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Transitioning from underground gas storage to underground hydrogen storage in the onshore Otway Basin, Australia

Introduction

The H2RESTORE Project located in Victoria, Australia aims to use depleted sandstone natural gas reservoirs in the Otway Basin for underground hydrogen storage (UHS). Renewable hydrogen would be generated during times of surplus renewable energy production and stored in the underground sandstone reservoirs. The stored hydrogen can be used to generate electricity during periods of high demand or to supply hydrogen for clean fuels production. The project seeks to use the flexibility afforded by UHS to deliver value by overcoming two emerging energy transition challenges: (1) the intermittency of renewable power generation and (2) the high cost of 'deep' energy storage systems.

The project plan is to be progressed in 5 phases – pre-feasibility, feasibility, demonstration pilot, stage 1 commercial and stage 2 commercial. The H2RESTORE Project completed pre-feasibility in early 2023 and is currently in the feasibility study phase which is expected to conclude in September 2025. This abstract will discuss the approach to, and selected learnings from the pre-feasibility and feasibility phases, while providing some context on the non-technical challenges for this Australian project.

Background

Lochard owns and operates the Iona Gas Storage facility (IGSF) located near Port Campbell in Southwest Victoria, Australia. The IGSF is the largest commercial Underground Gas Storage (UGS) operation in Australia. In 2021, Lochard commenced a multi-disciplinary subsurface review to assess the potential for UGS of several produced gas fields it had purchased in 2019. This work, while initially targeted for UGS, has proved to be an excellent basis for the subsurface UHS studies. These UGS workstreams included targeted 3D seismic pre-stack time migration (PSTM) reprocessing, geophysical mapping of key seismic horizons, "ground-up" petrophysical study to develop formation evaluation logs, porosity-permeability transforms, lithofacies schema, gas-water contact and saturation-height function derivations. Static geological models were constructed and brought into dynamic simulation for history-matching. The history-matched models were used to develop forecasts and assess the gas storage potential for the fields. An independent subsurface peer review was conducted over the completed work. This work has strongly influenced the pre-feasibility and current feasibility study workstreams. The existing UGS fields are shown in red and the available fields for further development are shown in orange in Figure 1.

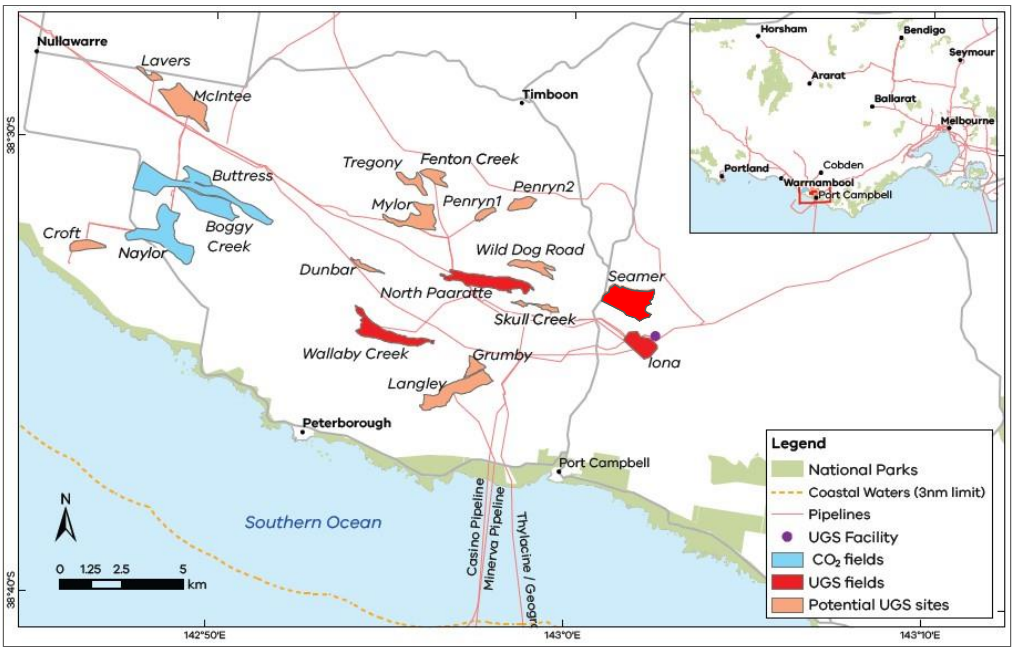

***Figure 1**: Onshore Otway Basin Gas Fields (after Buschkuehle et al. 2019)*

The onshore Otway Basin gas fields are characterised by the reservoir and caprock pairing of the Waarre sandstone and Belfast mudstone. The Waarre sandstone is a clean quartzose sandstone with high porosity and excellent permeability and has proven to be an outstanding formation for natural gas storage. The regionally extensive overlying Belfast mudstone is an effective seal with good containment based on historical retention of natural gas. This reservoir/caprock pairing provided Lochard the confidence to embark on its investigations towards the storing of hydrogen in the same geological system. All the fields depicted in Figure 1 are characterised by the Waarre/Belfast pairing.

Pre-Feasibility

As noted above, Lochard undertook pre-feasibility work in early 2023 with the objective of determining if there were any "showstoppers" for the project, either in the subsurface, surface development or project economics. The aim was to terminate the project early if insurmountable hurdles were identified, thereby, saving time, resources and cost on a project which couldn't be developed technically or economically. From a subsurface perspective, a risk factor table was developed utilising recent research (Heinemann et al. 2021) to inform areas of study focus.

Learnings

Overall, no 'showstoppers" were identified. However, all study areas yielded recommendations for future work, and these formed the basis for the scopes of work for the feasibility phase. Of all the different aspects of subsurface uncertainties and risks, the aspect identified with the greatest need for early research was with formation water and potential microbial activity with hydrogen.

Formation water samples were taken in one field. Baseline DNA was obtained on a preserved field sample. *Thermoanaerobacter pseudoethanolicus* and *Thermoanaerobacter kiva* were identified as the most abundant microbial species. Live samples were also obtained. These were returned to the reservoir temperature of 70ºC upon sampling at surface and then maintained at temperature through transport and within the laboratory prior to testing. Two testing phases were undertaken, exposing the water sample and microbes to hydrogen to determine losses, alteration of hydrogen volume and any changes in the abundant microbes. Both tests indicated negligible hydrogen losses with no H_2S production or methanation. The key control appears to be low presence of nutrients for hydrogen reactions.

The other pre-feasibility studies for the subsurface were desktop studies utilising Lochard field data and assessments and literature reviews. This did not identify any specific "showstoppers" but as noted above did yield recommendations for future studies. Studies on locations, power system access and constraints, water availability, pipeline route, plant requirements for hydrogen production and electricity generation confirmed the availability and feasibility of progressing the project, noting there were low levels of maturity across many aspects. This work culminated in a AACE Class 5 cost estimate which provided inputs to a Lochard developed Techno-Economic model. The economic modelling work indicated, at this early stage, the overall concept could support an economic return.

Feasibility Study

The 18-month feasibility study will investigate subsurface properties, report on concept design for the pilot and commercial project facilities, understand recycled water supply concept, techno-economics and power connection studies. Further, the study will identify potential development partners, undertake extensive community and regulatory engagement, and conduct environmental and cultural heritage due diligence. Outputs from the feasibility phase will inform investment decisions to progress to subsequent phases of the overall H2RESTORE project. The key objective of the feasibility is to determine if hydrogen can be safely stored underground in the depleted gas fields and underpin the commercial stage 1 of the project. The goal is progression to the demonstration pilot phase and continuance of early stage 1 activities.

The study workstreams are similar to the above noted pre-feasibility phase with emphasis on laboratory tests, hydrogen reservoir modelling, more specific and advanced concept design and costing including investigating technology selection and interaction with the power grid, internal and external techno-economic modelling and social license, community and First Nations people engagement. These workstreams are in progress with results and learnings not matured enough to share in this abstract.

Project Challenges

Regulation

As the project moves through the feasibility phase and into demonstration pilot phase there are several emergent challenges external to the feasibility study. At present in Victoria, there is no legislation or regulatory pathway to store hydrogen underground. The logical instrument to enable this, the Victorian Petroleum Act 1998 (Act), enables natural gas storage through the definition of petroleum in the Act. However, there is no definition for hydrogen as a gas that can be stored. This prevents the injection of hydrogen underground and the subsequent storage and withdrawal. A related challenge stemming from the lack of hydrogen definition within the Act concerns the tenure or ownership of the fields. Under the Petroleum Act, authority to produce or store gas in a field requires a Petroleum Production Licence (PPL) which covers an area above the field boundaries and gives the PPL holder exclusive rights to development of that field. Again, a PPL currently does not contemplate the storage of hydrogen, so tenure or ownership of these prospective UHS fields is at risk. Resolving these issues are very high priority. Lochard are working closely with the Victorian State Government and the Energy departments and regulators. These challenges feed into another area of concern – funding for the Demonstration Pilot and the stage 1 commercial project.

Funding

Lochard is an energy infrastructure business, owned by Australian superannuation funds with risk appetite for projects with ongoing stable returns. The demonstration pilot will require reasonable capital and is unlikely to provide a commercial return over the period of the pilot activities. As described above, currently there is not a pathway for regulatory authorisation or guaranteed tenure over the fields being investigated and contemplated for UHS. This doesn't align with the company's risk appetite and is a key risk to securing funding from our investors. In addition to seeking regulatory reform, options to mitigate this include seeking grant funding from Federal and/or State governments. In particular, the Australian Renewable Energy Agency (ARENA) has specific grant funds which they can apply to renewable energy projects. We believe H2RESTORE aligns with several objectives for the Advancing Renewables Program fund: (1) reduction in the cost of renewable energy, (2) increasing the value of renewable energy and (3) improving the Technology Readiness Level (TRL) of renewable energy technologies. Pleasingly, ARENA has provided AUD $2 million of the AUD $6.3 million for the feasibility study under the Advancing Renewables Program. Further government funding will be pursued for subsequent phases of the project.

Hydrogen Sourcing for Pilot

To assess the volume of hydrogen required for the demonstration pilot phase, Lochard utilised the previously developed 3D static and dynamic reservoir models to develop spreadsheet-based models for each reservoir. These were used to calculate a preliminary hydrogen storage volume for each field and then the cycling volume for the demonstration pilot phase. Sourcing hydrogen for the estimated cycling volume range (200-450 tonnes) presents as a major challenge in the Australian context with a very tight market for commercially available hydrogen and limited availability of electrolysers.

Social License

Lochard's experience of developing UGS projects in the Otway Basin has shown that early engagement with stakeholders is essential. Exploring social license considerations for the project is therefore a key component of the feasibility study. This aspect of the study has been split across three consecutive activity streams: (1) desktop research to understand sentiment towards hydrogen, key social risks, the local context and learnings from other projects, (2) key stakeholder sentiment testing, and (3) engagement and implementation. Early results from the desktop research indicate hydrogen understanding is low in Australia, but people are generally accepting of the technology. Increased understanding of hydrogen and its uses will help to facilitate greater acceptance and support. Topics of greatest interest and concern for the project were hydrogen safety, environmental impacts, water usage and cost. These topics should be addressed through proactive messaging. The key aspects for gaining acceptance are communication of shared benefits and the project's purpose, and the development of potential areas of interest for partnering with local First Nations people (Eastern Maar and Gunditj Mirring) (unpubl. results).

Summary

The reservoir/caprock pairing of the Waarre Sandstone and Belfast Mudstone are very promising for early deployment of UHS. Learnings from Lochard's recent UGS assessments and development, coupled with guidance from international studies have provided a foundation, and shaped the approach to investigating UHS in the onshore Otway Basin of Victoria. The planned staged approach allows for further de-risking of the technical challenges, learnings from other projects and time for the societal knowledge and readiness to align with the technology readiness. Currently, the regulatory framework is challenging and lagging behind the technical progress and is a key risk for deployment of UHS in Victoria, Australia. The combination of large hydrogen storage via UHS with electrolyser hydrogen production from renewable energy and hydrogen powered generation back to grid, provides a promising supplemental energy system for the energy transition.

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