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Interactions and Impacts on the Efficiency of Underground Hydrogen Storage in Saline Aquifers

Abstract

The intermittency of the renewable energy sources in the energy systems may require large-scale and long-term energy storage. Among different storage options, subsurface porous rock formations based on hydrogen acting as an energy carrier is an emerging topic in the energy transition to tackle this limitation in renewable energy sources. Despite its potential, the lack of existing commercial-scale projects necessitates further research on this topic.

This work is developed under the scope of the R&D project "H2GeoStore – Hydrogen geological storage and interactions in porous media of subsurface geology" and aims to provide a deeper understanding of the hydrogen behaviour in porous media, particularly in saline aquifers.

A comprehensive approach of reservoir simulation studies has been conducted in this work based on realistic scenarios of energy surplus and shortage from renewable sources by simulating injection and withdrawal cycles of hydrogen at different time scales (e.g., seasonal energy storage) and employing various well configurations. These operational scenarios were implemented on realistic heterogeneous reservoir models depicting distinct structural environments.

Key aspects of this work included the evaluation of the reservoir performance (i.e., injectivity and productivity) at both the operational cycle and storage lifetime scales (10-years in this work). The role of using cushion gas, prior to the storage operations, and the thermal-hydraulic effects were also examined to understand their spatial-temporal effects during the cyclic processes.

Preliminary results of this work indicate that heterogeneity effects play a critical role and may be advantageous depending on the geological environments considered for hydrogen storage. In addition, results suggest that the cumulative hydrogen rate increases over the storage time either using cushion gas or not, particularly tending to increasingly reduce the cumulative rate of the formation water (i.e., brine) when cushion gas is considered in the simulation scenarios.

The integration into the dynamic simulation of physical phenomena, such as residual saturation, solubility of hydrogen in the aqueous phase and diffusivity of hydrogen in water, and the interpretation of their impacts in the recovery efficiency of hydrogen is ongoing work. Future developments of this research project point towards the geochemical and geomechanical impacts associated with the integrity of different reservoir caprocks over time.