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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 hydrogen 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 northwestern 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, such as density, viscosity, relative permeability, and capillary pressure, which serves as a hypothetical base case for seasonal hydrogen storage, intending to store around 300 Mio sm^3. An isothermal compositional reservoir simulator with seven 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 only the cushion gas of 33-months of around 730000 (sm^3/d). Immediately after, withdrawal begins for 2 months from the working gas of around 3600000 (sm^3/d) and withdrawal/injection cycles for 3(W)/6(I) months were the amount of working gas injected increases to 1800000 (sm^3/d), and with a shut-down phase for 1 month after withdrawal and 2 months after injection, for 7 times; resulting in a total H_2 production over 8 cycles. 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 was increased to observe its changes over the next 7 years. To assess the overall recovery of hydrogen and the concentration of H_2S, a volumetric and molar storage balance was analyzed. Based on the results of all the 8 simulations, at least on the first four cycles, less H_2 is recovered, except if pure H_2 is injected from the beginning as a filling phase. Despite this, all simulations show a greater H_2 recovery for the last cycle, from 96% (pure N_2 as cushion gas) to 99% (pure H_2 as cushion gas). Regarding H_2S, shows a diluted concentration while the storage cycles are increased, resulting lower than 2×10^{-5} mole fraction for the last cycle. 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 for the observation of the temperature effect and how can it effect the storage process, and a preliminary economic study of the storage site to determine its feasibility.