Underground hydrogen storage: mapping out options for Australia (RP1.1-04)

Widespread adoption of hydrogen in Australia as an energy carrier will require storage options to buffer the fluctuations in supply and demand, both for domestic use and for export. For large-scale storage, underground hydrogen storage (UHS) is the preferred option for reasons of both cost and safety.

The literature on UHS was reviewed, highlighting the main options for UHS under consideration: salt caverns, depleted gas fields, saline aquifers, and engineered hard rock caverns. The reservoir engineering aspects of UHS in porous media were explored, providing some of the tools for assessing storage capacity, losses, and containment. The literature of UHS economics was also surveyed, indicating the variance in cost estimates and the need for an integrated assessment of total costs of hydrogen production, transport, and storage.

The scale of potential future demand for UHS was estimated by considering plausible scenarios in three areas of application for energy storage. For stabilisation of the electricity network, this corresponds to around 10,000 tonnes of hydrogen (1.3 PJ). For security of the gas network (fully converted to hydrogen), the amount is estimated at about 2.5 million tonnes (300 PJ). For potential export, the storage requirements are similarly estimated at around 2.5 million tonnes (300 PJ).

A methodology was developed for assessing the suitability of UHS options in Australia, and for making storage capacity estimates (only for depleted gas fields). This methodology was then applied to the whole of Australia. The key aim was to estimate the scale of prospective storage in each region, and classify options by their suitability, rather than to rank potential storage sites. The focus at this stage was on a technical assessment of geological factors and the assessment does not take social, environmental or economics issues into consideration.

UHS in salt caverns (created by circulation of water) is an established technology internationally, with individual sites able to store up to a few thousand tonnes of hydrogen. Various Australian sedimentary basins contain salt deposits potentially suitable for the creation of storage caverns; however, most of these salts are in areas that are not near potential hydrogen generation, ports, or processing infrastructure. The most likely locations are in the north-western part of the Canning Basin, which is relatively close to the North West Shelf gas processing facilities and in the vicinity of new renewable wind and solar energy projects. The salt deposits in the Adavale Basin in western Queensland, and the Amadeus Basin in the Northern Territory, may also be suitably located for some projects. Further exploration for salt deposits may open up additional locations where salt cavern storage for UHS is viable.

Depleted gas fields have also been used previously for storage of hydrogen-rich gas mixtures as well as natural gas storage and appear to be the most promising and widely available UHS option in Australia. There are still technical challenges to be addressed, such as the extent of possible contamination of the stored hydrogen with residual hydrocarbons, and the possible effects of geochemical reactions and microbial processes. The total prospective UHS capacity in such sites has been estimated using reserves and production data to be 310 million tonnes H_2 (38,000 PJ). Most Australian sedimentary basins contain multiple gas fields with an individual prospective storage capacity of more than 200,000 t H_2 (25 PJ). A much more detailed site-by-site assessment would be required to estimate how much of this prospective storage capacity could be commercial, considering various operating parameters and costs, as well as social and environmental factors.

UHS in saline aquifers is also possible, building upon widespread international experience with underground gas storage in such locations. Many Australian basins contain multiple reservoir-seal pairs that should be suitable for UHS. The further requirement is then to locate suitable structures which could contain the stored hydrogen. That will require additional exploration and characterisation in these basins, and so a quantitative estimation of UHS capacity was not possible within the scope of this project. Although UHS in saline aquifers has not yet been demonstrated in industrial applications, it represents an option with a larger regional extent than storage in depleted gas reservoirs and may be considered if contamination issues from residual hydrocarbons are found to be significant.

UHS in engineered hard-rock caverns, whether purpose-built or re-purposed from mining infrastructure, is a concept that builds on international experience with compressed air storage. It has a much lower technology readiness level (TRL) than the options discussed above, and there are major technical challenges around both containment and geomechanical stability. The main area of application would be in regions with significant potential for renewables but away from sedimentary basins, where the other geological options are not available. Each of the five regions analysed has some areas in which engineered caverns could be created, including mines with modern infrastructure which could potentially be lined and re-purposed for UHS. Given the abundance of prospective storage capacity in Australian gas fields it would seem unlikely that repurposing underground excavations is a necessary or practical large-scale storage option. There is perhaps the possibility of smaller-scale application in remote mining areas or in conjunction with temporarily storing export hydrogen in NW WA.

Even if only a small fraction of the prospective storage capacity in depleted gas fields (310 million tonnes) could be realised commercially, this would significantly exceed the storage needs of a fully developed hydrogen industry in Australia (estimated at around 5 million tonnes). This is also true in each of the five regions analysed. The most likely scenario is that the required UHS capacity could be met by a few storage facilities in each region. The focus will then be on finding the most suitable sites that match the needs of the emerging hydrogen production industry, considering the economic, social, and environmental constraints.

Additional research is needed to resolve the technical challenges around each UHS option, and to provide suitable criteria for site selection. Salt cavern storage will require better characterisation of known salt deposits, and exploration for new ones. Depleted gas field storage needs quantification of the impact of geochemical and microbial reactions on hydrogen purity, the impact of hydrogen on the properties of the storage reservoir and the seal, and more sophisticated modelling of how these processes affect the operation. Saline aquifer storage will require further exploration and characterisation of suitable structures for retaining the hydrogen. For hard rock caverns, the challenges are around containment and geomechanical stability, including the material used for liners, and the choice of excavation techniques. The techno-economic analysis requires an integration of the total costs of production, transport and supply of hydrogen, and a comparison between the different types of storage sites and possible applications.

Acknowledgements

The report was authored by Jonathan Ennis-King, Karsten Michael, Julian Strand, Regina Sander and Chris Green of CSIRO, and the project team included Ian Hay as well. Support was provided by the Hydrogen Future Science Platform within CSIRO. The industry advisory committee consisted of Dennis Van Puyvelde (ENA), Tim Aujard (AGIG), Tawake Rakai (AGIG), Aiden Trend (APA Group) and Ashley Roberts (Woodside).

Future Fuels CRC is supported through the Australian Government's Cooperative Research Centres Program. We gratefully acknowledge the cash and in-kind support from all our research, government and industry participants.

Australian Government
Department of Industry, Science, Energy and Resources

Business
Cooperative Research Centres Program