Everest Carbon

Carbon dioxide removal prepurchase application

Summer 2023

General Application

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

Public section

The content in this section (answers to questions 1(a) - (d)) will be made public on the Frontier GitHub repository after the conclusion of the 2023 summer purchase cycle. Include as much detail as possible but omit sensitive proprietary information.

Company or organization name

Everest Carbon Inc.

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

San Francisco (US), Bangalore (India)

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

Pascal Michel, Dr. Matthias Ginterseder, Prof. Dr. Rafael Santos

Brief company or organization description <20 words

Everest develops novel MRV technology and conducts Enhanced Weathering projects with fast-weathering minerals in the global south.

1. Public summary of proposed project 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. Aim for 1000-1500 words.

Enhanced Weathering in the global south for low-cost permanent removals at scale

Everest Carbon removes CO_2 from the atmosphere through enhanced weathering (EW) by grinding alkaline silicate materials to fine powders and spreading them on soils. The small particle size and large contact area with the atmosphere increases the effective weathering rate by multiple orders of magnitude, therefore enhancing the natural weathering process and removing atmospheric CO_2. Natural weathering is a thermodynamically irreversible chemical reaction, where the rock's silicate dissolves upon contact with water, releasing alkalinity in the form of base cations (e.g. Ca^{2+}, Mg^{2+}) that converts atmospheric CO_2 into dissolved inorganic carbon in the form of bicarbonates or solid carbonate precipitation. These species eventually leach into ground and further ocean waters, where the carbon is safely stored for at least tens of thousands of years. (source).

EW is known to be a major pathway capable of reaching permanent multi-gigaton carbon dioxide removal (CDR) capacity within the next few decades (source, source). Yet, the complex nature of the CO_2 transport process from the atmosphere to the soil, and further to the final storage waters, poses challenges to the measurement, reporting, and verification (MRV) of EW CDR activities (source), creating uncertainty and critically limiting economic viability and legitimacy.

Everest Carbon decisively addresses these issues through a holistic approach combining much needed advances in the quantification of CDR, scaling towards gigaton-scale EW through deployment of high-performance feedstocks under ideal climate conditions, and doing so while providing great co-benefits to rural communities in the global south.

Unlocking high-confidence EW CDR

We believe that significantly stronger measurement evidence and field data support are needed for robust proof of carbon drawdown in EW projects. Our aim is to unlock verification confidence levels (VCLs) 4-5 for EW through novel MRV technologies and protocols to get EW to the point where we can responsibly scale it up to megatons and beyond.

We develop novel measurement devices and methods that will greatly simplify tracking of alkalinity generation and transport of dissolved atmospheric carbon over the course of the project. Combining this with mass balance measurements will keep track of weathering products and generate significantly stronger measurement evidence of CDR in a complimentary, dual-approach fashion. Validation through a comprehensive and independent set of soil and hydrological measurements will simultaneously quantify key uncertainties in known loss channels.

By developing an autonomous analysis platform that can determine total alkalinity flux in-situ with very high temporal frequency, we will calibrate models that will determine a sparse but representative sampling schedule. Being able to then sample vast areas of land accurately and with high spatial frequency with decreased equipment demand will drive down costs while providing robust MRV.

Our ultimate goal is to support EW through the demonstration of a gold-standard measurement that is feedstock agnostic and applicable to a wide range of geographies without the need for technical staff intervention.

Novel sources of alkalinity and use of waste materials with unique advantages

By prioritizing fast-weathering non-basalt materials, such as the mineral wollastonite and specific alkaline industrial waste by-products, we solve multiple concerns with conventional feedstocks. Through fundamentally different thermodynamics and weathering products, our materials significantly reduce uncertainties in weathering chemistry and secondary mineral formation (source). Faster weathering kinetics further decrease project lifetimes, bringing down cost while accelerating MRV innovation cycles and overall carbon drawdown. EW projects with such waste by-products from industrial processes, that today still end up in landfills (source, source), have particularly favourable net-negativity and unit economics as costs and emissions associated with production of those materials are minimal to negligible.

Furthermore, those materials have distributed geographical availability, and a dense network of feedstock suppliers minimizes transportation penalties on unit economics and associated emissions. Leveraging these industrial waste by-products for EW applications also unlocks additional geographies and climates traditionally less ideal for EW, expanding its potential global system impact.

New application geographies: Entry market India and focus on tropical soils
We chose India as our initial hub due to the abundance and continued future growth of suitable weathering feedstocks, favorable climate and soil conditions, high cost-efficiency as well as outstanding socio-environmental co-benefits. It is well known that India will play a key role in a global gigaton-scale EW portfolio, and it is arguably the ideal location for EW from a cost and scale perspective. Indeed, India was predicted to be the only country worldwide where CDR costs through EW would drop to <$100/tCO_2$ at the 0.5 $GtCO_2$/year scale (source).

Thus, by building out EW operations in India, in particular with underexplored sources of alkalinity, we are making a fundamental leap forward for the global CDR community. Having tapped into India's potential, we will start expanding our operations across tropical countries worldwide, and see a global EW potential significantly above 1-2$GtCO_2$/year across all available feedstocks (source, source).

High CDR- and energy efficiency for near-term <$100/tCO_2$ removals
During EW operations significant emissions arise, primarily due to feedstock production, comminution and transportation. We have conceptualized and conducted life cycle assessment (LCA) for our own first-of-a-kind ultra-low emissions feedstock pre-processing and distribution facilities, including our own electrified transportation fleets and on-site generation of renewable energy, that will increase CDR efficiencies of our EW projects to more than 95%.

Our low-cost novel MRV technology, the use of industrial waste by-products, as well as our insourced supply-chain and the resulting record-high CDR efficiency, do not only maximize the climate impact that our projects have, but give our EW projects a clear path to permanent CDR with costs significantly below $100/tCO_2$ in the near future and a potential scale well above 0.5 $GtCO_2$/year.

Co-benefits and climate justice
Last but not least, the appeal of EW is that is can deliver permanent, scalable and low-cost carbon removals, in conjunction with an array of socio-environmental co-benefits that make the pathway truly stand out in global CDR portfolios. Applications of silicate powders in agricultural soils have been shown to have extensive positive co-benefits including improved soil health, lower usage of chemical fertilizers, improved heat and pest resilience of crops, more resilient food supply-chains (source, source, source, source), as well as direct socio-economic co-benefits.
These co-benefits are particularly impactful in the agricultural setting of India. Additional

income from carbon credit revenue share can oftentimes mean life-changing increases in income for typical farming households, as opposed to much smaller benefits for participating farmers in already industrialized nations. The majority of our carbon credit revenues will be spent on operations, thus supporting local economies in the global south.

India's agriculture is known to depend heavily on chemical fertilizers (source), soils in coastal regions are generally acidic and nutrient depleted from high tropical rainfalls (source, source, source, source), water management is problematic (source, source), and topsoil erosion is a challenge (source, source). These factors make Indian soils and farms ideal candidates for repeated application of weathering minerals that constantly improve the soil's health, nutrient content, and water retention capacity.

Thus, our EW operations show a particularly strong reparative justice component as capital flows predominantly from leading industrialized nations, having the highest historic emissions, to countries in the global south that have low historic emissions, but will face disproportionate negative impacts from climate change.

b. **Project objectives:** What are you trying to build? Discuss location(s) and scale. What is the current cost breakdown, and what needs to happen for your CDR solution to approach Frontier's \$100/t and 0.5Gt targets? What is your approach to quantifying the carbon removed? Please include figures and system schematics and be specific, but concise. Aim for 1000-1500 words.

Our overarching goal is the supply of high-confidence EW credits, significantly below \$100/t at gigaton-scale, while generating great co-benefits for the global south. This ambition leads us to several key objectives we solve for as we develop our business.

Moving EW to Verification Confidence Level 5

We are focused on developing novel MRV technology and protocols that will reduce uncertainties in quantifying carbon removal through EW to a point where it can be scaled up responsibly to capacities that make a true climate impact.

Our approach to quantifying carbon removals centers around rigorously measuring alkalinity efflux from the project site with subsequent modeling of the alkalinity transport to groundwater and ocean reservoirs. By applying two separate, established techniques, we provide a robust measure for CDR quantification, as well as the validation of novel devices we are developing in-house. By building a lab-in-the-field instrument that is capable of determining total alkalinity (TA) concentrations and infiltration fluxes in real-time with high precision, we form the foundation for a detailed water balance model when combined with other hydrological data. Once the model is calibrated, the measurement burden will decrease significantly. We then envision our device to become portable, steeply decreasing equipment cost while enabling rapid sampling of large swaths of land. By addressing several key uncertainties that go beyond today's established uncertainty frameworks - mineral weathering, secondary mineral formation, non-carbonic acid neutralization, terrestrial carbonate precipitation, plant uptake, and erosion - through measurement, we are making significant strides towards the confident delivery of CDR through EW.

In the long term, our MRV strategy minimizes the presence of technical experts in the field and need for soil sampling, significantly bringing down MRV costs as well as removing bottlenecks to scale. To do so, we are looking to build out our internal R&D facilities early and collaborate with a wide range of institutions to expand the public scientific understanding of EW - to the benefit of both our company and everyone else in the ecosystem. If successful, these innovative MRV approaches are slated to drastically improve the quality of EW CDR claims, rapidly advancing the maturity of EW.

Unlocking industrial waste materials as novel sources of alkalinity

Beyond MRV innovation, we set ourself apart through our choice of weathering materials, focusing on fast-weathering minerals like wollastonite and industrial waste by-products like recycled concrete and fly ash. The increased reaction rates of these materials open up new geographies and climate zones, thereby expanding the global potential scale of EW, will improve our unit economics, speed up our technology development cycles, and finally, allow us to drop our levelized costs to below \$100/tCO_2 in the near-term already. In addition, these materials benefit from cleaner weathering chemistry compared to basalt. With fewer competing side products, uncertainty in two of EW's least quantified aspects, general mineral weathering and secondary mineral formation (source), is greatly reduced. Moreover, working with industry waste by-products allows us to span a dense network of feedstock sources across operation geographies, drastically reducing transport costs and emissions.

Importantly, we make a leap forward for the global geochemical CDR community by establishing operations in India. India bears vast feedstock potential and has been projected to be the most cost-competitive country at the >0.5GtCO_2/a scale at prices well below \$100/tCO_2 (source). This cost-advantage can be attributed to a variety of factors, first and foremost being the availability of cheap feedstocks at scale, as well as the preferable climatic conditions. Building out our EW operations with novel sources of alkalinity in India thereby contributes a key piece to the global risk-adjusted CDR portfolio.

Entry market India and global potential

In our first projects we will be deploying Wollastonite in the north-west of India (Madhya Pradesh, Maharashtra, Gujarat) as weathering of wollastonite has particularly clean chemistry and is well understood from various field studies (source, source, source, source) serving as the ideal development and calibration studies for our novel sensor technology and models. We will then expand our operations to the coastal regions of India that receive large amounts of rainfall. We have identified suppliers for various industrial waste by-products across the country and will be able to span a dense network of feedstocks.

Today, we see availability of such industrial alkaline waste by-products at the multi-megaton per year scale in India (source, source), which to the best of our knowledge are not yet being used for EW commercially. Availability of these feedstocks has been forecast to grow quickly for multiple decades, reaching 0.5-1 Gt/year in India and >3-4 Gt/year globally in the 2030s (source) and leading to global CDR potential well above 1 GtCO_2/year. This potential does not yet consider the later addition of natural minerals like Basalt to our portfolio.

High CDR efficiency
Feedstock transport emissions and energy consumption for production and pulverization of weathering feedstocks generally account for the vast majority of GHG emissions during EW projects. To maximize our CDR efficiency, we intend to operate our own fleet of electric tipper trucks to deliver weathering material to our fields, as well as our own feedstock pre-processing facilities, powered by on-site utility-scale solar-PV. Optimizing our operations for low-carbon energy, together with the use of industrial waste by-products and low transportation distances, we foresee CDR efficiencies above 95% for our EW deployments within 5 years, which, apart from its carbon benefit, will also have a significant impact on our levelized costs.

Our current levelized cost of net CO_2 removal are \$430/tCO_2 which breaks down into \$291/tCO_2 fixed operational costs and \$139/tCO_2 variable operational costs. Fixed operational costs are primarily R&D and MRV measurement related and particularly high for our first projects as we reduce uncertainties and validate our novel technology. Variable operational costs are primarily feedstock as well as logistics related. We do not have capital costs during our initial projects as we outsource all measurement, feedstock processing, as well as logistics to third-party service providers.

MRV as well as R&D costs are a major component of current operational costs, which will drop steeply after we have validated our technology in initial studies. Another significant portion of operational costs are our feedstocks, which will drop steeply after switching from wollastonite to cheaper industrial waste by-products. Further major cost decreases come from insourcing and strongly decarbonizing our operations. **We foresee levelized costs of net CO_2 removal to undercut the \$100/tCO_2 mark well before 2030.**

c. **Risks:** What are the biggest risks and how will you mitigate those? Include technical, project execution, measurement, reporting and verification (MRV), ecosystem, financial, and any other risks. Aim for 500-1000 words.

We have high confidence in our ability to execute state-of-the-art EW projects, yet that will not be enough to establish EW as a credible CDR pathway at scale. Managing the uncertainty around EW as a general CDR approach majorly depends on managing the uncertainties in MRV procedures. Our drive to establish new MRV technologies and protocols comes with its own potential R&D bottlenecks. We therefore devised an MRV scheme that quantifies key aspects in several ways to allow for reliable validation of new technologies. We also conceptualized several alternatives to the instrument we prioritize here to move our proposed long-term MRV strategy forward swiftly.

We are pioneering the use of alkaline industrial waste materials, such as fly ash. The exact CDR potential in the field is subject to uncertainty. The use of new feedstocks also means that additional effort is needed to understand their full environmental impact. We have established partnerships with academic research groups in India (Dr. CT Subbarayappa, University of Agricultural Sciences, Karnataka, India & Dr Sudeshna Bhattacharjya, ICAR Indian Institute of Soil Science, Bhopal, India) that will allow us to tackle these questions holistically.

We foresee smaller operations, business as well as market risks. While India provides fantastic advantages in many regards when it comes to EW, its infrastructure is less developed than infrastructure in industrialized nations. Transportation and spreading of weathering material at scale may become a challenge in the future. Nevertheless, we have no doubt that operational difficulties will be overcome through operational experience and insourced supply-chains, rendering our perception of those risks as small to medium. Furthermore, at the proposed start of this project, we will have multiple years of operational experience. From a business and market perspective, we see some uncertainty on the price of industrial waste by-products. Innovations on competing alternative uses may impact their price. To hedge against this risk, we are setting up a feedstock-agnostic workflow that enables us to work with a diversified portfolio of weathering materials. Later on, our MRV approach can also be transferred to including Basalt straightforwardly, which has vast availabilities in the Deccan Traps in India. Financially, we have closed a first investment round and see strong demand for our carbon removal credits. Yet, our revenues are primarily derived from the Voluntary Carbon Credit markets (VCMs) at this point, which still harbor significant uncertainty as they, too, mature. Fortunately, we see a strong upward trend in purchase volumes for high-quality CDR (source), in particular in recent months. We therefore anticipate demand-side financial risks to be minor. With regards to our ecosystem, we see small risks from the public perception of EW. To preempt those, we engage with other EW firms in trade associations and industry groups to transparently educate the public about the advantages and risks of EW. Furthermore, government regulations of carbon credit exports could impact our business as well.

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)*	960tCO_2
Delivery window *(at what point should Frontier consider your contract complete? Should match 2f)*	June 2027
Levelized Price (\$/ton CO_2)* *(This is the price per ton of your offer to us for the tonnage described above)*	519 \$/tCO_2

** 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).*