Metalplant

Carbon dioxide removal prepurchase application

Summer 2024

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 2024 summer purchase cycle. Include as much detail as possible but omit sensitive and proprietary information.

Company or organization name

Metalplant Public Benefit Corporation

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

USA

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

Eric Matzner

Brief company or organization description <20 words

Removing carbon dioxide through enhanced rock weathering, while phytomining the weathering soils for nickel with hyperaccumulator plants.

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. 1000-1500 words

Metalplant removes carbon dioxide from the atmosphere through the enhanced weathering of olivine, while at the same time recovering nickel from the soils with hyperaccumulator plants.

Olivine is one of the fastest weathering, most efficient, and most abundant minerals available for enhanced weathering (EW). To date though, the use of olivine has generally been limited to use in

[1] We use "project" throughout this template, but the 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.

small quantities or is avoided completely because of the 0.1%-0.5% nickel typically contained within the mineral.

Metalplant's system is best-in-class because it was reverse engineered from first principles around the "problem" of this nickel being released during the enhanced weathering of olivine, to unlock this ideal mineral for EW by turning that from a weakness of the process into an economically valuable asset. While carbon removal has a <$100 per tonne target price in the future, nickel has a price of over $17,000 per tonne today.

We can turn approximately 3 Ha of land, 300 tonnes of olivine into 1 tonne of nickel and 300 tonnes gross of CDR.

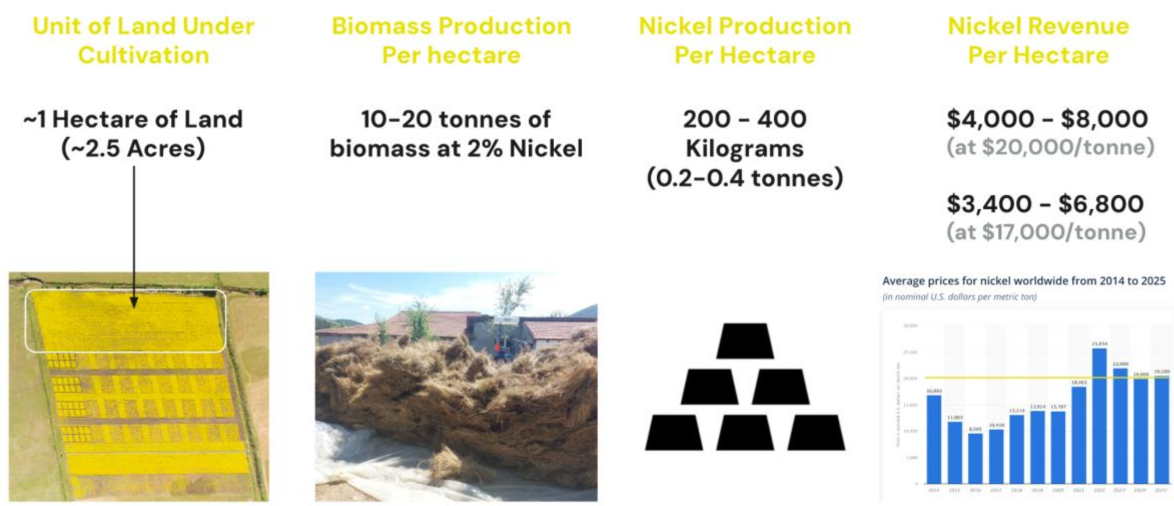
300 X 1 Tonne of Minerals (80% Olivine, 0.34% Nickel) **~3 Hectares of Hyperaccumulators Plants X 1 Year of Phytomining and Enhanced Weathering** **1 Tonne of Nickel & 300 X 1 Tonne of CDR**

Our process is differentiated from others the start, because instead of bringing minerals to the farm, we start by locating the mineral resources and bring the farm to the minerals. This minimize transport distances, but also generally means we are in a region containing ultramafic soils, naturally bearing metals like nickel in them.

Today, we cannot guarantee that we are able to recover 100% of the nickel released in the weathering through the use of hyperaccumulators, so a major environmental consideration today is that are we committed to only working on existing serpentine soils or anthropogenically contaminated soils. These soils already contain over a decade's worth of nickel and are the native habitat of nickel hyperaccumulator species.

Our demonstration site is located in north Albanian, a country composed 11% of soils of this type, which extend throughout the Balkans and globally make up 1-3% of the surface of the Earth.

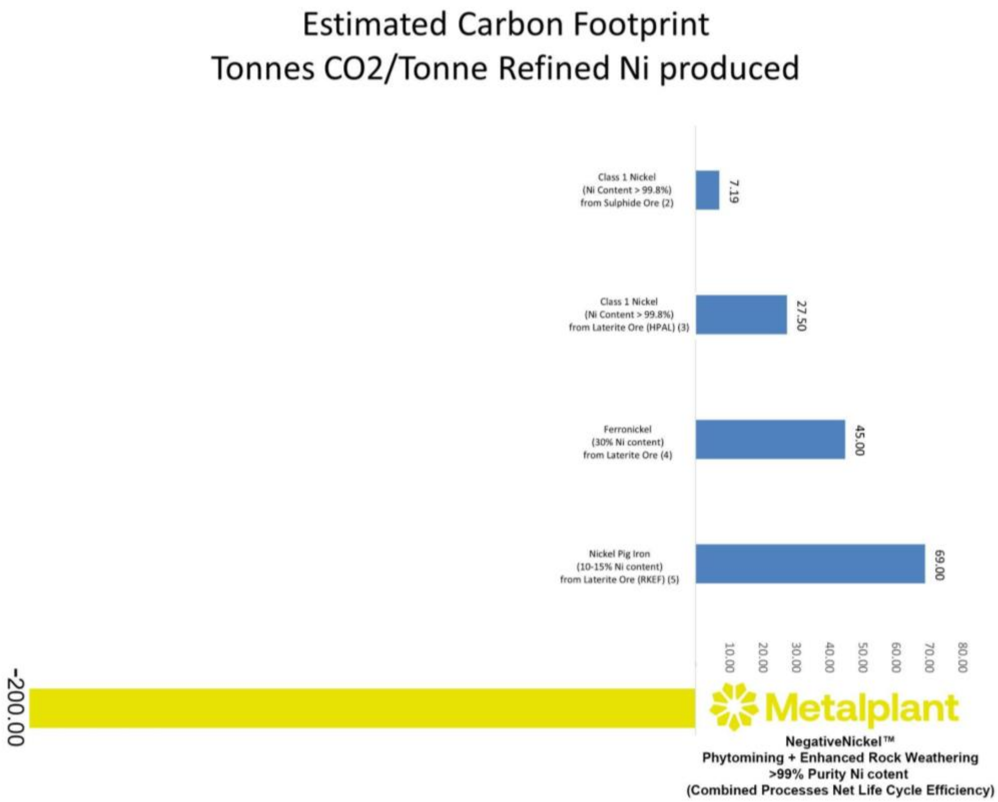
We address the priority innovation area of "Projects that can offer lower prices through additional revenue sources" and the EW area of "Deployment models that generate financial or environmental benefits at the site (e.g., reclamation, land/municipal development projects)" by generating revenue from the crop that we produce. This is an extremely lucrative crop, but by operating the land ourselves in a vertically integrated way, we can make sure we optimize the weathering and crops, instead of just crops as most EW is focused on.



Our project also "provides local environmental and economic co-benefits that build community and policy support" by creating farming jobs in areas that are depopulating as many of the younger people emigrate abroad or move to cities. Land abandonment is a major issues in the Balkans.

By implementing the use of nickel hyperaccumulator plants to "phytomine" the soils to draw nickel up out of the soil and into the tissues of the plant biomass. The plants are then harvested and the biomass containing around 2% nickel is processed metallurgically into pure nickel salts that are direct precursors for EV battery cathodes and as input to stainless steel.

In our combined process we can recover 200 net tonnes of CO_2 per tonne of nickel produced:



To confirm the carbon is removed through chemical weathering and not the biomass. Weathering is a crucial component of the long-term carbonate-silicate cycle, often referred to as Earth's "thermostat." This natural process helps regulate global temperatures by controlling the levels of CO_2 in the atmosphere. When volcanic activity releases excess CO_2, it leads to warming, which increases precipitation and rainfall. This, in turn, drives the chemical weathering of magnesium and calcium silicate minerals, forcing CO_2 to become stored as bicarbonate dissolved in runoff that eventually reaches the oceans. The lower levels of atmospheric CO_2 ultimately cool the planet, reducing precipitation and weathering rates, maintaining a balance until CO_2 levels rise again.

When dissolved bicarbonate anions produced by ERW reach the sea via rivers and groundwater, they become part of the ocean's inorganic carbon pool. Some CO_2 will outgas due to carbonate buffering as riverine waters mix with seawater (approximately 17% over timescales of years to decades after capture). However, the remaining carbon is stable in the oceans for millennia (Renforth and Henderson, 2017, DOI: 10.1002/2016RG000533). Further outgassing occurs over geological timescales as bicarbonate is converted to marine carbonate minerals.

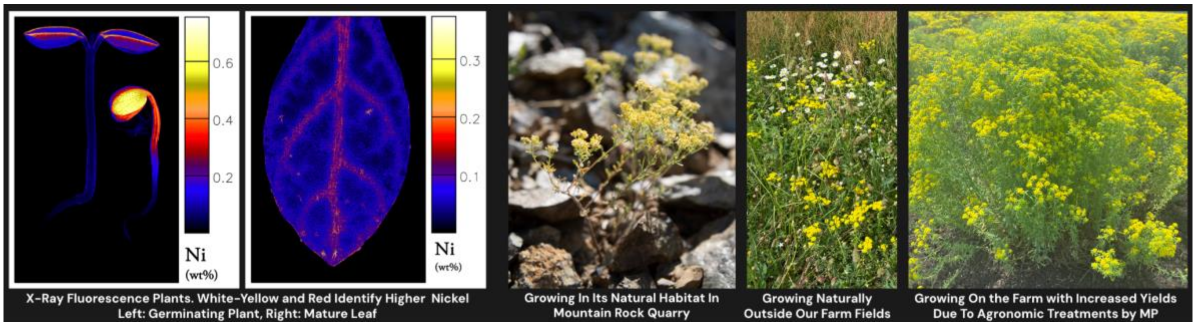
Metalplant's innovative approach to enhanced weathering and nickel recovery represents a significant advancement in the field of carbon dioxide removal. By addressing the challenge of nickel contamination and turning it into a valuable resource, Metalplant not only enhances the efficiency of CDR, but also contributes to the sustainable supply of critical minerals. This vertically integrated, dual-purpose system is has an opportunity to scale more rapidly than a company doing CDR alone could, and the business model has a resilience that eventually could allow "weathering" fluctuations in the markets of both end products.

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 cost and scale criteria?[2] What is your approach to quantifying the carbon removed? Please include figures and system schematics and be specific, but concise. 1000-1500 words

Metalplant is trying to build modular enhanced weathering farming operations located in close proximity to mineral resources and in the soils surrounding them using a "hub-and-spoke" model. At minimum, each site serves a radius at a minimum of 5-25 kilometers, depending on application rates, but can be scaled up to distances greater than 200 kilometers and still remain high-efficiency.

We locate a source of minerals and bring the farm to the minerals, and build a crushing plant on site to minimize transportation distances, then go out from there along the highest-efficiency utilization of the crushing plant and the distance traveled away from the quarry.

Our pilot project takes place in an ideal region of North Albania, sited of a 500 sq kilometers massif of the Mirdata ophiolite. The soils in the region contain naturally high levels of nickel, and our plant, a nickel hyperaccumulator that can achieve levels of 1%-2% nickel grows natively on these soils.



X-Ray Fluorescence Plants. White-Yellow and Red Identify Higher Nickel Left: Germinating Plant, Right: Mature Leaf | Growing In Its Natural Habitat In Mountain Rock Quarry | Growing Naturally Outside Our Farm Fields | Growing On the Farm with Increased Yields Due To Agronomic Treatments by MP

In 2022, we deployed a 32-plot field trial with 8 treatment levels, randomized within 4 blocks in order to demonstrate the concept of combining enhanced weathering with phytomining, to combine the carbon negativity from the minerals, along with the nickel produced by the plants.

This trial was in pursuit of the optimal application rate, utilizing the feedstock grain sizes we were able

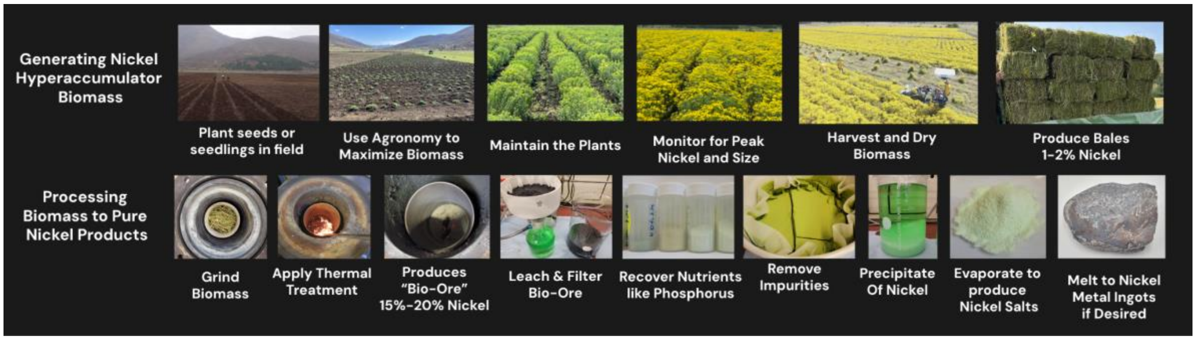
[2] We're looking for approaches that can reach climate-relevant scale (about 0.5 Gt CDR/year at $100/ton). We will consider approaches that don't quite meet this bar if they perform well against our other criteria, can enable the removal of hundreds of millions of tons, are otherwise compelling enough to be part of the global portfolio of climate solutions.

to have done locally at the time. We attempted levels high enough that they created so much alkalinity the process of weathering was slowed. We showed this through empirical measurements and modeling, understanding that sustained high pH levels would ultimately slow the weathering of the unweathered minerals.

We have taken this learning to heart and worked to understand the effect of grain sizes on weathering, which is in preparation for publication. Through various driving forces, we are now planning to utilize extremely fine-grained, sub-100 micron grain sizes.

Metalplant has other methods in grinding to recover impurities from the rock, using gravimetric, flocculation, and other methods of separation prior to mineral placement..

We have successfully produced nickel-containing biomass all the way through to pure nickel products.



Olivine feedstock dissolution is quantified empirically through a sampling regime that is both redundant and randomized. Sometimes reference samples are taken by an independent lab and tested on their equipment and abroad for calibration. Our sampling's spatial sampling protocol has been developed by statisticians and agronomists at research institutes in the UK.

In this proposed trial deployment in Fall 2024 we are trying to carry out a design that follows the processes of the protocols laid out in both Isometric's Enhanced Weathering in Agriculture protocol as well as Puro's Enhanced Rock Weathering Methodology. This will ensure we have empirical measurements that have a temporal and spatial strategy.

We will purchase 10,000 tonnes of olivine ground to sub-100 micron and deploy it over up to 35 hectares.

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. 500-1000 words

There are several categories of risks that need to be carefully considered and mitigated for Metalplant's ERW and Phytomining project. We have divided them into categories below.

ERW Risks

In practice, soil pCO_2 could potentially become rate-limiting for ERW where high application rates of fine-grained, olivine-rich rock material is applied. Carbonic acid formation in soil pore water is influenced by the partial pressure of CO_2 (pCO_2), which is predominantly biologically mediated, driven by soil (plant and microbe) respiration rates. We have addressed this risk by modeling, which shows that the availability of carbonic acid was not a rate-limiting factor for CDR in any of the modeling simulations conducted for this report.

Accurately quantifying CO2 removed through ERW at large scales remains a developing technology. In order to mitigate risks, we will be conducting measurements across soil, groundwater (with lysimeters) and gasses (with gas flow chambers), with robust baseline data, in order to best understand the full system. Third-party verification will be obtained, and ongoing research partnerships and contracts will help refine methodologies. Long-term monitoring will refine projections over time, and ongoing monitoring will track any potential carbon releases.

A key risk to consider is the potential lack of financial additionality due to the valuable nickel co-product. This could undermine the project's eligibility to sell carbon credits if the nickel revenue makes the project profitable without carbon finance. We will conduct and regularly update thorough financial analyses to demonstrate the necessity of carbon finance for project viability. We'll maintain transparent reporting on the relative contributions of nickel revenue and carbon credit sales to the project's financial sustainability. We're also exploring alternative uses for carbon finance, such as funding research or scaling up operations, to maintain additionality even as nickel revenues grow.

Ecosystem Risks

One of the primary ecosystem risks is the potential for nickel and other heavy metals to leach from the applied olivine into the watershed. While olivine weathering is intended to remove CO2, it also releases nickel as a byproduct. Excessive nickel in waterways could harm aquatic ecosystems. However, mitigation by nickel uptake by plants is core to our strategy. Application rates and particle sizes are optimized against the effects on pH, in order to maximize nickel uptake and CO2 sequestration while minimizing leaching. Our initial lab analysis shows that nickel will actually be immobilized by the increase in pH. In order to confirm and monitor for this in-field and throughout the watershed, we have worked with an independent Environmental Consultant group to develop a comprehensive ongoing hydrological survey and water quality monitoring program, regularly testing groundwater and surface water for nickel and other contaminants. If concerning levels are detected, we can adjust application rates and timelines of the feedstock, while continuing to draw up nickel with our hyperaccumulator plants. Further, the use of nickel hyperaccumulator biochar derived from phytomining has itself been proposed to be utilized as a Ni-adsorbent to use to absorb nickel from wastewater, soils, and waterways.

There is a risk that widespread planting of a single hyperaccumulator species could create a monoculture with negative impacts on local biodiversity and ecosystem function. To mitigate this, we will maintain areas of native vegetation and habitat between planted areas. Localized hyperaccumulator species will be developed and utilized when possible. Long-term monitoring of plant and animal biodiversity will be conducted, with adaptive management to promote overall ecosystem health.

The use of agricultural inputs like pesticides and fertilizers could contaminate soil and water, in areas that have been previously untouched by pesticides. We are seeking to minimize chemical inputs through integrated pest management and regenerative agriculture techniques. Organic and natural fertilizers will be prioritized, and buffer zones will be maintained around waterways. Regular soil and water testing will be conducted to ensure health and safety.

Farming Risks

As with any farming operation, we face risks from drought, pests, extreme heat, and other environmental factors that could impact both our crop yields and CO2 sequestration rates (in the case

of water scarcity). To mitigate this, drought-tolerant crop varieties will be selected. Irrigation systems will be installed where feasible. <u>Regional Risks</u> Shortages or price spikes in key inputs like olivine, seeds, or equipment could impact operations. We will secure long-term contracts with multiple suppliers where possible. On-site stockpiles of critical materials will be maintained. Alternative sourcing options will be identified. Local communities or environmental groups may oppose aspects of the project. We will prioritize early and ongoing stakeholder engagement. We have already worked to align the project with local needs and priorities. Transparent communication and third-party certifications will build trust, as will adherence to the highest environmental and ethical standards. Proactive communication of both benefits and risks will be maintained. Political instability in project regions could disrupt operations. We will diversify across multiple countries to spread risk. Strong relationships with local partners and communities will be developed. Political risk insurance will be obtained where appropriate. <u>Regulatory Risks</u> New regulations around ERW, carbon credits, or land use could affect the project. We will actively engage with policymakers and stay informed on regulatory developments. The project will be designed with flexibility to adapt to potential changes. <u>Summary</u> By proactively identifying and developing mitigation strategies for these varied risks, we aim to create a robust and resilient project capable of delivering scalable and durable carbon sequestration. Ongoing monitoring and adaptive management will be critical to navigating challenges as they arise. While risks cannot be eliminated entirely, we believe they can be managed effectively to unlock the significant potential of enhanced rock weathering as a nature-based climate solution.

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)*	600 tonnes
Delivery window *(at what point should Frontier consider your contract complete? Should match 2f)*	3 years
Levelized cost (\$/ton CO_2) *(This is the cost per ton for the project tonnage described above, and should match 6d)*	\$771.37/tonne of CO2

Levelized price (\$/ton CO_2)[3] *(This is the price per ton of your offer to us for the tonnage described above)*	\$799.37/tonne of CO2

[3] 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).