

CO₂ UTILISATION BY MINERALISATION: MUCH ADO ABOUT NOTHING

No form of CO₂ use should be considered a substitute for permanent geological storage of CO₂. Some forms of CO₂ use, such as EOR or EGR, can constitute or contribute to necessary CO₂ removal infrastructure and therefore play a role in developing CO₂ storage. However, other uses such as mineralisation do not appear to offer any such rationale as an alternative to geological CO₂ storage. **This brief takes a particular look at CO₂ use through mineralisation.**

The mineralisation of CO₂ is a concept where CO₂ is reacted with selected minerals to form a solid product. At first glance CO₂ use through mineral reaction or mineralisation could be considered advantageous to CO₂ storage: mineral carbonation offers the permanent storage of CO₂ in usable and saleable products, while forgoing the need for CO₂ pipelines and geological storage sites. However, CO₂ mineralisation has some significant drawbacks that must be taken into account when **assessing the technology's potential to reduce CO₂ emissions at necessary scale.**

Of **key concern** are: scalability, large scale material handling, mining and landfilling (of both feedstock and output) and resulting life-cycle emissions, which are not yet well understood. **Bellona sees a real danger in CO₂ mineralisation – as with CO₂ Capture and Utilisation (CCU) in general – becoming a distraction from the task at hand: reducing CO₂ emissions.**

While addressing these issues in more detail, this brief also outlines **a case study with mineralisation** with the naturally occurring and abundant mineral *olivine*. The case study measures the amount for feedstock needed to sequester a given amount of CO₂, the CO₂ sequestered in the resulting mineral, as well as the amount of mineral output and implications of undertaking this process.

What mineralisation encompasses

The technologies for mineralisation include a wide range of feedstocks, reaction processes and products. In essence, CO₂ mineralisation requires CO₂ to react with a substance or a series of substances to produce a stable mineral for use or permanent storage in landfill. This unavoidably increases or bulks the mass of CO₂ products that must be handled, as the CO₂ is now entrenched in other elements to mineralise it.

Mineralisation on a European scale: From the EU 2050 Energy Roadmap we can deduce that the scale of CO₂ to be captured under all scenarios is vast. Even the low-capture/high-temperature-rise scenario

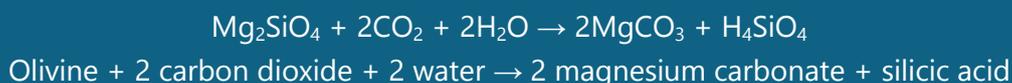
entails capturing 3 Gigatonnes¹ of CO₂ and the high-capture/low-temperature-rise scenario up to 12.8Gt. Using mineralisation to store all of this captured CO₂ will obviously not be possible for practical reasons.

But even when breaking the numbers down by sector, it is not feasible to rely on mineralisation, or indeed to consider it a significant part of the solution. Sequestering the volume of CO₂ captured from industry (cement, steel, chemicals production) alone, with the process described in the case study, would require 2.58Gt of olivine and produce 5.16Gt of product.

¹ Gigatonne = 1000 million tonnes or 1,000,000,000 tonnes

Case study: mineralisation for olivine

Below is an example of a simple and idealised (i.e. excludes real world inefficiencies in mineral crushing, reaction efficiency and reaction time) CO₂ mineralisation process with olivine. CO₂ removal by reaction with olivine is an attractive option within mineralisation, because olivine is widely available and reacts easily with CO₂. The end-products of the reaction are magnesium carbonate and silicic acid:



Using this idealised reaction scenario at 100% efficiency we can give an estimate of the required feedstock (CO₂) and mineral (olivine) that needs to be captured and mined in order to capture 1 million tonnes of CO₂ from an example cement facility. It should be noted that reaction rates reported in literature are much lower than 100% (15% – 80%) as higher reaction rates generally require longer reaction times.

1.5 million tonnes (olivine) + 1 million tonnes (CO₂) + 0.4 million tonnes (water) [total 2.9 million tonnes]
→ 1.9 million tonnes magnesium carbonate + 1.1 million tonnes of silicic acid [total 3 million tonnes]

Capturing 1 million tonnes of CO₂ with the above process would require 1.5 million tonnes of olivine. The process would produce approximately 3 million tonnes of product that must be sold or safely disposed of.

Scalability

On a smaller scale, mineralisation could be part of a solution to dealing with hazardous waste products like fly ash, cement kiln dusts and asbestos tailings. But the case study above makes clear that **the scale of CO₂ emissions that can be realistically dealt with through mineralisation is nowhere near the scale needed to lead to meaningful CO₂ emission reductions. It is therefore clear that CO₂ use, especially through mineralisation but also through other means, must not become a distraction from CO₂ storage.** Below is a closer look at the stages of mineralisation and their scalability with the use of the case study.

Feedstock: If the olivine is not locally sourced, the transport logistics and resulting emissions would significantly restrict deployment and contribute new CO₂ emissions. The transport of 1.5 million tonnes of pure olivine to a site for CO₂ capture would require 100,000 truck² journeys per year.

Placing our olivine case study into perspective with current mining operations of olivine is difficult, as the current market is not organised to supply olivine to the CO₂ mineralisation industry. But in 2006 global olivine production was approximately 8 million tonnes³. **At this relatively small scale, capturing the CO₂ emissions of a single example cement plant would consume approximately 20% of current global olivine production.**

Process: Wide spread use of mineralisation to store CO₂ would thus result in increased transport and mining operations. In addition, significant energy intensive processes such as rock crushing would be required to enable effective CO₂ reactions.

It is clear that the material handling requirements to capture 1 million tonnes of CO₂ with the process described in the case study could be problematic. The material to be moved to and from the site would constitute 4.5 million tonnes.

² Six-wheeler 15 tonne truck

³ Industrial Minerals & Rocks: Commodities, Markets, and Uses. Jessica Elzea Kogel

Such mass movement of materials would require effective transport infrastructure, access to local markets and landfilling for products as well as significant onsite storage space and equipment. Crucially, life-cycle emission assessments of this additional activity must also be taken into consideration and will obviously be considerable.

Where suitable conditions exist (e.g. mineral feedstock sourced near to CO₂ capture site), CO₂ emissions are much smaller and mineralisation as described could play a role. This however, must be expected to be the exception.

Output: Global production of our case study's output, magnesium carbonate (magnesite), in 2011 was approximately 20 million tonnes.⁴ The mineralisation reaction from the case study, with **just 1 million tonnes of CO₂, would already produce the equivalent to 10% of global magnesite demand.**

Moreover, magnesite is primarily used as a refractory material, as a lining in blast furnaces, kilns and incinerators. When magnesite is used in this way, the CO₂ that is trapped in it is released. For magnesite produced through mineralisation and used for such purposes, the CO₂ could not then be considered sequestered.

The global demand for silicic acid is unknown as various further reactions and products are possible. It is clear however, that for both silicic acid and magnesite, **the scale of product resulting from mineralisation will always be very large and in all likelihood significantly larger than demand** – as it will be from most products resulting from mineralisation on a scale that could be said to meaningfully reduce CO₂ emissions.

It must therefore be assumed that a considerable amount of mineralised CO₂ will be landfilled or used to backfill the mines from which the feedstock was taken. This of course, entails more transport as well as severe and damaging intervention in the natural landscape.

⁴ USGS, 2011 Mineral yearbook – magnesium compounds

From the Royal Society of Chemistry "[A review of mineral carbonation technologies to sequester CO₂](#)":

The costs of both in situ and ex situ⁵ mineral carbonation (MC) are currently too high for a large deployment of the technology and new systems are being investigated to attempt to overcome the unchanged technology challenges. The current technology research and development gaps that have to be addressed to enhance the understanding on mineral carbonation and its deployment are as follows:

- Scarce representative raw materials comparison
- Processes performance data incomplete and inaccurate
- MC integration with point source not well explored
- Incomplete information on cost/energy balance for thermal activation
- Insufficient knowledge of indirect carbonation fundamentals
- Insufficient knowledge of carbonation fundamentals using flue gas
- Lack of assessed reactor technology options and cost studies. A more systematic approach in costing the process should be addressed for comparison purpose
- Process scale and materials handling issue not well explored
- Scarce data on the environmental impact of large mining operations

⁵ In situ refers to mineral carbonation taking place where minerals are sourced. For example carbonation of minerals underground with CO₂ injection. Ex Situ refers to the process described in this brief, with minerals mined and transported to a reaction facility.

Inputs → Mineralisation → Product Use

CO₂: **1 Million Tonnes**



Minerals: **1.5 Million Tonnes**

Large quantities of the mineral olivine must be mined and transported to mineralisation reaction facility. Minerals must also be crushed to a very small size, an energy intensive process.



Magnesium Carbonate: **1.9 Million Tonnes**

Silicic Acid: **1.1 Million Tonnes**



Total bulk mineral handling of inputs and products at mineralisation site is **4.5 million tonnes**. In addition to **1 million tonnes** of CO₂ and the consumption of approximately **400 million liters** of water.

a Consumption in industry process

Mineralised products when used in industrial process may often emit trapped CO₂ back to the atmosphere.



b Use in building products

Mineralised products if suitable can be used in building products. This has the potential for longer term storage, assuming that the products will be in place for many decades or even centuries.



c Storage of products

Due to the very large production of minerals surpassing market demand a considerable amount of mineralised CO₂ product will be landfilled. Sufficient product to build the Great Pyramid of Giza ever two years.

