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Reservoir Simulation Studies in Underground Hydrogen Storage in a Depleted Gas Reservoir – Northwestern Germany

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To achieve a carbon-free economy in the medium term, hydrogen has been proposed as a viable solution. This requires large-scale subsurface storage options, especially, if green H_2 produced from fluctuating renewable energy sources like wind and solar energy is considered. While H_2 has already been stored successfully in salt caverns for decades, H_2 storage in porous media like hydrocarbon-depleted reservoirs and saline aquifers still requires further research. We use an almost depleted gas reservoir in NW Germany to test various scenarios regarding withdrawal/injection cycles and different cushion gases. The case study field presents a faulted reservoir in a highly fractured rock of Upper Permian (Zechstein) age, consisting mainly of dolomite as reservoir rock and anhydrite as cap rock. A history-matched dynamic model starting in 1959 of a gas-depleted reservoir calibrated from the comprehensive information available for the reservoir site serves as a hypothetical base case for seasonal H_2 storage, intending to store around 300 $MMsm^3$. From then, an isothermal compositional reservoir simulator with 7 components is used including H_2S to monitor its concentration. Eight prediction cases were simulated, excluding: diffusion, dispersion, and microbial reaction. Between each case, changes are made to the type and amount of cushion gas injected following the same injection/withdrawal cycle, mixing the cushion gas between N_2+CH_4, H_2+N_2, H_2+CH_4, H_2+CO_2, pure CH_4, pure CO_2, pure N_2, and pure H_2. Following an initial filling from entirely the cushion gas for 33 months of around 0.73 ($MMsm^3$/d), afterward, the initial withdrawal begins for 2 mos. from the working gas of around 3.6 ($MMsm^3$/d) and then the withdrawal/injection cycles for 3(W)/6(I) mos. The amount of working gas injected increases to 1.8 ($MMsm^3$/d) after the first withdrawal, with a shut-down phase for 1 mo. after withdrawal and 2 mos. after injection, for 7 times; resulting in a total of 8 cycles for H_2 production. The applied amounts were to avoid any spilling due to the highly-fracture nature of the reservoir. In a subsequent simulation from the case of using pure N_2, the prediction time increased to observe its changes over the next 7 years. To assess the overall recovery of H_2 and H_2S concentration, a volumetric and molar storage balance was analyzed. Based on the results of all 8 simulations, at least on the first 4 cycles, less H_2 is recovered, except if pure H_2 is injected from the beginning as a buildup phase. Despite this, all simulations show a higher H_2 recovery for the last cycle, from 96% (pure N_2) to 99% (pure H_2). Regarding H_2S, shows a diluted concentration while the storage cycles increase. A longer-time prediction reveals that H_2 recovery for the last cycle can nearly reach 100%. The next steps involve realizing a thermal simulation to observe the temperature effect on the storage process, alongside a preliminary economic study of the storage site to determine its feasibility.