HyStorPor: unlocking the UK’s hydrogen storage

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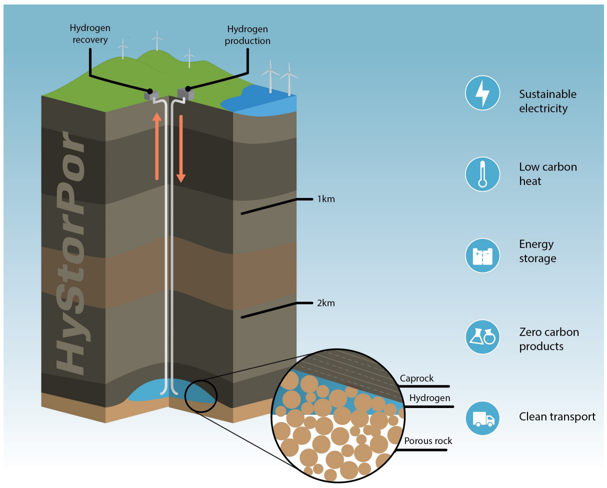
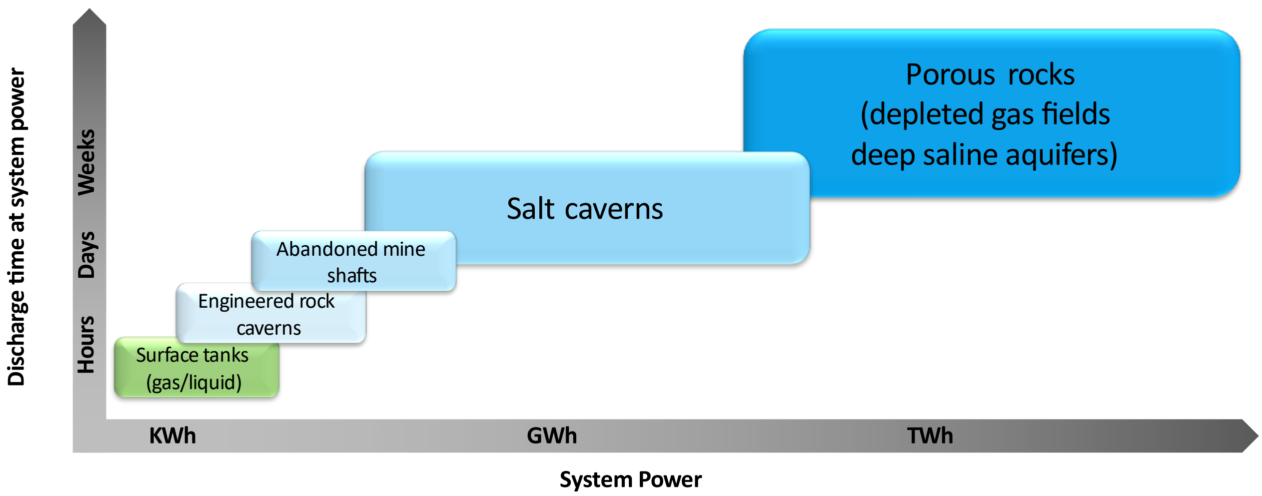


Hydrogen as a future low-carbon energy carrier is currently undergoing exceptional momentum on a global scale with the increasing recognition of the versatile role of hydrogen as a clean energy solution. Hydrogen can contribute to the decarbonisation of transportation, power, heating and fuel-intensive industries to enable large-scale greenhouse gas emission reductions and reach net zero targets.

Hydrogen does not often occur naturally so, for a sustainable future, it must be manufactured by either methane gas reforming with CCS (“blue hydrogen”) or electrolysis with renewable electricity (“green hydrogen”). It can then be stored at small or large scale until it is needed.

For hydrogen to play a role in balancing seasonal variations in energy demand, we will need access to large-scale geological storage. This briefing describes research under way in the HyStorPor project to develop this geological hydrogen storage asset in the UK.

Meeting future storage needs



While hydrogen has the highest energy density of all fuels, its low atomic mass means that large-scale storage solutions will be required for seasonal energy storage. The scales required for seasonal storage can only be provided by underground geological storage, which can be in engineered rock caverns (KWh-scale), salt caverns (GWh-scale) and porous sandstone rock (TWh-scale). There is significant experience of geological storage of natural gas at the scale needed for decarbonisation across the UK, EU and US. However, experience of the geological storage of hydrogen is limited to three saline aquifers used to store Town Gas (50% hydrogen), a handful of salt caverns storing hydrogen for the chemical industry and two recent projects (RAG Underground sun storage and HyChico) injecting hydrogen in the subsurface to undergo bacterial conversion to green methane. [Recent work] by the HyStorPor team developed a new methodology to estimate the hydrogen storage capacity of existing oil and gas fields. The work demonstrated that one large field could hold the UK's entire working gas energy storage demand, which is estimated to be around 77.9 terawatt-hour (TWh).

Understanding the geological asset

In the UK we have the ideal combination of abundant renewable energy resources for green hydrogen production, extensive offshore gas production to support blue hydrogen production, and excellent hydrogen storage assets in the form of depleted gas fields and salt caverns that can also support the required CO_2 storage for blue hydrogen. This is all supported by decades of experience in gas storage and production operations. The HyStorPor project is looking at the feasibility of porous media for hydrogen storage as these can provide TWh storage capacities. North Sea and Irish Sea depleted gas fields are considered particularly promising for future hydrogen storage as they have proven storage reservoir capacity, caprock integrity and data availability vital for safe and efficient operations, with existing infrastructure in place to enable rapid development of large-scale hydrogen storage. The HyStorPor project is also considering hydrogen storage in saline aquifers and onshore gas fields in the UK as these could also support future hydrogen grid operations closer to the consumer. HyStorPor will assess potential saline aquifers and onshore and offshore gas fields to identify low-risk storage assets for real-world hydrogen storage field demonstration projects.

Porous sandstones put to the test

Mapping of the offshore North Sea, Irish Sea and onshore assets for inter-seasonal hydrogen storage in porous gas fields has used criteria from well-established natural gas storage databases and calculations based on field histories, such as gas production curves. These analyses show that they offer between 2660 TWh and 6900 TWh of theoretical hydrogen storage, with a total capacity 17 to 46 times the annual storage needed by the UK. It is important to note that, while these capacity estimates are scientifically robust, it is not yet known if hydrogen can be injected and extracted from the store in a similar way to natural gas; as such, the actual hydrogen storage capacity estimates of the gas fields remains unproven. Further dynamic assessments of the proposed storage sites undertaken during the HyStorPor project will reveal if and how seasonal hydrogen injection and withdrawal can be performed. An important implication of these capacity estimates is that, while the working gas volumes of hydrogen require 75% larger stores than natural gas due to the lower energy density of hydrogen under storage pressures and temperatures, even then only a few stores will be required to accommodate our seasonal storage and, as such, will not compete for geological space with other gas storage operations, such as CO_2, compressed air or natural gas storage.

HyStorPor: exploring the UK's storage potential

The HyStorPor project at the University of Edinburgh, funded by EPSRC, is the UK's first project to explore the feasibility of storing hydrogen in underground porous reservoirs. The project's findings to date support the feasibility of hydrogen storage in porous rocks and support the move to proceed to a demonstration site to further support and validate the capability and effectiveness of hydrogen subsurface storage to decarbonise our energy system. Interim conclusions provide a wide range of evidence to support the possibility of commercial storage in porous sandstones.

Interim conclusions from HyStorPor:

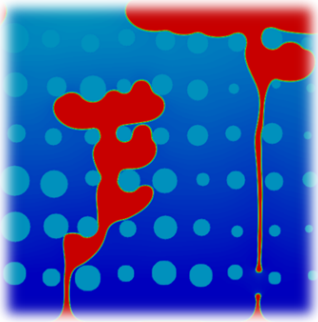
- Many North Sea reservoirs have temperature (over 120°C) and salinity (over 30% NaCl equivalent) conditions that inhibit the growth of hydrogen-metabolising bacteria, thereby avoiding issues, such as hydrogen loss or contamination. These life limits identified within the HyStorPor project act as an effective site screening parameter to reduce the risk of hydrogen loss or contamination through microbial reactions.

- No significant geochemical reactions of hydrogen with sandstone, which could potentially damage the operational capacity of a reservoir, have been observed so far in our experiments conducted under storage reservoir conditions.
- The very low permeability caprocks that seal natural gas in place in our North Sea gas fields have been shown to hold a higher gas column of hydrogen than they do for natural gas, meaning increased storage security.
- The HyStorPor project's open access H2ThermoBank tool can be used to assess the properties of hydrogen within gas mixtures, which will underpin the design of any new hydrogen supply chains.
- The HyStorPor project's open access H2CapEs tool can be used to estimate hydrogen storage capacities of various surface facilities and subsurface formations for hydrogen storage at different conditions.
- A small number of depleted gas fields offshore will provide enough energy storage, as hydrogen, to balance the entire seasonal demand for UK domestic heating.
- With storage assets located in the North Sea, the UK can become a hydrogen production and distribution hub, supplying green energy to European countries.

HyStorPor: project objectives

- To identify if **biological and chemical reactions** between the rock, fluids, cushion gas and hydrogen could compromise storage.
- To determine what **flow processes** will influence hydrogen migration and trapping during injection and withdrawal.
- **Reservoir simulations to estimate what volumes of hydrogen can be stored and recovered** from storage sites of varying scales.
- To **clarify what citizens and opinion shapers think about hydrogen storage.**

HyStorPor: future work



In the second half of the HyStorPor project there is still a significant body of work required to continue to establish the feasibility of hydrogen storage in porous rocks. In addition to the experimental outputs, there will be field-scale reservoir modelling outputs to understand how efficiently hydrogen can be injected and predict how much of the hydrogen can be recovered during operation. Volumes and types of cushion gas – to be left in the reservoir as a precaution to maintain operation pressure and minimise water encroachment during withdrawal periods – will also be assessed.

A number of tasks will be undertaken, which include:

- Geochemical modelling to finalise the impact of hydrogen storage on the reservoir quality and caprock integrity.
- Micro X-Ray CT imaging of hydrogen flow through porous rocks to identify hydrogen recovery factors, relative permeability and contact angles, all crucial inputs into the reservoir modelling.
- Pore network modelling to investigate the impact of multiple cycles of hydrogen injection and withdrawal.
- Experiments under reservoir storage conditions to confirm gas tightness to hydrogen of the Kimmeridge Clay caprock.
- Numerical simulations to investigate the geomechanical properties of the caprock.
- Development of 3D reservoir models of potential hydrogen storage sites representing different storage environments in Scotland, including a small onshore structure and an open offshore aquifer.
- Continued dialogue to elucidate public and stakeholder understanding of the geological storage of hydrogen and the role of hydrogen in achieving net zero and mitigating climate change.

The ultimate aim of HyStorPor is to establish that hydrogen storage in UK reservoir rocks is fundamentally feasible to lay the groundwork for further research and pilot projects as vital precursors to industrial-scale geological storage demonstration trials. Industry, researchers and public decision makers will then have the knowledge base to make justifiable decisions on the future of hydrogen storage in UK reservoir rocks.

HyStorPor: publications

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