Underground hydrogen conversion: simulations, sensitivities and the way forward

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The production rates of renewable energy sources vary in a way that typically does not correspond to time dependent energy consumption. This can lead to an energy surplus or a shortage of the energy supply from renewable energies. An enormous energy storage capacity is required to compensate the fluctuating power consumption and ensure a constant supply. Gas as energy carrier can be used to store large scale surplus renewable energy. Geological formations like depleted gas reservoirs offer sufficient capacity to store such large amounts of gas, hence energy. Especially hydrogen gas is an efficient energy carrier and can be produced from surplus renewable energy via electrolysis.
To estimate the risk of hydrogen loss due to physical, chemical, and biological processes in the reservoir, a first attempt to store hydrogen in a gas field was carried out in Austria. During this pilot project, it turned out that especially microbial processes lead to hydrogen loss and hence to loss of energy. In these processes, microorganisms convert hydrogen and carbon dioxide into methane. 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.
The presentation will focus on 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. The complex processes of in-situ methanation involve multiphase flow, gas saturation discrimination due to different gas solubilities, and transport of the gas constituents in the water and the biomass. Numerical field scale simulations are used to study the dynamics of the macroscopic conversion process under assumptions concerning conversion rates and field geometries. In the absence of reliable kinetic data, 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 implement physical and biochemical mechanisms in reservoir simulation tools and to achieve ultimately a calibrated reservoir simulation tool.