BLUE ECONOMY COOPERATIVE RESEARCH CENTRE

Australian Government
Department of Industry, Science, Energy and Resources

AusIndustry
Cooperative Research Centres Program

SHORT SUMMARY

3.20.001 Hydrogen Storage and Distribution

KEY POINTS

- The report examined 21 technologies for storing and/or distributing hydrogen, including pure gaseous hydrogen (GH2) and liquid hydrogen (LH2), chemical hydrogen carriers and materials-based absorption - desorption systems.
- Broadly speaking, GH2 and materials-based storage are technically viable at the smaller scales required for microgrids, while LH2 and chemical hydrogen carriers are technically viable at export scale.
- The only technologies with both Technological and commercial readiness levels (TRL and CRI) high enough to allow them to be widely implemented quickly are pressurised gas (GH2) and liquid (LH2), with GH2 more commercially mature. Each of the other technologies has a limitation on its readiness, caused by low CRI and/or TRL somewhere in the process chain. In most cases the weak link occurs in the decomposition of a chemical carrier and recovery of hydrogen.
- Hydrogen storage in metal hydrides is the next most ready technology, with high TRL and moderate CRI across the process chain.
- The costs of storing and transporting hydrogen are very sensitive to the energy investment required to operate the storage - recovery process. For this reason, chemical storage of hydrogen for energy is unlikely to be profitable in comparison to GH2, although the hydrogen-containing chemicals may have alternate markets that are more profitable.
- The technologies in which pure hydrogen is stored as GH2, LH2 or in solid form as a metal hydride are the most energy efficient and therefore likely to be the most cost effective.
- Pure hydrogen storage as GH2, LH2 or a metal hydride is best suited to the scale of the BE CRC's demonstration project.
- A team of four from three organisations contributed to this project.

THE CHALLENGE

Hydrogen is a highly flexible alternative energy carrier to fossil fuels and electricity. The penetration of hydrogen energy technology into the global energy system is accelerating. The fundamental attractiveness of hydrogen is that it can be produced from water using renewables and oxidised to liberate energy in a sustainable cycle that does not involve carbon directly.

The intermittency of most renewable energy resources makes inclusion of energy storage mandatory. Hydrogen storage is a major challenge because of its low density under ambient conditions: one kilogram of hydrogen gas occupies 11.94 cubic metres at 20 Celsius and 1 atmosphere pressure. Compression is required to store hydrogen gas in a reasonable volume, or alternatives such as liquefaction or solid-state storage must be employed.

The optimal mode of hydrogen storage/distribution depends on scale and end use. Some applications, such as islanded microgrids, require storage only, since the hydrogen is used internally, while export demands local storage and long-distance distribution. The challenge is to associate hydrogen storage and distribution modalities and technologies with the needs of the industry under consideration.

The Blue Economy CRC is funded in part under the Australian Government's CRC program administered by the Department of Industry, Science, Energy and Resources.

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THE OPPORTUNITY

In the context of the Blue Economy CRC, hydrogen will play a key role in integrating the supply side with the demand side, which needs not just electricity, but also oxygen and fresh water for aquaculture, and clean fuel for transport and survey vehicles.

Opportunity exists to build demand for hydrogen in the maritime sector, and the magnitude of this opportunity for Australia remains unclear. Growth is being seen internationally, with a targeted transition of shipping fleets to sustainable solutions (including hydrogen powered vessels) underway. Whilst much attention is paid to the global shipping fleet, service vessels, as used in the aquaculture industry, represent a significant fraction of global marine vessels and a major opportunity for a transition to sustainable propulsion. This presents an opportunity for the CRC but will require additional partners filling identified gaps. Further demand opportunities for hydrogen in the blue economy should be identified. Growth in demand for hydrogen will lead to increased need for cost-effective storage and distribution technologies.

In the wider picture, distribution of hydrogen within and between industries, and its export to international destinations, are increasingly recognised as important opportunities for Australia.

OUR RESEARCH

Objective
The objective of the study was to identify and characterise hydrogen storage and distribution technologies so that their applicability to the Blue Economy CRC and enterprises supported by it could be understood.

The study considered the technological suitability of particular hydrogen carriers and storage technologies for the range of energy scales from small islanded microgrid to major export industry, as well as technological readiness, reliability, survivability, economics and opportunities for new Australian industries.

Methodology
To conduct this study, we used energy and efficiency values extracted from the literature to calculate the energy requirements and costs of 16 hydrogen storage and transport modalities.

We analysed a total of 21 modalities, but were unable to complete the analysis on 5, due to insufficient data. There are three major assumptions made in this analysis:

- Each process has the same output to enable direct comparison;
- Energy input was generally best-case scenario (most efficient process); and
- Economic calculations are for comparison and should not be taken as absolute as they do not include costs such as labour, equipment, etc.

These assumptions enabled the calculation of energy costs for 16 hydrogen energy storage modalities: gaseous hydrogen, liquid hydrogen, ammonia, methane, methanol, dimethyl ether, formic acid, urea, carbons, metal-organic frameworks, two interstitial metal hydrides, two complex hydrides, methyl cyclohexane toluene cycle, and perhydro-dibenzyl toluene dibenzyl toluene cycle.

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OUTCOMES

The costs of storing and transporting hydrogen are very sensitive to the energy investment required to operate the storage recovery process.

From this work, we were able to show that for small-scale applications, storing pure hydrogen as compressed gas, liquid hydrogen, or hydrogen taken up by a material (e.g. adsorbed carbons or MOFs, or absorbed as an interstitial metal hydride) is the most energy efficient, providing the highest energy return on investment and the lowest break-even H2 sell prices in our example scenarios.

Because of the very high energy investment required, chemical storage of hydrogen for energy is unlikely to be profitable in comparison to GH2 at below-export scales, although the hydrogen-containing chemicals may have alternate markets that are more profitable.

NEXT STEPS

A number of opportunities arise out of this scoping study. To enable the use of hydrogen in supportive markets, short term opportunities might include:

- A detailed study should be carried out on storage scenarios for delivery of high-pressure hydrogen at 350-700 bar for vehicles and vessels, comparing (i) GH2 plus mechanical compression, (ii) LH2 plus mechanical compression, (iii) metal hydride plus mechanical compression and (iv) metal hydride with direct delivery at the demand pressure.
- A scoping study should be carried out on distribution scenarios at sub-export scales, comparing the newest near-commercial technologies: (i) compressed and containerised Type IV GH2 tanks, (ii) LH2, including the newest lattice-tank technology and (iii) metal-hydride in the form of a magnesium slurry.
- Compressed GH2 storage systems able to contain a higher mass percentage of hydrogen than the current Type IV tanks should be investigated for stationary storage and distribution, especially those able to be carried on current freight transport vehicles.
- Reversible hydrogen storage materials (principally metal hydrides, as these have higher TRLs) should be investigated for stationary long-term storage in the offshore context, noting that some metal hydrides are able to deliver hydrogen at 20 bar without compression.

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