Frontier

Verde AgriTech

Carbon dioxide removal prepurchase application

Summer 2023

General Application

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

Public section

The content in this section (answers to questions 1(a) - (d)) will be made public on the Frontier GitHub repository after the conclusion of the 2023 summer purchase cycle. Include as much detail as possible but omit sensitive proprietary information.

Company or organization name

Verde AgriTech Ltd

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

São Gotardo, Minas Gerais, Brazil

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

Cristiano Veloso, Vitor Carmo

Brief company or organization description <20 words

Verde innovatively expedites Enhanced Rock Weathering using microorganisms, redefining its global field.

1. Public summary of proposed project[1] to Frontier

a. **Description of the CDR approach:** Describe how the proposed technology removes CO_2 from the atmosphere, including how the carbon is stored for > 1,000 years. Tell us why your system is best-in-class, and how you're differentiated from any other organization working on a similar approach. If your project addresses any of the priority innovation areas identified in the RFP, tell us how. Please include figures and system schematics and be specific, but concise. Aim for 1000-1500 words.

Overview

Verde AgriTech ("Verde" or the "Company") is a global pioneer in the evolving field of Enhanced Rock Weathering ("ERW"). From 2017 to 2022, Verde successfully deployed 1.419 million tons of Rock in agricultural soils and has the capacity to deploy an additional 3.3 billion tons from its directly controlled mineral resources.

Verde employs Glauconitic Siltstone, commonly known as (the "Rock") in its carbon capture operations by Enhanced Weathering techniques. This naturally occurring mineral is notable for its potassium content (available to plants as potassium dioxide, "K_2O"), which is essential for plant growth as a vital nutrient. What sets the Rock apart is its faster dissolution rate in comparison to other minerals like Basalt, typically used in ERW processes. This accelerated dissolution enables a more rapid carbon capture from the atmosphere, enhancing the efficiency and effectiveness of Verde's Carbon Dioxide Removal ("CDR") project (the "Project").

Through an independent study conducted by Dr. David Manning from Newcastle University, it has been demonstrated that each ton of Rock applied to the soil can capture 120kg of CO_2.

After extensive research, Verde discovered that adding microorganisms to the Rock expedites the ERW process. Leveraging this discovery, we conducted multiple lab tests to identify the most efficient microorganisms for this acceleration. Expanding on this discovery, we conducted numerous laboratory tests to identify which microorganisms would be efficient in this acceleration process.

With the successful validation of these tests, we are working on measuring how the microorganisms we selected can expedite carbon capture through ERW. We have two microorganisms that have shown promising results in lab scale.

Currently, we anticipate conducting field trials to accurately assess the extent to which our product can accelerate Weathering compared to untreated Rock.

[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.

How our technology removes CO_2 from the atmosphere

The technology that we are testing is named Bio-Enhanced Weathering ("BEW"), which is based on the inoculation of microorganisms into the Rock to accelerate its normally occurring Weathering process.

This process removes CO_2 from the atmosphere through the Weathering of silicate minerals present within the Rock. This natural process is Enhanced by crushing, grinding and milling a Rock prior to application to soil. As the Rock weathers, it releases nutrients such as K, and consumes atmospheric CO_2.

Estimation of the potential for removal of CO_2 by Rock Weathering is based on the Steinour equation (Renforth, 2019), and uses weight % oxides from an analysis of the material.

In Equation 1, it is assumed that CO_2 consumption relates to the amounts of Ca, Mg, Na and K bound within the silicate mineral lattice, where dissolved bicarbonate charge-balances the cations removed by Weathering. The corrections relating to SO_3 and P_2O_5 reflect Ca and (to a lesser extent) Mg bound in sulfate or phosphate minerals, which are not affected by CO_2-driven Weathering processes. If phosphate and sulfate minerals dissolve, cation charge is balanced by phosphate or sulfate anions.

$$\text{erw}CO_2 = \frac{44}{100}.\left(\frac{CaO}{56}+\frac{MgO}{40}+\frac{Na_2O}{62}+\frac{K_2O}{94}-\frac{SO_3}{80}-\frac{P_2O_5}{142}\right).10^3.1.5 \quad \text{(1; Renforth, 2019)}$$

Equation 1 also includes a final coefficient here with the 'recommended' value of 1.5. This reflects the product of Weathering being bicarbonate, which in ideal circumstances yields a coefficient of 2.0. Renforth (2019) states that the coefficient varies between 1.4 and 1.7 and chooses a value of 1.5 as a conservative estimate. This reflects the presence in solution of anions such as chloride.

Through the BEW process, carbon is removed from the biological cycle and placed into the geological carbon cycle. This prevents the carbon from returning to the atmosphere through natural biological processes in the soil, allowing it to be stored for 100,000 years or more, eventually being transported to underground aquifers or the ocean.

Technological and competitive advantages

We possess unique capabilities that align with Frontier's target criteria for two key reasons.

Firstly, we are fully integrated. This is evidenced by:

a) We control the biotechnology responsible for selecting and testing the microbes.

b) We own and operate a bioproduction facility that already produces microbes at a commercial scale.

c) We own and operate a mine with 3.3 billion tons of mineral resources.

d) Over 2000 farmers are currently applying our Rock for ERW.

Secondly, we have already achieved cost efficiency in ERW by successfully charging farmers for the Rock we mine and sell. Implementing the deployment of microbes would be equally cost-efficient, as we have already developed the necessary production technology in a cost-effective manner.

Our distinctive innovation lies in our readiness to conduct field trials to measure the performance of our microbes. These microbes have already undergone validation from a production scalability perspective after a lengthy yet successful trial at the laboratory scale.

Our project is fully aligned with one of the priority areas of innovation outlined in the RFP, specifically the category of "Approaches to geochemical CDR that accelerate Weathering rates". Our main objective is to leverage on a commercial scale, microorganisms meticulously selected and tested to accelerate the Weathering process through impactful geochemical interactions.

b. **Project objectives:** What are you trying to build? Discuss location(s) and scale. What is the current cost breakdown, and what needs to happen for your CDR solution to approach Frontier's $100/t and 0.5Gt targets? What is your approach to quantifying the carbon removed? Please include figures and system schematics and be specific, but concise. Aim for 1000-1500 words.

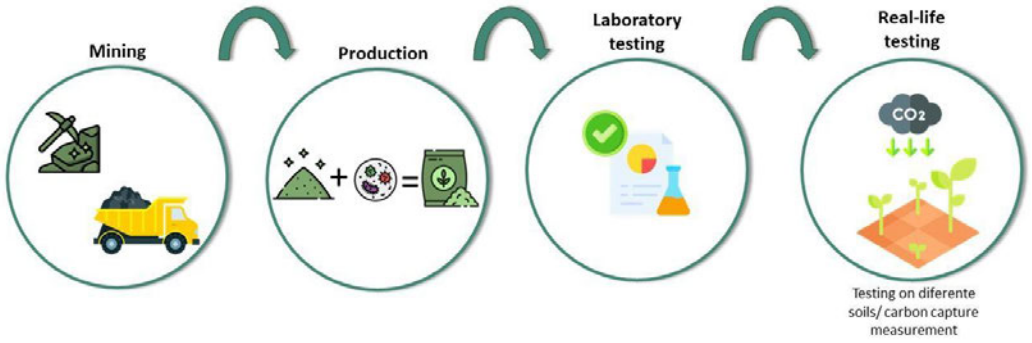
Our Project aims to build a carbon dioxide removal solution using microorganisms and the Enhanced Rock Weathering technique.

The current focus is conducting tests and analyses to measure the performance of selected microorganisms in accelerating carbon capture through ERW under field conditions. We have finalized the testing protocols and designated appropriate locations, and we are now fully prepared to commence the testing phase.

This stage is critical as it will generate data and scientific evidence to support the Enhanced effectiveness of Rock in capturing carbon, particularly through the process of Bio-Enhanced Weathering ("BEW").

Once the efficiency of the BEW technology has been validated, the revenue generated by the sale of carbon credits will enable the scaling up of Rock production with added microorganisms Rock with added microorganisms) to reach commercial-scale operations. This will be accomplished by implementing the microorganism incorporation technology at Verde's second industrial plant.

Figure 1: BEW technology validation process



Glauconitic Siltstone can be found in mineral occurrences with different K_2O contents:

- Higher K_2O content ("Higher-grade Rock"): Commercialized by Verde as a potassium fertilizer.
- Lower K_2O content ("Lower-grade Rock"): Despite being currently uneconomic for agricultural usage, the revenue from the carbon credits generated by the Project with the BEW technology will enable the Company to viably market the Lower-grade Rock as a fertilizer with added microorganisms for agricultural use.

In terms of scale, we currently operate two industrial plants located in São Gotardo, Minas Gerais state:

- The first industrial plant ("Bioproduction Facility 1") has the capacity to remove 6,360 tons of CO2 from the atmosphere per month, with an estimated sale price of $315 per ton of CO2.
- The second industrial plant ("Plant 2") currently produces potassium fertilizer from the Higher-grade Rock.

This stage involves the implementation of the microorganism addition technologies in Plant 2, enabling it as our second Bioproduction Facility. This facility will be financed through the sale of carbon credits derived from the lower-grade Rock. By generating revenue from these carbon credits, Verde will be able to lower the sale price of the lower-grade Rock to farmers, making it economically

feasible for Verde to market it as fertilizer in agriculture. This approach ensures that the lower-grade rock, which was previously considered uneconomical, can now be made accessible and viable for agricultural use.

The revenue generated from the sale of carbon credits will play a vital role in subsidizing the large-scale production of the Rock with added microorganisms. As a result, we anticipate a greater demand from farmers, thus enhancing the value of CDR through Bio-Enhanced Weathering.

The construction of our second Bioproduction Facility will increase Verde's carbon removal capacity by 21,267 tons of CDR. As a result, we expect a substantial reduction in production costs enabling the sale of carbon credits at $100 per ton of CO2 or at even lower prices, through the sale of the lower-grade Rock for agricultural use.

Bioproduction Facility 1 and Bioproduction Facility 2 will have a combined capacity to remove 27,627 tons of carbon monthly.

Considering our available resources and production capacity, the Project's total CDR capacity is 0.38 Gt.

Validating our hypothesis in laboratory conditions is crucial to ensure the microorganisms' capability to accelerate the Enhanced Weathering process in field conditions. This validation is essential for scaling up Rock production with added microorganisms to achieve commercial-scale operations.

While existing literature and research studies support this hypothesis, it is imperative to conduct field tests across various soil types and crops to assess the microorganisms' performance in natural conditions accurately. The primary goal of these tests is to quantify the amount of carbon removed through the BEW process.

To ensure the accuracy and reliability of our findings, we will employ mesocosms to closely monitor and evaluate the results. These controlled experimental systems will help validate the effectiveness of carbon capture and measure the impact of the microorganisms on the ERW process.

c. **Risks:** What are the biggest risks and how will you mitigate those? Include technical, project execution, measurement, reporting and verification (MRV), ecosystem, financial, and any other risks. Aim for 500-1000 words.

The main area of uncertainty lies in the effectiveness of the selected and validated microorganisms at a laboratory scale, especially in their ability to accelerate Weathering under field conditions. To demonstrate this, we will conduct tests involving various crops and soils to evaluate the impact.

Additionally, detailed soil studies will be conducted to gain insights into how specific soil management practices can influence the process.

d. **Proposed offer to Frontier:** Please list proposed CDR volume, delivery timeline and price below. If you are selected for a Frontier prepurchase, this table will form the basis of contract discussions.

Proposed CDR over the project lifetime (tons) *(should be net volume after taking into account the uncertainty discount proposed in 5c)*	1,590 tons
Delivery window *(at what point should Frontier consider your contract complete? Should match 2f)*	2023-2025
Levelized Price ($/ton CO_2)* *(This is the price per ton of your offer to us for the tonnage described above)*	US$315/ton CO_2

** 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 and reflect reductions from co-product revenue if applicable).*

[redacted]

[redacted]

[redacted]

[redacted]