Frontier

CDR Quantification Uncertainties

Supplement to Frontier's Fall 2022 Carbon Removal Purchase Application

Frontier, together with CarbonPlan and the broader carbon removal academic community, has laid out a number of open questions around measuring the carbon impact of different CDR technologies.

This Quantification Tool diagrams components that we anticipate should be measured or modeled to characterize ultimate carbon removal and durability outcomes, along with high-level characterizations of the uncertainty type and magnitude for each element. We encourage you to read the content in full relevant to your technology.

Within question 4(c) of Frontier's fall purchase application, please be sure to address the primary scientific, counterfactual, and execution uncertainties listed below within your approach (where applicable). If your approach does not fall clearly within one of these pathways, pick the closest one or identify major uncertainties that might not be listed:

Direct Air Capture

- Storage system leakage
- Storage monitoring and maintenance
- Energy replacement emissions (if not already included in the LCA)

Biomass Carbon Removal and Storage

- Storage system leakage
- Storage monitoring and maintenance
- Counterfactual biomass storage
- Feedstock replacement emissions
- Indirect land use changes

Enhanced Weathering

- Non-weathered portion
- Reduction in alkalinity due to reactions with non-CO_2 sources of acid or absorption of cations by vegetation
- Secondary mineral formation
- Leakage from evasion

Terrestrial Biomass Sinking

- Non-sunk at depth fraction
- Counterfactual biomass storage
- Feedstock replacement emissions
- Indirect land use change
- Deep water recirculation

Ocean Biomass Sinking

- Mass of biomass carbon
- Non-sunk at depth fraction
- Air-sea gas exchange efficiency
- Surface ocean competition effects
- Deep water recirculation

Ocean Alkalinity Enhancement

- Total alkalinity released
- Conversion of added alkalinity to theoretical atmospheric removal
- Secondary precipitation of $CaCO_3$
- Air-sea gas exchange efficiency
- Biotic calcification response
- Energy replacement emissions