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Cushion Gas Type and Optimal Volume for Underground Hydrocarbon Storage in a Depleted Gas Reservoir in the Celtic Sea

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Transitioning to renewable energy is crucial for combating climate change, but solar and wind power face supply-demand gaps due to seasonal dependencies. To bridge this gap, converting excess renewable energy into hydrogen for storage in depleted onshore and offshore gas fields offers a promising solution, enabling stored energy for use during high-demand periods without carbon emissions. These sites offer an attractive option for underground hydrogen storage, facilitating global distribution and using existing infrastructure.

However, selecting the type and required optimum volume of cushion gas is crucial to ensure the effective reproduction of working gas and economic feasibility. To address this, an analogue model was built based on the geology of the Kinsale field, a depleted gas field potential future hydrogen store in the Celtic Sea. This model uses reservoir and flow properties derived from wireline data of existing wells and the geological system in the area.

For fluid flow, a compositional simulator was used to model changes in fluid composition. Actual field operational control parameters such as maximum and minimum pressure ranges were considered. A uniform depletion procedure was initiated reflecting current field production data. The study investigated the impact of various aspects of the hydrogen storage operation, including reservoir heterogenity, number of wells, cushion gas types, and optimal scenarios for working gas production.

The findings reveal that after the first storage cycle, injecting hydrogen as a cushion gas yields the highest purity (93.5%) of produced hydrogen working gas, while methane as a cushion gas exhibits the lowest purity (85.2%). The hydrogen purity increases with increasing cycles, but 100% purity cannot be achieved because of the in-situ natural gas. Moreover, across production phases, the hydrogen purity in the produced gas within each cycle declines over time. This decline is attributed to decreasing pressure during production leading to the migration of methane from the surrounding flanks toward the wellbore area. Additionally, an increase in the number of wells decreases the required volume of cushion gas because multiple wells require lower production pressures to produce the same volume of stored gas.

Based on the findings derived from the simulations, we conclude that depleted natural gas reservoirs offer a viable option for hydrogen storage in terms of both dynamic storage capacity

and hydrogen purity.