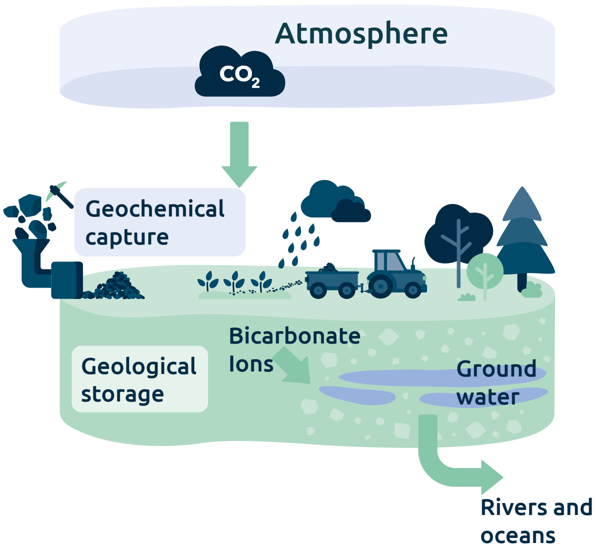
Terrestrial enhanced weathering

A practice that enhances a natural process to remove CO_2

NEGEM



Expected permanence	millenia
Reversal risk	low
Uncertainty in amount of initially captured carbon	high
Uncertainty in amount of carbon stored over time	high
Ease and accuracy of MRV	low
Key benefits	potential increased crop yields, reduced fertiliser use

What is enhanced weathering and how does it store carbon?

Terrestrial enhanced weathering (EW) is the application of silicate or carbonate mineral particles with high reactive surface area to soils. These minerals dissolve in water and react with CO_2 to produce bicarbonate ions that flow via groundwater to rivers and to the ocean or mineralise on land becoming stable carbonates. This does mean that the time of carbon removal is not identical to the time of application. Both the dissolved ions and the formed minerals are highly stable storage mediums that lock carbon securely for long periods of time (>10 000 years), with a low risk of leakage.

Different minerals can be used in enhanced weathering which have different chemical composition, dissolution reactions, CO_2 sequestration capacity, and contain different toxic heavy metals or compounds that could be health or environmental risks. Two commonly applied minerals are basalt and dunite. Basalt requires substantial mining operations and material transport, which if using fossil resources, will offset the climate benefits of the carbon removal itself. Dunite-based EW requires less material than basalt but does have higher toxicity due to its substantial of nickel content in the mineral. Hence each project requires assessment of its unique impacts based e.g. on application location, mineral applied.

Lime is commonly applied in agricultural practice to control the pH level in soil, pH but its use in carbon removal and storage is novel and research is on-going. Its usage as a NETP is not commonly considered in country portfolios within the EU (D8.1). According to the IPCC, economic, environmental and technological feasibility is first expected after 2030 or even 2050.

Relevant regulatory framework: There is currently no specific EU legislation that regulates enhanced weathering (as of 2021, according to the EU). However other regulations e.g. CBD, UNCLOS, may deal with the environmental impacts that may arise from EW activities, in addition to EU environmental protection.

ADVANTAGES

PERMANENT STORAGE
Sequested carbon is stored permanently with low risk of reemission of stored carbon.

NO ADDITIONAL LAND REQUIRED
Existing agricultural land can be used for EW and its application may enhance crop yields and reduce fertiliser use.

SIMILAR TO SOIL PH MANAGEMENT
Enhanced weathering is a similar process to lime application to soils and standard tests exist that can be used to measure reaction rates in soils for relevant projects.

COST EFFECTIVE APPLICATION
Comparatively cost-effective application, with large theoretical and indefinitely sustained capacity.

CHALLENGES

HIGH VALUE CHAIN GHG EMISSIONS
Both the rock crushing process and associated mining of minerals have high upfront GHG emissions.

HARD TO MONITOR
Applied over a large area it is difficult to monitor the dispersed storage of extracted CO_2 and adhere to MRV requirements with certainty.

SEQUESTRATION RATES VARY WITH LOCATION
Rate of CO_2 sequestration is variable due to different soil chemistry. In certain locations CO_2 may be released and lower the CDR efficiency.

DIFFICULT TO QUANTIFY IN FIELD
CO_2 sequestration is not immediate after application. The slow reaction rates are difficult to quantify accurately in the field.

What is the sustainable potential of terrestrial enhanced weathering to sequester carbon?

Estimate scale and cost (2050)

2-4 $GtCO_2$/yr
\$50-200/tCO_2

Economic performance

CapEx
High initial investment in mining/grinding/transport infrastructure

OpEx
Sustained monitoring, maintenance costs as High costs to power rock crushing, transport of minerals to deployment site. Application costs comparatively low.

Environmental performance

Large amounts of minerals required and sustainable sourcing is unlikely. Environmental impacts of mining depend on the source mineral. Mining can also cause freshwater pollution and GHG emissions.

Mineral application can leach metals into soils/groundwater.

Resource security

No extra land area is required for application, but maximum mineral application thresholds will exist.

Crushing, grinding and transportation of rock material could strain available renewable energy sources and transport networks.

Social and governance performance

Healthier soils boost food security and Social barriers to large-scale deployment include environmental impacts of mining, risk of human rights abuse in mining operations, international material transport.

Mining impacts human health (e.g. carcinogen production, fine particle pollution), but these may be outweighed by climate mitigation health benefits.

Current unknowns and future research perspectives

Field studies have not yet been able to replicate theoretically possible dissolution rates. Mineral reactivity is strongly influenced by environmental conditions, working more favourably in warm and humid locations (e.g. Brazil, SE Asia, China, India). More accurate modelling alongside field measurements is therefore necessary to boost understanding of chemical reactions, the dispersion of the mineral, reaction rates and any potential loss that may occur from secondary mineral precipitation.

The rate of grain dissolution is a key factor for the carbon sequestration rate within the weathering process. However, more research is needed to measure how fast rock grains dissolve under different soil conditions in the field, and to optimise its application. New methods for enhanced rock weathering are being developed, including the use of catalysts or organisms such as lichen or mosses, which, when applied to rocks, can dissolve them by modifying rock surface chemistry.

Policy recommendations

Develop appropriate and comprehensive MRV for the carbon sequestered and stored, as well as standardised environmental impact assessments to support EW applications as permanent CDR. This may include standardised modelling methodologies that enable accurate MRV of dispersed carbon stores and are validated by measurements of mineral dissolution rates in the field weathering rates for different minerals.

Consider interim incentives based on the co-benefits of enhanced weathering, and vehicle comprehensive MRV for EW as CDR is being developed.

Align the scale of enhanced weathering deployment with the scale of sustainable mineral powder availability, as opposed to the potentially inexhaustible application to agricultural fields.

Apply sustainability assessments and standards to mineral sources both inside and outside the EU and ensure all potential GHG emissions and environmental impacts are accounted for. Adapt existing EU environmental protection legislation, where needed.

Ensure project permits consider suitable locations for mineral extraction and grinding that have ample renewable energy available and are close to application sites so as to minimise value chain GHG emission.

Relevant literature

IPCC Information note: removal activities under the Article 6.4 mechanism

NEGEM Deliverables: D1.5, D2.1, D3.8, D3.9, D4.5, D5.2, D5.4, D6.3, D7.2, D8.2

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