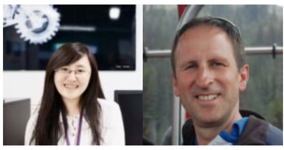
Underground hydrogen storage, the key to a green and sustainable future

By Lin Ma and Kevin Taylor

In response to the climate crisis, renewable energy production has increased significantly over the last decade. According to National Grid, the UK produced its trillionth kilowatt hour (kWh) of electricity generated from renewable sources on 15 May 2023, and solar energy and offshore wind are predicted to grow five-fold by 2030. Hydrogen, a potentially green energy carrier, is also seen to be increasingly important as part of UK energy decarbonisation. Hydrogen is one of a handful of new low carbon solutions which can help the UK to achieve its emissions reductions target for Carbon Budget Six (CB6), and net zero by 2050. Here Dr Lin Ma and Professor Kevin Taylor, consider how hydrogen will contribute to our energy mix, how its supply could be supported by underground hydrogen storage (UHS), and the associated challenges policymakers need to address.

- The UK is predicted to need 9.8TWh of large-scale hydrogen storage by 2035.
- Geological and scientific challenges faced by UHS include leakage, efficiency, and safety.
- A holistic approach is required to be taken by government and industry to ensure our hydrogen networks are able to supply the energy we need by 2035.

Hydrogen and Underground Hydrogen Storage (UHS)

The UK Government’s Ten Point Plan for a Green Industrial Revolution aims for 5GW of low carbon hydrogen production capacity by 2030 for use across the economy. Hydrogen could be a key element in helping to achieve net zero as it has the potential to be used to decarbonise heavy industry, transport, and heating. Hydrogen storage is an important part of the supply chain, allowing excess renewable energy to be stored in various formats.

In the UK, 3.4 TWh of large-scale hydrogen storage is predicted to be required by 2030, increasing to 9.8 TWh by 2035. Large-scale hydrogen storage will be the only realistic way to balance seasonal fluctuations of renewable energy and customers’ demands. UHS has been proposed as the most promising large-scale storage approach to provide ~GWh scale storage capacity. Here, electricity produced by renewable energy will be transferred to hydrogen by electrolysis (so-called green hydrogen). Gigatons of hydrogen could be generated at peak times of renewable energy production, in the summer for instance, and stored until it is needed in peak times of energy demand, like in winter. The stored hydrogen will be extracted from the subsurface as hydrogen gas and utilised.

Methods of UHS

Hydrogen can be injected and stored in a variety of geological structures including salt caverns, depleted gas reservoirs or depleted aquifers.

The safety and efficiency of hydrogen storage in salt caverns has been proven in several locations globally. Examples include the Teesside salt field, providing 25GWh capacity since 1972, and three salt domes, Clemens Dome, Moss Bluff and Spindletop in Texas providing 90 to 120 GWh capacity since the 1980. However, this type of storage will struggle to meet the rapidly increasing need for hydrogen, due to their restricted geological distribution.

Depleted gas reservoirs could provide high volumes of UHS due to the porous nature of the rock and have proven ability to store and trap natural gas for millions of years. However, pure hydrogen has never been stored in depleted gas reservoirs to date.

Deep aquifers could potentially store even higher amounts of hydrogen owing to their wide distribution and large volumes. However, deep aquifers require further assessment to understand whether their sealing ability is sufficient for hydrogen.

Challenges faced by UHS

Before UHS can play a full role in the supply of hydrogen there are still many scientific challenges that need to be addressed.

The small molecular size of hydrogen makes it moveable and migratable through porous rocks or fractures, potentially leading to the escape of hydrogen into the subsurface. A careful assessment of effective seals and containment mechanisms is critical to prevent leakage and maintain the integrity of the storage site.

While storing and recovering hydrogen from the subsurface, some energy is required for compression, injection, and extraction processes. Although challenging, improving the efficiency of these processes is important to maximize the energy storage potential and overall viability of UHS systems.

The interaction between hydrogen and the subsurface environment can lead to geochemical and microbiological reactions. These reactions may affect the integrity of the storage reservoir, alter the chemical composition of the surrounding rocks or fluids, and potentially impact the long-term storage capacity. Managing these reactions are crucial for maintaining the stability and safety of underground hydrogen storage.

UHS involves injecting and withdrawing large volumes of hydrogen, which can induce mechanical stresses on the storage reservoir and surrounding rocks. The mechanical response of the reservoir to these stresses, including the potential for induced seismicity or subsidence, needs to be carefully evaluated and monitored to ensure the safe operation of the storage facility.

Environmental impacts of UHS must also be assessed and mitigated. This includes evaluating potential risks associated with hydrogen leakage, such as its impact on groundwater quality, soil contamination, or air quality. Robust monitoring and mitigation strategies are essential to prevent and respond to any environmental concerns that may arise.

The deployment of UHS facilities will have social implications that need to be considered, such as concerns related to land use, community acceptance, and public perception of underground storage technologies. Engaging with local communities, addressing concerns, and ensuring transparency in the decision-making process are important for fostering acceptance and support for UHS projects.

Extensive research, pilot projects, and thorough risk assessments are necessary to develop safe, reliable, and environmentally sound UHS solutions. Scientists at The University of Manchester are driving the development of novel technologies and are delivering cutting-edge knowledge to the new areas of UHS, together with low-carbon hydrogen production techniques, to ensure a sustainable future.

Policy recommendations

A holistic approach is required to be taken by government and other policymakers to ensure our hydrogen networks are able to supply the energy we need by 2035.

Initially, research and development must be supported by further investment to help accelerate the progress of energy transition. Research and development of UHS is at a relatively early stage and the scientific challenges outlined above need to be addressed before it can become fully operational. These challenges will only be addressed through multi-disciplinary research undertaken by academics and industry.

Policies that encourage and regulate industrial development should be introduced. This includes setting targets for renewable hydrogen production, implementing carbon pricing mechanisms, providing financial incentives and subsidies, and removing barriers to market entry. This will help to stimulate market demand and encourage the private sector business to step into the market.

The government should also collaborate with other nations to promote development of a global low-carbon hydrogen market involving UHS. This cooperation could involve sharing best practices, harmonizing standards, and regulations, establishing cross-border infrastructure for hydrogen production, storage, transportation and trade, as well as resource sharing and knowledge exchange, which could accelerate progress in scaling up hydrogen storage technologies.

Finally, public acceptance and understanding of UHS is also vital for a successful transition to a hydrogen-based economy. The government and industry can work together to increase public awareness through educational campaigns, public demonstrations, and providing accurate information on the environmental and economic advantages of low-carbon hydrogen.

About Lin Ma

Lin Ma is a NERC Research fellow and Presidential Fellow, whose work uses multi-scale imaging for characterising rocks in geoenergy reservoirs and subsurface energy storage. She is currently developing novel approaches to characterise pore networks and rock properties, and how they react under subsurface conditions.

About Kevin Taylor

Professor Kevin Taylor is a lecturer in Geoscience. He has research links and interests in subsurface energy and the utilisation of the sub-surface for the decarbonisation of energy, storage of heat and energy, and in long term safe storage and disposal of CO2 and nuclear waste. His interests in the hydrogen economy focus around understanding the challenges that are presented by storage of hydrogen (and other gases) in porous rocks in the sub-surface (efficiency, mobility risks, and leakage risks) and he utilises multi-scale 3D imaging and rock characterisation to address these.