COREM

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

COREM

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

Palo Alto, CA

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

Jade Marcus & Matt Kanan

Brief company or organization description <20 words

COREM releases the Earth's alkalinity to create a fast-weathering fertilizer that removes CO_2 and reduces N_2O emissions

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

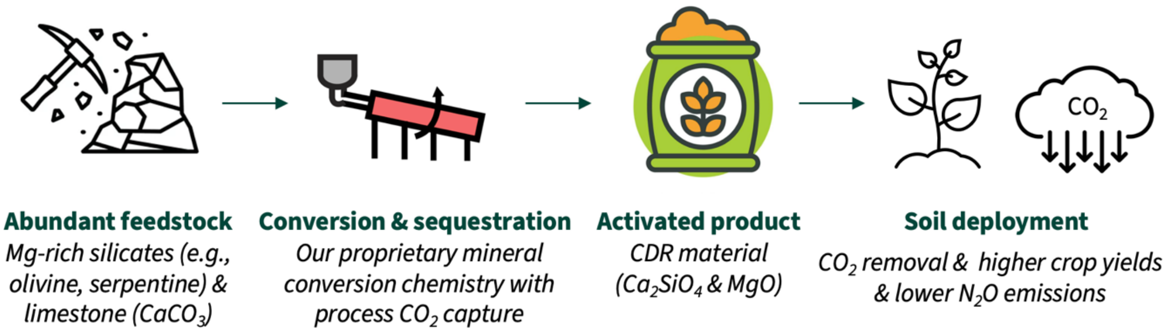
a. **Description of the CDR approach:** Describe how the proposed technology removes CO_2 from the atmosphere, including how the carbon is stored for > 1,000 years. Tell us why your system is best-in-class, and how you're differentiated from any other organization working on a similar approach. If your 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

How we remove carbon:

Enhanced weathering (EW) approaches to CO_2 removal (CDR) are currently limited by very slow

[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.

weathering rates of the silicate minerals that are available on Gt scales. To address this barrier, we have developed a thermal mineral conversion process that transforms limestone ($CaCO_3$) and magnesium silicates into calcium silicates (e.g. Ca_2SiO_4 (larnite)) and magnesium oxide (MgO, periclase). This mineral composite, which we call "CDR material", weathers orders of magnitude faster (100-1000x faster) than typical EW substrates under ambient conditions relevant for open systems and provides durable removal of CO_2 in the form of stable (bi)carbonate ions. While the mineral conversion process releases CO_2, it is emitted in a concentrated form that can readily be sequestered by subsurface injection. The amount of CO_2 removed from the atmosphere as (bi)carbonate ions by the CDR material substantially exceeds the amount of CO_2 that is sequestered by injection (~2:1 ratio with potential for improvement with further development). By unlocking the alkalinity trapped in the Mg silicate, we provide incontestable additionality.



When applied to soil, our material can serve as a Si fertilizer and pH adjuster, providing a substantial increase in plant yield and resistance to pests as well as potential reduction in N_2O emissions. Because of the fast weathering of our material, we can achieve these agronomic benefits and verifiable CDR at application rates of ≤1 ton/acre, which is critical for scalable agronomic adoption because farmers already apply inputs such as aglime at similar application rates.

How durable is our removal:

When CDR material weathers in soil, the removed CO_2 is ultimately stored as dissolved bicarbonate ions in the ocean, which persist for 10,000–100,000 years. If used in other applications, the removed CO_2 is either stored as dissolved bicarbonate or as precipitated carbonate minerals, which are essentially indefinitely stable.

What differentiates us?

- **CO_2 capture rate:** we weather 100-1000x faster than existing EW substrates that are available on Gt scales.
- **Low energy intensity:** we utilize 60% less energy per ton CO_2 removed when compared to leading direct air capture technologies
- **Cheap feedstocks with multi-Gt/yr abundance:** we can transform *any* Mg silicate into a fast-weathering product. Mg silicates provide an inexhaustible reserve of alkalinity, with >100,000 Gt CDR capacity just from the Mg silicates found in ultramafic rocks.
- **Incontestable additionality:** our innovation unlocks alkalinity presently trapped in silicate minerals, thereby mobilizing this ultra-abundant reserve of alkalinity that would otherwise be unutilized on a relevant timescale.
- **Scalable process & technology:** we can utilize rotary kilns to produce our materials at scale, one of the only technologies already used for multi-Gt/yr production. By eliminating the need to invent new process tech, we minimize scaling and technology risks.
- **Co-benefits:** Our product offers major agronomic co-benefits as a Si fertilizer. Materials that weather to release silicic acid ($Si(OH)_4$) have well established yield and resilience benefits for crops that are food staples, including rice, maize, soybeans, barley, and tomatoes. Because of its rapid weathering, our product can provide these benefits at low application rates that are feasible for large-scale, economic deployment.
- **Broader GHG impacts:** Beyond the benefits to yield and resistance, our product can be used

to tune soil pH to reduce farmland N_2O emissions, which currently account for 50-80% of anthropogenic N_2O emissions.

- **MRV:** The fast weathering of our material simplifies MRV by reducing the number of measurements needed.
- **Versatility:** We have the ability to tune our material composition and reactivity to meet needs of diverse soils in different geographies. Our product can be deployed for CDR in non-agricultural settings ranging from industrial waste sites to open terrain.

Why us?

We have a uniquely enabling technology: Earth's abundant and accessible alkalinity sources (silicates like basalt, olivine, serpentine) are just not very reactive. Our technology, to our knowledge, is the only product that solves this fundamental problem by converting these abundant feedstocks into completely natural but much more reactive minerals. Our products also have incontestable additionality as we are unlocking new alkalinity and our cradle to grave includes mining, processing, and deployment inefficiencies.

We are well positioned for deployment: Along with our partners, we span the value chain from material sourcing to MRV. We have deep expertise across our partners and core members: chemists who pioneered the mineral conversion process, chemical engineers who can scale the process efficiently, agronomists who can optimize the co-benefits, and MRV experts who can quantify removal of CO_2. Our team and partners are excited and energized to be working together to limit warming through carbon dioxide removal by activating our biggest weapon: the rock underfoot.

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

What are we trying to build

Our vision is to become a fertilizer company that removes CO_2 from the atmosphere at the Gt scale by 2050 relying not on the voluntary carbon market (VCM) to do so, but rather on our incontestable value as an agronomic input that helps fuel economies worldwide with increased agricultural productivity.

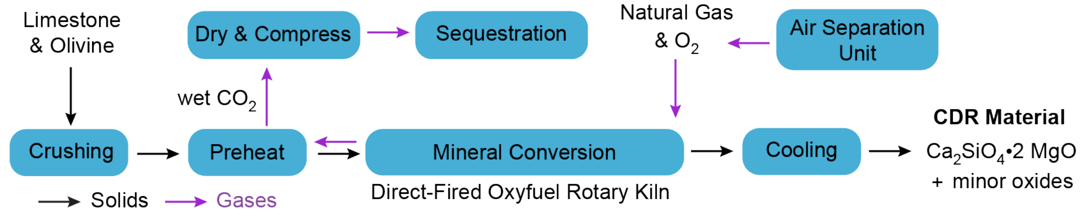
Our proposal to Frontier is to support COREM as we scale our novel thermochemical process to generate CDR material and meaningfully remove carbon in a way that is both additional and durable. To maximize Frontier's CO_2 purchasing power, we propose a two-phase approach that will remove 1,150 tons of net CO_2 as our material weathers to form stable dissolved bicarbonate ions. This approach will support us in scaling our production capacity and establishing the agronomic benefits of our material to drive adoption, signing on key offtakers for our fertilizer. For this project, we will use our proprietary mineral conversion process to produce CDR material comprising $Ca_2SiO_4 \cdot 2MgO$ (with Fe oxide and other minor oxide impurities) from limestone and olivine. While our technology works with *any* Mg silicate, we are prioritizing olivine for this project because of its very high Mg content. For the first phase, the process will be performed by a toll manufacturer where a small fraction of Frontier's removal will be generated. The bulk of the CO_2 removal will be delivered during our second phase where we build our FOAK 100 kt/yr facility in the Southeast US.

So what is our process?

A high-level schematic of our mineral conversion process is shown in the figure below. The limestone

[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.

and olivine are first crushed to an appropriate size for kiln processing, preheated using the hot flue gas stream, and then fed into a direct-fired kiln, where the limestone is calcined to form CaO and release CO_2, and the CaO reacts with the olivine to form Ca_2SiO_4 and MgO, the "CDR material". Metal impurities in the olivine are also transformed into oxide phases in this reaction. The CDR material is cooled and collected for shipment to farmland. The balance of system includes an air separations unit to supply O_2 to the kiln.



The flue gas from the mineral conversion process contains the CO_2 released from the limestone and an additional smaller amount of CO_2 and H_2O from the oxyfuel natural gas combustion. The flue gas is dried to provide a pure stream of CO_2 that is then compressed and injected into a pipeline for geologic storage.

Overall, >90% of the energy required to generate our CDR material is thermal energy, which drives down costs and insulates the tech from cost pressures arising from the projected growth in electricity demand in the coming decades. While our FOAK design and TEA/LCA currently assume the use of natural gas as the fuel for mineral conversion, the use of biogas or gasified biomass is a potential carbon-neutral alternative that would further improve the LCA.

How and where we are building

Phase 1: Our first phase will be conducted with a toll manufacturer in Indiana using a pilot-scale direct-fired rotary kiln with an operational capacity to produce 1,000 tons of CDR material per year. From here the material will be transported to our ag partner's farm in Mississippi and applied at the beginning of the growing season.

However, the use of toll manufacturing for this first pilot-stage of production is done at a substantial premium. As a result, we will offer only offer a modest volume of 50 tons of CO_2 removed to Frontier from this pilot-scale material. The advantage of using toll manufacturing is that it enables us to de-risk the design and operation of the rotary kiln without large capital expenditures while producing enough CDR material to perform substantive field trials and build ag market demand for our material by demonstrating its agronomic benefits.

Phase 2: The second phase will deliver the bulk of Frontier's removal which will be produced by our FOAK plant with a target CDR capacity of 100 kton of net removal/yr. The plant will be located in the Southeast region near the Gulf Coast, taking advantage of proximity to domestic limestone providers, maritime ports for access to low-emissions silicate feedstocks, and expansive agricultural land with soils and crops that stand to benefit greatly from Si fertilization. The plant will operate a direct fired kiln with oxyfuel combustion of natural gas and the CO_2 emissions will be sequestered by subsurface injection. With the help of an industry partner who has decades of large-project experience, we have developed a process flow diagram for this plant with all major unit operations and mass and energy balance.

How we measure

The CDR material will be transported to a farm in Mississippi and applied at the beginning of a growing season at 0.5 - 1 ton per acre. The weathering of the material and resulting CO_2 removed will be monitored and quantified by our MRV partner using a procedure they have already implemented and validated in multiple large field trials. We anticipate complete weathering within 1 growing season, which reduces the number of measurements and duration of monitoring needed to verify removal.

How we achieve < $100/ton @ 0.5 Gt/yr

Although our offer to Frontier is 1,150 tons of CO_2 at a price $337/ton CO_2, we see a clear path to offering CDR at <$100/ton driven by several factors: (1) we will take the production in-house, reducing the extremely high premium of toll-manufacturing once we have de-risked the technology, (2) economies of scale: we predict that by NOAK, we can viably achieve <$100/ton CO_2 by reducing the financing costs as the at-scale process is de-risked. We also believe we will unlock additional reductions through traditional benefits of scaling such as technical know-how in process optimization, decreased fixed opex per ton of material, etc. , (3) establishment of a healthy Si-based fertilizer market and the value of our product to increase crop yield can reduce the price paid for carbon removal substantially (4) by demonstrating that our product can reduce N_2O emissions, which are ~300x as potent as CO_2, we can drive additional value, especially for biofuel producers looking to reduce the carbon intensity of their product.

As we build market traction with (3) and (4), we can get to the 0.5 Gt/yr because there are >7 billion acres of farmland world-wide and we believe that more than 1 billion acres can have substantial benefits from Si fertilization alone. If the benefits of N_2O reduction are realized in our field trials, this unlocks even more potential to grow as regulatory bodies are pushing for these reductions.

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

Technical: Our process is more complex than competing EW approaches that rely mostly on grinding and spreading feedstocks, which means that we need a larger upfront investment to begin deployment. However, the benefits our product offers – much faster and complete weathering, the ability to use agronomically accepted application rates, improved plant yields and pest resistance – more than offset this initial investment to scale the technology. Importantly, our solution doesn't need to invent any new infrastructure as we can utilize rotary kiln technology that is already proven on the Gt scale. We need to optimize the kiln operation parameters for our chemistry, but we can leverage the depth of expertise that is widely utilized today in the cement industry. To minimize risks of delays in scaling our technology, we are building a network of experts in solids processing and kiln operation.

Financial: The Si fertilizer market in the US is in its infancy, unlike Asia's well established Si fertilizer market. The benefits have been widely demonstrated there, with crop yields on average increasing by >10%; however, the US, because of limited availability and lack of awareness, has yet to apply these types of fertilizers widely. We are currently working with our partners to deploy our materials across a variety of crops and soils in Louisiana to help demonstrate the benefits of COREM's product as a fertilizer. Additionally, we recognize that soil compositions vary drastically across geographies, so we will continue to work with farmers and expand our outreach to ensure formulations meet farmer's geographical needs for increasing crop yield and develop our products alongside farmers to build market traction. COREM's goal is to become a fertilizer company that can remove CO_2 at scale and reduce N_2O emissions through pH modulation and we invite farmers to join us on this endeavor to make farming both more sustainable and more profitable.

MRV: Soil is an inherently challenging environment for MRV because of its heterogeneity and high background cation levels. We mitigate the risks of MRV in soil by working with a partner who has spent years developing and validating an MRV protocol for EW in soil and by leveraging the emergence of standardized, rigorous protocols that have been thoroughly vetted by the scientific community. The fast weathering of our material simplifies MRV by reducing the number of measurements required. Eventually, we expect that our material could be deployed with minimal measurements required because its fast-weathering properties will be amply demonstrated across multiple soil types.

Ecosystem: With any new product introduced into an ecosystem, one needs to ensure that there are no unintended, harmful side-effects. While our product is made from only natural inputs (limestone and silicate minerals), there are metal ions present in these feedstocks (e.g. Ni) that are essential at low concentrations but could adversely affect plant health at high levels. We address this risk by using

application rates that ensure that impurity metal ions are well within safe limits at 100% weathering. We will do extensive field trial work prior to selling our product and use soil measurements to confirm ecosystem safety.

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)*	1,115 tons
Delivery window *(at what point should Frontier consider your contract complete? Should match 2f)*	Q4 2026 – Q4 2029
Levelized cost ($/ton CO_2) *(This is the cost per ton for the project tonnage described above, and should match 6d)*	$298 / ton CDR (FOAK) (with predictions to reach <$100 / t with NOAK)
Levelized price ($/ton CO_2)[3] *(This is the price per ton of your offer to us for the tonnage described above)*	$337 / net ton CDR (FOAK)

[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).