduce CO_2 drawdown, but might increase the probability of silicate weathering. Example: the dissolution of the mineral anorthite in the presence of CO_2 can be written as: $CaAl_2Si_2O_8$ (s) + 2 CO_2 (aq) + 3 H_2O (l) ⇔ Ca^{2+} (aq) + $Al_2Si_2O_5(OH)_4$ (s) + 2 HCO_3^- (aq) If the components on the right are removed by other processes in the soil, the reaction will tend to the right. Thus, a loss of soil cations actually favors mineral dissolution by undersaturation, which again increases dissolved CO_2 drawdown via ERW (dissolution of silicate rocks).
Secondary mineral formation	This uncertainty is included in the “mineral weathering” component. The uncertainty of secondary mineral formation does not relate to counteracting alkalinity, but to a reduced dissolution of rock particles on which surfaces secondary minerals precipitate. The formation of secondary minerals (see anorthite dissolution above), is an essential part of weathering and alkalinity generation.
Surficial carbonate precipitation	Uncertainty 1%. In very low pH soils, practically no carbonates are found as they rapidly dissolve. This is the case for oxisols, where even after decades of liming no carbonates are found and fields have to be re-limed every 3-5 years.
Leakage	Uncertainty 7%. The higher the DIC in the soil pore waters that arrive at surface waters the higher is the potential degassing, especially if CO_2 is dissolved but still in molecular form. However, alkalinization carbon-capture efficiency and hydroclimatic-driven scaling of mineral dissolution rates reaches the highest combined efficiency in the subhumid tropics (Source).

d. Based on your responses to 4(c), what percentage of the net CDR do you think should be discounted for each of these factors above and in aggregate to appropriately reflect these uncertainties? <50 words

We added the discount for each factor/component in the table above (4c). The aggregate uncertainty is 32%, and will be discounted from our CDR.

e. Will this project help advance quantification approaches or reduce uncertainty for this CDR pathway? If yes, describe what new tools, models or approaches you are developing, what new data will be generated, etc.? <200 words

One of the major challenges with ERW is the small difference between the enhanced weathering signal and the local and seasonal variability of the parameters used for quantification (e.g. pH, alkalinity, dissolved inorganic carbon). Moreover, these parameters can be influenced by other natural cycles such as nitrogen and biological cycles. We will use state-of-the-art scientific instruments (e.g. colorimetry, chromatography, spectrometry, x-ray) to fully uncover all parameters influencing our system. This will allow us to verify if our target and proxy parameters are influenced by external processes to the carbonic cycle.

The advancement of ERW depends on improving the understanding of (1) fluid-rock-soil interactions and (2) the development of measurement techniques that are economical and easy to use. We will focus part of our activities on (1)), by performing laboratory-controlled experiments, and (2), by developing tools to measure our target parameters directly in the field. For example, we will develop a method for using total alkalinity (TA) as a proxy for dissolved inorganic carbon (DIC) in low pH soils, because TA measurements are easy and cheap in comparison to DIC measurements.

f. Describe your intended plan and partners for verifying delivery and registering credits, if known. If a protocol doesn't yet exist for your technology, who will develop it? Will there be a third party auditor to verify delivery against that protocol or the protocol discussed in 4(a)? <200 words

Our monitoring station(s) will be representative of the soils, plants and climatic conditions used for our ERW projects, which we will complement with soil samples collected annually at each farm to compare soil physicochemical properties with the FMS and measure rock powder dissolution. For verifying the activities of the farmers (delivery, spreading), we developed an App through which farmers can easily upload pictures and pictures of the rock powder delivery and spreading procedure as well as track distribution and sample points via GPS.

For carbon crediting we plan to use one of the methodologies for carbon credits certification currently being developed by Puro Earth and CarbonFuture.

5. Cost

We are open to purchasing high-cost CDR today with the expectation the cost per tonne will rapidly decline over time. The questions below are meant to capture some of the key numbers and assumptions that you are entering into the separate techno-economic analysis (TEA) spreadsheet (see step 4 in Applicant Instructions). 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 work with you to understand your milestones and their verification in more depth.

a. What is the levelized price per net metric tonne of CO_2 removed for the project you're proposing Frontier purchase from? This does not need to exactly match the cost calculated for "This Project" in the TEA spreadsheet (e.g., it's expected to include a margin), but we will be using the data in that spreadsheet to consider your offer. Please specify whether the price per tonne below includes the uncertainty discount in the net removal volume proposed in response to question 4(d).

480 $/tonne CO_2

This price does consider the aggregate uncertainty of 32%.

b. Please break out the components of this levelized price per metric tonne.

Component	**Levelized price of net CDR for this project ($/tonne)**
Capex including 50 % margin	$ 416,5
Opex (excluding measurement)	$ 39
Quantification of net removal (field measurements, modeling, etc.)[2]	$ 24,5
Third party verification and registry fees (if applicable	Not considered and currently unknown
Total	$ 480

c. Describe the parameters that have the greatest sensitivity to cost (e.g., manufacturing efficiencies, material cost, material lifetime, etc.). For each parameter you identify, tell us what the current value is, and what value you are assuming for your NOAK commercial-scale TEA. If this includes parameters you already identified in 1(c), please repeat them here (if applicable). Broadly, what would need to be true for your approach to achieve a cost of $100/tonne?

Parameter with high impact on cost	**Current value (units)**	**Value assumed in NOAK TEA (units)**	**Why is it feasible to reach the NOAK value?**
Price of rock powder per ton	25 USD	10 USD	Distribution partnerships, purchase agreements for large volumes and an expected increase of production efficiency will reduce the price significantly. [redacted]
Cost and distance of transport	Ø 250* km distance and freight cost of 0.09 $/t/km	Ø 100 km distance and freight cost of 0.09** $/t/km	Creation of dense network of certified local partner mines (see policy goal of Brazil to include all mines with suitable residues into the production of rock powders for agriculture, PNF 2021) (*This is our currently observed average distance for project activity throughout Brazil. In our LCA we assume another value which we explain in section 3g.)

[2] This and the following line item is not included in the TEA spreadsheet because we want to consider MRV and registry costs separately from traditional capex and opex

			(** We are unsure if the cost of transport will actually decline, e.g. due to future inflation, thus conservatively assumed stable cost for now.)
MRV	24,5 USD/tCO2	3 USD/tCO2	Every field measuring station (FMS) will narrow down the best proxy parameters, implying less measurements needed as research progresses. Every FMS will progressively refine overall modeling calibration and verification, which in the long run equally reduces the extent of infield measurements. Additionally one may consider that the here presented FMS will be applicable to many more hectares of pasture than included in this proposal.
Spreading	-	-	We do not consider spreading costs as our current model is built around the farmer bearing these costs.

d. What aspects of your cost analysis are you least confident in?

Cost for MRV, as the detailed process is dependent on results of future research and the methodology requirements from third parties (e.g. certifier) which are currently under development.

e. How do the CDR costs calculated in the TEA spreadsheet compare with your own models? If there are large differences, please describe why that might be (e.g., you're assuming different learning rates, different multipliers to get from Bare Erected Cost to Total Overnight Cost, favorable contract terms, etc.).

The costs are lower in reality especially as EPC, process contingency, and project contingency costs are not or only partially applicable to our enhanced weathering projects.

f. What is one thing that doesn't exist today that would make it easier for you to commercialize your technology? (e.g., improved sensing technologies, increased access to X, etc.)

The availability of a low-price, accurate and high frequency device that could measure dissolved inorganic carbon directly in the field would be of great help. Also the availability of well equipped soil and mineralogy laboratories throughout the tropics are a key infrastructure to scale our business. Furthermore, the invention of remote sensing mechanisms that would allow detecting parameters related to mineral weathering in soil from space/via drone would be a gamechanger.

6. Public Engagement

In alignment with Frontier's Safety & Legality criteria, Frontier requires projects to consider and address potential social, political, and ecosystem risks associated with their deployments. Projects with effective public engagement tend to:

- Identify key stakeholders in the area they'll be deploying
- Have mechanisms in place to engage and gather opinions from those stakeholders, take those opinions seriously, and develop active partnerships, iterating the project as necessary

The following questions help us gain an understanding of your public engagement strategy and how your project is working to follow best practices for responsible CDR project 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 relevant 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. <300 words

Key stakeholders of our enhanced weathering activity are mines, farmers and the communities where these are located. For larger project volumes one may include transport companies, farmer cooperatives, national research institutions like EMBRAPA, agronomic consultancies, etc. as additional key stakeholders. We have identified these actors through our pilot activities in Brazil and conducted interviews with each party. For this project proposal all relevant stakeholders are located in the municipality of [redacted] Brazil (besides the actors involved in the MRV field monitoring station which is located in Piracicaba, some 100km from [redacted].

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 and Arnestein's Ladder of Citizen Participation for a framework on community input.* <300 words

We have visited the municipality and consulted potential areas and farmers. We also went to the mine to familiarize ourselves with the production conditions. All these activities have been performed in-house. Moreover, we are supported by scientific advisors like Suzi Huff Theodoro to ensure the integrity of our public consultation process. She led various public engagement processes related to Brazilian legislation for rock powders in agriculture and issued a range of publications related to these topics (Source, Source, Source). In regular meetings, Suzi makes sure that we keep our eyes on aspects beyond mere carbon removal so that we understand the full implications of our work and ask the right questions in our stakeholder consultations.

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? <100 words

The most important changes we made based on our consultation was a reduction of average rock powder application amounts per hectare because of the following reasons:

(1) Farmers and local communities feel uncomfortable with applying very high loads on their fields. They are used to application dosages between 3-5t/ha so we are already doubling that by aiming at an average 10t/ha. Operationally we put a great burden on them if we ask them to spread high dosages, even though they get the rock powder for free. Farmers prefer smaller dosages yearly and desire a long term guidance including orientation related to the combination of rock powders with other farming inputs.

(2) Currently mines do only produce small amounts (50.000 - 100.000t/year) of suitable rock powder as production lines are just about to be implemented.

(3) Our goal is to benefit as many farmers and as much soil as possible by our solution. Combined with the points above we think that a lower application amount on more land can help to create a greater impact in terms of soil regeneration and acceptance of rock powder fertilization by Brazilian farmers.

d. Going forward, do you have changes to your processes for (a) and (b) planned that you have not yet implemented? How do you envision your public engagement strategy at the megaton or gigaton scale? <100 words

Especially when scaling enhanced weathering to the Gt level, the necessary rock powder amounts will potentially require additional mining and put a considerable burden on the transport infrastructure. This means a more rigid consultation of the municipal stakeholders and effective management of available transport capacity is necessary to avoid conflict with other crucial transport activities.

Another challenge is the public acceptance of this practice. During some consultations we encountered critical views, e.g. that the mines do dump their “waste” on agricultural land. For large-scale operations, education and public consultation channels will be implemented to create trust and transparency.

Furthermore the necessary increase in mining activity to scale up carbon removal is a critique we are constantly exposed to. Our partnering mines will consequently be required to develop restoration plans for their mining sites to avoid devastated land strips.

7. Environmental Justice[3]

As a part of Frontier’s Safety & Legality criteria, Frontier seeks projects that proactively integrate environmental and social justice considerations into their deployment strategy and decision-making on an ongoing basis.

a. What are the potential environmental justice considerations, if any, that you have identified associated with your project? Who are the key stakeholders? Consider supply chain impacts, worker compensation and safety, plant siting, distribution of impacts, restorative justice/activities, job creation in marginalized communities, etc. <200 words

[3] For helpful content regarding environmental justice and CDR, please see these resources: C180 and XPRIZE’s Environmental Justice Reading Materials, AirMiners Environmental and Social Justice Resource Repository, and the Foundation for Climate Restoration’s Resource Database

Mining in accordance with sustainable standards is a crucial source of livelihood for tens of millions of people across the world, and has the potential to improve domestic supply chains and strengthen local communities' (Source, Source). Rock powders originating from local mines can be considered as “independence fertilizers” for small scale farmers who cannot access and/or afford typical fertilizers (Source). In the context of Brazil, the issue goes far beyond the small-scale farmers, as the transition to locally sourced rock powders is directly related to the countrys’ food security and national independence from global fertilizer supply chains. Currently 70-90% of synthetic farming inputs in the agricultural sector are imports, partially from geopolitically unstable locations (Source, Source). By catalyzing this new market, new jobs are created in the areas where rock powders are applied, in laboratory and analytical segments, and in the transport and freight sector .

The most critical aspect is that the resulting value creation remains as local as possible, allowing first and foremost municipally/locally owned businesses, mines and transport companies to benefit and build the above mentioned capacities.

b. How do you intend to address any identified environmental justice concerns and / or take advantage of opportunities for positive impact? <300 words

We differentiate a social and commercial line for our business model.

Social Line: This includes small scale farmers, marginalized groups (e.g. Movimento Sem Terra, Comunidades Quilombolas), and regenerative farming groups (e.g. agroforestry with high operational costs, afforestation and ecological restoration projects). These actors will receive a 100% discount on rock powder and freight.

Commercial Line: Large and lucrative farming operations (e.g. large scale sugarcane production), will receive a discount between 50-100% depending on a set of parameters such as distance to mine, extension of land, type of rock powder. We believe that actors that already have high profits should contribute to carbon removal while benefiting from cheap rock powder supply, less costs for conventional farming inputs and our farming tools.

Additionally, our projects happen with preference in a radius <150km from the rock powder sources. We collaborate with local partners for transport, agronomic consultancy and laboratory analytics. Based on distribution partnership and long-term purchase agreements, we intend to create an incentive model so that small, municipal mines invest into producing rock powders from their residues. The same mechanisms will also be used to incentivize transport companies to modernize their fleets, thus decreasing the environmental impact of rock powder freight.

We also demonstrated our respect towards environmental justice and public engagement by joining the carbon business council and signing the ethical oath to restore the earth.

8. Legal and Regulatory Compliance

a. What legal opinions, if any, have you received regarding deployment of your solution? <100 words

We work within the legal framework of the Brazilian laws 6,894, of 1980, and 12,890, of 2013, following the normative instruction no. 05, of 2016, issued by EMBRAPA and the Ministry of Agriculture (MAPA). Furthermore we have to take the Brazilian laws for transportation into account that limit the maximum load per hauling truck to 50t.

b. What permits or other forms of formal permission do you require, if any, to engage in the research or deployment of your project? What else might be required in the future as you scale? 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. <100 words

All permits for rock powder production are granted and the basalt has been certified by the Brazilian Ministry of agriculture. For application, the consent of the farmer must be given. We have already signed agreements with farmers representing approximately 80% of the area necessary for this proposal. When scaling to the Gt, rock powder supply may be limited due to delayed or rejected permits related to the intensification of mining activities.

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? <100 words

In the future, our project may be regulated through reformulation and refinements related to the Paris Agreement, Article 6. Currently no international regulations apply.

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. <100

Uncertainties are highly relevant for our future internationalization. Brazil has a favorable policy for ERW compared to other tropical geographies. We believe that the legislative approach of Brazil will influence other governments worldwide to adopt similar strategies related to the use of rock powders in agriculture. It is unclear how the Brazilian regulation around carbon removal credits will evolve and to what extent ERW will be regulated. Due to ERW presenting itself as a serious future strategy for Brazil's GHG emission management in the context of nationally determined contributions, we believe that regulators will become interested in our activities at some point in the future.

e. Do you intend to receive any tax credits during the proposed delivery window for Frontier's purchase? If so, please explain how you will avoid double counting. <50 words

N/A

9. Offer to Frontier

This table constitutes your **offer to Frontier**, and will form the basis of contract discussions if you are selected for purchase.

Proposed CDR over the project lifetime (tonnes) *(should be net volume after taking into account the uncertainty discount proposed in 4(c))*	1021 tCO2eq
Delivery window *(at what point should Frontier consider your contract complete? Should match 1(f))*	2028
Levelized Price ($/metric tonne CO_2) *(This is the price per tonne of your offer to us for the tonnage described above)*	480 $/tCO2eq

Application Supplement: Surface Mineralization and/or Enhanced Weathering

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

Source Material and Physical Footprint

1. What source material are you using, and how do you procure it? <100 words

We are using a basalt from this mine in [redacted], São Paulo State, Brazil. The local basalt residue stockpile has a volume of 1.5 Mt. For the procurement we have closed a partnership with the [redacted]. They are responsible for the production of the rock powder according to the standards of the above mentioned legislation.

2. Describe the ecological impacts of obtaining your source material. Is there an existing industry that co-produces the minerals required? <100 words

The accumulated basalt residues were initially mined for construction purposes, mainly gravel production. We consider the ecological impact of obtaining our source material equal to the impact of obtaining the primary aggregate. Environmental impacts of the quarry during sieving include air and noise pollution. Mitigation measures include dust suppression and dust extraction systems, and the development of green belts around the quarry. Green belts should respect local flora and biodiversity. Water pollution should also be monitored in the surrounding water bodies. All necessary facilities should be provided to workers such as clean water and resting places. More to this regard can be consulted in (Source).

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 3. <200 words

The basalt residue will pass three sieving steps until it reaches the following granulometry: 100%<2mm; 70%<0,84mm; 50%<0,3mm (according to requirements for rock powders in agriculture from the Brazilian Ministry for Agriculture). For handling and security purposes water is added to reach 5-10% humidity of the final basalt powder. Currently, the sieves are installed with a plan to start producing rock powder on the 1st of November 2022. With production running, we will realize a more detailed LCA for the process in cooperation with our partner [redacted]. To work with conservative assumptions we used (Source) to the extent as described in section 3.

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 table below.

	Land area (km^2) in 2022	**Competing/existing project area use (if applicable)**
Source material mining	0,01	Stockpile area, no competition
Source material processing	<0,01	A small area of 250m^2 is used to install the additional necessary equipment necessary. The mine has vast areas available to extend its infrastructure.
Deployment	7-8	Pasture, no competition

5. How much CDR is feasible globally per year using this approach? Please include a reference to support this potential capacity. <100 words

We estimate a potential of 1-1.5 Gt CO2eq/year in the global tropics (and subtropics), with an estimated rock powder demand of ca. 5-8 Gt/year (Source). The actual potential will depend on the investment into related infrastructure throughout the next decades, availability of rock powder types, and manifestation of climate parameters.

6. If you weren't proceeding with this project, what's the alternative use(s) of your source material? What factors would determine this outcome? <50 words

The source material in its pure form does not have many uses due to its heterogeneous granulometry. One possible use case could be the backfill of mining pits after the exploration of a reservoir is completed. The source material as we will use it (sieved mining residues), is not restricted to application on degraded pasture and can be used in any other agricultural and forestry settings . Additionally, there

are emerging applications in the construction industry where basaltic rock powder is used in concrete (Source). Another use case may be the improvement of biochar production through mineral additives prior to pyrolysis (Source).

Human and Ecosystem Impacts, Toxicity Risk

7. 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? <100 words

The heavy metal content of our rock powders fulfills the regulatory concentration thresholds for organic fertilizers from the EU, Brazil, and the USA (Source). Resulting soil heavy metal concentrations will be monitored biannually, but will very likely not be discernible from the control soil, as studies with similar basalts and 5x higher application rates found non-significant differences for heavy metals (Source). P loading into streams will be at minimum due to the low P concentrations (0,46%) and due to the high P-fixation of tropical oxisols (Source). Dust aerosol hazard will be at a minimum due to (i) water additions and (ii) proper handling instructions.

8. If minerals are deployed on croplands, what are the estimated effects on crop yields? Include citations to support this claim. How will actual effects be monitored? <100 words

Effects on croplands and pasture will be at a maximum on highly weathered soils in the tropics. Similar basalt powder increased ryegrass yield on two nutrient poor acidic soils by 25% and 43% (Source) and pasture yield by about 28% (Source). We will compare the yield performance of our pastures with control pastures that do not receive basalt amendments.

9. 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.) <100 words

Potential impacts will be monitored through our platform. Every registered farmer will add information about their health status and potential issues and challenges observed during the application process. Thereby, we also incrementally improve the application process, as these practical learnings outline unknown potentials and problems. As an additional safety precaution we keep a minimum safety distance of 1km from urban areas.