SEQUESTRATION OF CARBON DIOXIDE THROUGH IN-SITU CARBONATION OF (ULTRA-)BASIC ROCKS; AN ENERGY NEUTRAL SOLUTION TO THE CO_2 PROBLEM?

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Executive summary

Capture and subsurface storage of carbon dioxide in empty oil and gas fields and saline aquifers is regarded as a serious option to reduce future industrial CO_2 emissions from stationary sources. Although empty oil and gas fields have a very large capacity to permanently store CO_2, carbon capture and storage (CCS) substantially reduces the overall efficiency and leads to substantial increase of costs. In this report we review an alternative to classical CCS: in-situ carbonation (ISC) of (ultra-)basic rocks. This sequestration method might provide an energy neutral alternative for storage of CO_2 in empty and oil and gas fields.

In-situ carbonation is based on the reaction of CO_2 with ultra-basic rocks, whereby CO_2 is permanently mineralized. Besides mineralizing CO_2, the carbonation reaction produces a substantial amount of heat. This heat could be recovered using geothermal techniques, thereby providing an additional source of energy which is largely free of CO_2 emissions.

So far, mineral carbonation for CO_2 sequestration purposes has mainly focused on ex-situ carbonation of (ultra-)basic minerals like olivine. In order for this technique to have sufficient sequestration capacity, additional procedures – like acid dissolution or an increase of temperature – are required. By comparison, at depths of 500 – 3000 m in the subsurface temperatures are high enough for the initial carbonation reaction to start off, so that in-situ carbonation will be self-propagating.

In this pre-feasibility study, several aspects of in-situ carbonation are discussed and reviewed including the general principle, the chemical and physical properties of suitable rock types, the energy released during the carbonation reaction, the world-wide occurrence of ultra-basic rocks as well as the technical and financial aspects of in-situ carbonation. The major findings are summarized below.

One of the main questions regarding the in-situ carbonation mechanism is whether the reaction can mineralize sufficient amounts of CO_2 per unit of time. For ISC, not so much the reaction rate of the different minerals, but rather the overall porosity and permeability seems to be a potentially limiting factor. Under suitable conditions, however, it is estimated that the overall carbon sequestration capacity of (ultra-)basic rocks is comparable to that of empty oil and gas fields.

Basic and ultrabasic rock types most suitable for in-situ carbonation include dunites, periodotites, pyroxenites and basalts. Although basaltic rocks have a lower sequestration capacity compared to the other rocks types, this is compensated for by a higher average porosity/permeability. The aforementioned rock types occur in large intrusive bodies, ophiolite belts and basaltic complexes, which are found in many places on Earth. Their total

volume – and hence their sequestration potential – is virtually unlimited. To minimize transportation costs, CO_2 emission source(s) occurrence should preferably be located in the vicinity of large (ultra-)basic rock bodies.

Current laboratory testing indicates that the carbonation reaction proceeds at a rate sufficient to sequester all CO_2 within the expected residence time in the basic reservoir rock. The energy released by the carbonation reaction is estimated at some 2000 MJ/ton of CO_2. Provided that some 25% of this energy can be recovered and converted into geothermal electricity or heat, it compensates for the energy loss as a result of carbon capture or storage. As such, ISC provides a potentially energy neutral solution to classical CCS where CO_2 is only stored.

Technical aspects of in-situ carbonation are largely similar to those of CCS. Also, recovery of geothermal energy is by now well-established and no special modifications are envisaged. With respect to the economical aspects of ISC, it is important to know to what extent the recovery and exploitation of the produced energy can mitigate the total costs of carbon capture and storage/carbonization. As estimated in this study, additional income gained by geothermal energy exploitation of ISC will substantially reduce the cost of CO_2 storage. Obviously, this benefit will augment in the future with the expected increase of the cost of energy from fossil sources.

An added benefit of ISC is the fact that there is no need for a stringent separation of CO_2 and other flue gasses during capture. Some water is needed for the carbonation reaction and remaining nitrogen is inert and may even help in increasing the porosity of the reservoir rock.

To summarize, the in-situ carbonation mechanism provides a serious alternative to storage of CO_2 in large oil and gas fields and saline aquifers whereby:

- CO_2 is permanently fixed in a mineral form.
- Energy loss as a result of CO_2 capture, transportation and injection can be compensated for by the exploitation of artificial geothermal energy (green energy).
- Exploitation of geothermal energy covers for a part of the investment and production costs of capture, transportation and injection of CO_2.

Future research in the field of ISC should at first instance focus on a better understanding of the physical properties of different suitable rock types (porosity/permeability) in relation to the carbonation reaction (clogging versus natural fracking). A better understanding of these processes is required for a more rigorous technical and economical feasibility study of the ISC mechanism.