Submission
No 4

# INQUIRY INTO DEVELOPMENT OF A HYDROGEN INDUSTRY IN NEW SOUTH WALES

**Organisation:** Geoscience Australia

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Australian Government
Geoscience Australia

# Geoscience Australia's submission to the NSW Legislative Council's Standing Committee on State Development's Inquiry into the development of a Hydrogen Industry in New South Wales

5 February 2021

# Contents

# Inquiry Terms of Reference

That the Standing Committee on State Development inquire into and report on the current state of, and opportunities for, the development of a hydrogen industry in New South Wales, and in particular:

1. The size of the economic and employment opportunity created by the development of a hydrogen industry in NSW, in particular those opportunities for regional NSW, including having regard to:

a. the emerging domestic and international trends in the production and demand for hydrogen, including in South Korea, the Netherlands, Japan and other Australian states and territories; and
b. NSW's existing and potential linkages to those markets.

2. The State's existing hydrogen capabilities, including:

a. NSW's research and development capacity for all elements of the hydrogen supply and demand chain, including existing research and development work of the Government, academic and private sector; and
b. The State's energy and industrial infrastructure which could support the production, storage, distribution, use and export of hydrogen.

3. The capacity of and barriers to NSW becoming a major production, storage and export hub for hydrogen, including NSW's capacity to:
    a. develop and commercialise hydrogen technologies;
    b. manufacture and export hydrogen production componentry, including electrolysis componentry;
    c. manufacture and export hydrogen storage and transport infrastructure, including in heavy transport and shipping vessels;
    d. generate green hydrogen through renewable energy sources;
    e. use hydrogen for transport;
    f. use hydrogen in its own industrial processes, such as in steel, aluminium and chemical production;
    g. use hydrogen for electricity generation, including the feasibility of retrofitting existing and proposed electricity generation assets to use hydrogen; and
    h. manage the safety and safeguarding of hydrogen utilisation.

4. The economics of hydrogen's use in different sectors of the economy, including emerging opportunities to use hydrogen in industrial processes and as a feedstock.

5. The infrastructure, technology, skills, workforce capabilities and other things needed to realise the economic opportunities of hydrogen as and when it becomes commercial in different sectors of the economy.

6. The actions needed of the public and private sectors, to support the development of a hydrogen industry in NSW and to realise the associated economic opportunities, including actions to manage any safety risks in the hydrogen industry.

# Introduction

Geoscience Australia is pleased to make this submission to the NSW Legislative Council's Standing Committee on State Development's *Inquiry into the development of a Hydrogen Industry in New South Wales.*

Geoscience Australia is Australia's national geoscience public sector organisation. We are the nation's trusted source of information on Australia's geology and geography for decisions by government, industry and communities.

Geoscience Australia provides science-based analyses, data, and advice on Australia's resources. In relation to the development of a hydrogen industry in Australia, Geoscience Australia provides geospatial information and data to assist governments and industry with their planning and to identify regions with high potential for future hydrogen production.

Geoscience Australia partners with and provides foundational data to industry and governments in Australia to encourage increased investment into the emerging national hydrogen industry. We support the implementation of Australia's National Hydrogen Strategy by achieving the objectives of Geoscience Australia's ten year Strategic Plan: Strategy 2028.

In preparing this submission, Geoscience Australia has reviewed the Terms of Reference for the Inquiry and has focussed on the following areas: renewable energy resources, supporting infrastructure, underground hydrogen storage and water resources.

# Hydrogen production potential and supporting infrastructure

## Overview

Hydrogen can be used for a variety of domestic and industrial purposes: heating and cooking (as a replacement for natural gas); transportation (replacing petrol and diesel); as an alternative chemical feedstock; and energy storage (by converting intermittent renewable energy into hydrogen). The key benefit of using hydrogen is that it is a clean fuel that emits only water vapour and heat when combusted. A clean hydrogen industry provides a pathway to reducing $CO_2$ emissions in hard-to-abate sectors of the economy (e.g. heavy vehicle transportation) and is a source of revenue and jobs. Clean hydrogen can be produced from fossil fuels (coal, gas) with carbon capture and storage (blue hydrogen) or through electrolysis using renewable energy (green hydrogen). As per the terms of reference, only the renewable production method is considered in this submission.

In 2019, Geoscience Australia completed a geospatial analysis of hydrogen production potential across Australia for the National Hydrogen Strategy (Feitz et al., 2019), which found that large parts of NSW were prospective for renewable hydrogen production (Figure 1). Building on this initial work, Geoscience Australia has since developed new tools and datasets to assist governments and industry to assess hydrogen production potential in Australia, including:

- the AusH2 data portal (AusH2.ga.gov.au), which provides access to over 7,000 national-scale datasets including infrastructure layers. The data layers can be viewed and overlayed with other layers in the portal or can be downloaded for use in the user's own geospatial software;

- the Hydrogen Mapper, which is an online and multi-criteria geospatial assessment tool that maps hydrogen production potential across Australia; and
- the Hydrogen Economics Fairways Tool (HEFT), which combines large scale infrastructure and hydrogen relevant datasets and cost models to enable geospatial analysis of the economic viability of potential hydrogen operations across the country.

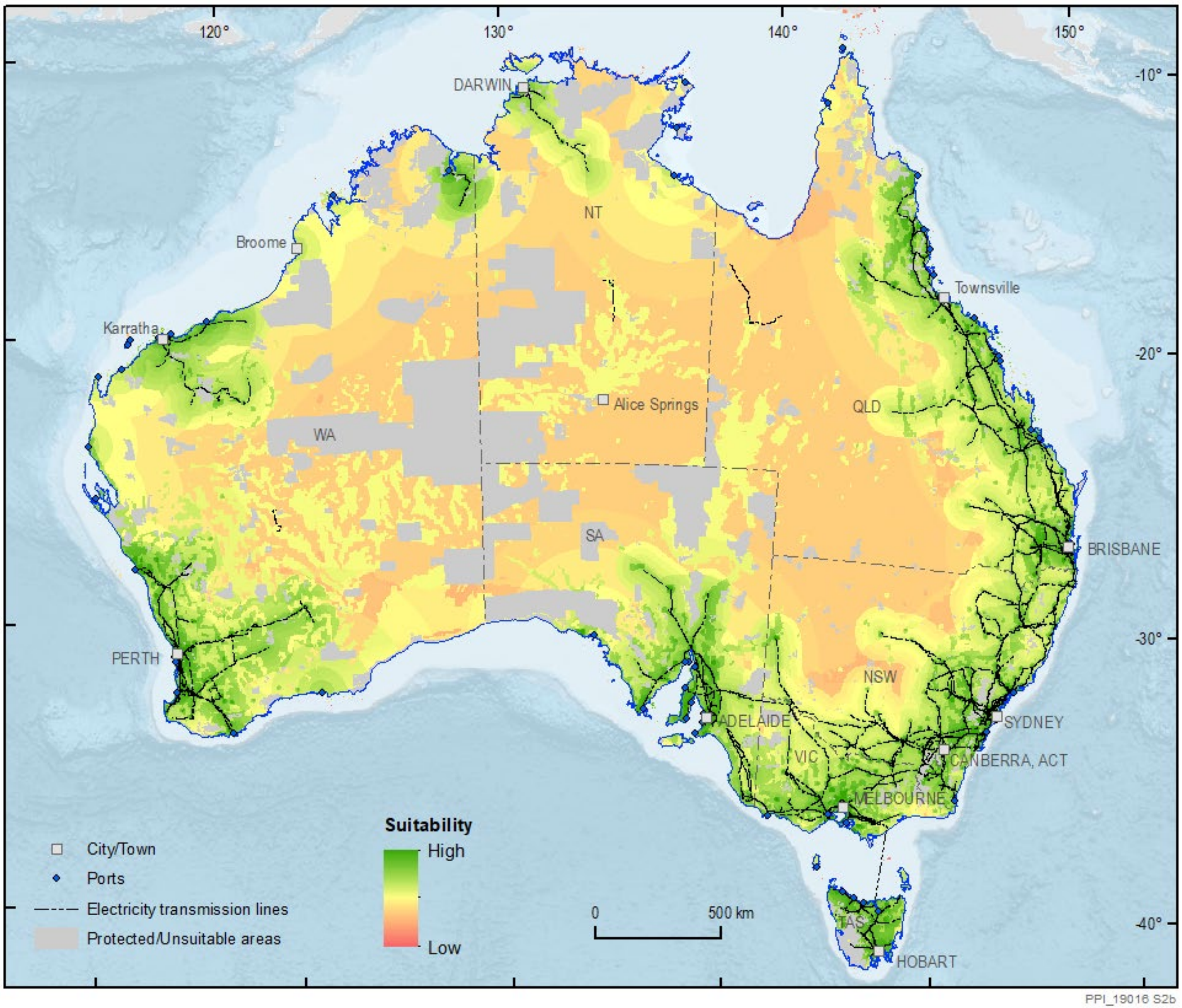



**Figure 1**: National hydrogen prospectivity heat map based on future production of renewable hydrogen in coastal areas. Areas with high potential for hydrogen production are derived by assessing the availability of renewable energy that can be transported through the existing electrical grid for use in coastal areas. This scenario assumes that most future hydrogen production will use desalinated seawater (Feitz et al., 2019).

Applying these tools, we demonstrate below that NSW has potentially suitable ports, infrastructure, water resources and good renewable energy resources to support a hydrogen industry.

## Water resources

The production of hydrogen requires large volumes of water. At least nine tonnes of water are needed for each tonne of hydrogen produced when using renewable energy and electrolysis. The most sustainable sources of water identified in Australia's National Hydrogen Strategy, especially for large scale hydrogen exports, are seawater desalination and wastewater recycling.

Water recycling is supported by the NSW government (NSW Health, 2018) and there are well established regulatory and approval processes to support its use. As identified in our study prepared for the National Hydrogen Strategy, NSW has vast wastewater resources that could be potentially used as a water resource for hydrogen production (Feitz et al., 2019). Sydney, for example, produces approximately 593 gigalitres (GL) per year of drinking water and collects approximately 463 GL per year of wastewater (treated to varying standards) (Sydney Water, 2018). Less than 10% of the collected wastewater is recycled. Increased harvesting of water from wastewater for hydrogen production could be an option for urban centres where there is often an excess of treated wastewater due to disposal restrictions. For example, depending on the receiving body, there may be no or limited river disposal options due to elevated nutrient levels in the treated wastewater.

It is worth putting these volumes of water into context: even under the most ambitious 2050 scenario for *national* hydrogen production as outlined in Australia's National Hydrogen Strategy (18 megatonnes (Mt) per year nationally), it is estimated that the total volume of water required is 207 GL per year (COAG, 2019). This is less than half of the treated wastewater discharged annually from Sydney.

Noting the above, Geoscience Australia does not consider water resources a limitation for large scale hydrogen production in NSW, provided it is limited to coastal and populated areas where desalinated water and wastewater can be utilised. Additional to surface water resources, wastewater recycling could also be a source of water for hydrogen production in regional communities.

## Renewable energy resources

There are sufficient renewable energy resources in NSW, particularly when using a combination of wind and solar. A key factor for assessing the potential for renewable energy generation is the capacity factor. The capacity factor is the ratio of actual electrical output from a renewable power plant compared to its maximum possible output. The higher the capacity factor, the greater the plant's ability to produce electricity. Electricity is essential for electrolysis - the process that splits water into hydrogen and oxygen.

As outlined in the National Hydrogen Strategy, there is arguably no country better placed than Australia to harness solar energy. Australia also has some of the world's best wind resources. Geoscience Australia has since undertaken further work with Monash University quantifying Australia's renewable energy resources and will shortly be releasing capacity factor maps for solar, wind and hybrid wind and solar across Australia.

These maps have identified that there are abundant solar resources located in western NSW with lower solar generation capacity along the eastern seaboard (Figure 2). Capacity factors for purely solar energy generation range from 15% to 23%. Excellent wind resources exist along the Great Dividing Range, with predicted capacity factors of up to 39% (Figure 2). The highest capacity factors, up to 53%, can be achieved with a combination of wind and solar, with a 50:50 split of solar:wind considered ideal for most locations (Figure 3). Importantly, the minimum predicted capacity factor in this scenario remains relatively high at 25%. This is because a site can reliably generate solar renewable energy during the day and can often supplement this with wind energy at other times of the day and night, increasing the overall renewable energy generation possible at a single location.

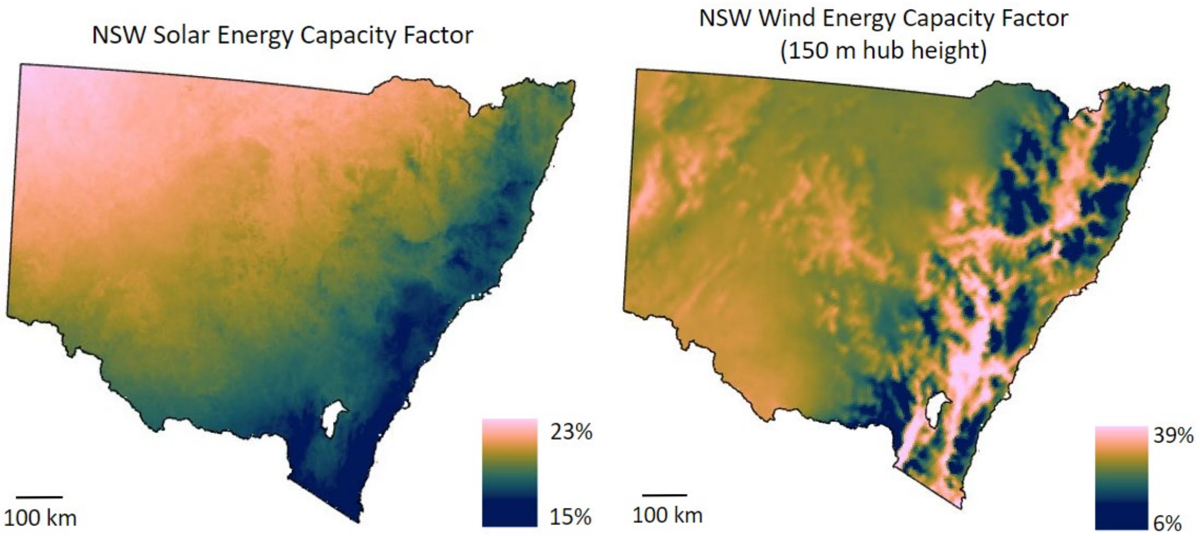



**Figure 2:** Solar energy (left) and wind energy (right) capacity factor maps for NSW. The capacity factor for wind is based on a wind turbine hub height of 150 metres.

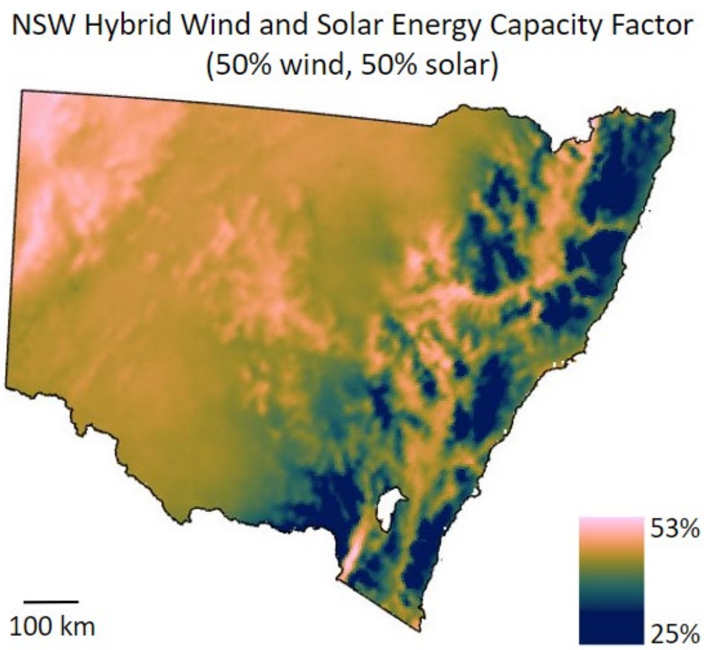



**Figure 3:** Hybrid wind and solar energy capacity factor map for NSW. The ratio of wind energy to solar energy is 50 % wind energy and 50 % solar energy. The capacity factor is based on a wind turbine hub height of 150 metres.

Regions with the highest capacity factor for hybrid wind and solar energy are located in the north-west, central west and along the Great Dividing Range. Due to the increased capacity factor and consequently larger amount of electricity potentially available for green hydrogen production, hydrogen operations could increase in scale when powered from hybrid wind and solar power plants. The availability of optimally mixed wind and solar energy resources (at locations such as the Great Dividing Range) in relatively close proximity to the coast and potential hydrogen ports indicates that NSW could host a large scale hydrogen export industry.

## Natural gas networks

Using clean hydrogen in Australian gas networks is a key strategic action under the National Hydrogen Strategy and helps to create an early market for hydrogen producers. Gas blending occurs when hydrogen gas is mixed into the natural gas distribution network. Volumes of up to 10% hydrogen gas can be safely blended into the existing natural gas network with no significant impacts on, or implications to, gas quality, safety and risk, materials, and network capacity (GPA Engineering, 2019).

Geoscience Australia's analysis of gas pipeline easements in NSW shows that they are well connected to potential hydrogen export ports, with major gas transmission lines connecting to Wollongong and Newcastle (Figure 4).

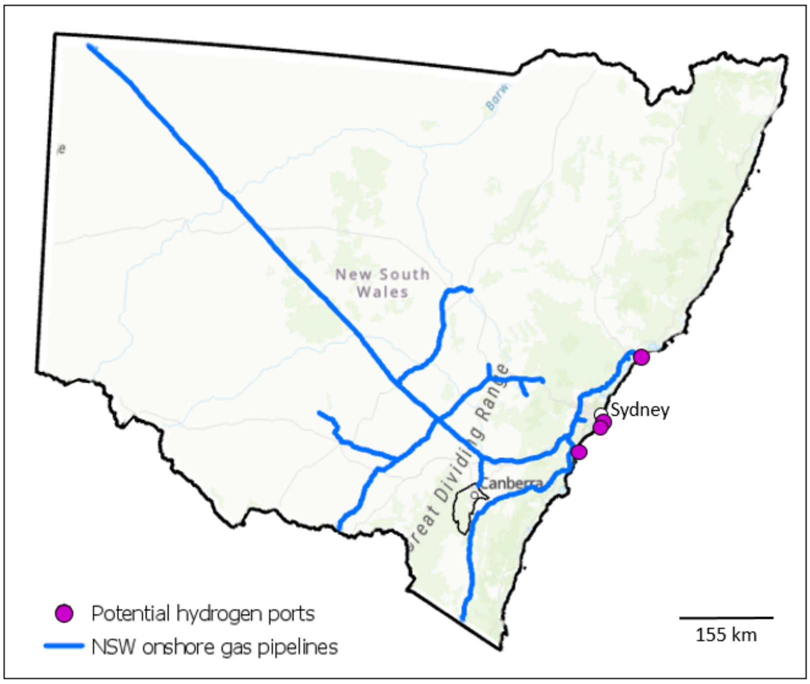



**Figure 4:** Onshore natural gas transmission network in NSW (potential hydrogen port data from Arup, 2019).

## Ports

Port infrastructure is an important consideration when determining NSW's suitability for a hydrogen export industry. In 2019, the engineering firm Arup conducted a technical study into hydrogen hubs in Australia and identified potential liquid hydrogen export locations across the country, including four sites in NSW: Kurnell, Newcastle (Kooragang Island), Port Botany, and Port Kembla (Figure 5). However, it should be noted that this list is not exhaustive and other ports may also be suitable.

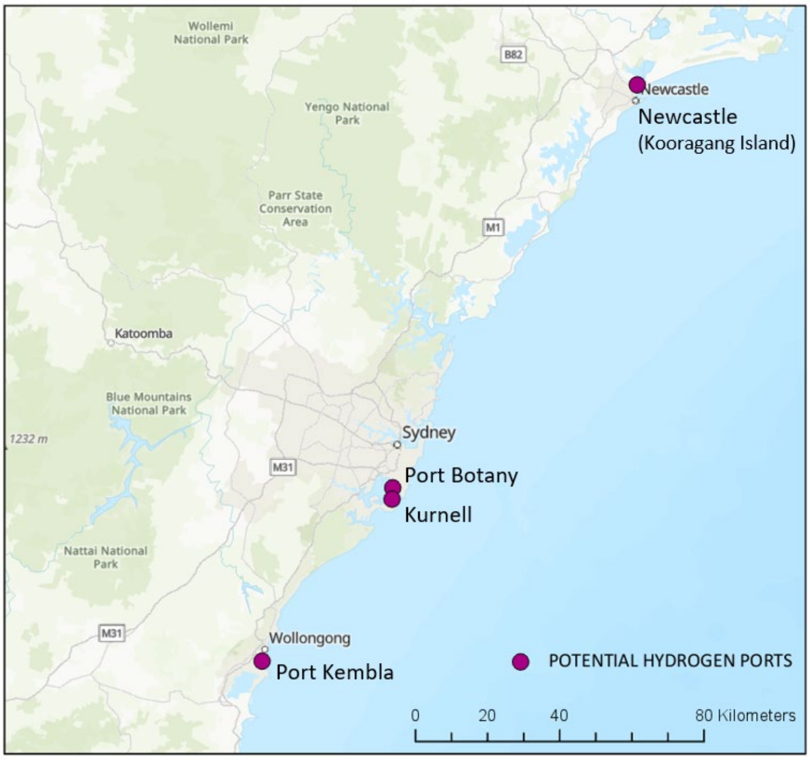


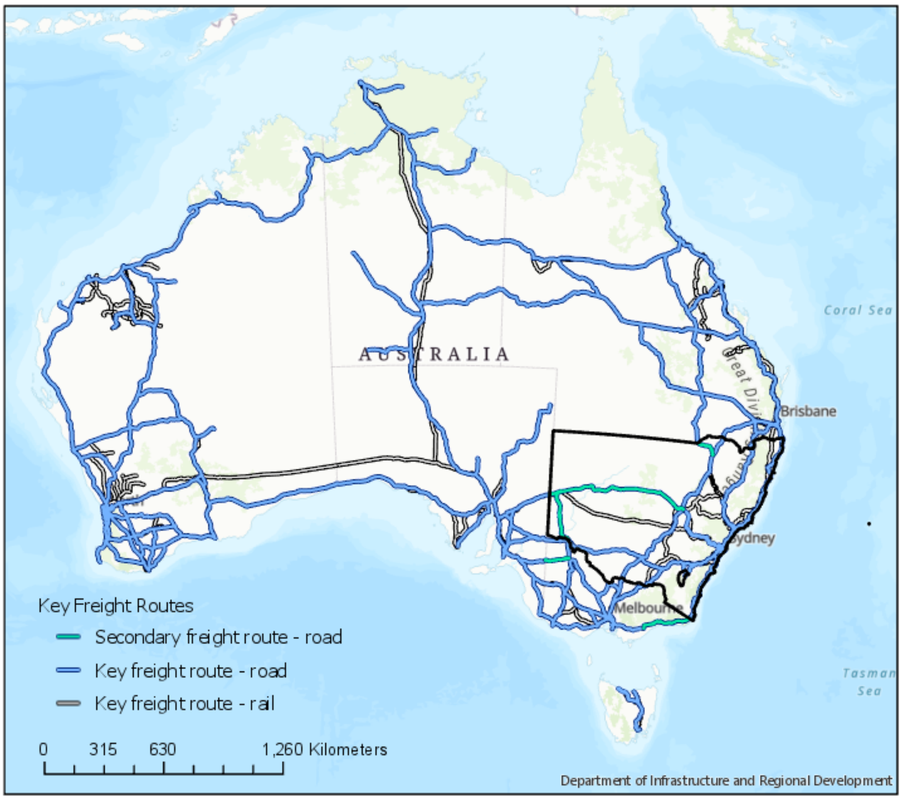

**Figure 5**: Potential ports for hydrogen export (potential hydrogen port data from Arup, 2019).

Arup (2019) considered minimum port infrastructure requirements when selecting sites. Criteria included the ability of a site to accommodate the transport of liquid hydrogen through either the modification of an existing liquids berth at the port, or the potential to develop a hydrogen specific berth at the site. Existing ports that do not require new channel development, dredging or deepening are considered to be more suitable than those that require extensive modifications due to lower development costs. Ports that are designed for new loading volume and have available space for berth extension, depth increase, and land-side development are considered to have potential as hydrogen export locations (Arup, 2019).

Building on this previous work, Geoscience Australia, in collaboration with Monash University, has undertaken a geospatial cost analysis of producing and transporting renewable hydrogen. A preliminary finding from this work is that hydrogen transport can add significantly to the overall cost of the hydrogen supply chain. Renewable hydrogen production close to the location of use or export could therefore improve the overall economics of the hydrogen supply chain. The four potential hydrogen export sites identified by Arup (2019) in NSW are located within urban areas close to potential domestic markets for hydrogen (e.g., gas blending, transport, etc.). The use of such port facilities as production sites for both the domestic and international export markets could lead to the development of 'hydrogen hubs' in these areas. Hydrogen hubs have been identified in the National Hydrogen Strategy as a key pathway for achieving the scale needed for a competitive industry. Hubs create clusters of large scale demand and make the development of infrastructure more cost-effective, promote efficiencies from economies of scale, foster innovation, and promote synergies from sector coupling (COAG, 2019).

## Key freight routes

Key freight routes for road and rail across Australia and in NSW represent existing transport corridors available for potential domestic hydrogen transportation (Figure 6). Existing freight corridors will be essential for the distribution of clean hydrogen for use in the transportation sector (refuelling stations for hydrogen fuel cell electric vehicles, including heavy vehicles such as trucks) and for gas blending in regional towns. Geoscience Australia's recent work on the location and suitability of key freight routes across Australia for transporting hydrogen show that in NSW they are well distributed across the state, connecting potential hydrogen production facilities on the coast with regional centres in NSW. Major freight routes also have good connectivity with neighbouring states, facilitating interstate transport of green hydrogen from NSW.



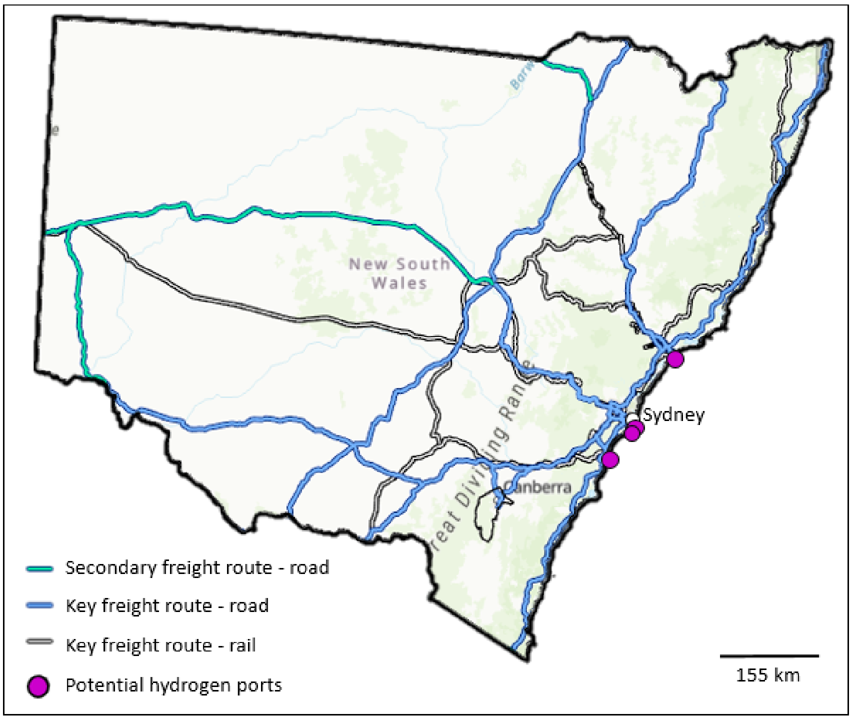




**Figure 6:** Key road and rail freight routes in Australia (top) and NSW (bottom) (potential hydrogen port data from Arup, 2019).

## Electricity network

Connection to electricity supplies is essential for hydrogen production. Any future renewable energy based hydrogen facility will either require access to the electricity grid (to purchase renewable energy) or to accessible land to develop a renewable energy plant that can power the hydrogen plant's electrolyser. Access to electricity networks also facilitates potential hydrogen firming of the electricity network during periods of low renewable energy generation, ultimately replacing natural gas firming facilities.

Geoscience Australia's analysis of existing electricity transmission lines for NSW demonstrates that the state has good coverage across most of the south and east (Figure 7). Limited access to transmission lines in the west and north-west regions of NSW indicates that off-grid renewable energy power plants would be required for green hydrogen production in these regions.

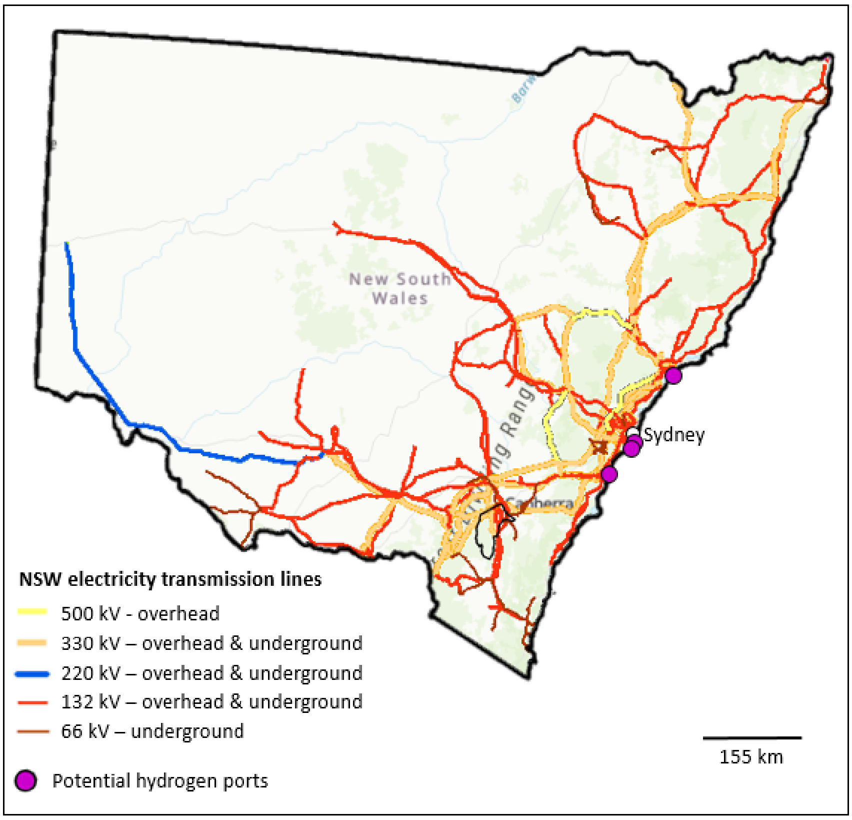



**Figure 7:** Electricity transmission line network across NSW (potential hydrogen port data from Arup, 2019).

# Current hydrogen capabilities and activities

## Research Projects and Centres in NSW

Geoscience Australia tracks the research and development of hydrogen projects and research centres in Australia in order to inform industry and government on the current status of clean hydrogen in the country. This information is displayed in the Australia's Hydrogen Opportunities tool (AusH2) online portal AusH2.ga.gov.au (Figure 8). Geoscience Australia works in collaboration with CSIRO's HyResource website to ensure the accuracy and national consistency of hydrogen project and research centre information.

As of January 2021, there are currently three active hydrogen projects in NSW listed on AusH2:

- The Manilla Solar Renewable Energy Storage Project
- The Port Kembla Hydrogen Hub
- The Western Sydney Gas Project

Details on each of the projects are displayed on AusH2 including the type of project, energy resource, size, project summary and spatial information (Figure 9). Project details are confirmed with the operator and new projects are updated every quarter. The information is useful for potential investors and shows where natural hydrogen hubs are forming.

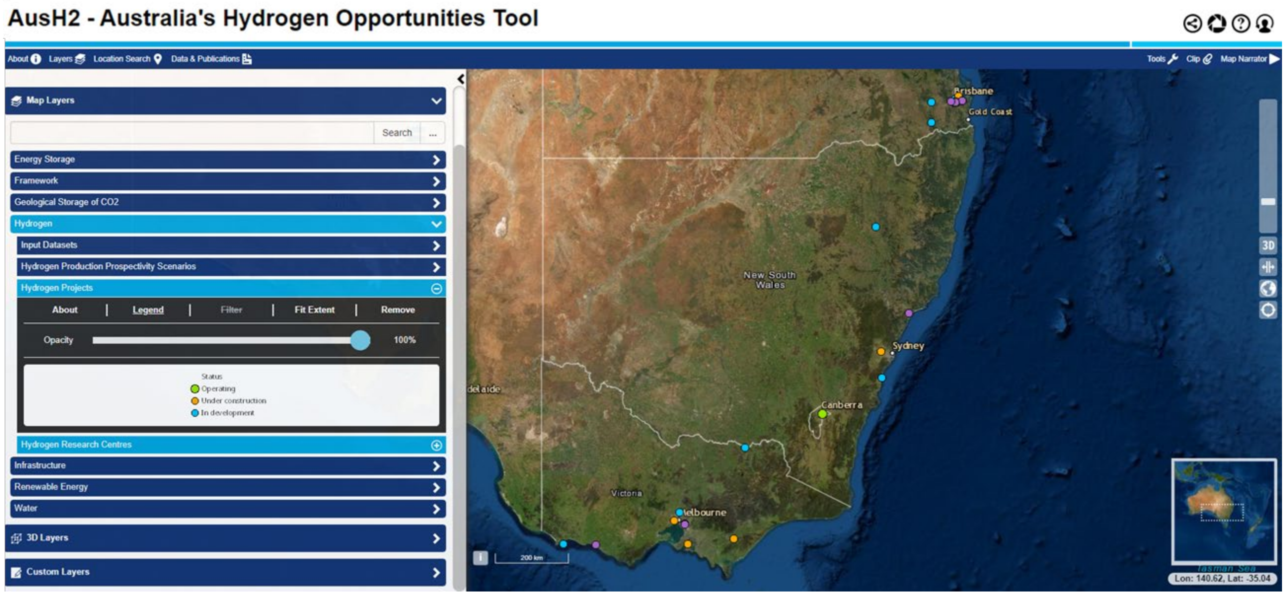



**Figure 8.** Screenshot of AusH2 showing location of hydrogen projects and research centres in NSW (AusH2.ga.gov.au)

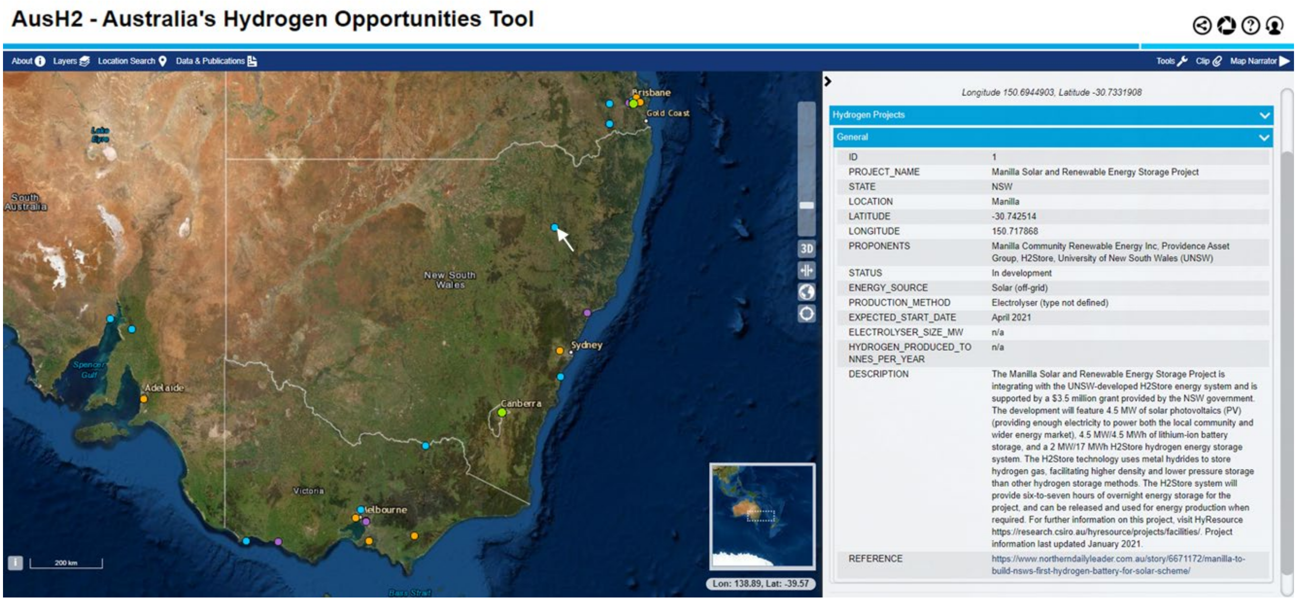



**Figure 9.** Screenshot of a project summary example showing the types of project details available at AusH2 (AusH2.ga.gov.au). Project information can also be downloaded from the data portal.

As of January 2021, there are currently five hydrogen research centres listed on AusH2, located at two universities (Table 1). The scope of research covers the entire hydrogen supply chain, most notably the production and storage of hydrogen. Information listed in Table 1 has been collected from AusH2 (2021) and HyResource (2021). With ever-growing interest in this field, it is probable that there are other hydrogen research centres and projects in NSW that have not yet been captured, and their number is expected to increase further over the coming years. To support development of the industry, relevant agencies in NSW will need to closely monitor the extent of hydrogen research in order to adequately quantify the state's hydrogen research capabilities, and the AusH2 and HyResource tools are user-friendly applications to enable this.

**Table 1:** Identified hydrogen research centres in NSW. Data sourced from AusH2 (2021) and HyResource (2021).

| Research Activity | Lead Participant | Status | Hydrogen Supply-Chain Category |
|---|---|---|---|
| **Highly Efficient & Low Cost Photovoltaic-Electrolysis System** | University of New South Wales | In progress | Hydrogen production |
| **Waste Biomass to Renewable Energy** | University of New South Wales | In progress | Hydrogen production |
| **ARC Training Centre for the Global Hydrogen Economy** | University of New South Wales | In progress | Whole supply chain |
| **Hydrogen Energy Research Centre** | University of New South Wales/Providence Asset Group | In progress | Hydrogen storage |
| **The Newcastle Institute for Energy and Resources (NIER)** | University of Newcastle | In progress | Whole supply chain |

## Hydrogen Economic Fairways Tool (HEFT)

Geoscience Australia is currently collaborating with Monash University to develop the Hydrogen Economic Fairways Tool (HEFT), which is an online tool designed to support decision making by policymakers and investors on the location of new infrastructure and development of hydrogen hubs in Australia. HEFT combines large scale infrastructure and hydrogen relevant datasets and cost models to enable geospatial analysis of the economic viability of potential hydrogen production operations across the country. It provides a high level, first pass assessment to identify prospective hydrogen production regions (Figure 10). Feedback during initial testing from a range on national and international companies has been positive with users seeing benefit in the nationally consistent, high level assessment the tool can provide. HEFT will be available on the AusH2 website in March 2021.

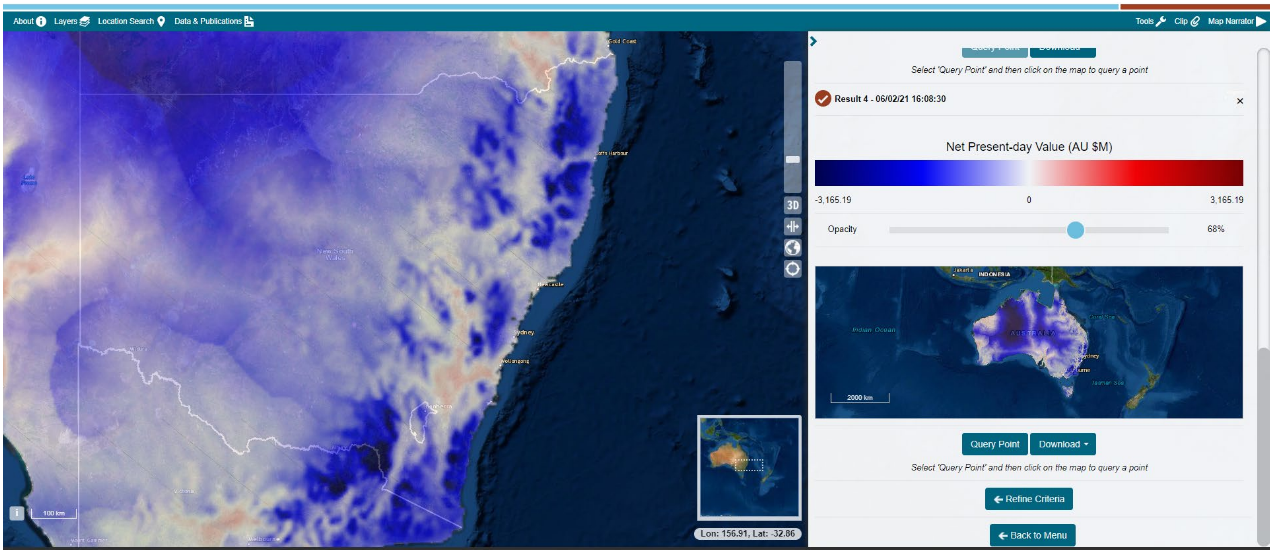



**Figure 10.** Screenshot of an example simulation using the Hydrogen Economic Fairways Tool (HEFT) for a hybrid wind and solar hydrogen production scenario. Given customisable assumptions around wind:solar ratios, target hydrogen price and other factors, maps like the one shown here can be produced showing regions with positive and negative net present value. The HEFT tool will be available at AusH2 (AusH2.ga.gov.au) in March 2021.

# Potential barriers

## Underground hydrogen storage

For a large scale hydrogen industry to develop in Australia, hydrogen storage is key to balancing variable hydrogen production from renewable energy with domestic and export demand. Pipeline storage, solid state hydrogen storage technology, and above ground tanks can provide small scale hydrogen storage, but for large scale storage, underground hydrogen storage is currently the only viable option.

Geoscience Australia is currently assessing practical options nationally for large scale underground hydrogen storage, with large storage capacity (volume) and lower cost than above-ground storage. Of the geological (underground) options, salt caverns are considered the most optimal for large scale hydrogen storage (HyUnder, 2013; Caglayan et al., 2020). A salt cavern is constructed by drilling a well into a thick sequence of salt rock (typically halite bearing rock that is hundreds of meters thick) and dissolving out the salt using fresh water, leaving a cavern for gas storage. All commercially produced hydrogen that is stored underground worldwide is currently stored in salt caverns, such as in the United Kingdom (e.g. Teesside) and the United States (e.g., Clemens Dome, Spindletop, and Moss Bluff). The majority of the internationally planned hydrogen storage facilities are also targeting salt caverns (Zivar et al., 2020).

Our assessment so far indicates that salt storage may not be possible in NSW as there are no known underground thick salt resources in the state (Figure 11). While the map is preliminary and more geological basins may be prospective for salt (Boreham et al., 2021), to date salt has only been detected from minor evaporates in wells drilled in the Bancannia Trough in far western NSW (Wells, 1980). However, it is very unlikely that these would be suitable for salt storage of hydrogen.

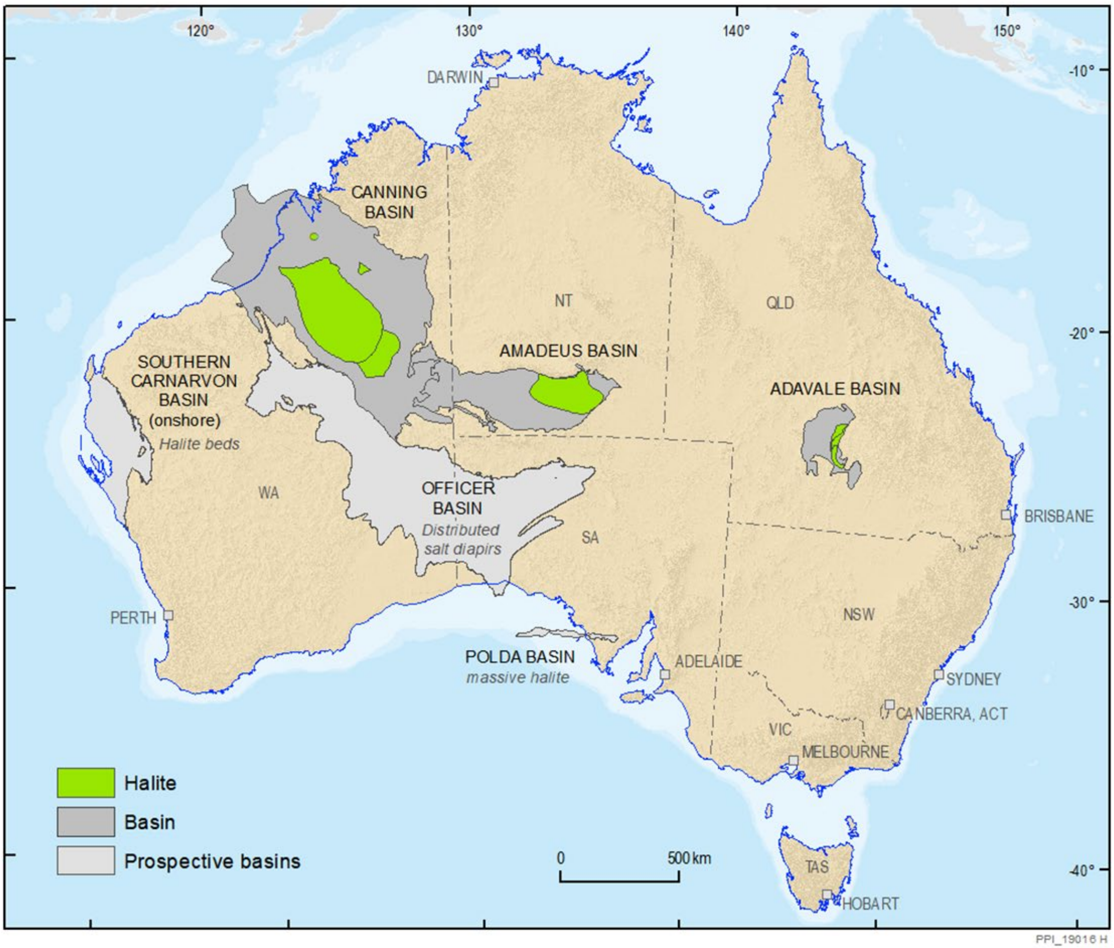



**Figure 11.** Preliminary map showing the location of major halite salt deposits for onshore Australia. Halite deposits could provide underground storage for hydrogen in Australia or act as seals for storing hydrogen in underlying permeable sandstones (Geoscience Australia, Version 2, June 2020).

Large volumes of natural gas (approximately 283 petajoules (PJ) of storage capacity nationwide) are stored underground in Australia in depleted gas reservoirs (Figure 12), providing seasonal and flexible gas supply. Although there are, as yet, no global examples of pure hydrogen stored in depleted gas reservoirs, they are a promising possibility for large scale hydrogen storage and several field trials are proposed or underway (e.g., the Underground Sun Storage project in Austria; https://www.underground-sun-storage.at/en/project/project-description.html). NSW does not have any identified conventional gas reserves or contingent resources and current and planned gas production in NSW is via coal seam gas. It is not possible to store and recover pure hydrogen from mined coal seams due to the reactivity between hydrogen and coal. One small depleted gas field is located at Coonarah Gas Field in northern NSW near Narrabri (Figure 12), however, this is located hundreds of kilometres from potential hydrogen ports and gas pipelines (Figure 4).

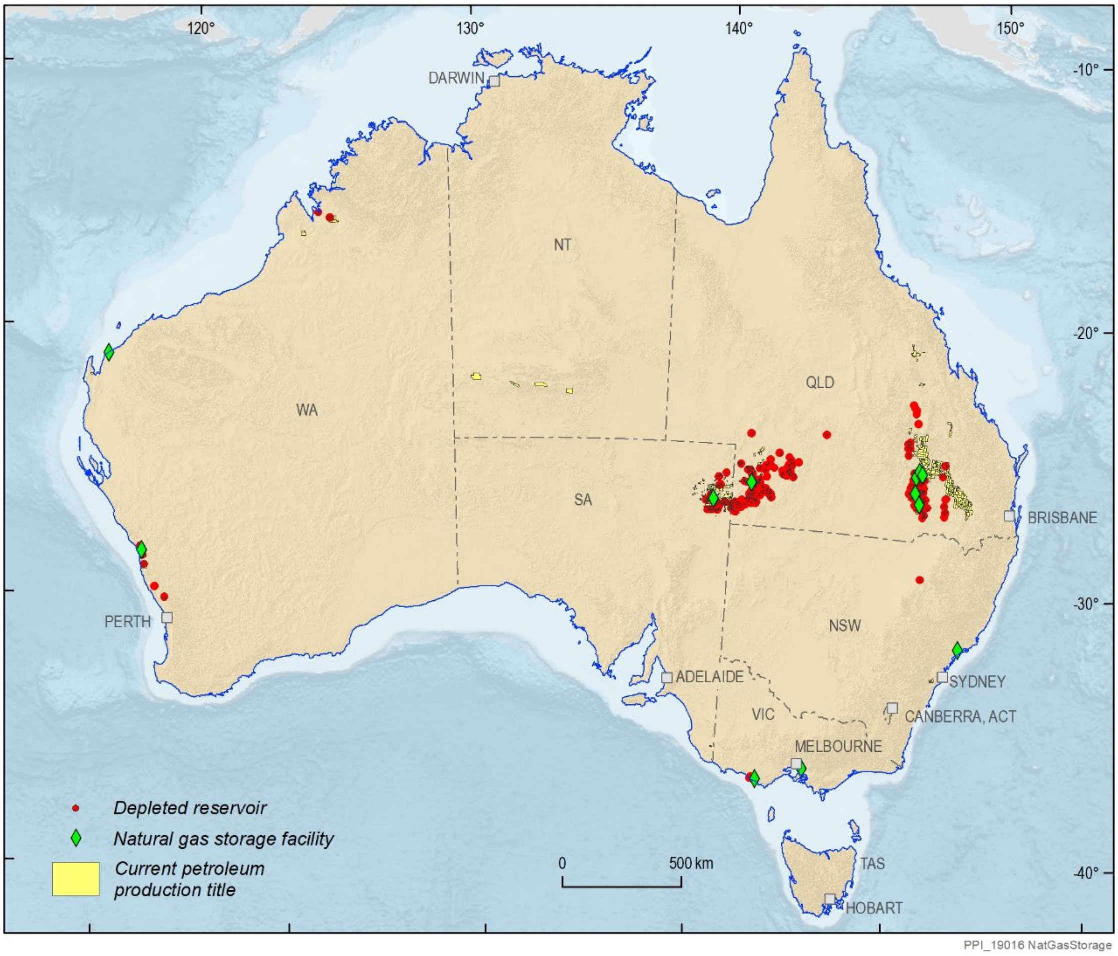



**Figure 12.** Onshore depleted oil and gas reservoirs, petroleum production areas, and natural gas storage facilities. The natural gas storage facility to the north of Sydney is the above ground Newcastle liquid natural gas (LNG) facility (capacity 1.5 PJ). The red dot in northern NSW is the depleted Coonarah Gas Field.

Similar to the requirements for geological storage of carbon dioxide, aquifer storage of hydrogen requires a groundwater reservoir with high permeability and a sealing caprock. The sandstones in NSW are generally very old, and their primary permeability and porosity has been altered during geological processes over many millions of years. The Kulnura Anticline near Sydney was identified as a possibility for saline aquifer storage of carbon dioxide (Bradshaw et al., 2001), but its depth (>2,000 metres (m)), thickness (~25 m or less) and low permeability and porosity make it a challenging target for hydrogen storage. Another potential saline aquifer storage option is located within the Pondie Range Trough north of Wilcannia in western NSW (CIN, 2021) although this option also does not appear to be particularly suitable for hydrogen storage. It is possible that in future additional shallower aquifers will be discovered that have the capacity to store hydrogen, which is not subject to the depth restrictions that govern supercritical $CO_2$ storage (i.e., >800 m depth).

Without access to salt resources and limited access to large conventional depleted gas reservoirs, NSW will need to consider alternative underground storage options if large scale hydrogen storage is required. Geoscience Australia recommends effort be placed into research and pilot studies exploring underground hydrogen storage in non-potable aquifers and hard rock caverns (igneous or metamorphic rocks) in NSW. The mining industry has extensive experience in hard rock mining that, in collaboration with Government, could be adapted to hydrogen storage in pilot or demonstration projects (e.g., underground gold and copper mines in the central west of NSW). Hard rock caverns can be lined with stainless steel or plastic to provide further security of storage and ensure contamination of the stored hydrogen is minimised. Abandoned mines could even be adapted for hydrogen storage (Zivar et al., 2021). While hard rock caverns are likely to be more expensive to establish than storage in depleted gas reservoirs (Lord et al., 2014), they have an advantage in that hydrogen can be injected and extracted multiple times per year, in comparison to aquifer storage where the process of injection and extraction is much slower (typically once per year).

# Conclusion

NSW has suitable renewable energy resources, infrastructure, and water resources to support development of a green hydrogen industry large enough for domestic use and export. Further work is needed to assess the economic viability of the hydrogen supply chain in NSW and to identify potential hydrogen storage options.

Geoscience Australia makes the following recommendations:

- *Investment from the public and private sectors into economic research to minimise hydrogen supply chain costs and maximise potential economic benefits for NSW.*

While the Hydrogen Economic Fairways Tool (HEFT) being developed by Geoscience Australia and Monash University will provide a useful first pass assessment to identify prospective hydrogen production regions, further in-depth supply chain studies will be required to promote investment into developing hydrogen industries in the state.

- *Research into hydrogen storage requirements and storage options.*

Current geological knowledge indicates that storage in salt caverns or depleted gas reservoirs may not be an option for NSW. Under this scenario, Geoscience Australia recommends, in the first instance, NSW should assess the degree of storage that will be required and determine the potential storage ‘gap’, especially for potential export markets. With respect to underground storage, NSW may need to consider alternative hydrogen storage options to storage in salt or depleted gas reservoirs. Pipeline storage, solid state hydrogen storage technology, and above ground tanks can provide a degree of hydrogen storage, but for large scale storage, underground hydrogen storage may be required. There should be support for research efforts, possibly as pilot or demonstrations projects in collaboration with industry, into identifying suitable aquifers and possibly hard rock caverns or abandoned mine conversions as alternatives to salt or depleted gas reservoir storage.

- *Closely monitor research and development efforts focussed on the hydrogen supply chain*.

Research and development of all aspects of the hydrogen supply chain are likely to increase over the coming years and Geoscience Australia recommends ongoing monitoring of the developing research capability within NSW. There are opportunities for government to work with the university sector to drive down hydrogen production and storage costs, and with industry on pilot and larger scale demonstrations.

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