CARBON DIOXIDE REMOVAL TECHNOLOGIES (CDR-T):

ENHANCED ROCK WEATHERING (ERW)

To neutralize the worrying increase in CO_2 concentration in the atmosphere, two possible strategies are being deployed: the first, well-known, is the reduction of emissions; the second, less well-known, is the removal of CO_2 from the atmosphere. Several techniques, known by the acronym CDR (Carbon Dioxide Removal), have been developed for this second strategy. This report is focusing on one of them: Enhanced Rock Weathering (ERW).

Weathering is the combination of the processes of in situ physical disintegration and chemical decomposition of rocks due to the effects of the atmosphere, hydrosphere, and biosphere. Weathering, which affects all types of rock, can in some cases involve CO_2 in chemical reactions that ultimately lead to the formation of new minerals, namely carbonates. In this way, part of the CO_2 is effectively and permanently removed from the atmosphere to form new stable minerals. In fact, the large deposits of carbonate rocks existing on the Earth represent the capture and sequestration of atmospheric CO_2 over geological time.

HOW DOES IT OCCUR?

Atmospheric CO_2 dissolves in water (rainwater, soil moisture, etc.), forming a weak acid (carbonic acid or H_2CO_3), which reacts with minerals, releasing cations, resulting in an increase in alkalinity in solution to form bicarbonate and new carbonate minerals.

To accelerate this process, rocks must be fine-grained and transported to specific locations where they can be dispersed to react with the CO_2-containing water. As grinding and transport involve the use of energy and the related emission of CO_2, it is advantageous to use mining waste that already has the appropriate grain size.

Among the possible places where these ground rocks could be dispersed, agricultural soils stand out, since ERW offers the dual benefit of capturing CO_2 and providing nutrients that improve crop yields. Another place can be the seashore, where ERW benefits from wave action for faster dissolution. ERW can also occur on a mine site where the waste material is stored.

WHAT TYPE OF ROCK?

As rocks are aggregates of one or more minerals, the correct question should refer to what types of minerals can be dissolved by carbonic acid and how fast is the reaction process. Studies have demonstrated that silicate minerals containing high concentrations of Ca, Mg, and Fe, are more prone to release cations that can co-precipitate with CO_2 to form carbonated minerals. The most notable minerals are olivine, pyroxene, and amphibole, which are abundant in rocks such as dunite and basalt. The most outstanding is olivine, as it is the most abundant and fast-weathering magnesium silicate mineral on Earth (Smet et al., 2021; Bullock et al., 2023). This means that olivine-rich rocks have the highest potential for carbon dioxide removal.

HOW MUCH CO_2 CAN IT CAPTURE?

The yield of ERW depends on several parameters such as the type of rock, grain size, climate conditions, and soil properties.

Igneous rocks containing olivine and other Ca-,Fe-, or Mg-bearing silicate minerals have strong CDR potential (0.5–2 Gt CO_2 year by 2050, Beerling et al., 2025), and containing at the same time a range of nutrients (e.g., Na, K, and P) released into solution, making them excellent natural fertilizers.

The reactive surface area of the CDR rock material is increased by reducing the grain size, therefore increasing the speed of weathering (Beerling et al., 2020; Smet et al., 2021).

According to Renforth (2012) and Smet et al. (2021), high temperatures accelerate the weathering process, and intense rainfall is crucial since water is necessary for the chemical reactions to

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take place. Therefore, tropical climates are the most suitable.

Finally, chemical, physical, and biological soil properties have a great influence on the ERW efficiency, since microorganisms boost the physical and chemical breakdown of silicate grains in the soil (Vandeginste et al., 2024).

HOW LONG DOES IT TAKE?

Carbonation rates range from a few months to a few decades (Strefler et al., 2018; Beerling et al., 2020). Some authors, such as Hangx & Spiers (2009), estimated a timeframe of 23 years for the full dissolution of 10 µm olivine particles on beaches. This duration increases to 233 years for a grain size of 100 µm.

HOW MUCH DOES IT COST?

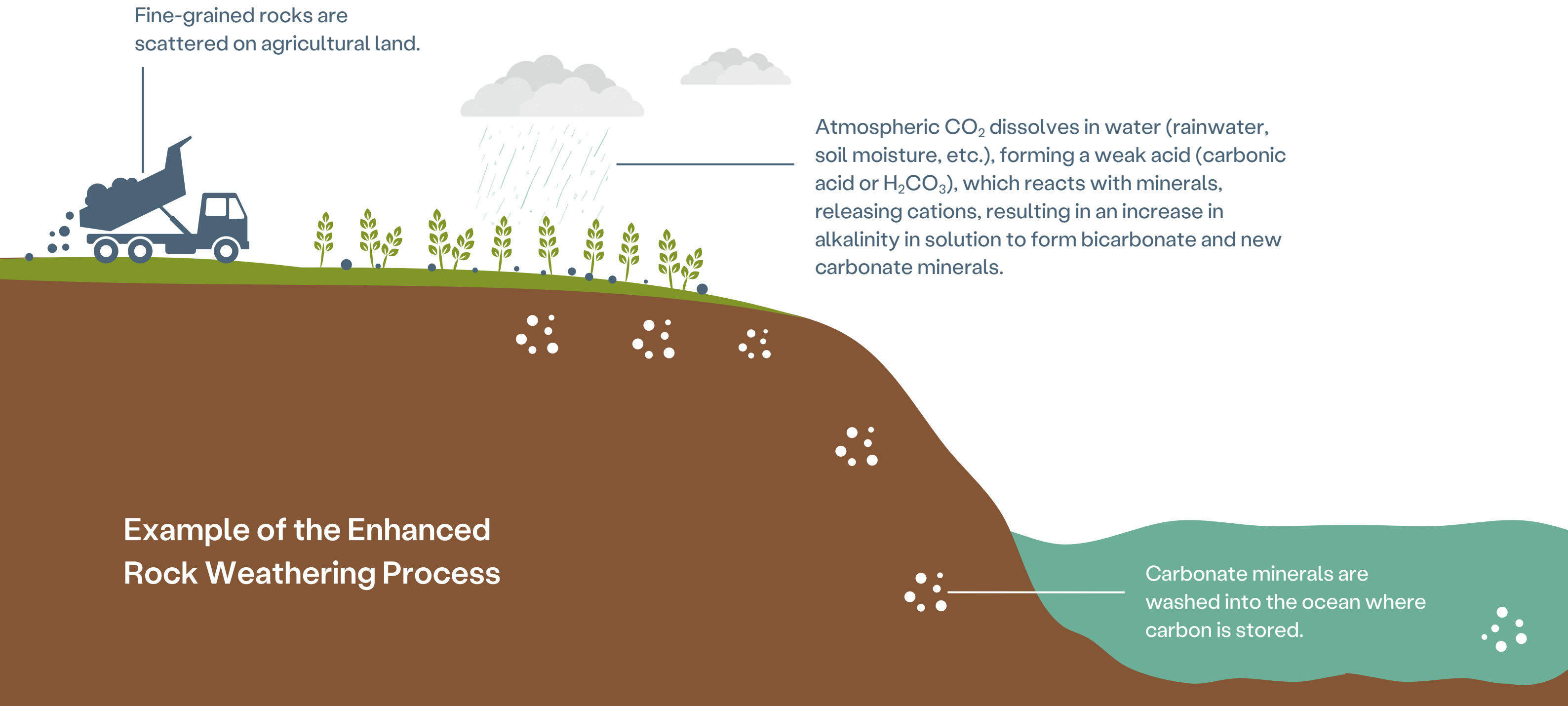
Different economic cost assessments have been carried out with variable results. The costs for ERW are site-specific and affected by factors such as sourcing the feedstock, additional pre-processing steps and transportation distances, and operational expenditure savings such as improved waste management and reduced fertilisers costs. For example, a recent study suggested Monitoring, Reporting & Verification (MRV) costs per tonne of carbon in agricultural deployments ranging from £25 to £425 (mean ~£150) using Frontier data, and from £5 to £95 (mean ~£40) using Grantham Research Institute data (Mercer et al., 2024). CO2RE and ERM research estimated that the cost of deploying ERW in the UK would be £350-864/tCO_2 captured (mean £487/tCO_2) in 2030, and £262-670/tCO_2 captured (mean £365/tCO_2) in 2050 for gross removals (Whitehead, 2025). Costs in a full life cycle are likely to be close to those of other CDR technologies, such as biochar, and lower than expected costs for energy-intensive processes such as direct air capture.

REGULATORY LANDSCAPE

Enhanced rock weathering is being considered by the EU Expert Group on Carbon Removals and Carbon Farming (CRCF) for its inclusion as a CDR method in the Regulation (EU 2024/3012). A certification methodology to allow ERW to generate carbon removal units may be adopted in the future (ICF, Cerulogy, and Ecodiversity, 2025). The Commission is set to assess in 2026 the potential inclusion of carbon removals with permanent storage in the EU Emission Trading Scheme (ETS).

C-SINK PROJECT

C-SINK is an EU-funded project that aims to establish the foundations for a standardized and transparent European Carbon Dioxide Removal (CDR) market. For ERW, C-SINK is developing two distinct field trials in Spain (David mine) and Finland (Kevitsa mine), where MRV is carried out in situ within active mine sites. Both trials test MRV under real, open-system conditions, focusing on transparent, scalable, and long-term sustainable removals through atmospheric CO_2 conversion into permanently stable carbonate forms.



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