Frontier

Andes

Carbon Dioxide Removal Purchase Application

Fall 2022

General Application - Prepurchase

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

Company or organization name

Andes Ag, Inc.

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

Alameda, CA

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

Kaitlyn Baab

Brief company or organization description

Andes empowers biology to enable positive action against climate change.

1. Project Overview[1]

a. Describe how the proposed technology removes CO_2 from the atmosphere, including as many details as possible. Discuss location(s) and scale. Please include figures and system schematics. Tell us why your system is best-in-class, and how you're differentiated from any other organization working on a similar technology.

Andes has developed a carbon dioxide removal (CDR) solution called Microprime™ CDR technology based on proprietary microorganisms that interact with plant roots. Andes' microorganisms accelerate the formation of bicarbonates in the soil. Contrary to agricultural approaches for Soil Organic Carbon (SOC) buildup

[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.

in soil, Andes Microprime™ CDR technology is focused on Soil Inorganic Carbon (SIC) formation in agricultural lands. Carbon dioxide (CO_2) can naturally be converted into bicarbonate and solids such as calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$); however, the process of abiotic hydration of CO_2 to generate bicarbonate (HCO_3-) is slow. Certain microbes can catalyze the bio-conversion of CO_2 through different pathways to accelerate fixation of carbon into organic and inorganic forms (Kajla et al., 2022).

Andes Microprime™ CDR technology uses a proprietary microbial strain to accelerate and stabilize the generation of SIC at a commercial scale. Andes' CDR strain is a naturally-occurring, beneficial soil bacterium, isolated from soil samples where traditional agriculture is practiced. This strain is robust at establishing on plant roots and in the soil rhizosphere, and there it forms a beneficial relationship with the plant, improving soil health and enhancing crop yields. Near the root of plants an elevated concentration of CO_2 is present due to plant, soil fauna and microbial respiration (note: a corn plantation has a soil CO_2 efflux of over 7 tons/acre/season, Rochette & Flanagan, 1997). When established in the rhizosphere, Andes' CDR strain actively enhances the alkalinity of its environment through different mechanisms. Through a combination of the enhanced alkalinity and enzymatic activity, the hydration of CO_2 to form bicarbonate is strongly accelerated by Andes' CDR strain. Similar to Enhanced Rock Weathering technology, the enhanced alkalinity of the environment promoted by Andes Microprime™ CDR strain ensures that the generated bicarbonate is stable, while at the same time buffering the soil for protons (H+) which are released in the process. We have observed this enhanced alkalinity in 2021 field trials, as well as our 2022 carbon program covering more than 25,000 acres. In addition, we have set up controlled environment assays in the laboratory and greenhouse. In these controlled environments, we have observed the same enhanced alkalinity and bicarbonate formation mediated by Andes' CDR strain as observed on the field.

In the presence of freely available cations such as calcium, negatively charged bicarbonate ions will readily convert into carbonate minerals (e.g. calcium carbonate). We have indeed observed this in controlled laboratory experiments. In field trials, we have found that the pools of available cations (Ca2+, Mg2+, Na+, K+) in the soil are not significantly affected, suggesting that a significant part of the SIC buildup we observe in field soils occurs in the form of bicarbonates. In greenhouse studies, we've also observed a significant increase in bicarbonate in soil from plants treated with Andes CDR strain compared to soil from control plants.

With Andes Microprime™ CDR technology placed in the soil, a significant amount of CO_2 is removed from the atmosphere (e.g., 3 tCO_2/acre/season). For more information on how Andes Microprime™ CDR technology works please see the diagram in the attached confidential addendum. For more details on MRV and some of our experimental results on the mechanism-of-action of the strain, please also see the attached confidential addendum.

Andes Microprime™ CDR technology requires no investment from farmers and integrates seamlessly into their existing agricultural practices, exponentially increasing adoption by lowering the cost of participation in carbon markets. Contrary to Andes approach, most soil carbon capture initiatives require farmers to make multi-year commitments and large investments associated with the change of practice, leaving many farmers averse to pursuing such projects. Andes Microprime™ CDR technology creates a win-win solution by lowering the barrier of entry for farmers to contribute to sustainably reduce CO_2 from the atmosphere while creating a new income stream. By working with Andes, farmers have access to Microprime™ CDR technology for free and receive a cash payment at the end of the season with a one year commitment. Additionally, farmers benefit from the positive effect of the microbes contained in the Microprime™ CDR technology, which (after 3 seasons of trials) is equal to roughly an extra 5.7 bu/ac in corn, 1.0 extra bu/ac in soybeans and 4.6 extra bu/ac in wheat.

The suitable agricultural land for Andes first generation Microprime™ CDR technology is roughly 200 million acres in the US, over 40 million acres in Canada, and more than 150 million acres in South America. With the low cost of production and seamless integration with existing agricultural technologies and practices, Andes Microprime™ CDR technology is highly scalable enabling a bold plan for upcoming years. By 2030, we plan to reach over 25 million acres, generating a yearly high-durability CDR rate of approximately 75 million tons CO2.

b. What is the current technology readiness level (TRL)? Please include performance and stability data that you've already generated (including at what scale) to substantiate the status of your tech.

Andes is at TRL 8 at this moment. After 2 years of trials, we launched our first commercial season on 25,000 acres across three states (North Dakota, Minnesota and Wisconsin). With the data from field trials and data that we started to receive from the 2022 commercial season, we see that our product works in its final form - under expected conditions, we are able to capture, on average, 3 tCO2/acre/season compared to control sites.

c. What are the key performance parameters that differentiate your technology (e.g. energy intensity, reaction kinetics, cycle time, volume per X, quality of Y output)? What is your current measured value and what value are you assuming in your nth-of-a-kind (NOAK) TEA?

Key performance parameter	Current observed value (units)	Value assumed in NOAK TEA (units)	Why is it feasible to reach the NOAK value?
TICS (Terrestrial	3 tCO_2/acre/season	9 tCO_2/acre/season	We're in the process of

Inorganic Carbon Sinking) performance			engineering strains with improved carbon capture performance and have made great progress.
Number of direct soil samples per field/season	9 to 63 soil samples/field/season	3 to 9 soil samples/field/season	Moving from direct sampling to a hybrid that includes modeling. Currently we are taking 9 soil samples per field/season.

d. Who are the key people at your company who will be working on this? What experience do they have with relevant technology and project development? What skills do you not yet have on the team today that you are most urgently looking to recruit?

We've brought together a stellar team of 31 world-class multidisciplinary professionals, 14 of whom have Ph.D. in biological sciences. Our team has extensive experience in microbiology, enzyme biochemistry, synthetic biology, soil science and agriculture. The team has already developed a breakthrough technology that removes 3 tonnes of CO_2/acre on average during one agricultural season. Some notable team members working on our technology include:

Tania Timmerman - 15 years of experience studying the interaction between plants and beneficial bacteria and developer of the first in-seed treatment. PhD in Complex Systems Engineering from Adolfo Ibáñez University.

Bjorn Traag - over 10 years of experience in industry working on development of microorganisms for agriculture (Bayer, Joyn Bio, Zymergen). PhD in Molecular Genetics from Leiden University, Postdoc at Harvard University.

Sharon Hoover Nademanee - over 10 years working in microbial genetics and molecular biology, engineering bacterial strains for enhanced performance. PhD in Biology from Stanford University, Postdoc at UCLA.

Phil Weyman - 20 years of experience in synthetic biology, strain engineering, NGS genome sequencing, and protein expression in academia and industry. PhD in Plant Pathology from UC Davis, Principle Investigator at J. Craig Venter Institute.

Anupam Chowdhury - Technical Expert in metabolic engineering, bioinformatics, and data science with 10 years of experience in building software ecosystems for genome engineering and technical ideation of bio-advantaged products. PhD in Systems Biology from Penn State University.

e. Are there other organizations you're partnering with on this project (or need to partner with in order to be successful)? If so, list who they are, what their role in the project is, and their level of commitment (e.g., confirmed project partner, discussing potential collaboration, yet to be approached, etc.).

Partner	Role in the Project	Level of Commitment
Farmers	Andes partners with farmers to deploy its Microprime™ CDR technology on their	One-year agreements signed for 2022 agricultural season and is

	fields, and provides them with compensation.	renewable upon mutual consent
Carbon credit buyer	Purchaser of carbon credit	Ideal outcome would be a multi-year offset agreement
Contract analytical laboratory	Independent 3rd party laboratory that conducts analysis of soil samples	One-year contract currently in place, planning to secure a multi-year agreement
Contract manufacturing organization	Produces microbial product for Andes	Have agreement in place for product needed in 2022 and 2023 (easy to extend for future years)

f. What is the total timeline of your proposal from start of development to end of CDR delivery? If you're building a facility that will be decommissioned, when will that happen?

The length of the project is one year from enrollment of agricultural fields to CDR delivery (December 2022 for this project).

g. When will CDR occur (start and end dates)? If CDR does not occur uniformly over that time period, describe the distribution of CDR over time. Please include the academic publications, field trial data, or other materials you use to substantiate this distribution.

With application of Andes' microbial product, CDR occurs during one agricultural season: March - October.

h. Please estimate your gross CDR capacity over the coming years (your total capacity, not just for this proposal).

Year	Estimated gross CDR capacity (tonnes)
2023	150,000
2024	300,000
2025	1,500,000
2026	4,500,000
2027	15,000,000
2028	30,000,000

2029	45,000,000
2030	75,000,000

i. List and describe at least three key milestones for this project (including prior to when CDR starts), that are needed to achieve the amount of CDR over the proposed timeline.

	Milestone description	**Target completion date** (eg Q4 2024)
1	Conduct final round of direct sampling	Q4 2022
2	Complete analysis of all soil samples	Q4 2022
3	Close-out of 2022 Commercial Carbon Program	Q4 2022

j. What is your IP strategy? Please link to relevant patents, pending or granted, that are available publicly (if applicable).

Our IP strategy comprehensively protects the Microprime seed treatment technology and the microbe-mediated carbon dioxide removal (CDR) technology. One non-provisional patent was published in April 2019 protecting the novel seed treatment method, Microprime, to deliver microbial strains for a broad range of applications.

One non-provisional patent was published in April 2022 protecting the use of microbial strains and enzymes to produce bicarbonates and carbonate minerals for carbon dioxide removal (CDR) in soil.

Two additional provisional patents were filed in April 2022 to protect strategies of improving the microbial CDR technology using computational and engineering approaches for soil and non-soil applications.

Title	Filing date	Filed in	Application number	Status
Novel Seed Treatment Methods and Compositions for Improving Plant Traits and Yield	4/17/2019	USPTO	PCT/US2020/028569 Link	Non-provisional
Compositions and Methods for Producing Bicarbonates and Minerals	4/28/2022	USPTO	PCT/US2021/056083 Link	Non-Provisional

k. How are you going to finance this project?

> The company and its scientific programs have been backed-up by leading incumbents in the agricultural industry including Bayer, a world leader in row crop seed genetics and traits, and Wilbur-Ellis, a U.S. leader in the supply and distribution of agricultural inputs. With the application of our product at commercial scale, we plan to finance the Opex of this project with revenue coming from the sale of carbon credits.

l. Do you have other CDR buyers for this project? If so, please describe the anticipated purchase volume and level of commitment (e.g., contract signed, in active discussions, to be approached, etc.).

> We are in discussions with direct buyers and have been offering our product through marketplaces.

m. What other revenue streams are you expecting from this project (if applicable)? Include the source of revenue and anticipated amount. Examples could include tax credits and co-products.

> N/A - we are not expecting other revenue streams from this project. In our partnership with the farmer we provide Microprime™ CDR technology for free.

n. Identify risks for this project and how you will mitigate them. Include technical, project execution, ecosystem, financial, and any other risks.

Risk	Mitigation Strategy
1) Inability to accurately measure the amount of carbon captured due to percolation. With rainfall, bicarbonate and carbonate minerals will percolate through the soil matrix. We take soil samples at a depth of 12 inches. With rainfall close to time of sampling, there is a possibility our soil samples are “missing” some of the carbon captured since it will have traveled deeper in the soil matrix.	We take three soil sampling points - pre-plant, mid-season, and post-harvest. Mid-season and post-harvest could be impacted by rainfall so we try to take these samples as close to the target date as possible. For future years, we plan to follow a hybrid approach - combination of direct sampling and model. The model would account for percolation.
2) Natural events that might impact durability. One potential risk of durability / reversals is abrupt changes in soil pH to become acidic from natural catastrophe (e.g., intense and continued acid rain). Events such as heavy rainfall or acid rain are considered low for the	We are monitoring weather conditions in our project area to further understand the potential risk of adverse weather events.

geographic areas covered in the project (based on data from NOAA, historical average annual precipitation in our project area ranges from 18 to 33 inches).	
Given the question, we focused our risks on this project for the 2022 season. Since the season is nearing an end few risks remain. For future seasons there are additional operational and natural risks (for example, extreme weather in North Dakota that limits agricultural practices from occurring), however we found they were out of scope for this question. We are happy to provide additional information if helpful.	

2. Durability

a. Describe how your approach results in permanent CDR (> 1,000 years). Include citations to scientific/technical literature supporting your argument. What are the upper and lower bounds on your durability estimate?

In soil with a pH between 6.4 and 10.3, bicarbonate is the main product from the dissolved inorganic carbon (DIC) pool (Xianwei et al, 2021). Andes Microprime CDR Technology is applied on soils with a pH between 6.5 and 8.5 in order to guarantee the stability of the bicarbonate that is formed and promoted by the action of our microorganism. With rainfall, and due to its solubility, bicarbonate and calcium bicarbonate molecules will readily percolate into deeper horizons and in those horizons the pH will stay alkaline due to the parental material of the type of soils where our technology is deployed. Due to the latter, the CO_2 sequestered in bicarbonate molecules, and in some fraction as calcium carbonate/calcium bicarbonate, will remain stable in groundwater rivers, and oceans (Sanderman, J. 2012).

Literature has shown under natural conditions and over millions of years, soil carbonate minerals have buffered the negative consequences of acid rain and soil acidification due to agricultural inputs such as nitrogen fertilizers (Raza et al, 2021, Zamanian et al. 2021, 2016; Turner and Laliberte, 2015; Cailleau et al., 2004; Monger and Gallegos, 2000; Retallack, 1990; Schlesinger, 1982) and thus can stay for long residence times (1,000 to 1,000,000 years).

Verification of permanence will be conducted via direct soil sampling as well as lab-based verification of the precipitation and percolation of bicarbonates.

b. What durability risks does your project face? Are there physical risks (e.g. leakage, decomposition and decay, damage, etc.)? Are there socioeconomic risks (e.g. mismanagement of storage, decision to consume or combust derived products, etc.)? What fundamental uncertainties exist about the underlying technological or biological process?

The risks of heavy rainfall, acid rain, and the use of acidic substances in the soil that might affect durability are considered low for the geographic areas covered in the Andes project. Additionally, we ask the farmers not to use acidic substances in substantial amounts that might impact soil pH in the fields enrolled in the carbon program. Andes Microprime™ CDR technology will be deployed on fields that have soil pH > 6.5 to accelerate and stabilize bicarbonate generation and therefore sequester significant amounts of CO_2. Under relatively basic pH (e.g. pH 7.0 - 8.5), there is a high degree of certainty that bicarbonates molecules will stay stable after they percolate through soil profile into groundwater and eventually reach water systems (e.g., streams, rivers, and ocean) (Sanderman, J. 2012). Andes team will be collecting extensive soil samples and data from all the fields in the project for direct measurement as part of its program offering to farmers implementing Andes Microprime™ CDR technology on their fields. Monitoring weather conditions in our project area will also be conducted to further understand the potential risk of adverse weather events.

3. Gross Removal & Life Cycle Analysis (LCA)

a. How much GROSS CDR will occur over this project's timeline? All tonnage should be described in **metric tonnes** of CO_2 here and throughout the application. Tell us how you calculated this value (i.e., show your work). If you have uncertainties in the amount of gross CDR, tell us where they come from.

Gross tonnes of CDR over project lifetime	We are targeting 75,000 tCO_2 for the 2022 season.
Describe how you calculated that value	Based on data we have to-date, we see our technology captures around 3 tCO_2/acre/season. The soil analysis from the 2022 fields is in progress and will be complete by the end of year. During this project lifetime (season 2022), we implemented our technology on 25,000 acres, we therefore assume 3 tCO_2/acre*25,000 acres = 75,000 tCO_2

b. How many tonnes of CO_2 have you captured and stored to date? If relevant to your technology (e.g., DAC), please list captured and stored tons separately.

In 2020 and 2021, we completed field trials and captured 949.18 tons of CO2. The soil analysis from this season 2022 is in progress and will be done by the end of 2022. From the data that has already been analyzed, we see that on average 3 tCO2/acre/season has been removed compared to UTC fields.

c. If applicable, list any avoided emissions that result from your project. For carbon mineralization in concrete production, for example, removal would be the CO_2 utilized in concrete production and avoided emissions would be the emissions reductions associated with traditional concrete production.

Do not include this number in your gross or net CDR calculations; it's just to help us understand potential co-benefits of your approach.

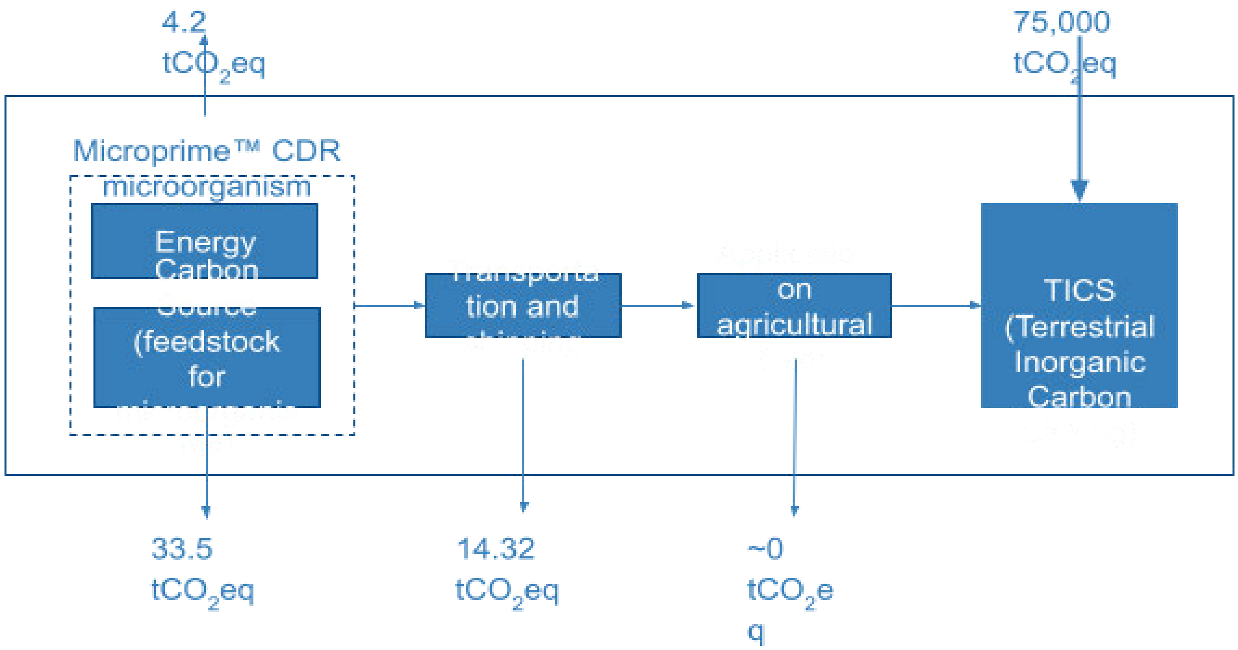
N/A

d. How many GROSS EMISSIONS will occur over the project lifetime? Divide that value by the gross CDR to get the emissions / removal ratio. Subtract it from the gross CDR to get the net CDR for this project.

Gross project emissions over the project timeline *(should correspond to the boundary conditions described below this table)*	52.02 tCO_2eq
Emissions / removal ratio *(gross project emissions / gross CDR–must be less than one for net-negative CDR systems)*	0.00069 tCO_2eq
Net CDR over the project timeline *(gross CDR - gross project emissions)*	74,947.98 tCO_2eq

e. Provide a process flow diagram (PFD) for your CDR solution, visualizing the project emissions numbers above. This diagram provides the basis for your life cycle analysis (LCA). Some notes:

- The LCA scope should be cradle-to-grave
- For each step in the PFD, include all Scope 1-3 greenhouse gas emissions on a CO_2 equivalent basis
- Do not include CDR claimed by another entity (no double counting)
- For assistance, please:
  - Review the diagram below from the CDR Primer, Charm's application from 2020 for a simple example, or CarbonCure's for a more complex example
  - See University of Michigan's Global CO_2 Initiative resource guide
- If you've had a third-party LCA performed, please link to it.



f. Please articulate and justify the boundary conditions you assumed above: why do your calculations and diagram include or exclude different components of your system?

Include: Production of the microorganisms consists of a fermentation process performed by a CMO. During this process, energy and a carbon source (the feedstock for the microorganisms) are used. The product is packaged and shipped to the agricultural operator (farmer). Transportation and shipping. The amount of product necessary to cover the 25,000 acres is up to 100 lbs, making the footprint of the transportation minimal. Exclude: Direct application of the microorganisms on the field doesn't require a special process as it is mixed with fertilizer applications that are typically performed by farmers as an in-field application or seed treatment.

g. Please justify all numbers used to assign emissions to each process step depicted in your diagram above. Are they solely modeled or have you measured them directly? Have they been independently measured? Your answers can include references to peer-reviewed publications, e.g. Climeworks' LCA paper.

Process Step	**CO_2(eq) emissions over the project lifetime (metric tonnes)**	**Describe how you calculated that number. Include references where appropriate.**

Microorganism Production	37.7 tCO_2eq	This number was provided by our third-party Contract manufacturing organization.
Transportation and shipping	14.32 tCO_2eq	We calculated the mileage our Field Ops crew traveled to conduct soil samples and the emissions from shipping soil samples for analysis and storage. These values were then converted into CO_2 equivalent.

4. Measurement, Reporting, and Verification (MRV)

Section 3 above captures a project's lifecycle emissions, which is one of a number of MRV considerations. In this section, we are looking for additional details on your MRV approach, with a particular focus on the ongoing quantification of carbon removal outcomes and associated uncertainties.

a. Describe your ongoing approach to quantifying the CDR of your project, including methodology, what data is measured vs modeled, monitoring frequency, and key assumptions. If you plan to use an existing protocol, please link to it. Please see Charm's bio-oil sequestration protocol for reference, though note we do not expect proposals to have a protocol at this depth at the prepurchase stage.

All claims of inorganic carbon buildup on soils by Andes Microprime™ CDR technology are based on direct soil sampling (not modeling). We follow a rigorous soil sampling protocol based on Verra's methodologies VM0042 and VM0021 and in particular, the module VMD0021 'Estimation of stocks in the soil carbon pool.' This process follows 'Quantification Approach 2' from VM0042 and not the modeling approach outlined as 'Quantification Approach 1.' We are performing direct soil sampling at both the control sites and treated acres (control sites represent 10% of the land in the project).
Each field covered by the Andes Carbon program is stratified based on soil texture and other soil characteristics. This stratification determines the locations of sample points. The number of strata is variable for each field, for 2022, on average there are three strata per field. For each stratum, three soil composites are collected at a 12 inches depth (following the USDA guidelines along with Verra's soil sampling procedures). Each soil composite consists of 12 core samples taken within a 10 feet circle of the center point. The coordinates of the center point are recorded. The soil composite samples are divided to make duplicates: one goes directly to an external analytical laboratory based in the Midwest for analysis and the other goes to Andes laboratory in California to keep an inventory of the samples.

Soil samples are taken at three different events during the season (pre-planting, mid-season, and post-harvest), at both the control sites and the sample units.

To calculate the captured CO_2, we measure the percentage of calcium carbonate equivalent (CCE) in the soil samples and take the CCE delta between the untreated fields (control site) and the treated fields. For more information on the calculations please see page 5 of the attached confidential addendum.

b. How will you quantify the durability of the carbon sequestered by your project discussed in 2(b)? If direct measurement is difficult or impossible, how will you validate those assumptions? *(E.g. monitoring of injection sites, tracking biomass state and location, estimating decay rates, etc.)*

Verification of permanence will be conducted initially via direct soil sampling as well as laboratory and greenhouse experiments to assess the dynamics of bicarbonate and carbonates percolation under different soil types and conditions (pH, cation concentration, rainfall regimes, others). As we generate data and have a better understanding of these dynamics, we will generate a model that will allow us to quantify the fate and durability of the carbonate species using a hybrid between direct measurement and modeling. Our estimation of durability will also benefit from recent studies about the fate of bicarbonate and other DIC species leaching from agricultural soils (e.g. ERW projects). Durability of bicarbonate and carbonate minerals under the right pH (greater than 6.4) is a well-established theory and is accepted within the community to lie somewhere between 10,000 years (oceans) and 1,000,000 years (sediments) (Kindler et al, 2011, Sanderman, J. 2012).

c. This tool diagrams components that we anticipate should be measured or modeled to quantify CDR and durability outcomes, along with high-level characterizations of the uncertainty type and magnitude for each element. We are asking the net CDR volume to be discounted in order to account for uncertainty and reflect the actual net CDR as accurately as possible. Please complete the table below. Some notes:

- In the first column, list the quantification components from the Quantification Tool relevant to your project (e.g., risk of secondary mineral formation for enhanced weathering, uncertainty in the mass of kelp grown, variability in air-sea gas exchange efficiency for ocean alkalinity enhancement, etc.).
- In the second column, please discuss the magnitude of this uncertainty related to your project and what percentage of the net CDR should be discounted to appropriately reflect these uncertainties. Your estimates should be based on field measurements, modeling, or scientific literature. The magnitude for some of these factors relies on your operational choices (i.e., methodology, deployment site), while others stem from broader field questions, and in some cases, may not be well constrained. We are not looking for precise figures at this stage, but rather to understand how your project is thinking about these questions.
- See this post for details on Frontier's MRV approach and a sample uncertainty discount calculation and this Supplier Measurement & Verification Q&A document for additional guidance.

Quantification component Include each component from the Quantification Tool relevant to your project	**Discuss the uncertainty impact related to your project** Estimate the impact of this component as a percentage of net CDR. Include assumptions and scientific references if possible.
Soil Inorganic Carbon Capture ("Mineral application" from CDR Verification Framework, but re-worded because in our case we are using a biotic substance (microbes) vs. abiotic substance and directly measuring SIC)	Negligible (<1%). Represents error in direct soil sample measurements of soil inorganic carbon.
Alkalinity loss	Negligible (<1%). We are measuring the soil inorganic carbon

	and cation content from direct soil samples. We see an increase in soil inorganic carbon while actively enhancing the alkalinity, but we observe no significant change in the levels of available cations.
Leakage	We expect 10% of the created bicarbonate to convert back to CO_2 . This estimation is consistent with literature and also ERW projects where there's formation of bicarbonate in agricultural soils, same as this project (Ocean Biogeochemical Dynamics by Sarmiento and Gruber 2006).
Materials	Not included because accounts for less than 0.1% of CO_2 captured. Since this is an important part of Enhanced Weathering emissions (the pathway that most resembles our technology), we felt it important to note why we did not include this in our total carbon removal calculation.
Energy	No included because accounts for less than 0.1% of CO_2 captured. Since this is an important part of Enhanced Weathering emissions (the pathway that most resembles our technology), we felt it important to note why we did not include this in our total carbon removal calculation.

d. Based on your responses to 4(c), what percentage of the net CDR do you think should be discounted for each of these factors above and in aggregate to appropriately reflect these uncertainties?

> To account for the factors above, we think the new CDR should be discounted by 12%.

e. Will this project help advance quantification approaches or reduce uncertainty for this CDR pathway? If yes, describe what new tools, models or approaches you are developing, what new data will be generated, etc.?

> This year we will generate over 40,000 data points from our commercial carbon program, field trials, greenhouse and lab experiments . With the data from this and following years we're building a Terrestrial Inorganic Carbon Sinking (TICS) model. Since our project is creating a unique CDR pathway, all new projects in this space that come online can find this model valuable for them.

f. Describe your intended plan and partners for verifying delivery and registering credits, if known. If a protocol doesn't yet exist for your technology, who will develop it? Will there be a third party auditor to verify delivery against that protocol or the protocol discussed in 4(a)?

> We are planning to register our credits on carbon offset registries such as Verra. As mentioned in 4(a), we are following soil sampling protocol based on Verra's methodologies VM0042 and VM0021. There are currently no methodologies that account for soil inorganic carbon so we have been in discussions with Verra to modify the existing methodologies.

We are also in the process of engaging with a 3rd party for validation and verification. All data will be generated by an external laboratory and will be held on a database for future access by stakeholders, including verification bodies and buyers.

5. Cost

We are open to purchasing high-cost CDR today with the expectation the cost per tonne will rapidly decline over time. The questions below are meant to capture some of the key numbers and assumptions that you are entering into the separate techno-economic analysis (TEA) spreadsheet (see step 4 in Applicant Instructions). There are no right or wrong answers, but we would prefer high and conservative estimates to low and optimistic. If we select you for purchase, we'll work with you to understand your milestones and their verification in more depth.

a. What is the levelized price per net metric tonne of CO_2 removed for the project you're proposing Frontier purchase from? 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), but we will be using the data in that spreadsheet to consider your offer. Please specify whether the price per tonne below includes the uncertainty discount in the net removal volume proposed in response to question 4(d).

$157/tonne CO_2 – this includes the uncertainty discount in the net removal volume proposed in response to question 4(d)

b. Please break out the components of this levelized price per metric tonne.

Component	Levelized price of net CDR for this project ($/tonne)
Capex	$0/t$CO_2$
Opex (excluding measurement)	$51.77/t$CO_2$
Quantification of net removal (field measurements, modeling, etc.)[2]	$98.95/t$CO_2$
Third party verification and registry fees (if applicable)	$6.28/t$CO_2$
Total	$157/t$CO_2$

c. Describe the parameters that have the greatest sensitivity to cost (e.g., manufacturing efficiencies, material cost, material lifetime, etc.). For each parameter you identify, tell us what the current value is, and what value you are assuming for your NOAK commercial-scale TEA. If this includes parameters you already identified in 1(c), please repeat them here (if applicable). Broadly, what would need to be true for your approach to achieve a cost of $100/tonne?

[2] This and the following line item is not included in the TEA spreadsheet because we want to consider MRV and registry costs separately from traditional capex and opex.

Parameter with high impact on cost	Current value (units)	Value assumed in NOAK TEA (units)	Why is it feasible to reach the NOAK value?
MRV Process	\$98.95/tCO_2	\$10/tCO_2	Transition to hybrid model (direct sampling & modeling)
Payment to farmers for enrollment in program	\$10/acre	To be defined	To be defined

d. What aspects of your cost analysis are you least confident in?

> For the 2022 commercial season, the fixed payment per acre structure worked well. We received good feedback from farmers that this is an attractive offer for them. We plan to continue this structure in the near future. However, we expect in several years we might need to adjust our payment structure.

e. How do the CDR costs calculated in the TEA spreadsheet compare with your own models? If there are large differences, please describe why that might be (e.g., you're assuming different learning rates, different multipliers to get from Bare Erected Cost to Total Overnight Cost, favorable contract terms, etc.).

> The TEA structure is not fully applicable to our technology and therefore it does not well represent the different aspects of our project costs. For example, today we use a CMO to produce our product so there is no capital cost for our project. We populated the "other variable costs" line to ensure the overall number was an accurate representation of our Opex costs. Also, as you see in 5(b), costs associated with MRV are a high percentage of our total costs, but not accounted for in the TEA. MRV costs are important aspects to consider when evaluating a technology like ours.

f. What is one thing that doesn't exist today that would make it easier for you to commercialize your technology? (e.g., improved sensing technologies, increased access to X, etc.)

> Given the challenges with direct sampling (high cost, inability to accurately measure the amount of carbon captured due to percolation, etc.), a model that can estimate soil inorganic carbon while accounting for percolation would make it easier for us to commercialize our technology.

6. Public Engagement

In alignment with Frontier's Safety & Legality criteria, Frontier requires projects to consider and address potential social, political, and ecosystem risks associated with their deployments. Projects with effective public engagement tend to:

- Identify key stakeholders in the area they'll be deploying
- Have mechanisms in place to engage and gather opinions from those stakeholders, take those opinions seriously, and develop active partnerships, iterating the project as necessary

The following questions help us gain an understanding of your public engagement strategy and how your project is working to follow best practices for responsible CDR project development. We recognize that, for early projects, this work may be quite nascent, but we are looking to understand your early approach.

a. Who have you identified as relevant external stakeholders, where are they located, and what process did you use to identify them? Please include discussion of the communities potentially engaging in or impacted by your project's deployment.

> For the current year (2022), our most relevant external stakeholders are the farmers we partner with to implement Andes Microprime™ CDR technology on agricultural lands. Farmers that we work with this season are across three states in the U.S. (North Dakota, Minnesota, Wisconsin). We identified them through our contact in the Midwest and we selected fields that met our technical criteria. In terms of community impact, farmers working with Andes gain monetary benefit and economic development from the extra revenue stream. By participating in the project, farmers in these regions will typically increase the net income of their operations by up to 30%. With this net income increase, farmers can bring this money to local communities. We have not identified any potential environmental or social harms by deploying Andes Microprime™ CDR technology while partnering with U.S. farmers, but we are continuing to monitor and seek feedback from stakeholders.

b. If applicable, how have you engaged with these stakeholders and communities? Has this work been performed in-house, with external consultants, or with independent advisors? If you do have any reports on public engagement that your team has prepared, please provide. *See Project Vesta's community engagement and governance approach as an example and Arnestein's Ladder of Citizen Participation for a framework on community input.*

> Our primary form of public engagement to date is performed in-house and involves talking with farmers directly in our target areas. We are working with farmers to understand their opinions and incorporate feedback into our processes. We are in the process of better understanding the appropriate public engagement pathways for the communities we work with.

c. If applicable, what have you learned from these engagements? What modifications have you already made to your project based on this feedback, if any?

> From engagements with farmers, we have learned about the financial impact of our project and the ease of incorporating Andes Microprime CDR technology into their existing practices. They have also provided valuable feedback on product format and packaging. We will be incorporating the changes (e.g. liquid vs. powder form, container size, etc.) into the 2023 season.

d. Going forward, do you have changes to your processes for (a) and (b) planned that you have not yet implemented? How do you envision your public engagement strategy at the megaton or gigaton scale?

> As we grow, we want to engage with the broader public and bring focus to the impact of climate change on those that will be most affected, including farmland operators on marginal land. We also

plan to engage with relevant governmental bodies including the DoE and USDA with an interest in supporting technologies to tackle climate change.

7. Environmental Justice[3]

As a part of Frontier's Safety & Legality criteria, Frontier seeks projects that proactively integrate environmental and social justice considerations into their deployment strategy and decision-making on an ongoing basis.

a. What are the potential environmental justice considerations, if any, that you have identified associated with your project? Who are the key stakeholders? Consider supply chain impacts, worker compensation and safety, plant siting, distribution of impacts, restorative justice/activities, job creation in marginalized communities, etc.

When designing our carbon program, it was very important to us to have a product and structure that creates a win-win for farmers. In our carbon program, we see farmers as our partner, not our customer - we give Andes CDR microorganisms for free and are not asking for a long-term commitment. Even with this structure, environmental justice concerns still arise and the agriculture industry is notorious for its wide range of environmental injustices. There is one primary environmental justice concern that is most relevant to our project, and it is a broader social justice issue: the issue associated with equitable access and partnership. By participating in our project, farmers get additional income. Even though we choose farmers to partner with on a technical basis (field parameters), this means some farmers participate while other farmers do not. We started our first commercial season in the US, but as we scale, we plan to expand our operations in other regions, including areas with marginalized communities. This will bring an additional revenue stream to families in these communities. We will continue to engage with farmers and other stakeholders to monitor and identify any environmental justice concerns that might arise in the future.

b. How do you intend to address any identified environmental justice concerns and / or take advantage of opportunities for positive impact?

As we expand, our positive impact will also grow as we put more money in the hands of farmers around the world. Today, we do not have a solution to address the broader social justice issue explained above. We will continue to think of ways to address this injustice and others that arise, and we will do our best to integrate these considerations into our strategy.

8. Legal and Regulatory Compliance

a. What legal opinions, if any, have you received regarding deployment of your solution?

We have received a greenlight from the USDA and EPA for the use and commercialization of Andes Microprime™ CDR microorganisms in agriculture intended for use as a soil amendment. The strains belong to the same

[3] For helpful content regarding environmental justice and CDR, please see these resources: C180 and XPRIZE's Environmental Justice Reading Materials, AirMiners Environmental and Social Justice Resource Repository, and the Foundation for Climate Restoration's Resource Database

genus/species of microorganisms which are GRAS (generally recognized as safe) and commonly applied in agriculture for their plant-beneficial attributes.

b. What permits or other forms of formal permission do you require, if any, to engage in the research or deployment of your project? What else might be required in the future as you scale? Please clearly differentiate between what you have already obtained, what you are currently in the process of obtaining, and what you know you'll need to obtain in the future but have not yet begun the process to do so.

We've obtained the following permits/licenses:

- North Dakota Fertilizer Distributor License
- Wisconsin Soil or Plant Additive License
- Minnesota Soil or Plant Additive License
- USDA-APHIS PPQ 526 permit for interstate movements
- Determination by EPA that Andes CDR microbes do not fall under their regulation as a regulated pesticide product

These permits allow us to use our microorganisms in ND, WI, and MN on agricultural lands, covering the use in our 2022 program. As we expand, we will need to obtain relevant state permits. We have everything in place to obtain these permits and will submit required applications.

c. Is your solution potentially subject to regulation under any international legal regimes? If yes, please specify. Have you engaged with these regimes to date?

Today, our Microprime CDR technology is implemented in the US. In future years, we plan to expand internationally (e.g. Canada, South America) and are currently understanding regulations in these regions.

d. In what areas are you uncertain about the legal or regulatory frameworks you'll need to comply with? This could include anything from local governance to international treaties. For some types of projects, we recognize that clear regulatory guidance may not yet exist.

N/A - This project (carbon generated during the 2022 agricultural season) is in compliance with all relevant regulations.

e. Do you intend to receive any tax credits during the proposed delivery window for Frontier's purchase? If so, please explain how you will avoid double counting.

N/A

9. Offer to Frontier

This table constitutes your **offer to Frontier**, and will form the basis of contract discussions if you are selected for purchase.

Proposed CDR over the project lifetime (tonnes) *(should be net volume after taking into account the uncertainty discount proposed in 4(c))*	5,000 tCO_2 *This is a portion of the total CDR generated during 2022 and takes into account the uncertainty discount proposed in 4(c).*
Delivery window *(at what point should Frontier consider your contract complete? Should match 1(f))*	December 2022
Levelized Price (\$/metric tonne CO_2) *(This is the price per tonne of your offer to us for the tonnage described above)*	\$157/metric tonne CO_2

Application Supplement: Surface Mineralization and/or Enhanced Weathering

(Only fill out this supplement if it applies to you)

Source Material and Physical Footprint

1. What source material are you using, and how do you procure it?

   The source material for our technology are Andes Microprime™ CDR microorganisms. These microbes feed from the plant root exudate so no additional source material is required. Once established the microbes take up 0.01% of the microbiome. These microbes are produced via fermentation at a CMO.

2. Describe the ecological impacts of obtaining your source material. Is there an existing industry that co-produces the minerals required?

   N/A

3. Do you process that source mineral in any way (e.g., grinding to increase surface area)? What inputs does this processing require (e.g. water, energy)? You should have already included their associated carbon intensities in your LCA in Section 3.

   N/A

4. Please fill out the table below regarding your project's physical footprint. If you don't know (e.g. you procure your source material from a mining company who doesn't communicate their physical footprint), indicate that in the table below.

	Land area (km^2) in 2021	**Competing/existing project area use (if applicable)**
Source material mining	N/A	N/A
Source material processing	N/A	N/A
Deployment	5.7 km^2	101 km^2

5. How much CDR is feasible globally per year using this approach? Please include a reference to support this potential capacity.

Greater than 1.2 GtCO2. We assessed weather and soil conditions on two continents: North and South America. The suitable agricultural land for Andes first generation Microprime™ CDR technology is roughly 200 million acres in the US, over 40 million acres in Canada, and more than 150 million acres in South America.

6. If you weren't proceeding with this project, what's the alternative use(s) of your source material? What factors would determine this outcome?

N/A

Human and Ecosystem Impacts, Toxicity Risk

7. What are the estimated environmental release rates of heavy metals (e.g. Cr, Ni, Pb, Hg)? Dust aerosol hazards? P loading to streams? How will this be monitored?

N/A - no heavy metals will be released as a result of our technology.

8. If minerals are deployed on croplands, what are the estimated effects on crop yields? Include citations to support this claim. How will actual effects be monitored?

Although our technology is distinct from Surface Mineralization and Enhanced Weathering, we observe an increase in crop yields with the implementation of Andes CDR technology. After 3 seasons of data, we have observed a yield bump of 5.7 bu/ac in corn, 1.0 extra bu/ac in soybeans and 4.6 extra bu/ac in wheat.

9. How will you monitor potential impacts on organisms in your deployment environment? (e.g. health of humans working in agricultural contexts, health of intertidal species, etc.)

Our first generation Microprime™ CDR technology uses natural, non-engineered strains. The strains are closely related to microorganisms which are GRAS (generally recognized as safe), have a history of safe use in food and agriculture, and are considered not to possess traits that cause disease. The EPA has granted an exemption from their regulation, and the USDA granted us a permit for commercial sales and movement within continental US for our microbial product.

Frontier

We have further evaluated the safety of Microprime™ CDR microorganisms with an external contract research organization, performing acute toxicity studies and found no detrimental effects on mice.