Geophysical Research Abstracts
Vol. 17, EGU2015-12108, 2015
EGU General Assembly 2015

Feasibility and induced effects of subsurface porous media hydrogen storage

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Fluctuations in energy production from renewable sources like wind or solar power can lead to shortages in energy supply which can be mitigated using energy storage concepts. Underground storage of hydrogen in porous sandstone formations could be a storage option for large amounts of energy over long storage cycles. However, this use of the subsurface requires an analysis of possible interactions with other uses of the subsurface such as geothermal energy storage or groundwater abstraction. This study aims at quantifying the feasibility of porous media hydrogen storage to provide stored energy on a timescale of several days to weeks as well as possible impacts on the subsurface. The hypothetical storage site is based on an anticlinal structure located in Schleswig-Holstein, northern Germany. The storage is injected and extracted using five wells completed in a partially eroded, heterogeneous sandstone layer in the top of the structure at a depth of about 500 m. The storage formation was parameterized based on a local facies model with intrinsic permeabilities of 250-2500 mD and porosities of 35-40%. Storage initialization and subsequent storage cycles, each consisting of a hydrogen injection and extraction, were numerically simulated.

The simulation results indicate the general feasibility of this hydrogen storage concept. The simulated sandstone formation is able to provide an average of around 1480 t of hydrogen per week (1830 TJ) which is about 5% of the total weekly energy production or about 10% of the weekly energy consumption of Schleswig-Holstein with the hydrogen production rate being the limiting factor of the overall performance. Induced hydraulic effects are a result of the induced overpressure within the storage formation. Propagation of the pressure signal does not strongly depend on the formation heterogeneity and thus shows approximately radial characteristics with one bar pressure change in distances of about 5 km from the injection wells. Thermal effects are mainly limited to the gas phase and the near vicinity of the injection wells. However, conductive heat transport into the overlying barrier formations can be observed, causing temperature changes of 1 K in distances less than 300 m in lateral and 30 m in vertical direction. The area of induced chemical effects is given by the distribution of the injected gas phase. The spatial distribution of the gas phase shows a strong dependence on formation heterogeneity, with a maximum reach of around 3 km from the injection wells and a covered area of around 4 km^2. The results indicate that it is possible to use porous media hydrogen storage to store and retrieve energy from the subsurface to mitigate shortages in energy production. The induced effects associated with such a storage operation range from the meter to the kilometer scale depending on the individual process.