Frontier

Applicant Instructions: Offtake track

Thank you so much for your work on carbon dioxide removal (CDR), and thank you in advance for taking the time to apply for Frontier's purchase. Please read the following information carefully and in full before beginning your application, as well as take a look at Frontier's Fall 2022 Request for Proposals which includes information regarding our target purchase criteria, how we review applications, and what our team is looking for. For your reference, all previously submitted applications are available here (2020-2021) and here (2022 onwards).

We invite you to attend one of two application coaching sessions we will be hosting at 9 am PDT on Sept 20 and 10 am PDT on Oct 4 for general application guidance. If you have any further questions as you work through, please email us at suppliers@frontierclimate.com.

Timeline

- **October 14, 2022 9:00 pm PDT:** This application is due. You are welcome to submit early.
- **Mid October:** Frontier will review your application for completeness and basic scientific validity with respect to our criteria. Qualified applications will be sent to our expert reviewers for review against the criteria we outlined in the RFP. Each application will receive 2 scientific reviews and 1 governance review.
- **Early November:** Frontier will share anonymous reviewer comments and questions with you, and give you two days to submit a response to these comments, if you choose to.
- **Mid November:** Frontier will invite a subset of applicants to advance to a video interview to discuss your application.
- **Late November:** Frontier finalizes decisions and notifies applicants of prepurchase (FYI, a separate template) and small offtake awards. Together, Frontier and teams define project milestones and tonnage pricing within Frontier's standard purchase agreement templates[1]. Larger offtake applicants will be notified if they are Finalists and invited for additional diligence that we will perform in early 2023.
- **Mid December:** Frontier will announce prepurchase and small offtake purchases and upload applications to Frontier's public GitHub.
- **First half of 2023:** Frontier's review team will conduct additional diligence with larger offtake Finalists, including a site visit to your facility.
- **Mid 2023:** Frontier signs larger offtake agreements.

How to apply

Step 1: Determine which category supplements apply to your project

- This document includes the General Application as well as all category supplements. All applicants should fill out the General Application, as well as whichever (typically 1 - 2) supplements apply to your approach.

[1] Frontier's offtake agreement template is currently under review, so it is not yet available to the public. Once the template has been finalized we will upload to the Frontier GitHub repository.

- You should fill out applicable supplements IN ADDITION to the General Application.
- Using examples from Frontier's existing portfolio:
    - AspiraDAC would fill out the DAC supplement AND the Geologic Injection supplement.
    - Lithos Carbon would fill out the Surface Mineralization/Enhanced Weathering supplement
    - Running Tide would fill out the Biomass supplement AND the Ocean supplement.
    - CarbonBuilt would fill out the CO_2 Utilization to storage supplement.
- If it's not clear which supplements apply to your project, please ask at suppliers@frontierclimate.com.

Step 2: Delete the supplements that don't apply to you.

- This results in a document with the General Application and your applicable supplements only. Please delete these first five pages of instructions too!

Step 3: Fill out the application in this document.

- If you have any questions, attend one of two application coaching sessions we will be hosting at 9 am PDT on Sept 20 and 10 am PDT on Oct 4 for general application guidance or email us at suppliers@frontierclimate.com. Please reach out with questions as early in the application process as possible.

Step 4: Complete the techno-economic analysis (TEA) spreadsheet.

- We included a Google Sheet containing a TEA in the same Google Drive folder (specific to your application) as this template. Instructions on how to fill it out are included in the START HERE tab.
- We recorded a webinar with instructions for filling out the spreadsheet. The passcode is provided in your application invitation. We encourage you to review the spreadsheet early on and ask any questions you might have–either by email or attending an application coaching session.

Step 5: Prepare any materials you would like to submit confidentially [optional].

- We remain committed to a public RFP process because commercial-scale permanent CDR is a nascent field, and we are trying to advance transparency and knowledge-sharing across the ecosystem. However, information shared in the TEA spreadsheet and a confidential addendum will not be made public. This confidential addendum can be up to 15 pages.
- To submit a confidential addendum, create a Google Doc or upload a Word or PDF to the same Google Drive folder as this application and the TEA. All of your application materials must be in this folder.
- Frontier's expert reviewers have non-disclosure agreements (NDAs) in place with Frontier, which covers application reviews. If you choose to submit a confidential addendum and wish to enter into an NDA with Frontier, please notify our team before submission and we will send our standard mutual NDA.

Step 5: Submit your application by October 14, 2022 9:00 pm PDT

- This application, the TEA spreadsheet, and confidential addendum (if applicable) must be in the Google Drive folder by this time.

- **Your submission constitutes your consent for Frontier to make your full application and all of its content - excluding the TEA spreadsheet and confidential addendum– available publicly under a CC-0 "Public Domain" License, regardless of whether or not Frontier selects you for purchase.** For more details, see "Why we make applications public" below.

What we're looking for

Please refer to Frontier's Fall 2022 Request for Proposals for a characterization of projects Frontier is excited to support and details on our selection process. There, we discuss the three lenses we use when making purchase decisions: approach, execution, and portfolio. Our approach criteria are

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

About Frontier's Offtake track

The offtake track is new for fall 2022. The application below is similar to the prepurchase application (for earlier-stage projects requesting $500,000 in upfront purchases). We encourage you to review our Request for Proposals to understand whether your stage of development is more appropriate for a prepurchase or offtake. In general, as the requested purchase amount increases, so do our expectations, including:

- The amount of performance data you already have
- How comprehensive your TEA is, and to what extent it's validated with data and engineering estimates
- How established your measurement, reporting, and verification (MRV) protocols are
- Having minimal environmental/ecosystem risk
- The technical and commercial experience of your staff and project partners
- How substantive your business strategy is

Thus, while many of the questions below are the same for companies requesting $500,000 of prepurchases and companies requesting millions of dollars in offtakes, we expect the latter to include more details and data in their responses below.

This application is the first step for offtake agreements. Applicants asking for smaller and larger offtakes (we currently estimate the threshold for the latter to be $10M but that's subject to change) that we are considering for purchases will participate in video calls in November. We anticipate notifying applicants who are requesting larger offtakes whether they are Finalists by late November, including information regarding additional diligence steps and an approximate timeline.

Why we make all applications public

All applications to our earlier purchase cycles were made public, and can be accessed here and here. We're grateful to all our applicants for providing this level of transparency; hopefully this will enable impact beyond the dollar amount of any particular purchase we may make, including visibility and the opportunity for potential collaborators and investors to connect with you. Making applications public enables subsequent academic works and independent analysis from nonprofits like CarbonPlan (examples here, here), and we've heard from a wide range of investors, engineers, and scientists that the shared applications are a valuable source of data on the current state of the field and opportunities for advancement. For these reasons, we're again making applications from this purchase cycle primarily public.

That said, 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 data and 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. Thus, will accept a confidential addendum alongside applications. But we still expect as much information as possible to be included in the public-facing portion of the application so that it is a comprehensive, standalone representation of the merits of what you're building.

Fine print

We intend to make the selection process as informal as possible. However, we do expect that (a) the content of your application is, to the best of your knowledge, complete and correct; (b) you do not include any content in your application that breaches any third party's rights, or discloses any third party's confidential information; (c)

you understand that we will publicly publish your application, excluding the TEA spreadsheet and materials in the confidential addendum, at the conclusion of the selection process. You also understand that Frontier is not obliged to explain why or how it decided to purchase the CDR that it did, and that Frontier may decide to not purchase CDR from your application or make an offer to purchase less than what you proposed. Finally, if you are selected as a recipient for funding, Frontier will not be under any obligation to provide you with funding until such time as you and Frontier sign a formal written agreement containing the funding commitment.

Acknowledgements

Frontier gratefully acknowledges assistance and discussions from the following, who helped improve this application template and our purchasing process:

- AirMiners environmental justice working group for their many suggestions on the Public Engagement and Environmental Justice sections
- CarbonPlan for their partnership on shaping measurement, verification and reporting requirements
- M. Van der Spek (Heriot-Watt University) for developing the TEA spreadsheet
- Microsoft and XPRIZE Foundation for perspective on life cycle analysis (LCA) and TEA tools

Frontier

[Company Name]

Carbon Dioxide Removal Purchase Application

Fall 2022

General Application - Offtake

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

Company or organization name

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

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

Brief company or organization description

<20 words

1. Project Overview[2]

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.

<1500 words

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.

[2] 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.

<500 words

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?**
[add rows as needed)			

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?

<300 words

e. Are there other organizations you're partnering with (or need to partner with in order to be successful) on this project? Examples could include: feedstock suppliers, component suppliers, storage providers, engineering/procurement/construction (EPC) firms, permitting consultants, etc. 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**
[add rows as needed]		

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?

<30 words

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.

<100 words

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	
2024	
2025	
2026	
2027	
2028	
2029	
2030	

i. List and describe at least five 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		
2		
3		
4		
5		

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

<200 words

k. How are you going to finance this project? Please include organization names, funding amounts, and level of commitment (e.g., contract signed, in active negotiations, in preliminary discussions, to be approached, etc.). How are you going to reach a final investment decision on whether or not to proceed with the project? How much have you raised to-date?

<300 words

l. What percentage of this project's CDR volume are you asking Frontier to purchase? Why did you choose that number?

<300 words

m. 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.).

<200 words

n. 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.

<200 words

o. How does this project fit within your business plan and the current CDR market and policy landscape?

<300 words

p. What have been your major milestones to-date? What have been your biggest failures? What have you learned and how have this informed your strategy looking forward?

<300 words

q. Identify risks for this project and how you will mitigate them. Include technical, project execution, financial, and any other risks. These template tables have room for 3 risks, but please include whatever number of rows you think is appropriate.

Technical Risk	Mitigation Strategy

Project Execution Risk	Mitigation Strategy

Ecosystem Risk	Mitigation Strategy

Financial Risk	Mitigation Strategy

Other Risk	Mitigation Strategy

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?

< 300 words, including number/range of durability estimate

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?

<200 words

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	
Describe how you calculated that value	

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.

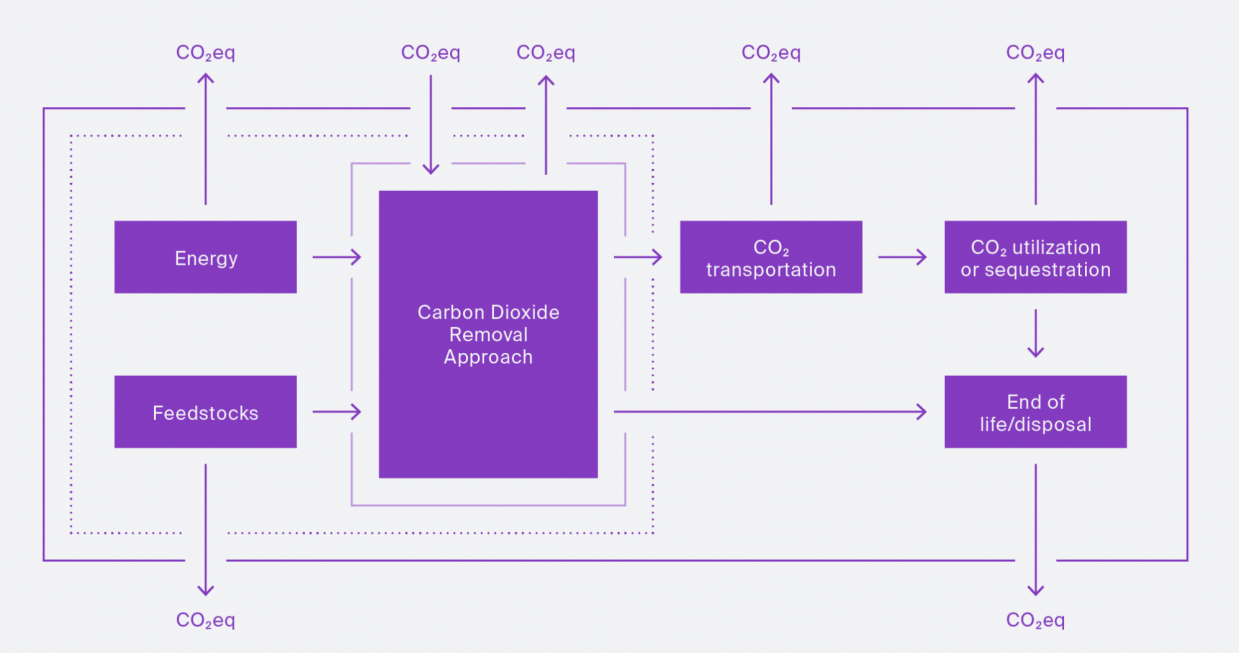
c. If applicable, list any avoided emissions that result from your project. For carbon mineralization in concrete production, for example, removal would be the CO_2 utilized in concrete production and avoided emissions would be the emissions reductions associated with traditional concrete production.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

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)*	
Emissions / removal ratio *(gross project emissions / gross CDR–must be less than one for net-negative CDR systems)*	
Net CDR over the project timeline *(gross CDR - gross project emissions)*	

e. Provide a process flow diagram (PFD) for your CDR solution, visualizing the project emission 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?

<100 words

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.**
(include additional rows as needed)		

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 as one example.

<500 words

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 rely on models or assumptions, and how will you validate those assumptions? *(E.g. monitoring of injection sites, tracking biomass state and location, estimating decay rates, etc.)*

<200 words

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 and third columns, 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, but we are looking to understand how your project is incorporating these considerations.
- 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	**Uncertainty discount** Estimate the impact of this component as a percentage of net CDR volume	**Explain how you calculated that value** Discuss the uncertainty's impact related to your project. Include assumptions and scientific references if possible.
Ex: storage leakage	*Ex: 1%*	*Ex: Based on historical monitoring data XYZ from well operator*
(include additional rows as needed)		

d. Based on your responses to 4(c), what percentage of the net CDR do you think should be discounted in aggregate (acknowledging any interdependent components) to appropriately reflect these uncertainties? For projects at Verification Confidence Levels (4 or 5) this may be minimal. See the Q&A document for detailed guidance.

<50 words

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.?

<200 words

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)?

<200 words

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 expect to 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).

$/tonne CO_2

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

Component	**Levelized price of net CDR for this project ($/tonne)**
Capex	
Opex (excluding measurement)	
Quantification of net removal (field measurements, modeling, etc.)[3]	
Third party verification and registry fees (if applicable)	
Total	(should match 5(a))

[3] 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.

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?

Parameter with high impact on cost	**Current value (units)**	**Value assumed in NOAK TEA (units)**	**Why is it feasible to reach the NOAK value?**
[add rows as needed]			

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

<100 words

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.).

<200 words

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.)

<50 words

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.

<300 words

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.*

<300 words

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?

<100 words

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?

<100 words

7. Environmental Justice[4]

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.

<200 words

[4] 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

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

<300 words

8. Legal and Regulatory Compliance

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

<100 words

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.

<100 words

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?

<100 words

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.

<100 words

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.

<50 words

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))*	
Delivery window *(at what point should Frontier consider your contract complete? Should match 1(f))*	
Levelized Price ($/metric tonne CO_2) *(This is the price per tonne of your offer to us for the tonnage described above)*	

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Application Supplement: DAC

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

Note: these questions are with regards only to air capture: e.g. your air contactors, sorbents or solvents, etc. Separately, there exist Geologic Injection and CO_2 Utilization supplements. We anticipate that most companies filling out this DAC supplement should ALSO fill out one of those supplements to describe their use of the CO_2 stream that's an output of the capture system detailed here.

Physical Footprint

1. What is the physical land footprint of this project, and how do you anticipate this will change over the next few years? This should include your entire physical footprint, i.e., how much land is not available for other use because your project exists. Also, what is the estimated footprint if this approach was removing 100 million tons of CO_2 per year?

Land footprint of this project (km^2)	
Land footprint of this tech if scaled to 100 million tons of CO_2 removed per year (km^2)	

Capture Materials and Processes

1. What material(s) is/are you using to remove CO_2?

<50 words

2. How do you source your material(s)? Discuss how this sourcing strategy might change as your solution scales. Note any externalities associated with the sourcing or manufacture of it (e.g, hazardous wastes, mining, etc.). You should have already included the associated carbon intensities in your LCA in Section 3.

<300 words

3. How much energy is required for your process to remove 1 net tonne of CO_2 right now (in GJ/tonne)? Break that down into thermal and electrical energy, if applicable. What energy intensity are you assuming for your NOAK TEA?

<100 words

4. What is your proposed source of energy for this project? What is its assumed carbon intensity? How will this change over the duration of your project? (You should have already included the associated carbon intensities in your LCA in Section 3)

<100 words

5. Besides energy, what other resources do you require (if any, such as water)? Where and how are you sourcing these resources, and what happens to them after they pass through your system? (You should have already included the associated carbon intensities in your LCA in Section 3)

<100 words

6. Do you have experimental data describing how your system's CDR performance changes over time? If so, please include that data here and specify whether it's based on the number of cycles or calendar life.

<100 words

7. What happens to your capture medium at end-of-life? Please note if it is hazardous or requires some special disposal, and how you ensure end-of-life safety.

<100 words

8. Several direct air technologies are currently being deployed around the world. Why does your DAC technology have a better chance to scale and reach low cost than the state of the art?

<200 words

Frontier

Application Supplement: Biomass

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

Feedstock and Physical Footprint

1. What type(s) of biomass does your project rely on?

<100 words

2. How is the biomass grown (e.g., kelp) or sourced (e.g., waste corn stover)? Do you have supply agreements established?

<200 words

3. Describe the logistics of collecting your waste biomass, including transport. How much carbon emissions are associated with these logistics, and how much does it cost? How do you envision this to evolve with scale?

<200 words

4. Please fill out the table below regarding your feedstock's physical footprint. If you don't know (e.g. you procure your biomass from a seller who doesn't communicate their land use), indicate that in the table.

	Area of land or sea (km^2) in 2022	**Competing/existing project area use (if applicable)**
Feedstock cultivation	E.g. 1 km^2 (floating kelp array) OR N/A (procuring waste biomass)	
Processing	E.g. 0.1 km^2 (boat yard, manufacturing facility) OR 0.5 km^2 (manufacturing facility for mobile biochar plants)	
Long-term Storage	E.g. N/A (uncertainty in final state of kelp) OR 2 km^2 (ag fields in which biochar is deployed)	

Capacity

5. How much CDR is feasible globally per year using the biomass you identified in question 1 above? Please include a reference to support this potential capacity.

<100 words

Additionality and Ecosystem Impacts

6. What are applications/sectors your biomass feedstock could be used for other than CDR? (i.e., what is the counterfactual fate of the biomass feedstock)

<100 words

7. There are many potential uses for waste biomass, including avoiding emissions and various other approaches to CDR. What are the merits and advantages of your proposed approach in comparison to the alternatives?

<200 words

8. We recognize that both biomass production (i.e., growing kelp) and biomass storage (i.e., sinking in the ocean) can have complex interactions with ecological, social, and economic systems. What are the specific, potential negative impacts (or important unknowns) you have identified, and what are your specific plans for mitigating those impacts (or resolving the unknowns)?

<300 words

Frontier

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?

   <100 words

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

   <100 words

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.

   <200 words

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		
Source material processing		
Deployment		

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

<100 words

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?

<50 words

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?

<100 words

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?

<100 words

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.)

<100 words

Application Supplement: Ocean

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

Physical Footprint

1. Describe the geography of your deployment, its relationship to coastlines, shipping channels, other human or animal activity, etc.

<200 words

2. Please describe your physical footprint in detail. Consider surface area, depth, expected interaction with ocean currents and upwelling/downwelling processes, etc.

    a. If you've also filled out the Biomass supplement and fully articulated these details there, simply write N/A.

<200 words

3. Imagine, hypothetically, that you've scaled up and are sequestering 100Mt of CO_2/yr. Please project your footprint at that scale, considering the same attributes you did above (we recognize this has significant uncertainty, feel free to provide ranges and a brief description).

    a. If you've also filled out the Biomass supplement and fully articulated these details there, simply write N/A.

<200 words

Potential to Scale

4. Building large systems on or in the ocean is hard. What are your core engineering challenges and constraints? Is there any historical precedent for the work you propose?

<200 words

Externalities and Ecosystem Impacts

5. What are potential negative impacts of your approach on ocean ecosystems?

<200 words

6. How will you mitigate the potential for negative ecosystem impacts (e.g., eutrophication and alkalinity/pH)? How will you quantify and monitor the impact of your solution on ocean ecosystems and organisms?

<200 words

Application Supplement: Geologic Injection

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

Feedstock and Use Case

1. What are you injecting? Gas? Supercritical gas? An aqueous solution? What compounds other than C exist in your injected material?

<50 words

2. Do you facilitate enhanced oil recovery (EOR), either in this project or elsewhere in your operations? If so, please briefly describe.

<50 words

Throughput and Monitoring

3. Describe the geologic setting to be used for your project. What is the trapping mechanism, and what infrastructure is required to facilitate carbon storage? How will you monitor that your durability matches what you described in Section 2 of the General Application?

<500 words

4. For projects in the United States, for which UIC well class is a permit being sought (e.g. Class II, Class VI, etc.)?

<10 words

5. At what rate will you be injecting your feedstock?

Environmental Hazards

6. What are the potential environmental impacts associated with this injection project, what specific actions or innovations will you implement to mitigate those impacts? How will they be monitored moving forward?

<200 words

7. What are the key uncertainties to using and scaling this injection method?

<200 words

Application Supplement: CO_2 Utilization

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

CO_2 Feedstock

1. How do you source your CO_2, and from whom? If your approach includes CO_2 capture and it's described above (e.g., general application and one of the supplements), simply respond N/A here.

   <200 words

2. What are alternate uses for this CO_2 stream?

   <100 words

Utilization Methods

3. How does your solution use and permanently store CO_2? What is the gross CO_2 utilization rate? *(E.g. CO_2 is mineralized in Material at a rate of X tCO_2 (gross) / t storage material).*

   <100 words

4. What happens to the storage material (e.g. concrete) at the end of its service life, and how does that impact its embodied carbon storage over time? How do you know?

   <100 words

5. How do you ensure that the carbon benefits you are claiming through a CO_2 utilization process are not double counted? *(E.g. If sourcing CO_2 from a DAC system, or selling your product to a user interested in reducing their carbon footprint, who claims the CDR benefits and how could an independent auditor validate no double counting?)*

   <200 words