Comparison of Natural Gas and Hydrogen Withdrawal Profiles of Subsurface Porous Storage Sites

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Excess renewable electrical energy can be converted to hydrogen and stored in the subsurface, for example in salt caverns or pore storages. Underground gas storage sites are vital to ensure reliable supply and to meet the demand in energy. For the construction of underground gas storage facilities, the technical components (wells and surface facilities) must be designed in such a way that they are compatible with the geological conditions. Merging these components results in a specific withdrawal profile, which differs for every storage site. During a storage production period, the production rate is usually limited to a plateau value, which accounts for the constraints in the maximum operational capacities of the surface facilities until the critically produced working gas volume is reached. After this point, the gas flow rate decreases as this rate is limited by reservoir and well performance until all working gas has been extracted. To convert existing natural gas storage and to potentially construct new hydrogen storage sites, the differences in gas properties, for instance density, viscosity, and compressibility, and their influence on the storage performance as well as the withdrawal profiles need to be considered.

In this work, a simulation study is performed to investigate the storage performance as a function of the stored gas. For the simulations, a geological model resembling a sandstone formation in North Germany is implemented into the open-source numerical simulator DuMu^{X}. This model covers an area of approximately 3 x 3 km and has a slightly varying height. The average values of porosity and permeability are 15% and 143 mD. All boundaries are impermeable so that the storage is operated with a nearly constant volume. Two underground storage cases are simulated: (I) underground natural gas storage and (II) and underground hydrogen storage. For both cases, one complete storage withdrawal period is simulated and gas is extracted at the identical plateau production rate until the critical working gas volume is reached. Afterwards, the production rate is governed by the bottom-hole flowing pressure. A minimum bottom-hole flowing pressure is defined which would allow gas to flow into the gas transmission network without re-compression. For both cases, the withdrawal profiles are generated and compared.

Differences in the storage performance between natural gas and hydrogen can be noticed. On the one hand, hydrogen is less compressible, which causes the storage pressure to drop sooner. On the other hand, hydrogen has a lower viscosity, which increases the inflow performance of the storage wells. These findings can be used in the design of future subsurface hydrogen storage systems.