



## CDR Measurement & Verification Q&A

### Guidance for current and potential Frontier suppliers

Getting measurement, reporting and verification (MRV) right is critical to ensuring high quality climate outcomes as CDR scales. The goal of this document is to provide suppliers transparency into Frontier's expectations for quantifying and verifying carbon removal outcomes and accounting for uncertainties. This is a guide for the system we have today, and we expect this to evolve as the ecosystem for permanent CDR MRV does.

#### What does MRV include?

MRV broadly refers to a many-part process of producing trustworthy quantitative estimates for key carbon removal outcomes. It includes:

- Defining the **protocol** (carbon accounting, process, and data required) for net carbon removal quantification and revising this methodology based on best available science.
- Using **measurements and modeling to quantify** net carbon removal outcomes and durability according to the protocol, inclusive of lifecycle impacts and discounting for uncertainties. Note: we use 'quantification' throughout this guide to include both measured and modeled inputs.
- **Verifying carbon removal delivery** against the specific criteria for that protocol through an independent assessment of reported data and a rigorous verification in the field.
- **Reporting deliveries** and the methodology upon which they rest in a consistent, transparent manner, and listing verified removals as credits on public registries.

Note: We consider a project's ecosystem and community impacts as separate from the quantification of carbon removal outcomes, but it is a similarly critical consideration in Frontier's purchasing assessments.

#### What are Frontier's expectations for project MRV?

Expectations for rigorous MRV are a core part of Frontier's purchasing approach:

- **Verifiability** is a cornerstone of Frontier's [target purchasing criteria](#).
- Quantification expectations are **baked into eligibility criteria for pre-purchase and offtakes** in Frontier's [Fall 2022 RFP](#) and an important part of Frontier's purchase application and decisions.
- **Milestones** designed to support projects' development of stronger quantification approaches and drawdown of pathway uncertainty are built into Frontier contracts.

We expect high quality MRV to be a central goal of all permanent CDR projects. While we want to ensure rigorous quantification, we also want to avoid stifling early-stage innovation. Rather, we want to drive *more* funding to novel, promising CDR approaches that are tackling MRV questions. Some uncertainty is expected and a portion may even be irreducible in some pathways – we look for projects and a system that incentivizes shrinking uncertainties over time.

We aim to buy a diverse portfolio of permanent carbon removal technologies and will consider a project's

ability to quantify removal and durability outcomes alongside a number of other considerations for high-quality CDR, including cost, potential for scale, technology risk, and ecosystem and community impacts. Frontier's mandate includes buying both large offtakes and making early advanced purchases to support a number of shots on goal. In practice, this means that technologies in the Frontier portfolio will vary in their ability to accurately quantify carbon removal and durability. We plan to incorporate this uncertainty into our understanding of tons delivered, and will expect more stringent MRV as a precondition for scaling from small advanced purchases to larger offtake agreements.

For more details on our approach, please see [“Quantifying delivered carbon removal as a buyer of early technologies.”](#) We'll note that this is an imperfect guide for the system we have today, and we hope to improve and evolve it as the MRV ecosystem for permanent CDR does.

## Project Diligence

### To apply for purchase, what measurement and verification questions should suppliers address?

In pre-purchase and offtake [applications](#), Frontier asks suppliers to detail:

- Their approach to quantifying the project's net carbon removal, including methodology, what data is measured versus modeled, monitoring frequency, key assumptions, and treatment of uncertainties
- The discount (when applicable) associated with the relevant uncertainty components [listed here](#) for their pathway, based on a conservative (high end) estimate of likely uncertainties.
- A discounted total volume—what we call “delivered volume”—reflecting this uncertainty (i.e., the volume offered should be the net volume after accounting for the discounts above).
- How the project is contributing to the field's reduction of these open questions, if applicable
- Intended plan and partners for verifying delivery and registering credits

### What are uncertainty components?

Component uncertainties include things like storage leakage for DAC or secondary mineral formation for enhanced weathering that may contribute to error or variation in assessing carbon removal outcomes for CDR technologies. Please see this [Quantification Uncertainty Map](#) built in partnership with CarbonPlan for details. If your pathway is not included, please assess your project's quantification uncertainties individually.

### What is a Verification Confidence Level (VCL)?

VCL is a [directional metric](#) which represents how confident we are that carbon removal and durability outcomes can be accurately quantified for each pathway, using the best scientific understanding, instrumentation, modeling and methodologies available today. They are based on the combined uncertainty across all of the quantification components we identified for a given pathway, and are intended to help buyers understand current certainty ranges for various carbon removal pathways. Note that this represents a current snapshot, and we expect the VCL for different CDR pathways to improve over time.

**How does my approach to quantifying removal outcomes impact my application?**

High-quality MRV can serve as an important point of differentiation for projects, particularly in cases where their CDR approach is similar to other projects we have purchased from in the past. In purchasing selection, particularly for open-system technologies like enhanced weathering or ocean-based technologies, we give more weight to companies who are contributing to better MRV approaches for the field and addressing high magnitude uncertainties by building innovative measurement or modeling techniques or pushing the development of cheaper, more accurate methods. We also encourage companies to be transparent with MRV findings and scientific research to help reduce pathway-level uncertainties.

**Will Frontier purchase from technologies with yet-to-be-established protocols or that are early in addressing uncertainties?**

Yes. We remain committed to making early advance purchases from new CDR pathways and companies. For pre-purchases, we are open to purchasing at VCL 2 or greater, particularly if there is high potential for verification confidence to improve over the project's lifetime. For larger, offtake purchases, we look for pathways at VCL 3 or greater. For details on the MRV requirements for pre-purchases and offtakes, please see the eligibility requirements in our RFP.

**Will system-level uncertainties impact my application?**

There may be areas of scientific uncertainty that are beyond the ability of a project to resolve in isolation. This is particularly true for open systems pathways like enhanced rock weathering and ocean-based technologies. While systems-level uncertainty will factor into purchasing decisions and carbon removal estimates, we will work with project providers, buyers, academics, and philanthropic organizations to support larger scientific efforts aimed at reducing these uncertainties.

**Do I need to have a protocol developed and verifier and registry secured before applying for pre-purchase?**

No. We request that pre-purchase applicants have thought critically about their measurement and verification approach, but appreciate that if a deployment is a few years from delivering tons, protocol development and registry selection may come at a later stage. We also hope to see the development of new registries and protocol developers focusing specifically on high-quality permanent removals in the future, which will provide opportunities beyond current voluntary carbon market organizations.

**What does Frontier's expectation for protocol development look like for offtakes?**

We ask for a robust, externally verified project MRV protocol as an Exhibit within any offtake contracts we sign that meets our MRV guidance by pathway and addresses the components on our uncertainty list. Each year, we request suppliers to provide a report that (i) identifies any potential deviations or gaps from the outlined protocol, (ii) proposes recommended improvements to the protocol, and (iii) responds to any questions the buyer sends the supplier about the protocol. Sellers & buyers will confer if any amendments to the protocol should be made.

## Project Contracting

### How should quantification and verification expenses be reflected in project pricing?

We ask applicants to make MRV costs visible by breaking out capex; opex; quantification costs of in-field measurement, modeling, and data collection; and third party verification and registry fees.

### Does Frontier expect suppliers to take on the cost of verification?

No. We want to ensure that rigorous MRV does not create unfavorable economics for projects. We anticipate the operational cost of measurement – and the higher early cost burden expected with building robust MRV for novel approaches – to be paid for by us as early buyers as a pass-through cost baked into the price per ton.

### How should I reflect the sources of removal outcome uncertainty listed [here](#) into the volume of net carbon removal offered?

Projects should include uncertainty components as factors impacting net carbon removal outcomes within project protocols. Within the Frontier purchase application, we request that projects conservatively quantify and justify the uncertainty of each component identified for their pathway. We expect applicants to discount the total volume of tons to be delivered by the project based on the combined uncertainties estimated by applicants.

### How are uncertainty discount rates determined?

The specific uncertainty quantification discounts will vary both by pathway and project. Medium-term, we expect project and system quantification uncertainties to be reflected and standardized within protocols that are developed and verified by independent organizations. Nearer-term, the below is an imperfect rule of thumb for calculating uncertainty quantification discounts in proposals and purchases.

#### Near term

- Projects will provide individual estimated uncertainty discounts for their tons delivered based on the aggregate effect of individual uncertainty elements identified in the [Quantification Uncertainty Map](#) as part of their application.
- The uncertainty discount will vary based on pathway\* (e.g. ocean alkalinity enhancement), specific approach (e.g. electrochemical additions), and company operations. As a rule of thumb, we would roughly expect a supplier's discount to fall within the following range depending on the pathway VCL:

Verification Confidence Level *Revised at least annually	Rule of Thumb Minimum Uncertainty Discount As a percent of net removal volume
VCL 1 Current quantification capacity is unlikely to establish permanent carbon removal (on a net CO <sub>2</sub> e basis accounting for all GHGs) with confidence.	<i>Candidate for exploration and R&amp;D funding.</i>  <b>N/a</b> - too uncertain to measure carbon removal.

<b>VCL 2</b> Current quantification capacity may be able to establish permanent carbon removal occurred.	<i>Small, pre-purchase eligible</i>  <b>40% or greater</b>
<b>VCL 3</b> Current quantification capacity can establish that permanent carbon removal occurred, but significant uncertainties remain.	<i>Offtake eligible</i>  <b>20% or greater</b>
<b>VCL 4</b> Current quantification capacity can establish permanent carbon removal with confidence, and medium uncertainties remain	<i>Offtake eligible</i>  <b>10% or greater</b>
<b>VCL 5</b> Current quantification capacity can establish permanent carbon removal with confidence. Only small sources of uncertainty remain.	<i>Offtake eligible</i>  <b>0% or greater</b>

\*If your pathway is not yet included within the [Quantification Uncertainty Map](#), please follow a similar process: identify key drivers of variation in quantifying carbon removal and permanence outcomes, and account for them accordingly in your proposal to Frontier.

- These estimates will be further evaluated by Frontier staff scientists and independent expert reviewers. For project's that do not have an analytical estimate for an uncertainty component, we will assume the higher end of the range.
- The above is a guideline only – if your project includes advancements in models, field data collection, tools or other methods that allow you to quantify your removal outcomes with greater accuracy than the current assessed VCL for your pathway and approach, please include your assumptions.
- For an example of what this looks like, please see Frontier's [post here](#).

We have already seen this approach partially applied in practice by a number of enhanced rock weathering applications, where removals are reduced by 10% to 15% to account for uncertainties in the evasion of carbon between fields and oceans.

Although there is not a system to enforce the application of uncertainty discounts across the market, we would advocate for a similar approach to be taken in all volume claims made by projects, including in offers to other buyers.

#### Medium term

- Eventually, we'd like to see uncertainty discounting codified and standardized in MRV protocols developed and then verified by credible third parties. This will enable standardization of uncertainty discounting across all buyers and projects with specific CDR pathways.

As a result of this requirement, we may conservatively underestimate tons delivered initially, but we expect discounting to lessen over time as we reduce uncertainties by pathway, in turn increasing the tons available for sale and associated payment.

### **How will Frontier's aim to incentivize purchase-level and field-level incentives to reduce MRV uncertainties show up in contracting?**

Within pre-purchase contracts, Frontier will set interim milestones related to the development of a project's quantification and verification approach, as well as establish efforts that draw down uncertainty as conditions for purchase renewal (e.g., Project develops a protocol to fully address X uncertainties and publishes research which informs the field's estimation of leakage, etc.). Similarly, offtake contracts will include milestones related to drawing down uncertainty at a project level or for providing a field contribution, with payments linked to achieving these contributions.

## **Delivery Reporting & Verification**

### **Does Frontier have a pre-approved list of third party verifiers, protocol-developers, or registries suppliers should use?**

Frontier does not yet have a pre-approved list since the landscape and governance system for carbon removal verification is evolving. In the interim, we use the following criteria to guide our decision to accept protocol development or verification from a given registry:

- Is protocol development conducted by an independent scientific advisory, and do the protocols conservatively address the sources of uncertainty listed [here](#)?
- Does the registry also have a marketplace for selling credits? If so, is there a clear boundary between the registry and marketplace business to reduce the risk of relaxed verification to increase credit sales?
- If the registry has previously or currently serves the avoided emissions offset market or temporary carbon removals market, are permanent carbon removal credits clearly differentiated to avoid creating a false sense of equivalency?

### **How does Frontier accept deliveries?**

For delivery of tons as part of offtake agreements, we require a life cycle analysis and assessment of delivery to be conducted by a third party verifier according to the protocol in the contract which has been approved, appropriately accounting for pathway quantification uncertainties by our scientific advisors. In addition, Frontier's scientific advisors screen project delivery data and assess projects against any contract milestones and renewal criteria in order to determine whether Frontier should accept delivery.

### **What level of measurement reporting and transparency is Frontier looking for?**

Transparency around both what is known and where uncertainties remain could build broader community trust in CDR claims. For all Frontier purchases, we expect transparent communication of protocols, data reflecting a company's execution against that protocol, and reporting to the market of tons delivered.

### **What type of long-term durability monitoring does Frontier require?**

We expect projects to actively monitor project deployments (storage systems, mineral amendment applications to land, etc.) until "functional stability," a concept from landfill management, is reached. This is

the point at which the system no longer poses serious reversal risk and doesn't require any active control systems for continued storage.

For permanent carbon removal projects, we expect protocols to address durability by 1) developing monitoring processes and data requirements to track reversals or storage leakage, and 2) identify an appropriate threshold and what must be observed in order to confidently assess that "functional stability" has been reached and monitoring can be discontinued. This point will vary based on the nature of the deployment (i.e., the stability timeline for basalt mineralization vs geologic storage of supercritical CO<sub>2</sub> vs biomass burial looks differently).

### **How should protocols evolve as new information comes out? Will Frontier revise past vintages?**

**Uncertainty components should be reflected within your protocol.** We expect projects to adopt conservative protocols that appropriately discount the net removal quantification based on uncertainties. In the case that significant learnings (e.g., scientific consensus determines that geologic storage leakage is 10x our previous assumption), it is up to a buyer's discretion whether they write off that carbon removal purchase and re-buy if the credit was retired. We would not retroactively claw back payments from companies.

**We ask that protocols be updated periodically:** frequently enough to reflect the best available science, but not so quickly that it makes operationalizing the protocol impossible, recognizing that suppliers need time to set up the appropriate quantification (sensors, lysimeters, modeling, etc.) and reporting infrastructure. From the time an agreement is signed, there is an expectation that suppliers are following the protocol committed to in the agreement. On an annual basis, suppliers are required to identify to buyers if any protocol modifications are needed based on best available science and approaches. Based on this annual review, suppliers and buyers may adjust the protocol and expectation for future delivery. These discussions would not impact past deliveries.

### **Can I share suggestions?**

Our thinking is iterative and we welcome your input. If you have questions or feedback on this document, please email [suppliers@frontierclimate.com](mailto:suppliers@frontierclimate.com).