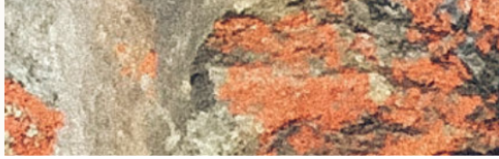
Frontier



Health & ecosystem impact assessment for enhanced weathering deployments

Updated July 13, 2023

Context

Frontier seeks to support promising carbon removal projects that can be done responsibly and maximize benefits to communities and ecosystems while minimizing potential harms. As a part of purchasing diligence, independent reviewers assess the project's approach to legal and regulatory compliance, ecosystem safety and community benefit distribution.

The science is clear that rapid innovation in carbon removal is required if the world is to limit the worst impacts of climate change. But as in other areas of science and technology, carbon removal faces a "dilemma of control," wherein we may not be able to *fully* predict the effects of approaches unless and until they are used[1]. Complicating matters further, the potential effects of carbon removal approaches–positive and negative–must be weighed against the effects of climate change itself.

Purchasing can be a useful tool for advancing responsible innovation in carbon removal and we have built mechanisms into Frontier's purchasing diligence and contracting to (1) minimize the potential known risks of projects; and (2) establish processes for adaptive management over time to ensure that projects stop if negative impacts are identified.

This assessment rubric

This rubric was developed by environmental, safety and health sciences firm Ramboll to help reviewers in Frontier's 2023 purchasing cycle assess whether an enhanced weathering project (1) is set up for safe deployment and (2) has a best-in-class approach to monitor and mitigate any potential ecosystem and health and safety risks.

We do this by selecting for projects with low substantive risk and strong procedural controls across key risk categories:

- Low substantive risk - Risks are inherently lower because of the nature of the approach and the way the company has designed a deployment. For example, a project that uses a particularly safe feedstock in a field with relatively low baseline heavy metals.

- Strong procedural controls - A project has appropriate instrumentation and processes in place to monitor ecosystem interactions along with governance controls that trigger deployment shifts if any negative impacts are observed. For example, third party monitoring of soil impacts and crop yields in areas of enhanced weathering deployments.

A project must pass all assessment categories to be eligible for purchase.

[1] Collingridge: 1980

Pre-Deployment assessment rubric

Assessment Category		Assessment Type	Assessment Description	Assessment Rubric			Guidelines for advanced monitoring & mitigation
				High pass	Low pass	Needs improvement	
1 - Overall Project Governance							
a	Regulatory Compliance	Procedural	Project has controls in place to comply with local, state, and federal regulations	• Proponent has a regulatory compliance expert and has a plan for compliance • Planning prioritizes hazard elimination where practical	• Proponent has a regulatory compliance expert and has a plan for compliance	• No regulatory compliance expert engaged and no plan for compliance	In the U.S., potentially applicable regulations include: • State licensing for distribution of agricultural soil amendments • OSHA worker exposure, safety data sheet requirements • Federal or state permitting for releases to water (storm runoff), air (fine particulates), or waste disposal (if EW material is a waste product) International regulations may vary.
b	Compliance with project-specific plans & objectives	Procedural	Project has established requirements for project reporting and auditing	• Proponent will receive regular, independent audits of environmental and safety outcomes for this project • Proponent plans to transparently report audit findings and safety data to relevant project stakeholders, including communities	• Proponent will receive regular, independent audits of environmental and safety outcomes for this project	• No plans for third party review or transparent reporting	
2 - Local Ecological Impacts							
a	Soil nickel (Ni) concentration increase	Substantive	Project represents minimal risk of nickel toxicity to soils Determine whether EW material application rate must be limited to protect crops from Ni toxicity in soil, and if necessary, identify such a limit	• Proponent proposes an application rate that will not exceed the Ni protective concentration rate and has a strong soil monitoring and adaptive management plan. For High Pass: • Proponent has existing data demonstrating safe Ni concentrations in field trials and a plan to publish findings for future deployments See “Guidelines for advanced monitoring & mitigation” for requirements.		• Ni concentration in EW material is assumed without detailed basis, and no Ni monitoring planned	1. Conduct trace metal (Ni) analysis of specific EW material 2. Collect representative soil samples and analyze for pH, total organic carbon, clay content, and cation exchange capacity (Threshold Calculator inputs) 3. Use Threshold Calculator to determine site-specific soil Ni concentration protective of plants 4. Compare EW material Ni concentration to protective soil Ni concentration; if it is less, no need to limit application rate on account of Ni 5. Otherwise, calculate Ni in amended soil based on application rate (kg/ha), number of applications, till depth, soil bulk density, and baseline soil Ni; if calculated soil concentration exceeds protective concentration, then revise application plan until soil Ni concentration is protective 6. If margin of safety for predicted soil Ni is less than 3-fold, develop soil monitoring and adaptive management plan. Consider representativeness and statistical robustness when determining monitoring design. Monitor both Ni and Threshold Calculator input parameters.

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b	Groundwater protection (Ni)	Substantive	Project presents minimal risk to groundwater. Determine whether EW material application rate must be limited to protect groundwater, and if necessary, identify such a limit	• Proponent proposes an application rate that will not exceed the Ni protective groundwater concentration rate and includes leachate testing in soil monitoring plan. For High Pass: • Proponent has existing data demonstrating safe Ni concentrations from leachate tests in field trials and a plan to publish findings for future deployments See “Guidelines for advanced monitoring & mitigation” for requirements.		• Groundwater protection not adequately evaluated	1. Determine whether groundwater protection is relevant to the project site, based on factors such as existing groundwater quality (is it potable?) and depth to groundwater 2. Determine locally applicable protective concentration for Ni in groundwater (e.g., 39 µg/L in U.S.). 3. Prepare bench-scale amended soil per application rate to protect soil quality and perform leaching test (SPLP or FLT method) 4. Compare leaching test results to protective groundwater Ni concentration; if protective concentration is exceeded, revise application plan to achieve target leachate test result. 5. If margin of safety from initial leachate test is less than 3-fold, include soil leachate testing in soil monitoring plan
c	Surface water protection (Ni and pH)	Substantive	Project presents minimal risk to surface waters Determine whether surface water Ni and pH monitoring is needed	• If necessary, proponent includes a surface water monitoring plan • Plan to publish findings is encouraged for High Pass rating. See “Guidelines for advanced monitoring & mitigation” for requirements.		• Surface water protection not adequately evaluated	1. Determine whether surface water protection is relevant to the project site based on proximity of water bodies to application area 2. Determine locally applicable protective concentration for Ni and pH in surface water based on aquatic life criteria (may require analyzing hardness of surface water) 3. If protective surface water concentration is greater than or similar to protective groundwater concentration, then groundwater protection plan will be sufficient to protect surface water 4. Otherwise, compare leaching test results to protective surface water concentration; if margin of safety is at least 3-fold, then surface water monitoring is not necessary 5. If necessary, develop surface water monitoring plan
d	Soil nutrient balance	Procedural	Project presents minimal risk of negatively impacting soil nutrient balance Understand nutrient content of EW material and plan how to balance soil fertility and control nutrient runoff	• Proponent plans to partner with farmers to adjust soil quality management holistically based on macro- and micronutrients of EW material • Proponent has plans to control nutrient runoff from deployments • Proponent plans to monitor soil quality and crop yield impacts and for High Pass, has existing data supporting positive soil quality and crop yield impacts from field trials • Plan to publish findings is encouraged for High Pass rating See “Guidelines for advanced monitoring & mitigation” for requirements.		• No plan to address nutrient balance, no consideration of nutrient runoff	1. Analyze EW material for macro- and micronutrients 2. Perform standard agronomic soil analysis with recommendations for planned crop 3. Determine how to adjust other fertilizer/soil amendments for appropriate soil quality management when incorporating EW material at planned application rate 4. Plan to monitor soil quality with standard agronomic analyses over time 5. Plan to apply best management practices to control nutrient runoff 6. Plan to monitor crop yield, preferably in comparison to a reference field without EW amendment

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a	EW material sourcing	Substantive	The project's material sourcing plan presents minimal environmental risk Assess carbon emissions, other environmental emissions, and land conversion if applicable. These depend on: • Whether selected EW material is a by-product of existing mineral extraction • Whether grinding is required to achieve target particle size • Distance from source to application area	• EW material is sourced as a by-product of existing mineral extraction with minimal additional grinding and limited transportation distance	• If mining, grinding, and/or long-distance transport are required, perform environmental impact assessment and assess acceptability of environmental and socioeconomic tradeoffs	• EW material sourcing not optimized based on environmental impacts, or environmental tradeoffs have been assessed and are not acceptable	Apply life cycle analysis concepts to compare candidate sources of EW material and field application sites. If impacts and tradeoffs are substantial for all options, compare EW to other carbon capture & storage technologies.
4 - Worker Wellbeing							
a	Asbestos	Substantive	EW material used does not contain asbestos	• Asbestos confirmed absent from EW material		• No asbestos analysis	Routine laboratory analysis for asbestos
b	Dust control for field application	Procedural	Project has clear plans to protect workers' health from: • Inhalation of fine particles (risks heart disease, asthma, etc.) • Inhalation of crystalline silica dust (risks silicosis/lung cancer)	• Dust control plan for field application based on elimination of hazard by pelletizing fine particles (or similar modification)	• Dust control plan for field application based on modification of application methods (e.g., wetting, wind monitoring etc.)	• No dust control plan	Dust exposure can be mitigated through standard dust suppression actions (e.g., wetting, restrictions based on wind speed, etc.). May work with a professional supplier to develop site-specific dust control and health & safety plans.
c	Dust control for material sourcing	Procedural		• Worker health & safety plan prepared for material sourcing and preparation		• No health & safety plan	
5 - Community Wellbeing							
a	Community Engagement	Procedural	Project has begun early implementation of engagement with the community surrounding the deployment site	• Obtains buy-in and community support for deployment through education, partnership with local leaders, etc.	• Keeps community informed on deployment strategy through one-way communications	• Community is not informed	
b	Off-site air quality	Procedural	Project has a clear plan to assess and monitor whether community air quality could be affected by field application	• Minimal potential for community air impacts, or dust control plan will mitigate such impacts		• Not assessed or not mitigated	PM10 and PM2.5 monitoring could be planned if necessary, depending on proximity of community and stakeholder concerns

If a project passes the assessment and is selected for a purchase through Frontier, the guidelines for advanced monitoring and mitigation along with other project controls are reflected in the project's measurement protocol and included in the purchase contract.

On an ongoing basis, post-deployment, Frontier requires third party verification that a project has delivered on the activities proposed in compliance with the protocol as well transparently and publicly reported relevant ecosystem impact data.