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Numerical Assessments of Repurposing a Natural Gas Cavern for Hydrogen Storage

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Utility-scale hydrogen storage will be essential in the UK for meeting carbon emission goals[1]. It is estimated that approximately 150TWh of seasonal energy storage is necessary to negate seasonal variations in natural gas production[2]. This capacity can be easily met through compression and storage of hydrogen within depleted gas reservoirs and deep saline aquifers[2]. However, there are several limitations to porous storage, such as the mixed composition of the produced fluid, higher cushion gas requirements, slower release kinetics and longer storage cycles.

Due to the storage dynamics of salt caverns, single gasses can be stored with minimal mixing, allowing for reduced post-storage processing and higher deliverability. This provides caverns with an essential role in both seasonal and daily load management as well as providing a source of energy for high purity hydrogen applications (i.e. transport and fuel cells). The national grid estimates 51TWh of cavern storage will be necessary by 2050[3].

Although new caverns will be necessary, there are several benefits to repurposing current facilities:

- Above ground infrastructure is already available
- Freshwater savings, approximately 7-8m^3 per m^3 cavern size[4]
- Shorter lead times on storage development
- The reduced expense for geological exploration

Current methods for repurposing suggest the reflooding of the cavern with high salinity brine to replace the gas within, brine production and hydrogen injection then follows this; a process estimated to take 3-7 years. Although less time than for new developments, the risk of unacceptable leakage and the still considerable cost acts as barriers to its implementation.

Our research aims to provide the first investigation into repurposing through gas replacement, determining the number of cycles necessary before an acceptable purity can be attained. This will be simulated with GPSFLOW (General Purpose Subsurface Flow simulator), a software capable of modelling multiphase-multicomponent storage within salt caverns, deep saline aquifers and depleted gas fields[5]. The geological model utilised will be an idealised version of the Stublach cavern in Cheshire, England.

Two approaches are proposed, the first being an injection cycle of high purity hydrogen and the monitoring of hydrogen quality in the produced fluid as the number of cycles increases. Alternatively, the use of CO_2 as means to replace the CH_4 and then the subsequent hydrogen injection cycles will be simulated. The significance of this work is to provide an initial insight into repurposing through gas replacement which, if functional, may provide a reduced transitionary period and considerable resource savings.

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