Frontier

Request for prepurchase proposals

2023

Frontier is an advance market commitment to accelerate the development of carbon dioxide removal (CDR) technologies. We announced our first set of prepurchases in June 2022, our second in December 2022, and are now releasing a call for applications for Frontier's next round of purchasing.

To support technologies at different stages of development, we have two purchase tracks: prepurchases and offtakes. Each track has its own eligibility criteria, diligence process, and funding amounts. The bulk of Frontier's spend will go toward *offtakes*, larger multiyear agreements with companies preparing to start scaling their technologies. However, we believe we have not yet seen the full scope of promising carbon removal approaches. Our *prepurchase* track is designed to pressure-test the viability of novel CDR solutions, with an emphasis on expanding the number of carbon removal pathways and companies working on carbon removal.

This document is the request for proposals for Frontier's prepurchase track. As the first step in applying, please use the table below to understand our purchasing program and decide which track is the best fit for your company.

If you have any questions, please join our purchase office hours at 12 pm EDT on May 11, 2023 or get in touch at suppliers@frontierclimate.com. For the offtake track, go here.

	Track 1: Prepurchases	Track 2: Offtakes
Summary	Low-volume prepurchase agreements to support early-stage suppliers piloting new technologies	Larger offtake agreements to support more mature suppliers preparing to scale
Purchase amount	$500K	~$10M - $50M
Purchase structure	Paid upfront, before tons have actually been delivered	Commitment to buy future tons at an agreed price if and when delivered
Frontier expectations and risk tolerance	Thorough diligence, higher risk tolerance than offtakes	More extensive diligence, lower risk tolerance than prepurchases
Application cadence	Once-per-year purchase cycle	Applications accepted on a rolling basis
Application deadline	Pre-applications due May 19, 2023	For consideration in 2023 and 2024, please express interest as early as possible
	Expected status across evaluation criteria	
Performance data	• There is lab-scale performance and preliminary stability data (preferably for days or more) showing proof of concept that the company's approach removes CO2 from the atmosphere.	• Tech has been validated, preferably at or beyond small pilot scale, with data establishing performance and stability baseline. Roadmap defined for how the company will narrow gaps between current data and techno-economic analysis (TEA) assumptions. • For larger offtakes: Tech has removed CO2 in the

		field, preferably 1 ton+ per day; minimal remaining technology risk.
Monitoring, reporting, & verification (MRV)	• Clear MRV approach outlined. • For CDR pathways with lower verification confidence levels (VCLs), risks are identified and a method presented for how new data will be generated to increase the VCL and/or reduce the VCL uncertainty.	• Company has a published protocol that addresses key pathway uncertainties and has responded to scientific community feedback. • Volume offered is discounted based on identified MRV uncertainties (if any) and we have high confidence in the ability to quantify volumes purchased. • Company has a plan for independent verification of CDR outcomes.
Techno-economic analysis (TEA)	• A TEA based on a process flow diagram and mass and energy balance, using realistic engineering values (or similar) for equipment pricing, first principles estimates of performance, and basic assumptions for utility costs (format provided).	• A high-fidelity TEA based on a pre-FEED design or similar, including a full process model. Key performance assumptions identified and validated with data. • For larger offtakes: TEA validated from past systems with quotes for major equipment, utilities, and O&M costs for specific locations.
Ecosystem safety (e.g., impact to soils and oceans)	• Compelling case for why this CDR project does not cause additional ecosystem damage, based on experimental data and models. • Company identifies potential risks and presents a plan to generate new data to confirm ecosystem safety at scale across early deployments.	• Compelling case for why their CDR project does not cause additional ecosystem damage, based on experimental data. • Company has published ecosystem impact data and responded to feedback from the scientific community regarding potential risks. • There is minimal remaining uncertainty around ecosystem impact, and company will actively manage deployments based on ongoing ecosystem monitoring.
Community engagement	• Clear plans to collect input from stakeholders impacted by the project at early stages and to improve deployment based on that input.	• Has proactively engaged stakeholders and revised deployment plans accordingly. • Has a community benefits plan and an ongoing process to collect and act on community input.
Team and operational capability	• There is demonstrated expertise on the team for initial development work. • Company has a hiring and/or partnering plan for other aspects of the project.	• Company has experienced technical and commercial staff in place and project partners are identified and committed.
Business strategy & financing	• Key business case assumptions and risks identified. • Preliminary plan established for next steps if the project is successful.	• Company can define how the project fits within their strategy and the CDR market and policy landscape. • Team has a credible path to securing financing and reaching a final investment decision. • For larger offtakes: Company has supply chain, manufacturing, and risk management strategies.

Continue reading if you would like to apply for a prepurchase. If the offtake track is a better fit, please go to our offtake RFP. If you're still not sure which track makes the most sense for you at this time, get in touch at suppliers@frontierclimate.com.

Frontier prepurchase track

2023 request for proposals

To apply for a Frontier prepurchase, please fill out the pre-application by May 19, 2023, *after* you've read this RFP.

The pre-application is a short form to help us understand whether your technology is likely to be a fit for this purchase cycle. We will pre-screen submissions and invite a subset to submit full applications with the goal of minimizing time spent applying by projects that likely don't meet the criteria of this RFP.

If you've submitted a pre-application in a prior cycle and want to reapply, please do! We know it's common for early-stage projects to shift directions and/or make rapid progress. In this case, please focus your response on *what's changed*.

If you have any questions, please join our purchase office hours at 12 pm EDT on May 11, 2023 or email suppliers@frontierclimate.com.

Contents

1 | Timeline

	Step	Approx. date
1	Companies submit pre-applications	May 19
2	Frontier reviews pre-applications for basic eligibility against our approach criteria (e.g., 1000+ year durability, etc.) and fit to our innovation areas of focus defined below. We may ask for a short conversation to clarify any questions.	Late May
3	Frontier invites projects to apply (application writing period will be 3 weeks)	By June 5
4	Companies submit full applications	Late June
5	Frontier reviews applications for completeness and basic scientific validity with respect to our criteria. Qualified applications are sent to external experts for scientific, commercial, and governance review.	Late June
6	Frontier sends anonymized expert review comments to applicants, who will have ~2 days to submit a short response to Frontier (if they choose to do so).	Mid-to-late July
7	Frontier may request a video meeting with applicants to further discuss their proposal.	Late July
8	Frontier notifies applicants of prepurchase decisions	Mid August
9	Frontier and selectees jointly build application-specific contract terms such as milestones.	Mid-to-late August
10	Frontier announces prepurchase agreements	Early September

2 | How we evaluate projects

We look for permanent CDR solutions that have the potential to be low-cost and high-volume in the future, even if they're not today. The goal is to send a strong demand signal to researchers, entrepreneurs, and investors that there is a growing market for these technologies. Importantly, Frontier aims to help create net new CDR supply rather than compete over what exists today.

To give you a sense of how we've done this in the past, please take a look at prepurchases Frontier announced in December 2022 and June 2022.

We use three lenses to make purchasing decisions:

- **Approach**: Does the CDR approach meet our target criteria?
- **Execution**: Can this team deliver on the proposal, given where the technology is today?
- **Portfolio**: Will this purchase help us build a diverse, risk-adjusted portfolio of CDR approaches?

Lens 1: Approach

Rigorous external scientific and governance assessment against Frontier's CDR criteria is the first and most critical qualifying step in Frontier's purchasing process.

Criteria	Description
Durability	Stores carbon permanently (>1,000 years)
Physical footprint	Takes advantage of carbon sinks and sources less constrained by arable land
Cost	Has a path to being affordable at scale (<$100 per ton)
Capacity	Has a path to being a meaningful part of the carbon removal solution portfolio (>0.5 gigatons per year)
Net negativity	Maximizes net removal of atmospheric carbon dioxide
Additionality	Results in net new carbon removed, rather than taking credit for removal that was already going to occur
Verifiability	Has a path to using scientifically rigorous and transparent methods for monitoring and verification
Safety and legality	Is working towards the highest standards of safety, compliance, and local environmental outcomes; actively mitigates risks and negative environmental and other externalities on an ongoing basis

Because of Frontier's 1,000-year durability threshold, we do not consider the following CDR approaches as being in scope for Frontier procurement:

- Afforestation and reforestation
- Coastal restoration (blue carbon)
- Organic soil carbon

Lens 2: Execution

We look for evidence that the team will be able to execute their proposed plan rigorously, quickly, and responsibly. The specifics of what we look for will vary based on the stage of the project, but generally we look for:

- **Technology readiness level:** Is the technology far enough along to make the proposal realistic/plausible? We typically look for an existing proof of concept (i.e., all major elements of the solution are at least at TRL-3+).
- **Team:** Does this team have the expertise and experience to deliver? This could include scientific, technical, operations, manufacturing, commercial, or regulatory expertise depending on the solution.
- **Delivery timing:** When will this project deliver first tons? We prefer earlier delivery (i.e., 2025/2026), even if it means smaller volumes. We rarely purchase from projects with no delivery for 3+ years.
- **Past and expected learning rates**: If this team has applied before, how much progress have they made since, and over what time period? Is this approach fundamentally compatible for fast iteration? How costly is each iteration?
- **Ambitious but plausible and responsible scaling plans:** We are looking for companies that move urgently, but also responsibly and realistically. For most approaches, this likely means increasing scale by no more than 10x per deployment, whereas for others, 100x might be acceptable if the applicant includes a justification for that scaling magnitude.
- **'Area under the curve':** How high is the starting cost, and how quickly does it decline? If this approach has a very high starting cost, we'd expect it to have a particularly steep slope such that it's plausible the team can secure enough demand to scale.

Lens 3: Portfolio

We believe it will take a portfolio of CDR solutions and companies to achieve the gigatons of annual scale needed. Frontier's goal is to build a risk-adjusted portfolio that maximizes the likelihood of that happening. This means that there is a possibility that even if a company meets our criteria, we may not make a purchase if, for example, we're over-indexed on that type of solution.

3 | Areas of focus for 2023 cycle

We're especially excited to see more geographic diversity in our applications. Our prepurchase track also favors novel approaches distinct from those already reflected in our portfolio. To that end, we have identified a number of pressing innovation needs across the field and will prioritize inviting applications across these topics. In particular, we are looking for:

- **Novel approaches to CDR and crosscutting technologies**
    - Approaches that are conceptually distinct from other current CDR companies. Concepts of interest include (but are not limited to) the development of biomimetic systems for protein-based direct air capture or the integration of CDR into existing industries via changing/adapting processes or leveraging waste streams such as brines.
    - Projects that include breakthrough innovation in low-energy synthesis of acid and base, as well as solutions for acid use/neutralization, are of particular interest given the relevance across multiple CDR pathways.
- **Approaches to ocean-based CDR that further field knowledge and enable decisionmaking about responsible deployment**
    - Innovative, cost-effective new approaches to ocean alkalinity enhancement (OAE) and direct ocean removal (DOR) that also advance quantification methods for CO2 drawdown and assessment of potential associated ecosystem effects.
- **Approaches to geochemical CDR that accelerate weathering rates**
    - Novel approaches to kinetic enhancement that come with limited penalty to overall net-negativity, e.g., via chemical or biological accelerants (because in-field rock weathering rates are typically slow).
    - Innovative approaches to geochemical CDR, including solutions that leverage novel sources of alkalinity, new application geographies, or integrate with the mining and waste management industry to decrease costs and emissions associated with transporting and processing rocks.
- **New DAC approaches that enable dramatic cost reductions**
    - Novel approaches that provide significant reductions in the energy requirements (given the large energy requirement of first-generation DAC). This includes (but is not limited to) non-temperature-vacuum swing adsorption (TVSA) approaches, or solutions that combine partial enrichment of CO2 (as opposed to full purity) with storage solutions that work with lower-purity CO2 streams. Such projects should ideally apply as an integrated DAC+ storage project rather than capture or storage only.
    - We will consider applications of TVSA-DAC if they meaningfully differentiate from our current portfolio and offer step-change cost reductions vs. existing approaches, e.g., via breakthrough innovation in heat management within sorbent-based DAC contactors.
- **Approaches to BiCRS that co-optimize CDR efficiency and energy production, with nutrient export and cost**
    - Approaches that maximize CDR efficiency while minimizing cost. If this is done via storage other than geologic sequestration of CO2, we are looking for rigorous MRV approaches to assessing storage losses and potential ecosystem effects including nutrient management.
    - Novel approaches that retain high CDR efficiency while maximizing co-benefits, including (but not limited to) advanced gasification or hydrothermal liquefaction tailored to specific biomass characteristics and/or target products, low-energy-penalty CO2 capture technologies, and innovations around modularity to address challenges with biomass transport.

4 | Other considerations

Transparency & confidentiality

If you are invited to submit an application and do so, please be aware that a portion of your application, such as project description, high-level cost summary, and measurement approach, will be made public at the conclusion of Frontier's purchase cycle. We do this because commercial-scale permanent CDR is developing, and we are trying to advance transparency and knowledge-sharing across the ecosystem as it does. Hopefully this will enable impact beyond the dollar amount of any particular purchase we may make.

However, this year we are making less of the application public (see the next section). In the application template, we will clearly specify for which questions we will publish applicants' responses. The rest of the application information will remain confidential among Frontier staff and our expert review team (who have non-disclosure agreements in place with Frontier). This includes a techno-economic spreadsheet that we will ask all applicants to fill out.

Changes from prior cycles

Every cycle, we update our prepurchase program to make the process smoother for both applicants and reviewers. This cycle, we have made three updates that go beyond small tweaks and are worth calling out:

- One prepurchase cycle per year: The bulk of Frontier's spend will go toward large offtake agreements, and this year we have gone from two prepurchase rounds to one to accommodate our growing offtake program.
- Less application information released publicly: In prior cycles, we published each prepurchase application in full on our GitHub repository. With more companies and increasing competition (a good thing!), we want to ensure we are not putting supplier IP at risk, particularly as our application form expands. We remain committed to transparency in our purchasing and to contributing resources to the ecosystem, but this cycle we will be publishing a subset of application details on GitHub, rather than the full application.
- No $1M renewal commitment: This cycle, we have removed the commitment to purchase an additional $1M in CDR if companies meet select renewal criteria. This $1M was put in place before Frontier (and the offtake track) existed. Our hope is that most prepurchase companies will eventually be eligible for a larger offtake, so instead of the renewal commitment, we invite our prepurchase companies to discuss offtake purchasing after delivering the prepurchased tons and achieving prepurchase milestones.

Communication

All communication related to Frontier's 2023 CDR purchasing cycle should be sent to suppliers@frontierclimate.com.

Supplemental information

- Introducing Frontier
- Purchasing Q&A
- Frontier GitHub source materials (applications, contracts, templates)