Storage of carbon dioxide and hydrogen; geological capacity and risk

Glenn Bark[a], Emelie Crafoord[a], Emily Rees[a], Christina Wanhainen[a], Mathis Warlo[a]

[a]Department of Civil, Environmental and Natural Resources Engineering, Luleå University of Technology, Luleå, Sweden, glenn.bark@ltu.se

To limit global warming to 1.5–2 °C, the Intergovernmental Panel on Climate Change predicts the need for carbon capture and storage (CCS). For CCS to work, CO_2 storage capacity on a global scale is crucial. It is estimated that the required storage capacity for 2050 (3–10 Gton CO_2 per year) will probably not be achieved for most of the IPCC scenarios (Krevor et al. 2023). Geologically, there is potential for onshore/offshore storage, but reservoirs need to be investigated and verified for capacity. The storage rate of today is the bottleneck for the CCS value chain as less than 0.1% of the global CO_2 emissions are captured and stored in the subsurface (Zhang et al. 2022).

Presently, CO_2 storage focuses on marine subseafloor reservoirs. However, there are a few noteworthy onshore examples such as the Icelandic Carbfix site. These sites utilize the reactivity of the volcanic bedrock with CO_2 and take advantage of natural or induced bedrock permeability to facilitate the injected CO_2 for subsequent mineral carbonation. During mineral carbonation, CO_2 is naturally converted into stable carbonate minerals, which is a potentially safer way of permanently storing the CO_2 in the subsurface compared to marine storage (Snæbjörnsdóttir et al. 2020). In the pioneering INSURANCE and TAILOR-MADE projects, the potential for onshore storage in the Swedish bedrock and in mining waste materials is investigated, respectively, together with the utilization of industrial waste streams from paper/pulp and mining to optimize the CO_2 capturing efficiency. Compared to Iceland, the Swedish bedrock is metamorphosed, deformed, and altered. The geological conditions for mineral carbonation will be different but, as the storage capacity is the bottleneck, lithologies other than the ones in Iceland also need to be investigated for their storage potential. Sampled lithologies throughout Sweden will be subjected to carbonation experiments covering suitable mineralogy, reactive surface areas, porosity and permeability, fluid pH, pressure, and temperature. The suitability of the reservoir rock is dependent of all these parameters (Snæbjörnsdóttir et al. 2020).

Since the global scale-up of storage capacity is uncertain, global CO_2 emissions need to be strongly reduced by phasing out fossil fuels to meet the projected storage capacity. Reductions in emissions through electrification of industry sectors is likely required. CCS should then be used in industries that are hard to abate, i.e. cement and paper/pulp where the carbon enters the industrial processes through the raw materials used. In northern Sweden, the steel industry will shift to renewable energy sources coupled with hydrogen storage (for battery capacity) and thereby reduce the CO_2 emissions by an estimated 90% from point emitters through electrification (the HYBRIT technology). When scaling this technique from present pilot- to industry implementation, the potential for geological storage of hydrogen and potential subsurface reservoir leakage into the surrounding environment is addressed in the HYDROTRANS project. Here, flow modelling of hydrogen (and also CO_2) through the bedrock down to the nanoscale is analytically investigated at LUMIA (Luleå Material Imaging and Analysis) and the MAX IV synchrotron laboratory.

Acknowledgement

Projects mentioned above are funded by the Swedish Energy Agency and EU NextGeneration (INSURANCE, TAILOR-MADE), and EU COFUND (HYDROTRANS) and our collaborative partners are Billerud, Carbfix, Boliden, LKAB, Copperstone Resources, Vattenfall (HYBRIT), H2 Green Steel, Svensk Kärnbränslehantering AB (SKB), and MAX IV.

References

Krevor et al., 2023: Subsurface carbon dioxide and hydrogen storage for a sustainable energy future. Nature Reviews Earth & Environment 4, 102-118

Snæbjörnsdóttir et al., 2020: Carbon dioxide storage through mineral carbonation. Nature Reviews Earth & Environment 1, 90-102

Zhang et al., 2022: An estimate of the amount of geological CO2 storage over the period of 1996-2020. Environmental Science & Technology Letters 9, 693-698