Frontier

Exterra Carbon Solutions

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

Exterra Carbon Solutions

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

Quebec, Canada

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

Olivier Dufresne, David Fennell

Brief company or organization description <20 words

Exterra generates low carbon alkalinity and byproducts from mineral waste

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

Exterra Carbon Solutions is pioneering the production of low-carbon metal oxides from mineral waste, crucial for enabling large-scale Ocean Alkalinity Enhancement (OAE) and other carbon dioxide removal (CDR) technologies. This project focuses on the extraction of high-purity, low-

[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.

carbon metal oxides, which are essential for the OAE process that sequesters CO2 permanently by transforming it into stable bicarbonate and carbonate ions in the ocean.
Figures 1 and 2 below outline the technological pathway and chemistry of the CDR approach.

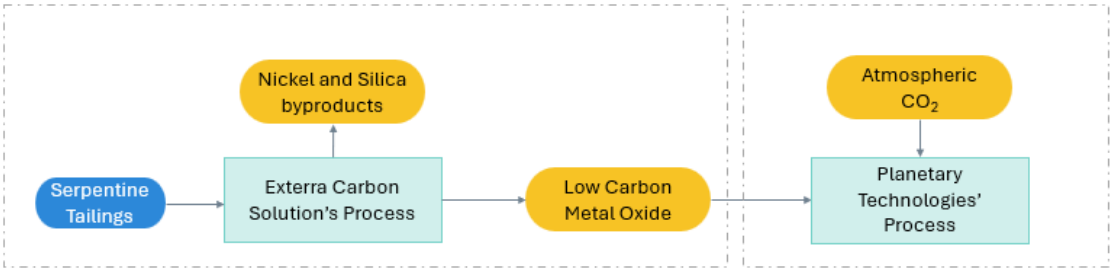


Figure 1: High-Level Technologic Pathway of OAE

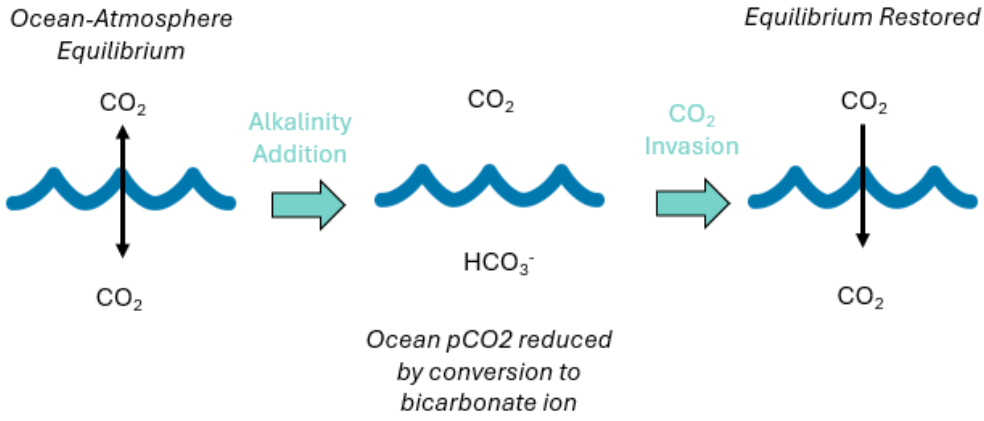


Figure 2: Chemistry of OAE

Our process begins with the extraction of metal oxides from serpentine tailings or other mineral wastes. The extracted metal oxides are then used in OAE, where they react with dissolved CO2 in seawater to form stable carbonates and bicarbonates. This reaction ensures the permanent sequestration of CO2 for over 1,000 years. The chemical reactions involved are as follows: CO2+H2O+MO→MCO3+H2O, where MO represents metal oxides like magnesium oxide (MgO), which react with CO2 to form stable carbonates.

Why Our System is Best-in-Class:

1. **Low-Carbon Alkalinity Production**: Unlike traditional methods of metal oxide production, which emit between 2 to 7 tonnes of CO2 per tonne of metal oxide, Exterra's process generates metal oxides with a minimal carbon footprint. This is achieved by leveraging waste materials from mining operations, thus turning a liability into a valuable resource, and by regenerating nearly all reagents used in our extraction process.
2. **Enabling Large-Scale CDR**: The OAE industry will require millions of tonnes of high-purity metal oxides annually to reach commercial scale. Exterra is uniquely positioned to supply this demand sustainably. Our process not only meets the purity requirements but is also applicable to not only serpentine minerals, but the broader silicate mineral category.

3. **Synergy with Planetary Technologies**: By partnering with Planetary Technologies, we ensure that our low-carbon metal oxides are efficiently utilized in the OAE process and that CDR benefits are maximized. Planetary Technologies' expertise in ocean deployment of metal oxides and MRV complements our strength in low-carbon metal oxide production, creating a robust and scalable CDR solution. The combination of two CDR companies allows to leverage the best of each team and ensure robust and rapid growth to reach commercial scale.

Exterra Carbon Solutions stands out in the carbon dioxide removal (CDR) landscape due to several unique differentiators:

1. **Novel Configuration of Mature Equipment**: Exterra's approach uses mature mineral processing equipment rather than nascent electrochemical processes. This ensures reliability and scalability, with plans to begin commercial scale work (Hub I project) in 2026 to process up to 5,000 tonnes of asbestos mine tailings daily, producing 500,000 tonnes of metal oxides annually.
    1. In the case of Hub I, our process not only facilitates CO2 removal but also addresses asbestos hazards, produces valuable byproducts like amorphous silica for cement replacement and nickel for the clean energy transition, and creates significant economic benefits for local communities with depressed economic activities since the end of asbestos mining.
    2. We have partnered with the City of Val-des-Sources, home to 400 million tonnes of asbestos mine tailings and received $1.8 million in grants from the Quebec government, highlighting our integrated approach and strong community and governmental support, enhancing our project's feasibility and impact.
2. **Secured Feedstock;** Exterra has secured multiple decades worth of feedstock through agreements with owners of mineral waste, enabling a direct path to reaching megatonne scale, and allowing Exterra to prove its technology at scale as it proves the application to other minerals sources in parallel.
3. **Strong Leadership Team with Proven Track-record:** Exterra was founded by mining engineers with a deep understanding of the industry. Our team has grown to 9 employees with a combined experience of 75 years in mine development and mineral processing. Our team has a proven track record of engineering, commissioning and operating 14 mines in North America, South America, and Africa.
4. **Pioneering in the Voluntary Carbon Market**: Exterra has been a leader in the voluntary carbon market, developing multiple protocols for CDR with organizations like puro.earth, Verra, and Isometric. Our active participation in this market has positioned us at the forefront of creating and validating effective carbon removal methodologies, ensuring that our processes are recognized and certified, which enhances their credibility and marketability.

By focusing on low-carbon alkalinity extraction from mineral waste, utilizing established and scalable technology, offering comprehensive co-benefits, leveraging strategic partnerships, and pioneering the voluntary carbon market, Exterra uniquely positions itself to support and scale CDR solutions effectively and sustainably.

The project addresses several key priority innovation areas identified in the RFP:

1. **Leveraging Existing Industrial Assets**:

- **Utilizing Legacy Infrastructure**: The Val-des-Sources site offers critical infrastructure, including an electrical substation, transportation networks (truck and rail access), already mined and crushed silicate minerals, geologic data, and water infrastructure from historical mining operations. This reduces both capital and operational costs and accelerates project development while minimizing the overall environmental and land footprint.

2. **Creating Redundancy and Scalability Across CDR Approaches**:
   - **Low-carbon metal oxides have many sources:** Exterra's technology is adaptable and can produce low-carbon alkalinity from various silicate mineral waste and ore streams, not just serpentine tailings. Each year, global mineral waste streams alone contain upwards of 1 billion tonnes of alkalinity.
   - **Low-carbon metal oxides have many uses:** By providing a reliable and sustainable source of low-carbon metal oxides, Exterra supports the scalability of multiple CDR approaches, including OAE, enhanced weathering, and carbon mineralization.
3. **Lowering Costs through Additional Revenue Sources**:
   - **Valuable Byproducts**: Our process yields high-value byproducts such as amorphous silica and nickel, which generate additional revenue streams. This economic benefit helps offset the costs of producing low-carbon alkalinity, making our CDR approach more financially viable.
   - **Economic Resilience**: The diversified revenue from byproducts ensures that our business model remains resilient and less dependent on carbon credit revenues alone, thereby enhancing the long-term sustainability of our operations.
4. **Marine CDR with Clear Feedstock Strategies**:
   - **Sustainable Feedstock Supply**: The partnership between Exterra and Planetary Technologies represents a new type of CDR project. It leverages the strengths of two companies rather than a single company trying to perform all aspects of carbon dioxide removal. Exterra is focused on the extraction of low-carbon metal oxides from mineral waste while Planetary Technologies is focused on the addition of metal oxides to the ocean and the monitoring, report, and verification associated with it. This combination of two climate technology businesses in a single project that relies on the strengths of each organization is unique compared to a more typical approach where a single business has a particular strength but is positioned to perform all aspects of the CDR project.

By addressing these priority innovation areas, Exterra not only meets the criteria outlined in the RFP but also positions itself as a key enabler of sustainable and scalable carbon dioxide removal technologies.

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

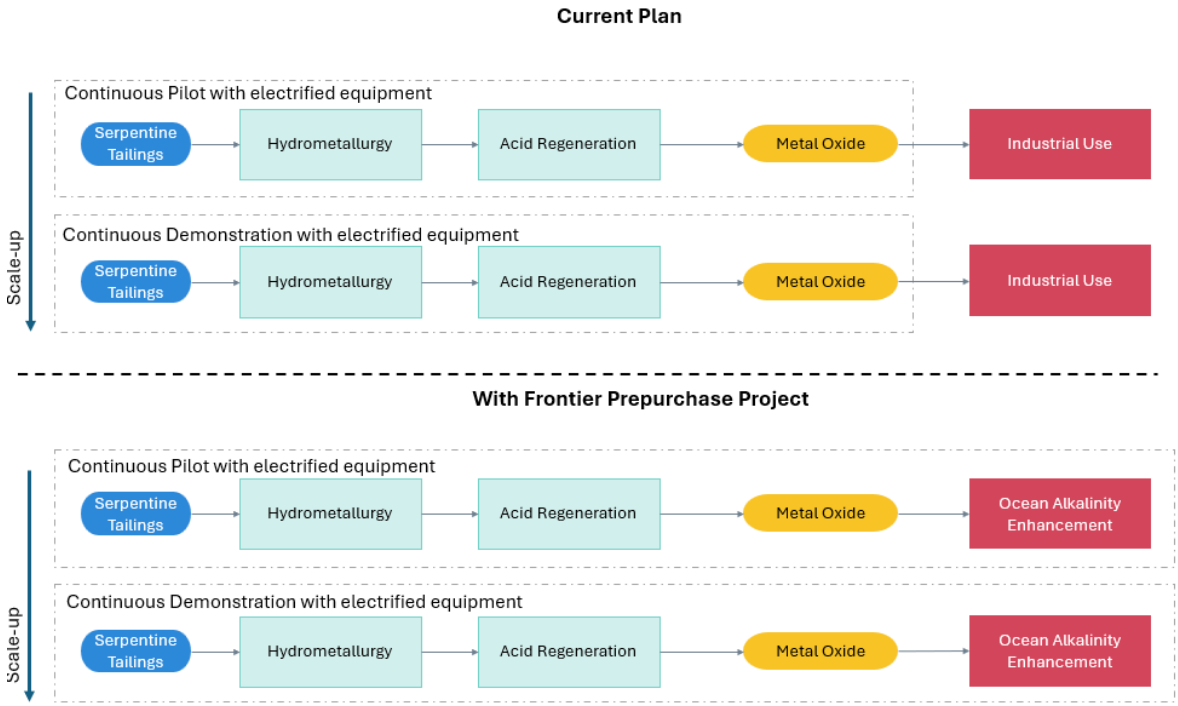
Objective and Scope: This project aims to validate the pathway for Ocean Alkalinity Enhancement (OAE) using metal oxides produced from mineral waste. The primary goal is to demonstrate the feasibility and scalability of producing low-carbon metal oxides from serpentine tailings in Southern Quebec and utilizing them in an OAE facility operated by Planetary Technologies in Nova Scotia, Canada. This initiative is a critical step towards establishing a sustainable and scalable process capable of reaching a removal capacity of 1 million tonnes of CO2 per year by 2030.

Location and Scale:

- **Production Site:** The metal oxides will be produced at Exterra's facility in Southern Quebec, utilizing locally available serpentine tailings.
- **Deployment Site:** The produced metal oxides will be transported to an ocean discharge facility in Nova Scotia, Canada, operated by Planetary Technologies.
- **Scale:** Initially, the project will produce 360 tonnes of metal oxides during the pilot and demonstration phases. This production will serve to optimize the engineering for a full-scale commercial plant, Hub I, which aims to process up to 5,000 tonnes of serpentine tailings daily, producing up to 500,000 tonnes of metal oxides annually. We aim to begin work for the Hub I facility in 2026 and we expect an accelerated construction timeline due to the use of already available infrastructure.

The exact quantity of metal oxide produced at the pilot and demonstration scale is not set because their objective is not for production volume but rather to inform engineering of the commercial plant. This project will use 360 tonnes produced by the pilot and demonstration operations and, if necessary, also use material produced during the startup and commissioning of the Hub 1 plant. The diagram below compares Exterra's operation with and without the Frontier project.

[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.



Cost Breakdown and Path to Cost Reduction:

- **Current Cost Breakdown:**
  - **Transportation:** One of the primary costs involves transporting metal oxides approximately 1150 km by road from Southern Quebec to Nova Scotia. In the pilot phase, trucking is necessary, but this incurs higher costs and CO2 emissions.
  - **Energy Consumption:** Producing metal oxides from serpentine tailings requires significant energy. The use of local hydropower in Quebec helps mitigate the carbon footprint but contributes to operational costs.
  - **Reagents:** The chemical reagents used in the extraction and processing of metal oxides are another significant cost factor. Exterra's process focuses on regenerating nearly all reagents used, reducing overall costs and environmental impact.
- **Approach to Cost Reduction:**
  - **Rail Transportation:** In the long term, rehabilitating the historic rail connection between the mine and the rail network can significantly reduce transportation costs and CO2 impact. However, the initial volumes are too small to justify this capital expenditure.
  - **Scaling Up Production:** As production scales up, economies of scale will reduce per-unit costs. The Hub 1 commercial plant will leverage these efficiencies to lower the overall cost of metal oxide production.
  - **Additional Revenue Streams:** Generating revenue from byproducts such as amorphous silica and nickel will offset costs, making the CDR solution more economically viable. More broadly identifying silicate minerals which contain higher concentrations of Nickel, many of which are known, can significantly reduced the cost of CDR.

- **Optimized Operations:** Continuous optimization of the process through pilot and demonstration phases will enhance efficiency and reduce operational costs.

Quantifying Carbon Removal:

- **Monitoring, Reporting, and Verification (MRV):** Exterra collaborates with Planetary Technologies to ensure robust MRV protocols are in place. The MRV process involves:
  - **Baseline Assessment:** Establishing baseline carbon levels in the ocean at the deployment site.
  - **Continuous Monitoring:** Using advanced sensors and analytical tools to measure the changes in ocean alkalinity and carbon levels after metal oxide deployment.
  - **Third-Party Verification:** Independent verification by recognized organizations to validate the carbon removal claims and ensure transparency and accuracy.

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

Risk	Mitigation Strategy
Technical Process	• Favor commercially available equipment for first plant • Achieve multi-month continuous operation of complete process at pilot and demonstration scale before engineering of commercial plant • Contract experienced process development consultants from early stage • Perform significant engineering work prior to project construction • Leverage team's past experience in mine and mineral processing development to avoid common pitfalls
Scale-Up Risk	• Favor already-scaled mineral processing technologies with well understood scale-up curves • Robust pilot and demonstration operations ensuring maximum data gathering to identify opportunities and address uncertainties • Work with leading global experts in the most critical areas of the process, leveraging decades of experience in a wide range of feedstock types
Carbon Price	• Exterra will produce non-carbon products to diversify revenue and reduce sensitivity to carbon pricing • Exterra is working towards a pilot project to be able to secure a CO2 price for a portion of its Hub I project's production ahead of time
Viability of byproducts	• Exterra is working with end users and developing a technical data sheet to advance discussions with buyers • The annual production from Hub I will consider the market capacity for each product stream • Exterra will advance discussions and test work with end users who engaged with past projects with similar byproducts
Processing Cost	• Exterra is conducting 3 phases of engineering study in parallel with pilot and demonstration operations to gain certainty on the

	operational parameters, which will define the costs at commercial scale • Exterra has contracted experienced engineering firms to perform this work
Feedstock Availability	• Exterra has secured option agreements on feedstock for +30 years of production • Exterra will work to grow the material • Exterra has submitted a bid for a recently bankrupt company's serpentine feedstock and relevant intellectual property including geologic characterization work
Health and Safety	• Exterra is working with laboratories and test work providers who are experienced and approved to work with Asbestos containing materials. • All products and by-products of the process are sent for analysis to confirm the full destruction of asbestos fibers

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)*	504 net tonnes CDR (Note, volume as associated with project delivery window, not total project lifetime)
Delivery window *(at what point should Frontier consider your contract complete? Should match 2f)*	December 2024 to Q2-2026 (if necessary, extended to March 2027)
Levelized cost ($/ton CO_2) *(This is the cost per ton for the project tonnage described above, and should match 6d)*	446
Levelized price ($/ton CO_2)[3] *(This is the price per ton of your offer to us for the tonnage described above)*	992

[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).