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Underground hydrogen storage and in-situ gas conversion: macroscopic investigation on reactive transport mechanisms

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The bulk of renewable energy production varies in a way that typically does not align with time-dependent energy consumption. This can lead to an energy surplus or a shortage of the energy supply causing a challenge in supporting the baseload requirements. Enormous storage capacity is required to accommodate these fluctuations in supply and enable large-scale storage of excess renewable energy. Gas as chemical energy carrier, and hence energy, can be stored in such large amounts in subsurface structures of depleted reservoirs. Especially hydrogen gas is an excellent energy carrier and can be produced via electrolysis from the surplus of renewable energy.

First pilot tests in the field were carried out to estimate the risks of hydrogen loss and a reduction of the stored energy due to physical, chemical or biological processes. It turned out that most notably microbial processes lead to a decline of hydrogen and hence to loss of energy. In these processes, microorganisms convert hydrogen and carbon dioxide into methane. This observation, which is detrimental in terms of hydrogen storage security, yield to a new approach to efficiently store excess renewable energy in the form of "renewable" methane. Such operations include a (possibly cyclical) usage of CO2 and can therefore be treated as CCU projects (Carbon Capture and Utilization). The possibility of using these processes as in-situ bioreactor to generate and store "renewable"methane is investigated. The biochemical reactions which convert the gases also lead to a growth of biomass in the pore space. The expansion of biomass will reduce the available pore space for gas storage and likely the permeability of the reservoir rock as well. Consequently, biomass may compromise storage capacity and injectivity substantially.

This work aims to investigate crutial processes of the in-situ methanation on different time and length scales containing numerical simulations and laboratory experiments. With core flooding experiments on the meter scale, we want to get a macroscopic insight into the reactive transport mechanisms which are governing (a) the hydraulic properties, and (b) the gas conversion rate and hence the overall performance of the subsurface reactor. Numerical field scale simulations are used to study the dynamics of the macroscopic conversion process under assumptions concerning conversion rates and field geometries. By using simplified models, mechanisms are identified and their performance is investigated by sensitivity analysis. The approach is to perform generic field scale simulations in order to understand the flow and reaction kinetics and their coupling.

The aim of the presented study is to develop a workflow that contains both, numerical and experimental components to gain a holistic understanding of the physical and biochemical mechanisms of the in-situ methanation. With the resulting comprehensive datasets, we expect deep insights into bio-reactive hydrogen transport and the controlling parameters to be applied to future field cases.

Participation

In-Person

References

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