Frontier

Boomitra

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

Boomitra

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

San Francisco Bay Area

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

Aadith Moorthy

Brief company or organization description <20 words

Boomitra works on enabling carbon removal at gigaton scale – through the actions of farmers – today across 5M acres and 150,000+ farmers.

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

[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.

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.

Boomitra is working on a novel enhanced weathering program, centered around the application of a new silicate mineral source of alkalinity that has high levels of essential plant nutrients and can function as a drop-in replacement for certain conventional fertilizers applied by farmers around the world at scale on a yearly basis today (See Section 2). The mineral is very efficient at undergoing weathering, and Boomitra's satellite and AI-based soil MRV tools will enable an accurate and low cost quantification of the total carbon removal achieved (as outlined further below).

Since the mineral is a drop-in replacement for certain types of conventional fertilizers applied at scale today, the true financially additional cost of achieving carbon removal in the long term is the "green premium" of the mineral over the conventional fertilizer. The rest of the cost of applying the mineral may be borne by the farmers similar to how they purchase NPK fertilizer today. The green premium is greater than 0, but is under $100/t when supply chains are scaled.
Furthermore, the mineral is found in many places around the world in coastal or formerly coastal regions, making it quite abundant for global deployment, and surpassing the 0.5Gt/yr target.
Finally in this project, Boomitra is pioneering new satellite-based MRV to dramatically reduced MRV costs, so that most of the carbon removal payment goes towards the green premium. Boomitra's satellite and AI based soil bulk density and nutrient level measurements will allow for efficient implementation and monitoring of the project. Boomitra's satellite based soil bulk density measurement will allow for the remote verification of when the weathering material is physically applied on the farm, and when it reaches a final weathered state (equilibrium bulk density). In environments with basic pH, where there is a concern of carbonate/bicarbonate ratio to determine the extent of weathering, the measured bulk density trend will reveal the exact extent of weathering by indirectly measuring the extent of carbonate formation (the final bulk density is affected by the amount of insoluble carbonate formation). In addition, Boomitra's weekly satellite-based crop nutrient levels will provide semi-real time data on the uptake of the nutrient in the material by the plants. This allows for an optimization of the amount of material applied to meet the nutrient needs of the plants while maximizing carbon removal.

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.

For this pilot project, we are attempting to do an end-to-end implementation and monitoring of enhanced weathering on a series of farms in Brazil, across 1,000 ha. This will involve bringing the mined materials to the chosen farms and their deployment on the farms. $245/ton is the expense associated with material procurement and transport to site, $25/ton for deployment, and $100/ton for monitoring expenses. Procurement and transport will be leveraging existing fertilizer dealer networks, so expenses are grouped together on a dealer level. Deployment across the project acreage involves using a tractor to transport the material across the area. Finally, the monitoring today involves taking

soil samples for both physical (bulk density) and chemical (chemical composition, minerology, carbonate ratios, cation concentrations) tests, alongside Boomitra's bulk density remote sensing technology. The soil samples will enable us to accurately quantify the carbon removed through an analysis of the rock weathered and the extent of carbonate formation directly through chemical means. These samples will be taken yearly right before any new application of the weathering material. At the same time, these samples will facilitate the building of a new advanced MRV system leveraging Boomitra's remote sensing technology to measure bulk density. In a nutshell: we have developed an existing satellite-based system at Boomitra to measure soil organic carbon and bulk density to 30+ cm depth and on a monthly basis for the existing soil organic carbon sequestration projects we do around the world. This same bulk density measurement has immense value for quantifying enhanced weathering as well, but several field-level and weathering material-specific nuances remain to be worked out for it to be fully functional. Firstly, when the weathering material is applied, satellites detect a jump in bulk density of the soil. This jump gradually subsides as the material weathers. However, the exact trend in the subsidence in bulk density towards its final equilibrium is related to the extent of formation of carbonates versus bicarbonates during weathering. The formation of carbonates versus bicarbonates is one of the big sources of uncertainty in enhanced weathering's total carbon sequestration in general today. The extent of bulk density decrease with time after the initial application of the material on a farm ultimately tells us the extent of carbonate vs bicarbonate. If there are more carbonates formed, the bulk density does not decrease as rapidly as if soluble bicarbonates were primarily formed. The exact ranges of these relative decreases are yet to be quantified for different soil types and climatic conditions, but we are confident that this pilot project will give a strong level of detail and field-testing for at least the tropical moist regions of the world for a variety of soil types.

In the long run, we anticipate that the material deployment cost will be fully born by farmers in the usual course of their yearly application of fertilizers. We also anticipate that a good chunk of the material procurement and transport expenses will be covered by farmers themselves, leaving only about ~$50/ton in green premium to be covered by CDR credits. Lastly, with Boomitra's monitoring innovations with remote sensing, we anticipate the MRV cost to come down to under $10/ton, leaving a conservative $60/ton total cost.

Scaling to 0.5Gt and beyond will primarily require the development of more mines for this material in different parts of the world. Since it is known to be abundant, we do not anticipate an availability issue. Additionally, large scale upskilling and behavior change for fertilizer dealers and farmers worldwide is necessary.

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 biggest risks are around the deployment of the material, specifically around farmer acceptance and adoption, and around the capability of the MRV system.

Farmer acceptance and adoption is a crucial component of the deployment, and it involves convincing the farmer that this material can be used on their farms without negative affecting their yields. The scientific literature suggests a positive increase in yields, but convincing farmers is not as simple as pointing to scientific literature. For every new product, every farmer always focuses on testing the impacts to their specific farm before proceeding. Due to this material's long history of use, we do not anticipate it being too difficult to get farmer adoption, but this is nevertheless a challenge to be surmounted.

Secondly, there is risk associated with the MRV system. Intensive soil sampling will inform a significant part of this pilot project, for the purposes of eventually ground truthing the remote sensing and model based system. For the intensive soil sampling itself, we do not foresee much risk because the chosen project area has a sufficient number of trained field technicians and access to certified soil testing labs. For the remote sensing and model based MRV system, Boomitra has the benefit of building from a system that is already usable for bulk density in soil organic carbon sequestration projects. However, for this particular case of enhanced weathering, there are still some scientific questions to resolve on the observability of the resultant effects to the bulk density from the application of the material to its weathering, and whether the signal to noise ratio is ultimately sufficient. Our initial analysis suggests that it will be sufficient and observable, particularly on scales larger than tens of acres.

Ecosystem and financial risks will not be significant for this project, because the material itself has been used for hundreds of years, albeit in a limited way and without any MRV, and capex is low.

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)*	1,000
Delivery window *(at what point should Frontier consider your contract complete? Should match 2f)*	~15 months from start of deployment
Levelized Price ($/ton CO_2)* *(This is the price per ton of your offer to us for the tonnage described above)*	$500/ton initially

** 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]