Frontier

Request for Applications

Fall 2022 carbon removal purchase cycle

Frontier is an advance market commitment to accelerate the development of carbon dioxide removal (CDR) technologies. We announced our first purchases in June 2022, and are now releasing a call for applications for Frontier's Fall 2022 CDR purchase cycle. To support technologies at different stages of development, Frontier will purchase carbon removal through two separate tracks – prepurchases and offtakes – that vary by eligibility criteria, diligence process, and funding amounts.

To apply for a Frontier prepurchase or offtake, please fill out this form by Friday, September 2, 2022 at 10:00 pm EDT.

This form is a brief pre-application to help us understand whether a proposal is likely to meet our eligibility criteria. We will pre-screen submissions and invite only eligible projects to submit full applications. We hope this minimizes the time spent applying by projects that don't meet the direction of this RFP. If you submitted an interest form or application in a prior cycle and want to reapply, please do! We have your initial response but know it's common for early-stage projects to shift directions or make rapid progress such that it could make sense to apply again. In this case, please focus your response on what's changed.

If you have any questions, please join Fall purchase office hours at 12:30 pm EDT on August 23 or 26, 2022 or email suppliers@frontierclimate.com.

Contents

The purpose of this document is to outline Frontier's purchasing process and what we're looking for in full applications, so that you can decide if your project might be a good fit for a Frontier prepurchase or offtake. It includes the following:

1 | Timeline

	Step	Approx. date
1	Companies submit pre-applications	Sept. 2, 10pm EDT
2	Frontier screens pre-applications at a high level for basic eligibility (i.e., 1000+ year durability; TRL 3+ status; estimated CDR delivery window; team, etc.) and may ask for a short conversation to clarify any questions.	Early Sept
3	Frontier invites eligible projects to apply; application writing period will be 3 weeks	Early Sept
4	Companies submit full applications	Early Oct
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.	Early Oct
6	Frontier sends anonymized excerpt review comments to applicants, who will have ~2 days to submit a short response to Frontier (if they choose to do so).	Early Nov
7	Frontier may request a video meeting with applicants to further discuss their proposal. Offtake applicants will receive more questions and should expect longer discussion time.	Mid Nov
8	Frontier finalizes decisions and notifies prepurchase and smaller offtake (roughly < $10M request) applicants of decisions.	Late Nov
9	Frontier and selectees jointly build application-specific contract terms such as renewal criteria (prepurchases only) and milestones	Early Dec
10	Frontier announces prepurchase and smaller offtake agreements	Mid Dec
11	For larger offtake applicants (≥ $10M request) who are Finalists, the diligence progress will be more extensive, including in-person due diligence meeting at the applicant's site, increased assessment of commercial viability, thorough techno-economic analysis review, etc.	Early 2023
12	Larger offtake applicants receive decision notifications*	Spring 2023

*We anticipate a Spring purchase announcement for larger offtake applications given the greater degree of due diligence and contracting conversations involved. $10M will likely be the threshold between smaller and larger offtakes (and the corresponding difference in diligence), though we reserve the right to adjust that value (e.g., ask an $8M applicant for an on-site meeting).

2 | How we evaluate projects

We look for permanent carbon removal 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 carbon removal 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 six prepurchases that Frontier announced in in June 2022 under an RFP issued in February 2022 (prior to the launch of Frontier). Before that, Stripe Climate conducted three rounds of prepurchasing.

This is an evolving process for us, and we learn a lot with every purchase cycle. We've made multiple changes this round, including new offtake applications and a corresponding deeper diligence process. Please bear with us as we try out some new ideas (and let us know how we're doing!).

We use three lenses to make purchasing decisions:

- **Approach**: Does the carbon removal approach meet our target criteria?
- **Execution**: Can this team deliver on the proposal, given where the technology is today?
- **Portfolio**: Would this purchase help us build a diverse, risk-adjusted portfolio of carbon removal 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 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	Results in a net reduction in 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)
- Soil carbon

Lens 2: Execution

Broadly, we want to feel confident 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 stage of the project, but generally we look for:

- Whether a proof of concept has already been established (i.e., all major elements of the solution are at least at TRL-3).[1]
- The expertise and experience of the proposing team in both technology and project development.
- When the applicant would be able to begin delivering tons removed. Across tracks, we prioritize earlier delivery (i.e., 2024/2025, though for prepurchase projects, this may be of small volumes) and rarely purchase from projects with no delivery for 5+ years.
- The pace of development. We are looking for companies to move urgently but responsibly. 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.

Lens 3: Portfolio

For companies that demonstrate a compelling path to delivering against Frontier's target criteria, the Frontier team will make final purchase decisions to create a balanced portfolio of CDR purchases that supports project-level and field innovation, deliver tons to Frontier buyers, and maximize the climate returns of each Frontier dollar spent.

3 | Considerations for writing an application

This section includes additional detail on what we look for in evaluating projects as you consider applying or shaping your proposal. If you have any questions on our fall purchase cycle, the pre-application form, or the content below, please feel free to join us for fall purchase office hours August 23 or 26. For companies that we invite to submit a full application, we will also host office hours in mid-September to answer further questions you might have about the process.

Track structure

Frontier purchases fall into tracks to reflect different purchase amounts, contract structures, application requirements, and risk. Applicants should use this figure and the table below to select the application path that best fits their project.

	Prepurchases	Smaller ← Offtakes → Larger	
Total purchase amount	$500,000 + option for additional $1M upon achieving renewal criteria	$2M ⟷ $10M	$10M+ →
Contract structure	$500,000 paid upfront	Small fraction paid on early project milestone completion; majority paid upon tons delivered. Max contract length ~ 5 years	
Expectations and risk tolerance (more details below)	Fewer application requirements Higher risk tolerance ⟷	More application requirements Lower risk tolerance	
Anticipated Fall 2022 cycle contract signature dates	November-December 2022	First half of 2023	

This first step for each track is to complete the pre-application form by September 2, 2022.

[1] In prior cycles Stripe issued R&D grants, but Frontier does not anticipate doing this moving forward. If you are working on a promising idea that's TRL-1 or 2, feel free to send us a pre-application. We will not invite you to submit a full application, but will look for opportunities to connect you to relevant funders in the CDR ecosystem and look forward to a future application.

To help potential applicants figure out which track might be the best fit, we created the table below to present progress we expect prior to application for a given track:

	Prepurchases	Offtakes
Performance data	Company has their own lab-scale performance and preliminary stability data (preferably for days or more) showing proof of concept and that their approach removes CO2 from the atmosphere.	Tech has been validated at the bench or preferably small pilot scale with data establishing CDR performance and stability baseline. Roadmap defined for how gaps between current data and TEA assumptions will be narrowed. For larger offtakes: Tech has removed CO2 in the field, preferably 1 tonne per day or more; minimal remaining technology risk.
Monitoring, reporting, & verification (MRV)	MRV approach outlined. For CDR pathways with higher MRV uncertainty, risks are identified and a method presented for how new data will be generated to reduce MRV uncertainty.	For CDR pathways with high MRV uncertainty, protocols have been published and company has responded to feedback from the scientific community. MRV protocol addresses all key pathway uncertainties and establishes a plan to further reduce uncertainties and meet regulatory requirements. Proposed offtake discounts tonnage offered based on identified MRV uncertainties (if any). For larger offtakes: minimal remaining MRV uncertainty.
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.	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 and includes quotes for major equipment, utility, and O&M costs for specific locations.
Ecosystem safety (e.g., impacts to soil/croplands and oceans)	For CDR pathways with higher uncertainty of ecosystem impacts, company identifies those risks and presents an R&D plan for how they will generate new data to assess ecosystem safety of their approach.	For CDR pathways with higher uncertainty of ecosystem impacts, company has published their data in peer-reviewed literature and has responded to feedback from the scientific community.
Team and operational capability	Company has demonstrated expertise on the team for initial development work, and has a hiring and/or partnering plan for other aspects of the project.	Company has experienced technical and commercial staff in place. Project partners identified and commitments confirmed. Team has a project financing strategy, including how they will reach a final investment decision.
Business strategy	Key business case assumptions and risks identified. Preliminary plan established for next steps if the project is successful.	Company has defined how the proposed project fits within their business plans and the current CDR market and policy landscape. For larger offtakes: company has supply chain, manufacturing, and risk management strategies.

The descriptions are not perfect, as it's hard to consolidate what we're looking for across the gamut of CDR solutions and circumstances for each company. We expect this structure to evolve over time and reserve the right to purchase from a company on a track different from the one they applied to, and for a different contract amount.

Areas of interest

We are open to any CDR approach that could meet our criteria, but there are few areas in which we're especially keen to see applications:

- Synthetic biology
    - **Protein-based CDR:** Innovative bio-approaches to CDR, such as use of enzymes to speed up CO2 dissolution kinetics
    - **Production of recalcitrant molecules:** Bioproduction of recalcitrant polymers, including analysis of possible degradation pathways and intervention strategies

- Ocean alkalinity enhancement (OAE)--but see also an area of concern below related to ecosystem safety. We are looking for prepurchase applications for concepts that are distinct to prior OAE purchases.
    - **Rigorous and holistic approaches to MRV:** Projects that push the field level understanding on viable methods to enhance additional CO2 uptake in the oceans; e.g. measuring CO2 dissolution rates under environmental conditions; data, design of trials, and modeling to better quantify CO2 drawdown and associated ecosystem effects via OAE
    - **Low-emission alkalinity:** innovative, low-emissions sourcing and production of alkaline materials with negligible heavy metal content

- Direct air capture
    - **Scalability:** technologies that include specific concepts as to how they will be able to scale quickly towards gigatons, as well as process innovation to reduce both capital and operational costs
    - **DAC for colder climates:** separation technologies, such as cryogenic processes, that leverage thermodynamic benefits at cooler temperatures and allow for more geographic diversity
    - **Water management:** concepts that require minimal additional water for the capture and regeneration process

- Geochemical CDR
    - **Biochemical enhanced rock weathering and mineralization:** exploring the feasibility of leveraging biological processes to speed up reaction kinetics
    - **Low-emission alkalinity:** innovative, low-emissions sourcing and production of alkaline materials with negligible heavy metal content for carbonization

- Novel CDR solutions
    - Given how nacent the CDR field is, we believe that we are only scratching the surface of technological solutions. If you are working on something that hits our CDR criteria but does not fit into the mentioned pathways - we'd love to hear about it!

- Also, Lowercarbon Capital published some great ideas here that we'd be excited to see apply – check it out.

Pathway uncertainties

Reflecting on the past cycles, there are a few challenging topics or sources of uncertainty where our experts have pressed applicants. We are open to receiving applications for the following CDR pathways, but encourage companies to focus on thoroughly addressing these concerns:

- Biomass conversion & sequestration
    - **Opportunity cost:** biomass could have other uses that are not permanent CDR but could mitigate climate change in other ways such as avoiding emissions. We want to better understand whether using biomass explicitly for CDR is an optimal approach from a broader climate perspective.
    - **Sustainable sourcing:** we prefer waste biomass or biomass produced on non-arable land where the biomass growth is restoring contaminated land, rather than dedicated energy crops, because of land use and net negativity concerns.
    - **Net negativity:** we prefer approaches that permanently remove as much of the carbon in the input biomass as possible; LCA needs to be detailed on this point.
    - **Avoided emissions:** co-products that avoid emissions in hard-to-decarbonize sectors. New builds where electricity is the sole co-product (i.e., new conventional BECCS) is not a priority for Frontier.
    - **Transport**: we want to understand the cost, emissions, and logistics associated with biomass transport.

- Biomass burial/sinking (land/ocean)--here we are looking for prepurchase applications only
    - **Nutrient leaching:** approaches and data that address the effects of nutrient removal
    - **Opportunity cost:** biomass could have other uses that are not permanent CDR but could mitigate climate change in other ways such as avoiding emissions. We want to better understand whether using biomass explicitly for CDR is an optimal approach from a broader climate perspective.
    - **Durability and MRV:** field trials and data that provide knowledge on ecosystem effects (e.g., of introducing field grown crops to oceans, state of biomass in anoxic basins, etc.) and measurement uncertainties (e.g., shedding of sinking biomass, methane leakage risks, etc.)
    - **Methane emissions:** prevention of methane formation
    - **How low the cost could go**: to understand value of this approach relative to biomass conversions that also create co-products that avoid CO2 emissions
    - **Transport**: we want to understand the cost, emissions, and logistics associated with biomass transport.

- Ocean-based CDR
    - **Ecosystem safety:** pathways such as biomass sinking and OAE can have ecological consequences that are far from known. We remain open to these pathways but want to see applicants address how their work will reduce the uncertainty of ecological impacts.

- Biochar[2]
    - **Additionality**: biochar has value as a soil amendment. It is not clear to us whether paying biochar projects for their CDR value will result in outcomes that would be different from today's biochar revenue streams.
    - **Durability**: we want to know how to produce biochar with >1,000 year CDR durability under environmental conditions. Arguments should be supported by scientific literature.
    - **MRV**: field trials and data that provide knowledge on ecosystem effects and measurement uncertainties around degradation pathways.
    - **Sourcing and transport of biomass:** The above considerations around opportunity cost, sustainable sourcing of biomass and associated transportation logistics also apply for biochar applications.

[2]Note: biochar has been excluded from prior purchasing rounds, in part because of concerns related to CDR durability. While we still have those concerns, a number of scientific articles make it clear that some of the biochar applied could have 1,000 year durability. Purchasing from biochar projects is not a priority for Frontier in this cycle, but we are open to receiving innovative prepurchase applications that address the concerns stated above.

Transparency & confidentiality

If you are invited to submit an application and do so, please be aware that your application will be made public at the conclusion of Frontier's purchase cycle. We do this because commercial-scale permanent carbon removal is a nascent field, and we are trying to advance transparency and knowledge-sharing across the ecosystem. Hopefully this will enable impact beyond the dollar amount of any particular purchase we may make.

In previous cycles, some companies have told us that this level of transparency can be challenging, particularly if the company is in stealth or in the process of patent filing. And, since we expect a greater level of detail to be provided in offtake applications–including process specifics, performance data, cost estimates, business plans, etc.–we understand the need to balance transparency with protecting business-sensitive information.

In this cycle, companies will be able to share select information directly with Frontier staff and our expert reviewers (who will have non-disclosure agreements in place) in a short addendum that will not be made public at the conclusion of the purchase cycle. This includes a techno-economic spreadsheet that we will ask all applicants to fill out. However, we still expect as much information as possible to be included in the public-facing portion of the application. We will communicate how to share non-public information when we send invitations to apply.

Communication

All communication related to Frontier's Fall 2022 carbon removal procurement cycle should be sent via email to suppliers@frontierclimate.com.

Supplemental information

- Introducing Frontier
- Q&A on the Fall 2022 cycle on the Frontier website
- Spring 2022 cycle source materials (applications, contracts, templates) on the Frontier GitHub
- Prior purchase cycle source materials on the Stripe Climate GitHub