Cascade Climate Consultation Response: Review Paper on Carbon Removal Through Enhanced Rock Weathering

EU transparency Register: 458006698011-01

Cascade Climate welcomes the opportunity to provide input on the review paper on carbon removal through enhanced rock weathering (ERW) developed by the EU Commission's consultants. We believe the report provides a robust foundation for how the Commission could consider developing an ERW methodology under the Carbon Removal and Carbon Farming (CRCF) Regulation.

Cascade is committed to supporting the Commission's process in assessing ERW as a viable pathway under the CRCF through ongoing research and collaborative engagement. We are actively partnering with the scientific community to address critical questions that will strengthen ERW methodologies, including through our Field Data Partnership Grants, and welcome opportunities to further support the Commission's work in this area.

It is our belief that rigorous methodologies can be developed today to quantify carbon removal from ERW deployments under specific conditions. Where uncertainties exist, they can be managed through conservative, risk-mitigating approaches to MRV, such as deeper measurement requirements and strategic geographical exclusion of areas where carbon losses are likely high or difficult to measure.

Our response seeks to translate the current state of science into MRV design recommendations for a potential CRCF methodology based on four key issue areas from the review paper and workshop discussion:

1. **Reversal and Loss Terminology:** We recommend explicitly defining and consistently distinguishing between "loss" (carbon lost before reaching durable storage) and "reversal" (carbon released after durable storage) given the implications these definitions have for how to consider risk and liability.
2. **Non-Carbonic Acid Weathering:** We recommend treating non-carbonic acid weathering as a default loss in MRV methodologies as a conservative approach to quantification, while being open to MRV design that allows individual projects to show via empirical evidence that non-carbonic acid weathering leads to a net carbon gain.
3. **Soil Organic Carbon (SOC) Impacts:** We recommend mitigating risks of impact to soil organic carbon by restricting deployment in higher-risk contexts (such as soils with greater than 5% SOC) and implementing regionalized SOC monitoring with project-level credit discounts if negative impacts are identified.
4. **Secondary Mineral (e.g., clay) Formation:** At this time, we recommend including site selection guidance to avoid areas prone to rapid clay formation, recognizing that current quantification methods already capture most losses from secondary mineral formation in the upper soil region.

Detailed technical input on each of these areas is provided in the sections below.

To inform and enable broader application of ERW, we also recommend the EU invest in R&D through existing research frameworks such as Horizon Europe, the LIFE programme, and research activities under the Common Agricultural Policy. Additional research can help expand the conditions in which ERW will be eligible under a high-rigor methodology. This should include high-priority research needs such as:

1. **Research and innovation in ERW carbon quantification:** The fundamental efficacy of ERW is well-established, but continued innovation can improve CDR quantification such that ERW can be quantified with high confidence in a wider range of deployment conditions. This should include intercomparison of MRV approaches across different contexts, advancement of novel approaches to MRV, and further research to bound uncertainty on the effect of soil organic carbon and secondary silicates on net CDR.
2. **Reliable, model-based verification over time:** The current state of ERW requires extensive field measurements in the near field zone. However, just as modern weather models now generate accurate forecasts with far fewer ground measurements than once seemed necessary, well-trained ERW quantification models could reduce the need for costly field monitoring while maintaining—or even improving—the accuracy of carbon removal estimates. Research funding is needed to generate robust datasets that can be used to train and validate the models that will become the future of ERW MRV.

In addition to these research areas, which will enable quantification across a broader range of deployment, we recommend coordinated field research to expand the evidence base of ERW's agronomic impacts and benefits to farmers.

Technical Input on the Review Paper and Workshop Discussion

1. Reversal and loss terminology

We recommend that the review paper explicitly define the terms "loss" and "reversal", and use them in a consistent manner throughout the document given the implications they have for how to consider risk and liability. We propose definitions for each (first introduced in our recent blog), which align with CRCF usage where possible. Based on these definitions, reversal risk for ERW is very low and the risks of undercounting "losses" can and should be mitigated through conservative carbon accounting choices in the MRV methodology.

We propose the following definitions:

- **Loss**: carbon that has been drawn down by reacting with applied rock, but that is lost *before* making it to the durable reservoir. Loss can occur through a variety of pathways in terrestrial and hydrological systems.
- **Reversal**: the release of carbon from the durable reservoir back into the atmosphere. Reversal, therefore, can only occur after both carbon drawdown and durable storage have occurred.

Where:

- **Drawdown** is the transfer of carbon dioxide from the atmosphere to the soil system through the chemical processes of rock weathering; and
- **Storage** is the addition of carbon to the durable reservoir of the ocean or groundwater, where it is stored in the form of dissolved bicarbonate or carbonate ions on the order of 10,000 years or more.

We find this distinction important because while losses can and do occur, *reversal risk in ERW is very low*, meaning that once carbon has reached the durable reservoir, we can be highly confident that it will not be re-released to the atmosphere, based on decades of research (Henderson and Gideon, 2017; Walker et al., 1981). In the current ERW quantification paradigm, losses are measured or modeled, and factored into (i.e., subtracted from) the calculation of net CDR.

In the current version of the paper, loss and reversal are not explicitly defined and are used somewhat interchangeably throughout. For example, page 27 states: “There are various ways that dissolved inorganic carbon may be re-emitted to the atmosphere as gas (i.e. reversal of the sequestration) during the in-field weathering stage.” Cascade would define the process described in the sentence above as “*loss”*, because it describes previously drawn down (referred to in the sentence as “sequestered”) carbon being lost back to the atmosphere. This is not a reversal because it occurs before durable storage.

Further, page 75 discusses whether improvements in our collective understanding of downstream losses should be treated as giving “rise to reversals” (e.g., if the modeled downstream losses were not conservative enough and led to an event of overcrediting). Based on our proposed definition, this would not be an instance of a reversal, but an underaccounting of losses.

Ensuring robust quantification of losses to arrive at accurate and conservative estimates of net CDR is extremely important. Bringing clarity to differentiate between types of risk is equally critical; in the context of policy and carbon markets, risk of reversal (post-storage loss of carbon) represents a different type of risk than loss, which can and should be addressed through rigorous quantification.

2. Non-carbonic acid weathering

We recommend conservative accounting of non-carbonic acid weathering—weathering of ERW rocks that does not lead to direct carbon removal—as a default loss in methodologies at this time. However, we are open to methodology design that allows individual projects to show via empirical evidence that non-carbonic acid weathering leads to a net carbon gain for potential crediting.

Non-carbonic acid weathering is when ERW rocks dissolve due to acids other than carbonic acid. This can indirectly lead to carbon removal and prevention of CO_2 loss back to the atmosphere. The review paper discusses considering a 'full-system' approach to alkalinity that would account for carbon removal benefits from non-carbonic acid weathering. Current voluntary certification schemes, meanwhile, discount non-carbonic weathering because the chemical reactions do not lead to carbon drawdown within the zone of measurement in the soil. The former approach best represents the net effects of ERW on atmospheric CO_2 over time; the latter approach adopts a conservative accounting framework, acknowledging the difficulty of quantifying CO_2 sequestration that may happen far away and years or decades from the deployment.

A true 'full-system' approach to alkalinity would need to consider the weathering of silicate and carbonate rocks by non-carbonic acid in the counterfactual scenario below the zone of measurement in the soil. It will also be important to identify the timescales that the non-carbonic acids are removed and replaced by dissolved inorganic carbon and evaluate this against the crediting timeline. If this can be confidently evaluated—either through empirical measurements, robust, peer-reviewed models, or a combination of the two—projects should be permitted to demonstrate the full-system alkalinity impact of their intervention. If this cannot be sufficiently evaluated, projects should take discounts for non-carbonic acid weathering.

If the EU Commission decides to move forward with an ERW methodology, we recommend addressing non-carbonic acid weathering risks through the following measures:

Conservative accounting principles:

- Fully discount non-carbonic acid weathering unless projects can demonstrate—either through empirical measurements or robust, peer-reviewed models—that non-carbonic acid weathering is sequestering carbon on appropriate timescales (e.g., within 5 years of project commencement) above the counterfactual scenario.

3. ERW impacts to soil organic carbon

To ensure ERW does not adversely affect soil organic carbon stocks, we recommend avoiding deployment in sites where SOC stocks exceed 5% of total soil mass, or have other high-risk characteristics.

The primary pathway for carbon removal via ERW operates through *inorganic* carbon transferred to the soil when alkaline rocks dissolve. However, workshop participants raised concerns about ERW's potential to lead to losses in soil organic carbon (SOC). SOC typically represents a larger carbon reservoir than inorganic pools, meaning that adverse impacts to SOC could reduce net CDR. Current evidence—while limited—indicates that silicate-based enhanced rock weathering does not consistently deplete SOC stocks (Sokol et al. 2024, Steinwidder et al. 2025). Moreover, conventional agricultural liming—a comparable practice—has well-documented neutral-to-positive effects on soil carbon, suggesting that widespread SOC losses are unlikely under ERW deployment (Paradelo et al. 2015, Wang et al. 2021).

As a precaution to mitigate any risks while the evidence base grows, we recommend designing a methodology that restricts deployment in contexts where there is a higher risk of substantial SOC loss.

If the EU Commission decides to move forward with an ERW methodology, we recommend addressing SOC risks through the following measures:
Restrict deployment in higher-risk contexts:

- Avoid sites where existing SOC stocks exceed 5% of total soil mass.
- Restrict deployment in certain higher-risk soil types where SOC impacts are more likely (see detailed guidance in Foundations document).

Implement regionalized SOC monitoring:

- Require the development of regional models estimating SOC impacts across all treatments within a geographic area, incorporating SOC data from all sites regardless of whether individual fields are part of specific deployments.
- Apply project-level credit discounts based on regional model results if any negative SOC impacts are identified.
- Mandate SOC measurements on all solid-phase quantification samples, or—for suppliers using alternative primary quantification methods—require SOC sampling at comparable densities to solid-phase protocols.
- Facilitate data-sharing on SOC measurements.

This regionalized approach balances precaution with the recognition that SOC responses may vary by context, allowing evidence to accumulate while protecting against significant negative outcomes.

Advancing our understanding of ERW's impact on SOC remains a key priority for Cascade's Field Data Partnership Grants. We continue to advocate for meaningful SOC sampling requirements in voluntary carbon market protocols.

4. Carbon losses due to secondary mineral formation

We recommend creating site selection criteria that exclude locations where rapid formation of secondary minerals (particularly clays) is likely, as this precipitation can reduce or delay net CDR.

Secondary mineral formation (particularly clays) is a natural consequence of rock weathering that poses some risk to ERW carbon accounting (Mills et al., 2024). As reviewed in the paper, current voluntary market methodologies treat secondary mineral precipitation in the near-field zone as a loss term in the calculation of net CDR.

Clay formation varies as a function of feedstock type, soil characteristics, and local hydrology, and its effects on net CDR depend on both clay type and formation rate. Some clays incorporate minimal base cations during formation and therefore have negligible effects on CDR, while others can have larger impacts. For instance, the risk of clay formation is greatly reduced when carbonate feedstocks are used. However, even clay types with higher base cation incorporation will not significantly affect CDR if formation rates are slow or if precipitation is inhibited by other soil processes.

In many systems, clay formation is most likely to occur in the near-field zone (NFZ), where reactant concentrations are highest due to feedstock dissolution and where evapotranspiration from plant activity further concentrates reactants. Importantly, all currently accepted quantification strategies implicitly account for secondary phase formation in the NFZ when best practices are followed, substantially reducing the risk of over-crediting. Consequently, the primary zone of concern is well addressed by existing approaches.

As emphasized during the workshop, the critical consideration for clay formation outside of the near-field zone is *additional* clay formed as a direct result of ERW processes. While clay forms naturally in many environments from soil to ocean, additional formation only occurs where both thermodynamic and kinetic conditions exist *and* where ERW provides a concentration increase sufficient to trigger formation beyond baseline rates.

Scientific understanding of clay formation thermodynamics allows for informed site selection that can mitigate potential NFZ and FFZ clay precipitation. Certain agricultural soils are thermodynamically unfavorable for clay formation, and others face kinetic inhibitors that slow formation rates. Sites can therefore be selected based on their propensity for rapid clay formation that would meaningfully reduce net CDR. Further research will continue to refine these site selection parameters.

While long-term research will be important for determining ERW impacts on clay formation at significant scale, robust methodologies can be developed as the field advances, given that current approaches already address the primary zone of concern. Cascade is actively working to address knowledge gaps on this topic through targeted research priorities in our Field Data Partnership Grants and ongoing engagement with experts to refine recommendations for voluntary carbon market protocols.

If the EU Commission moves forward with an ERW methodology, we recommend:

Restrict deployment in higher-risk contexts:

- Provide clear criteria for identifying and avoiding locations where rapid formation of CDR-reducing clays is thermodynamically favorable and/or kinetically uninhibited. Site exclusion will be most important where clays are likely to form *outside* the measurement zone. Areas with high clay formation within the measurement zone will depress net CDR levels, but do not require methodological site restriction since the clay formation will be captured via measurement.

Conservative accounting principles:

- Ensure quantification methods in the NFZ follow best practices that capture secondary mineral formation effects. These best practices are already present in many voluntary market methodologies, which require measurement approaches that capture this loss pathway.

This approach balances scientific understanding with appropriate precaution while the evidence base continues to develop.

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About Cascade Climate

Cascade Climate is a philanthropy-backed climate not-for-profit organization focused on addressing aspects of the climate challenge that are underrepresented and underresourced in the current global climate strategy. These challenges-–which have potential for significant impact on the climate and our way of life—are unlikely to be resolved through decarbonization alone. For these emerging climate solutions, Cascade helps remove the biggest bottlenecks to progress by coordinating ambitious cross-sector initiatives, building tools and infrastructure to unlock cycles of learning-by-doing, and resourcing high-leverage R&D and policy work.