Australian Government

Department of Climate Change, Energy, the Environment and Water

State of Hydrogen

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Message from the Minister

Green hydrogen is at the heart of our vision for Australia as a prosperous, self-reliant nation in a net zero future; as a renewable energy superpower; and as a country that makes things.

Australia has a world class renewable opportunity and an enviable track record of standing up new energy industries and Australian industry champions with international partners. We owe it to ourselves and to the next generation to make the most of these early advantages. We must shape an economic and energy export future for Australia as the world shifts towards net zero.

Bringing down the price of energy with new renewables is essential to realising low-cost green hydrogen at scale.

But renewable electricity and hydrogen are just the start. Upstream, we want to see advanced manufacturing for key technologies like electrolysers, underpinned by a green hydrogen industry's developing scale. Downstream, green hydrogen opens the door to value adding investments towards products such as green metals, green fertiliser, and green chemicals – products increasingly in demand from the Australian economy and export markets.

I am pleased, therefore, to release this 2022 State of Hydrogen report. Australia's announced pipeline of over 100 hydrogen projects is worth around $230-300 billion of potential investment. This represents close to 40% of all global clean hydrogen project announcements, and underlines Australia's potential to be among the global leaders.

But this year's report is also a call to action. Most of the project announcements in this pipeline are yet to reach final investment decisions. Global hydrogen leaders have caught up to our early lead and are advancing fast. We face determined competition from other countries in the hydrogen race, that also see the hydrogen opportunity and are implementing substantial and practical measures to stimulate their own industry growth.

All Energy and Climate Ministers recognise the need to do more. That is why on February 24, I and all State and Territory Government Energy and Climate Ministers agreed to refresh and update Australia's National Hydrogen Strategy.

This report is an important input into how and where we need to focus our effort. The next steps will be critical to keeping Australia on the path to be a global hydrogen leader by 2030, with an industry that will help decarbonise our economy as well as developing the new export industries our economy will need to ensure our ongoing prosperity.

Chris Bowen
Minister for Climate Change and Energy


H2 HYDROGEN POWER
CLEAN ENERGY OF THE FUTURE


Hydrogen


Hydrogen
Purification


H2
Hydrogen H2
zero emission H2

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State of Hydrogen at a glance

Purpose of this report

Australian governments have committed to publishing an annual State of Hydrogen report to track Australia's hydrogen industry development and progress against global developments.

Australia's hydrogen powerhouse opportunity

Hydrogen is a safe, flexible, transportable and storable energy carrier that has been used across a range of industries for many years. The newfound global interest in hydrogen reflects the potential to produce hydrogen in a way that is both cost effective and emits drastically less carbon than traditional production techniques that rely on the unabated use of fossil fuels. Once produced, this low emissions hydrogen can support current industrial uses, and new decarbonisation pathways in sectors that are otherwise largely dependent on fossil fuels such as heavy transport and industry, chemical feedstocks, industrial process heat and long-term energy storage.

According to the IEA's Global Hydrogen Review 2022[1], there has been a modest increase (5%) in demand for hydrogen worldwide since its previous review, with most of this demand met through unabated fossil fuel-based production[2]. Hydrogen produced using low emissions technology met a very small component of demand, but the level increased by 20% on the preceding year. Geo-strategic developments have also put upwards pressure on the price of natural gas (methane), reducing the cost gap between traditional fossil-fuel based hydrogen production and production based on the electrolysis of water using renewable electricity. It has also reduced the gap between gas to hydrogen fuel switching pathways for industry.

There are some signs of increasing demand. For instance, in 2022 the European Commission doubled the previous EU renewable hydrogen target to 10 million tonnes of annual domestic production and an additional 10 million tonnes of annual hydrogen imports. Additionally, there are substantial increases in announced production projects in anticipation of demand. The IEA also report in 2022 that global electrolyser capacity may reach 134 GW in 2030[3], more than twice the IEA's projected level of 54 GW in the preceding 2021 report.

The International Energy Agency (IEA) has declared 2022 as the year that hydrogen moved to centre stage in global energy and climate policy deliberations. The IEA's flagship 2022 World Energy Outlook report states "*The cost advantages of mature clean energy technologies and the prospects for new ones, such as low-emissions hydrogen, are boosted by the Inflation Reduction Act in the United States, Europe's increased push for clean energy, and other major new policies.*" And "*Investment in low-emissions gases, such as hydrogen, is set to rise sharply in the coming years…to reach over 30 million tonnes (Mt) per year in 2030. Much of this is produced close to the point of use, but there is growing momentum behind international trade in hydrogen and hydrogen-based fuels*."[4]

Australia is well placed to play a significant role in the global hydrogen industry due to our renewable energy potential, the availability of space to support renewable electricity generation, fossil fuel resources and stable geology to enable carbon capture and storage to be combined with fossil fuel-based hydrogen production as well as provide a cost-effective option for long term hydrogen storage. Australia also has a skilled resource and energy workforce and a long history as a trusted energy and resources exporter.

According to Bloomberg New Energy Finance, Australia's hydrogen and derivatives industry investment pipeline of AUD$230 to $300 billion[5] represents approximately 40 per cent of all global renewable hydrogen projects announced to date[6]. Australia stands to gain significant economic benefits by ensuring this pipeline of potential investments progresses to completion. The number of proposed, approved (final investment decision) and operational hydrogen and ammonia projects in Australia has more than doubled in the last year to over 100[7] (Appendix 6).

1 IEA (2022) Global Hydrogen Review. IEA. Paris
2 IEA estimates meeting this demand results in the production of approximately 900 Mt CO2
3 IEA (2022) Global Hydrogen Review. IEA. Paris
4 IEA (2022) World Energy Outlook 2022. IEA. Paris
5 DISR (2022) The Resource and Energy Major Projects Report. www.industry.gov.au/publications/resources-and-energy-major-projects-2022
6 BNEF, 'Australian Hydrogen Projects' (2022)
7 HyResource (2022) Industry projects - https://research.csiro.au/hyresource/projects/facilities

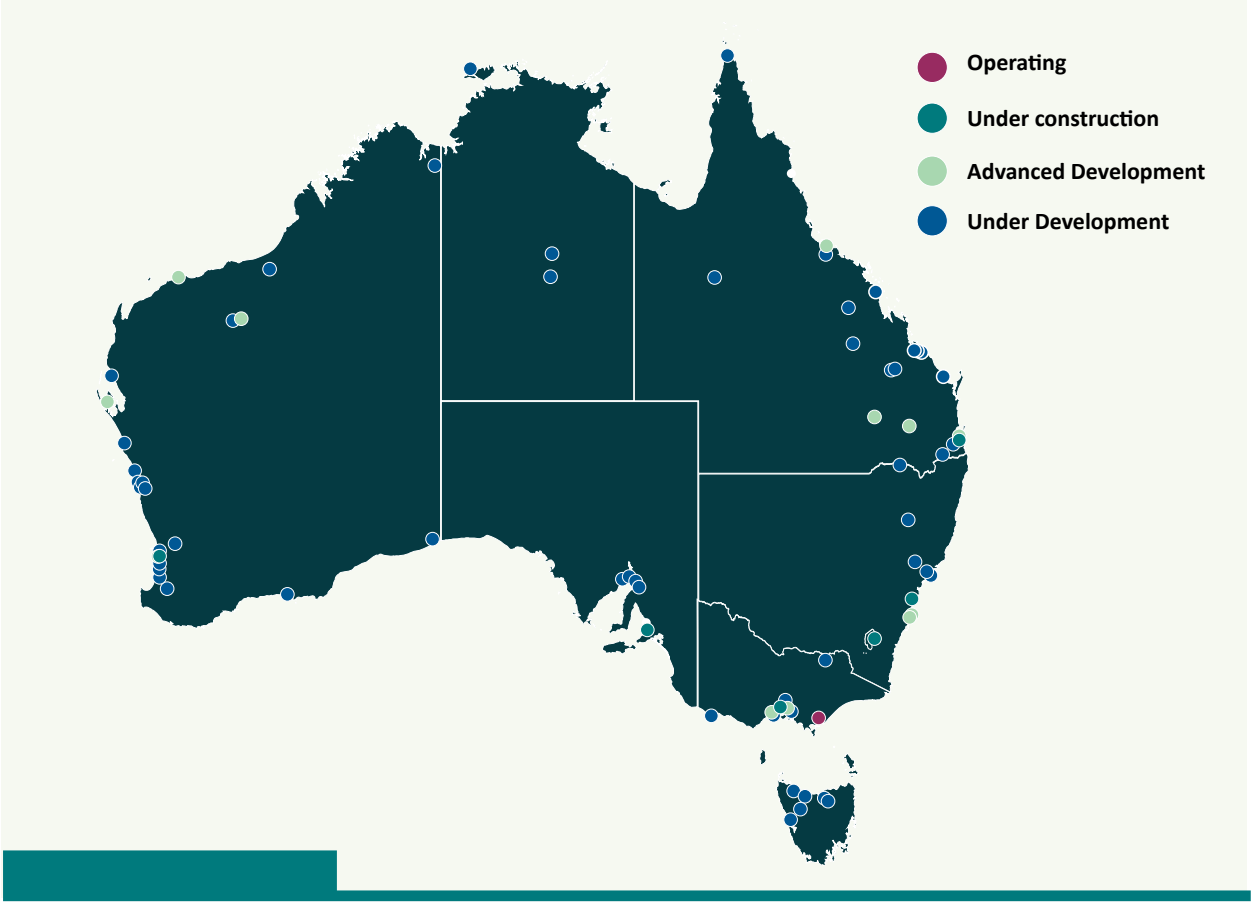


Figure 1: Geographical distribution of hydrogen projects

Contribution to global decarbonisation

To limit global warming in accordance with the Paris Climate Change Agreement, 15 per cent of global energy use by 2050 is forecast to be from hydrogen[8].

The IEA's 2022 World Energy Outlook observes that if all governments implement ambitious policies to meet their climate pledges, hydrogen could help avoid 14 billion cubic metres of natural gas use per year (approximately 534 PJ) and 20 million tonnes of coal equivalent per year (approximately 520 PJ) and 360 kilo-barrels per day of oil (approximately 804 PJ per year) use by 2030[9]. The development of an international hydrogen market can also add to the diversity of potential energy suppliers, enhancing energy security for energy importing countries.

Most of Australia's largest trading partners, covering over 90 per cent of Australia's exports by value[10], have committed to achieving net zero emissions by around mid-century. Many of these trading partners do not share the same attributes which make Australia ideally suited to hydrogen production, yet their reliance on hydrogen is likely to be significant given the extent of their decarbonisation ambition[11]. This presents an opportunity for Australia to establish new hydrogen-based trade arrangements with these countries, addressing both our own emissions reduction targets and contributing to the decarbonisation of other country's economies.

8 DNV – Hydrogen Forecast to 2050, 2022 report.
9 IEA (2022) Global Hydrogen Review.
10 Department of Foreign Affairs and Trade (DFAT), ABS official export data, 2022
11 HYPAT Working Paper (2022) Future hydrogen demand: A cross-sectoral, global meta-analysis – finds use of hydrogen is unavoidable to achieve an 80 per cent reduction (or more) greenhouse gas emissions reductions compared to 1990 levels.

Manufacturing, jobs, regional development and decarbonisation co-benefits

In addition to exporting hydrogen and its related energy carriers, the development of a hydrogen industry also provides an opportunity for Australia's manufacturing sector, jobs, regional development and decarbonisation of the domestic economy. As the Commonwealth Government's 2022 Annual Climate Change Statement to Parliament stated, "As new industries like hydrogen…emerge and grow, they will create demand for workers with both new and existing skills in renewable electricity generation manufacturing and many other sectors. These industries will in turn become the new foundation of many regional economies and communities."[12] For instance, the $3 billion investment by Fortescue Future Industries in their Gladstone electrolyser[13] manufacturing plant, means Australia will have one of the largest hydrogen electrolyser manufacturing plants in the world.

As the world's largest iron ore producer, exporting almost 900 tonnes annually, Australia can play a major role in transitioning iron and steelmaking from an industry producing around 7 per cent of global emissions to a net-zero emissions industry. For instance, analysis by the Australian National University indicates Australia could effectively reduce emissions from the Asia-Pacific region by one billion tonnes CO2-e annually (roughly 3% of global emissions) if our current commodity exports shifted to green iron and steel[14]. Some of Australia's mining companies have already recognised this opportunity and begun researching green iron and steel production, and most recently demonstrating the production of high-quality magnetite pellets to support future Direct Reduced Iron (DRI) production.[15]

Hydrogen industry development progress

The 2019 National Hydrogen Strategy[16] was developed by the Commonwealth Australian Government with State and Territory Governments. The strategy reflects a shared vision for a clean, innovative, safe and competitive hydrogen industry that benefits all Australians.

To track Australia's progress in implementing the 2019 National Hydrogen Strategy, the Department of Climate Change, Energy, the Environment and Water engaged Deloitte to conduct an independent assessment of the progress of the Australian hydrogen industry. The assessment considered the likely progress in 2025 and 2030 against the 13 industry development signals identified in the National Hydrogen Strategy (Table 1). For each signal, Deloitte rated the industry's development as either:

- Advancing quickly
- Advancing
- Advancing slowly

This year's assessment indicates Australia is progressing well towards using hydrogen:

- As a *chemical feedstock* – where progress has been seen in the last year in the areas of new hydrogen and ammonia projects, replacing fossil-fuel based hydrogen and ammonia production, green ammonia for fertilisers and materials for explosives for the mining sector. The number of these proposed projects in this sector doubled in Australia in the last year and the first 10 MW electrolyser project in Australia passed FID[17]. Energy security issues arising out of Europe have meant that in 2022, green ammonia prices are increasingly competitive with grey ammonia prices[18].

12 Australian Government (2022) Annual Climate Change Statement at www.dcceew.gov.au/sites/default/files/documents/annual-climate-change-statement-2022.pdf
13 Fortescue Future Industries – Media Release
14 Burke, P et al (2022) Contributing to regional decarbonization: Australia's potential to supply zero-carbon commodities to the Asia-Pacific. Energy. Volume 248, 1 June 2022, 123563 – Journal Paper
15 2022 GFG Whyalla: https://gfgalliancewhyalla.com/our-journey
16 Commonwealth Government (2019) National Hydrogen Strategy - www.dcceew.gov.au/energy/publications/australias-national-hydrogen-strategy
17 Deloitte (2022) Hydrogen Market Analysis and Comparison. Deloitte
18 IEA (2022) Global Hydrogen Review. IEA. Paris

Table 1: Deloitte's assessment was also compared with the equivalent independent assessment from last year.

	2021 Assessment		2022 Assessment	
Industry Development Signal	**2025 Pace**	**2030 Pace**	**2025 Pace**	**2030 Pace**
Investment	Advancing Quickly	Advancing	Advancing	Advancing
Project Scale	Advancing Quickly	Advancing Quickly	Advancing	Advancing
Cost-competitiveness	Advancing Quickly	Advancing Quickly	Advancing	Advancing
Australia's exports	Advancing	Advancing	Advancing	Advancing
Chemical feedstock	Advancing Quickly	Advancing Quickly	Advancing Quickly	Advancing
Electricity grid support	Advancing slowly	Advancing slowly	Advancing	Advancing slowly
Mining and off-grid	Advancing	Advancing slowly	Advancing	Advancing slowly
Heavy transport	Advancing slowly	Advancing slowly	Advancing slowly	Advancing slowly
Light transport	Advancing slowly	Advancing slowly	Advancing slowly	Advancing slowly
Gas networks	Advancing	Advancing	Advancing	Advancing slowly
Electricity generation	Advancing Quickly	Advancing	Advancing Quickly	Advancing Quickly
Steel and iron making	Advancing slowly	Advancing slowly	Advancing slowly	Advancing slowly
Industrial heat	Advancing	Advancing	Advancing slowly	Advancing slowly

- In export for overseas *electricity generation* – The performance against this indicator is primarily driven by the increasing use of hydrogen for electricity generation in countries with whom Australia has existing trade relationship that could evolve to include hydrogen. For example, in Japan, JERA is trialling the co-firing of ammonia with coal, with ammonia making up 20 per cent of the fuel mix. The same company has also announced plans to increase the use of ammonia to 50 per cent of the fuel mix by 2028. Progress was made in 2022 to deliver proof of concept for shipping hydrogen and ammonia.

Progress has been slower on other demand-side indicators given the higher cost of hydrogen compared to the chemicals and fuels currently being used.

Australia continues to advance in relation to:

- *Investment* – Australia has a substantial pipeline of announced projects of more than $230-$300 billion (details Appendix 6 and 7) with 64 new projects announced since the release of the 2021 State of Hydrogen report[19]. It is important to note, however, that as of December 2022, only one project with a 10 MW capacity or higher has passed FID from this pipeline of investment. Australian governments are seeking to create an enabling investment environment for investment through the provision of enhanced regulatory certainty and the development of a domestic hydrogen Guarantee of Origin sche.me as well as grants, incentives and access to lower interest financing via the Clean Energy Finance Corporation $300 million Hydrogen Fund details in Appendix 2.

19 This figure is based on projects for which cost information is available. There are many other significant projects for which this information is not available. The Resources and Energy Major Projects 2022 Report stated that hydrogen projects accounted for an estimated $266 billion worth of potential investment, approximately double that of the previous year's report – https://www.industry.gov.au/sites/default/files/2022-12/resources-and-energy-major-projects-2022_0.pdf.

- *Project scale* – Industry has announced 11 gigawatt scale Australian based clean hydrogen and ammonia projects of global scale and is partnering with Australian governments in the establishment of hydrogen hubs. The colocation of hydrogen users, producers and exporters reduces industry start-up costs and allows for the rapid establishment of supply chains. The model is also being employed in several other countries. Australian governments [have also completed/will shortly complete] the National Hydrogen Infrastructure Assessment, and commenced more detailed, region-specific infrastructure studies in support of hydrogen industry growth.
- *Australia's exports* – Future export opportunities are being examined through international supply chain studies. The Australian Government has also established new international clean energy partnerships with the United States and India and is progressing work through multilateral forums such as Mission Innovation - Clean Hydrogen Mission and Clean Energy Ministerial Hydrogen Initiative including on trade and supply chains. Australian state and territory governments have also progressed partnership agreements centred on hydrogen trade with the Port of Rotterdam in the Netherlands and the Australian and Victorian Governments have partnered with Japan and Japanese industry through the Hydrogen Energy Supply Chain project in the Latrobe Valley.
- *Electricity grid support* – In Australia, battery and pumped-hydro storage are currently being favoured over hydrogen for load balancing and grid firming. However, Australia will be at the forefront globally in using hydrogen for grid support when the South Australian government's 200 MW hydrogen-fired power station is constructed in Whyalla. Other projects include the Tallawarra B gas generator under construction and the Kurri Kurri gas generator.
- *Mining and off-grid* - At present, there is limited hydrogen use for mining and off-grid diesel replacement for electricity generation, with battery storage systems in more advanced stages of application relative to hydrogen systems. Despite this, small-scale hydrogen off-grid electricity generation projects have come online over 2022, such as the Denham Hydrogen Demonstration Plant and Toyota Ecopark.
- *Gas networks* – The blending of hydrogen into existing gas pipelines offers a source of domestic demand for an emerging hydrogen industry, a means of hydrogen storage and a means of transporting hydrogen and enabling the progressive decarbonisation of further uses for gas. Western Australia has recently started to blend small amounts of hydrogen into a portion of its gas distribution network. Further blending trials have commenced such as Jemena's Western Sydney Green Gas Project.

- *Infrastructure Regulation* – Since the last State of Hydrogen report, Australian governments agreed to amendments to extend the National Gas Law and Regulations to hydrogen and biomethane. Investment in new infrastructure (hydrogen pipelines) as well as in the repurposing of the existing gas network will have important roles in enabling the development of a hydrogen infrastructure backbone.

The assessment found progress to be slowest against:

- *Heavy transport* - In Australia, federal and state governments have tended to focus on battery electric vehicles rather than hydrogen fuel cell vehicles. In contrast several countries have already invested in deploying hundreds or thousands of hydrogen powered vehicles and hydrogen refuelling stations. There has been a shift during 2022, with committed projects that will trial hydrogen fuel cell buses, and the creation of stretch targets for hydrogen vehicles on the road and in government fleets under the NSW Hydrogen strategy. The Victorian, NSW and Queensland governments are collaborating on the development of hydrogen refuelling networks on primary freight highways. The first step of this is the Victoria and NSW Hydrogen Hume Highway initiative that will deliver Australia's first hydrogen refuelling network in 2025 to kick-start demand for hydrogen in the heavy transport sector and get FCEV transport on the road. The federal government recently committed up to $80 million in support of these state-based hydrogen highway initiatives. The WA government has also committed $10 million in matched funding for a back to base hydrogen fuelled transport project at Woodside's H2Perth facility, which is expected to be commissioned in 2024.
- *Light transport* - Australia has only recently commenced the deployment of infrastructure required to support light transport hydrogen refuelling, with four demonstration scale refuelling stations currently operational. This includes the ActewAGL run renewable hydrogen refuelling facility in Canberra, the renewable Toyota refuelling station in Altona, Victoria, the renewable Hyundai refuelling station in Sydney, and in WA supplying ATCO's fleet of Toyota Mirais. The establishment of hydrogen highways along the Australian east coast will likely be tailored to the needs of long-distance freight rather than light transport.
- *Steel and iron making* – As the world's largest iron ore producer, Australia has a significant opportunity to combine its iron ores, renewable energy resources and hydrogen production to establish a new low emissions onshore iron ore processing industry that value adds and exports to steel plants overseas. There is strong interest in establishing low emissions onshore iron ore processing from major Australian iron ore companies but no specific projects to date. This includes work co-funded by ARENA being led by Bluescope Steel[20] to undertake low emissions steel feasibility analysis, and by Calix, who are leading a low emission steel feasibility study and pilot[21]. Additional support is occurring through the Heavy Industry Low-Carbon Transition (HILT) CRC.
- *Industrial heat* - At present, hydrogen has not been deployed for any applications of industrial heating beyond natural gas grid injection within Australia. There is limited activity within Australia for small and large-scale hydrogen use for industrial heating with only feasibility studies being undertaken. There is no clear pipeline of projects for industrial heating applications, although alternative electrification technologies are being considered.

20 ARENA – Investigating Low Emission Steel Production at Port Kembla at https://arena.gov.au/news/investigating-low-emissions-steel-production-at-port-kembla
21 ARENA – New Iron Reduction Technology Targeting Low Emission Steel https://arena.gov.au/news/new-iron-reduction-technology-targets-low-emissions-steel

Australia on a global stage

Australia was the third country to announce a national hydrogen strategy. Today, there are 30 national strategies, with a further 7 in development. Many of these strategies are export oriented and include both potential buyers of Australian hydrogen as well as potential competition for our industry. As technology and climate changes, existing strategies are being refreshed with new targets, incentives or higher ambition, further accelerating the growth of the sector.

For Australia to be a player in the global hydrogen industry, it will need to consider decisions by competing producer nations to offer increasingly more attractive operating cost competitive environments could have a negative impact on decisions to invest in hydrogen projects in Australia by international firms. It could also further experience challenges in supply chain security for critical items such as electrolysers and solar PV panels, as manufacturers give preference to markets with greater scale and better prospects for growth. Australia risks falling behind other countries who are implementing market-based policy mechanisms and new economic incentives to propel their hydrogen industries, most notable the recent policy announcements in the United States, Canada and Germany. Whilst Australia is advancing on all areas of development of the local hydrogen industry, it is important to check how that progress compares globally with progress by other nations.

Deloitte's independent assessment included consideration of how Australia is tracking in an international context (in relation to the 15 measures of success outlined in Australia's National Hydrogen Strategy), and rates Australia as either a leader or a follower in the global market Australia.

The analysis summarised in Table 2 suggests that Australia is no longer the global policy leader in developing a new clean hydrogen industry. For instance, while Australia has a large pipeline of announced hydrogen projects, it still trails many OECD nations in terms of projects proceeding to deployment.

To be a global leader in the hydrogen industry by 2030, Australia will need to accelerate its delivery of the early actions identified in the National Hydrogen Strategy. In particular, the advancement of priority pilot projects, the establishment of hydrogen hubs, and the assessment of supply chains will be essential to achieving the scale necessary to compete internationally. Considering increasing international appetite for hydrogen and emerging competition with other producing nations, Australia may need to reconsider the need for targets and incentives and other measures to ensure its industry is globally competitive.

Success will rely on Australian industry, governments, researchers and the community working together. If we get this right, we can realise our vision to establish a new hydrogen export industry in Australia, unlocking jobs, assisting the energy transition, reducing emissions (particularly in hard to abate areas) and potentially unlocking billions of dollars in GDP by 2050.

Table 2: Comparison between Global Leader and Australian Progress – by Industry Development Signal

Industry Development Signal	2022 International Comparison
Investment	Follower – Leader
Project Scale	Follower – Leader
Cost-competitiveness	Follower – Leader
Australia's exports	Follower – Leader
Chemical feedstock	Follower – Leader
Electricity grid support	Follower – Leader
Mining and off-grid	Follower – Leader
Heavy transport	Follower – Leader
Light transport	Follower – Leader
Gas networks	Follower – Leader
Electricity generation	Follower – Leader
Steel and iron making	Follower – Leader
Industrial heat	Follower – Leader

(Source: Deloitte, 2022[22])

22 Deloitte (2022) Hydrogen Market Analysis and Comparison. Deloitte.

Chapter 1

Australia's hydrogen powerhouse opportunity

Australia is well positioned to be a global hydrogen export leader to meet rising global demand.

Australia has abundant renewable energy resources. The National Hydrogen Strategy[23] estimates that Australia has 262,000 square kilometres of land that is highly suitable for hydrogen production using renewable electricity. This area represents only three per cent of Australia's total land area, which is larger than the average European Union Member State. Furthermore, this area of land would be capable of producing more hydrogen than the global demand predicted by the Hydrogen Council for 2050.

Australia also has considerable fossil fuel and mineral resources that have underpinned our ability to establish large scale energy and resource export industries in the past. Australia's stable political system and robust regulatory environment have ensured Australia is highly trusted as an export partner. While practically all hydrogen produced in Australia today is based on unabated fossil fuel use, importantly for the hydrogen industry going forward is the availability of suitable geology to enable the long-term storage of carbon that can be captured at the point of hydrogen production. Australia's geology is also highly suitable for the long-term storage of hydrogen in salt caverns to allow for either seasonal fluctuation in supply and demand or in support of large-scale export operations.

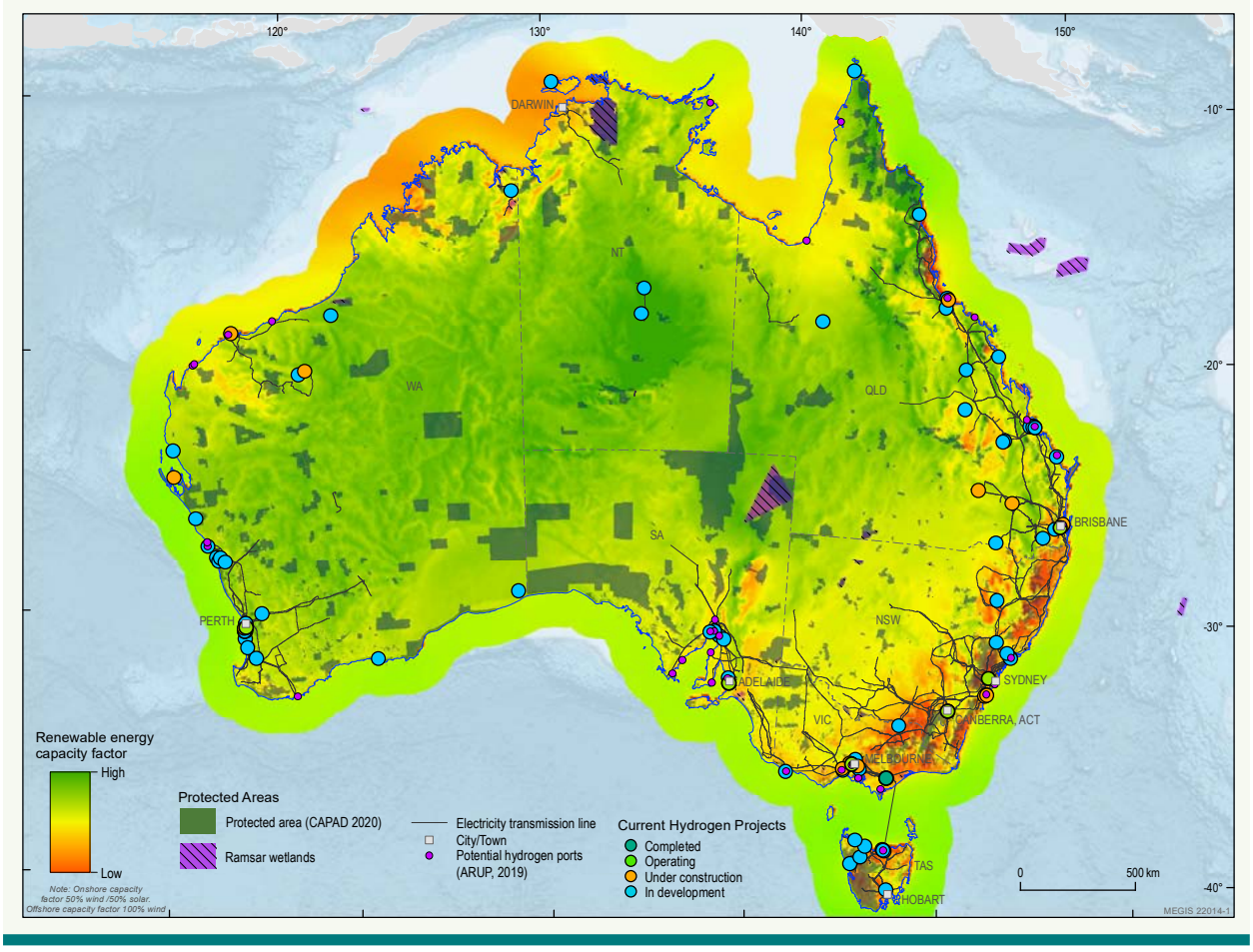


Figure 2: Australia's renewable energy potential for widespread electrification. Protected areas are included (Geoscience Australia, 2022).

23 Commonwealth Government (2019) National Hydrogen Strategy - www.dcceew.gov.au/energy/publications/australias-national-hydrogen-strategy

Many of our trading partners do not share these attributes, which means we are well placed to produce hydrogen and export it at a large scale. Australia's goal is to be a major supplier of hydrogen by 2030. This could see the Australian hydrogen industry reach the scale of our current liquefied natural gas industry, the value which totalled $48 billion in 2019-20 (approximately 16 per cent of Australia's total resource and energy exports)[24].

According to the IEA's Global Hydrogen Review 2022[25], there has been a modest increase (5%) in demand for hydrogen worldwide since its previous review, with most of this demand met through unabated fossil fuel-based production[26]. Hydrogen produced using low emissions technology met a very small component of demand, but the level increased by 20% on the preceding year. There are some signs of increasing demand. For instance, in 2022 the European Commission doubled the previous EU renewable hydrogen target to 10 million tonnes of annual domestic production and an additional 10 million tonnes of annual hydrogen imports. Additionally, there are substantial increases in announced production projects in anticipation of demand. The IEA also report in 2022 that global electrolyser capacity may reach 134 GW in 2030[27], more than twice the IEA's projected level of 54 GW in the preceding 2021 report.

Demand for hydrogen is growing as it is a safe, flexible, transportable and storable energy carrier that has been in use across a range of industries for many years such as in the production of fertiliser, explosives and other chemicals. However, the ongoing reductions in the cost of renewable energy, and increasing global ambition with regards to emissions reduction will see the application of low emissions hydrogen production to additional sectors currently using fossil fuels. These sectors include transport fuels, industrial process heat, electricity generation, grid stabilisation and long-term energy storage.

The scale of future export operations provides an opportunity to develop domestic use cases around the availability and affordability of hydrogen. Realising this opportunity for hydrogen could provide enormous growth in domestic manufacturing.

It would also create ongoing jobs in project financing and management and operation and maintenance.

Domestic and global decarbonisation contribution

Domestic decarbonisation - The transition to renewably powered hydrogen production can contribute to domestic decarbonisation of the current manufacturing of hydrogen, already used as a chemical feedstock to make products for sectors central to the Australian economy such as agricultural, mining, and chemicals. Hydrogen is noted for its versatility in decarbonising hard to abate sectors such as iron, steel, aluminium, ammonia, and chemicals production, as well as heavy transport, shipping, and air travel. Hence, developing a competitive domestic hydrogen industry is an important part of Australia's energy mix to help decarbonise industrial and hard to abate sectors. This will support decarbonisation by businesses covered under the Commonwealth's Safeguard Mechanism to achieve Australia's net zero 2050 target. These sectors account globally for over 15 per cent of global greenhouse gas emissions. Next, hydrogen can play an important role in energy storage to support the decarbonisation and transformation of national grids as well as off grid applications. Finally, hydrogen also offers an early and readily available option to reduce emissions by decarbonising the existing Australian gas network.

24 Office of the Chief Economist, Resources and Energy Quarterly, March 2021
25 IEA (2022) Global Hydrogen Review. IEA. Paris
26 IEA estimates meeting this demand results in the production of approximately 900 Mt CO2
27 IEA (2022) Global Hydrogen Review. IEA. Paris

Figure 3: Hydrogen can help decarbonise multiple sectors including "hard to decarbonise" sectors.

Global decarbonisation - Hydrogen has been identified for several years as an important technology to reduce global emissions by the EU, and many countries including Australia, the United States, Germany, Japan and the Republic of Korea. Twenty-five nations have created national hydrogen strategies to date and another twenty are planning to do so.

The International Energy Agency sees "vast potential" for hydrogen[28]. Bloomberg New Energy Finance (BNEF) finds hydrogen "*can help address the toughest third of global greenhouse gas emissions by 2050*"[29]. Nations around the world are recognising this in their national hydrogen strategies and plans, explicitly acknowledging the role hydrogen can play in helping to decarbonise many sectors, as shown in this table.

28 The Future of Hydrogen (IEA, 2019)
29 Hydrogen Economy Outlook: Key Messages (Bloomberg L.P., 2020)

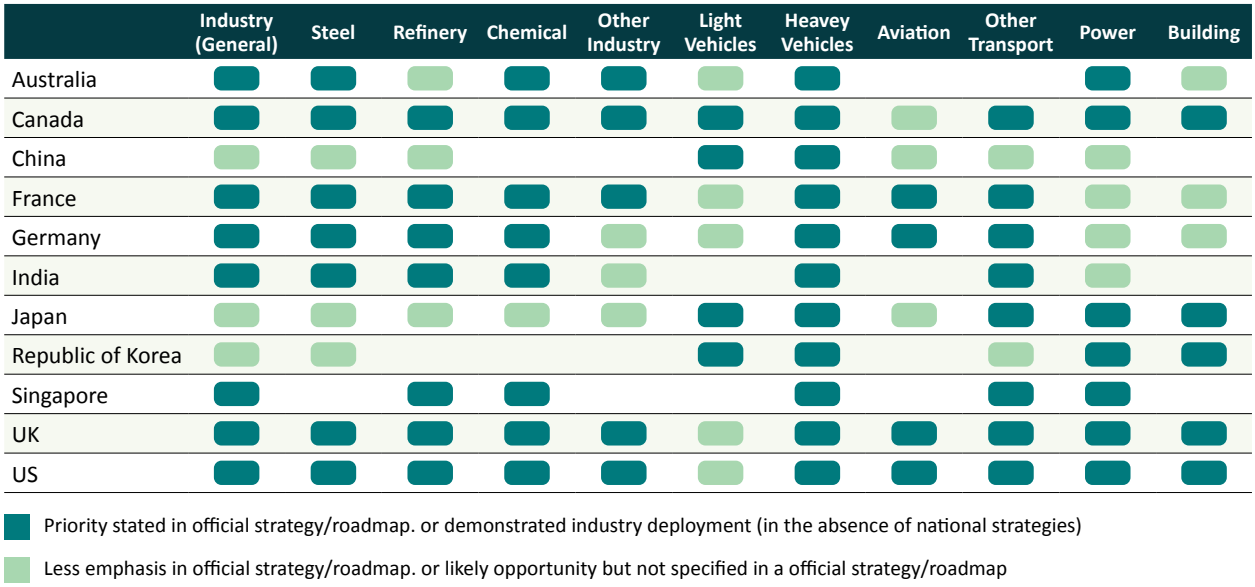


Figure 4: Primary utilisation sectors identified end uses in country industry strategies. (Source. CSIRO, 2022[30])

Countries have increasingly implemented hydrogen incentives and domestic hydrogen/ammonia demand targets to derisk investment and ensure energy security this decade. For example, the European Commission in 2022 doubled the previous EU renewable hydrogen target to 10 million tonnes of annual domestic production and an additional 10 million tonnes of annual hydrogen imports.

Australia has a chance to contribute to global decarbonisation by developing a hydrogen industry. All but one of Australia's largest 20 trading partners have committed to achieving net zero emissions by around mid-century, impacting over 90 per cent of Australia's 2021 exports by value[31]. Analysis indicates that a country will have a high reliance on hydrogen to achieve a net zero emissions target because net zero targets cannot be achieved. [32]

The Australian National University has also shown that there is potential if Australia realises its hydrogen superpower ambitions and replaces its current fossil fuel exports with clean hydrogen, ammonia, green iron/steel and green aluminium exports this could help reduce global greenhouse gas emissions by 8.6% by 2050[33].

New hydrogen investment and trade

Australian governments and industry leadership has contributed to an announced pipeline of at least $127 billion of hydrogen and ammonia projects[34]. This figure is based on projects for which cost information is publicly available in the CSIRO HyResource database (Appendix 6). There are many other significant proposed hydrogen projects in Australia for which this cost information is not publicly available. The Resources and Energy Major Projects 2022 Report stated that hydrogen projects accounted for an estimated $230-300 billion (Appendix 7) worth of potential investment, approximately double that of the previous year's Resources and Energy Major Projects 2021 report.[35]

30 CSIRO (2022) Hydrogen RD&D Collaboration Opportunities: Global Report at http://mission-innovation.net/wp-content/uploads/2022/09/H2RDD-Global-FINAL.pdf
31 Department of Foreign Affairs and Trade (DFAT), ABS official export data, 2022
32 HYPAT Working Paper (2022) Future hydrogen demand: A cross-sectoral, global meta-analysis
33 Burke, P et al (2022) Contributing to regional decarbonization: Australia's potential to supply zero-carbon commodities to the Asia-Pacific. Energy. Volume 248, 1 June 2022, 123563 – Journal Paper
34 HyResource (2022) Industry projects - https://research.csiro.au/hyresource/projects/facilities/ This figure is based on projects for which cost information is available. There are many other significant projects for which this information is not available. The Resources and Energy Major Projects 2022 Report stated that hydrogen projects accounted for an estimated $266 billion worth of potential investment, approximately double that of the previous year's report – www.industry.gov.au/sites/default/files/2022-12/resources-and-energy-major-projects-2022_0.pdf.
35 www.industry.gov.au/sites/default/files/2022-12/resources-and-energy-major-projects-2022_0.pdf.

This report undertakes analysis of the likely investment costs involved for each project based on publicly available information using on extensive experience in costing energy and resource projects. This report then provides a range of the potential investment cost for each project. Overall, The Resources and Energy Market 2022 report provides the best estimate for Australia's current announced pipeline of investment.

According to BNEF in June 2022, this represents approximately forty per cent of announced global hydrogen projects. Australia stands to gain significant economic benefits by ensuring this pipeline of potential investments progresses beyond final investment decisions.

The IEA's 2022 Global Hydrogen Review found that, with Australia's existing pipeline of investment, Australia could be one of the top global hydrogen exporting countries by 2030. (Figure 5)

Accenture estimates that Australia's renewable hydrogen industry development and related exports could produce $28.9 billion per annum in 2040 and create around 33,000 direct and indirect jobs[36].

Consistent with Australian governments' vision for a globally significant hydrogen industry, the Australian Energy Market Operator added a new Hydrogen Superpower scenario to its 2022 Integrated System Plan. In this scenario, by 2050, Australia's National Electricity Market will produce over 12 million tonnes of hydrogen for export each year.

Manufacturing and regional development co-benefits

A scaled-up hydrogen industry has enormous potential to decarbonise hard-to-abate industrial sectors and offers an opportunity to restructure our economy around increased on-shore manufacturing and production of clean products and technologies.

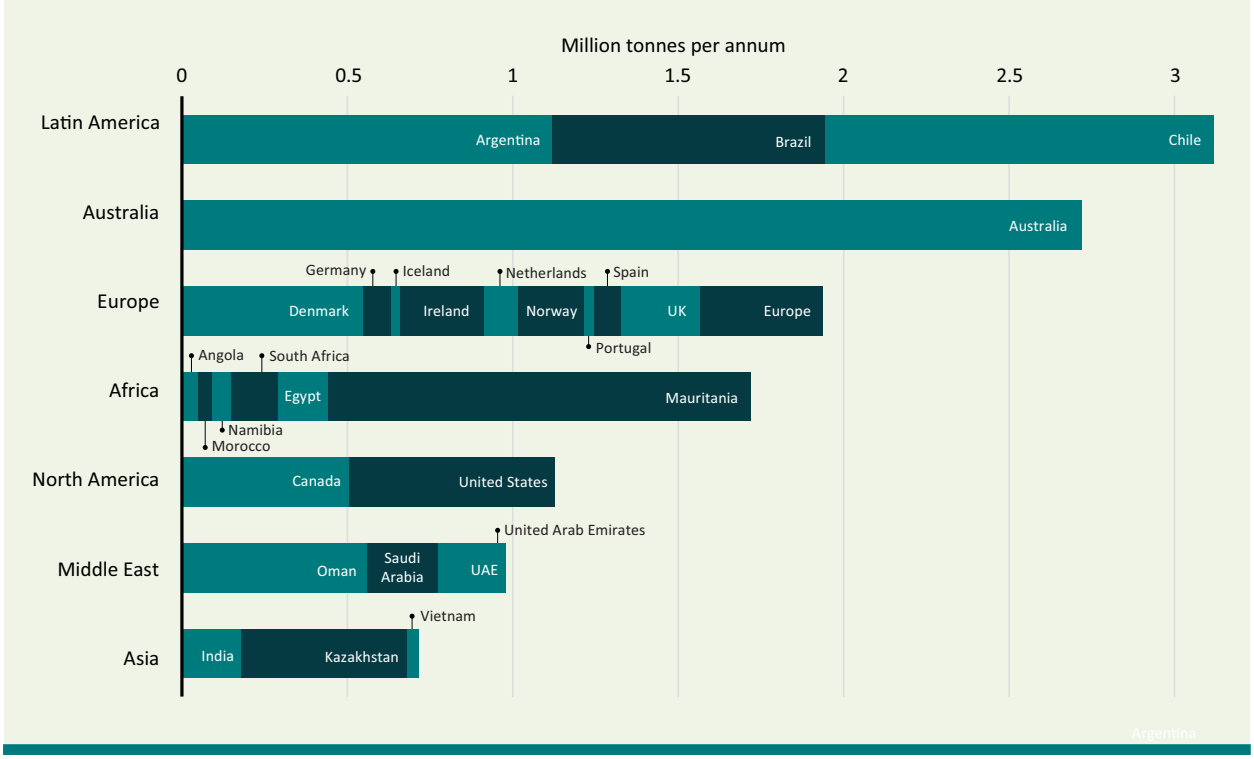


Figure 5: Planned hydrogen exports – by Country, 2030. (Source International Energy Agency, Global Hydrogen Review, Page 165, 2022)

36 Accenture and WWF (2021) Sunshot: Australia's opportunity to create 395,000 clean export jobs. www.wwf.org.au/news/news/2021/clean-exports-could-deliver-395-000-new-jobs

The development of a hydrogen industry provides an opportunity to revitalise Australia's manufacturing sector by enabling the production of low emissions products for both domestic and international economies. The potential to value add to Australia's iron ore exports is significant (BOX 1). For instance, the Grattan Institute assessed that an Australianmade green iron and steel industry has 'particularly good economic prospects'. If Australia can seize the green iron and steel value chain opportunity, Australia could generate $65 billion in value per year by 2050, creating around 25,000 ongoing direct jobs[37].

The potential for Australia to be a major green ammonia exporter is also recognised by the private sector with 17 large scale ammonia export related projects in Australia's project pipeline (as of December 2022) (Appendix 6) . This includes projects such as Engie's Yuri Ammonia Project, which reached FID and will start producing renewable ammonia following the installation of a 10 MW electrolyser. Fortescue Future Industries (FFI) is looking to retrofit via the Gibson Island Renewable Ammonia Project one of the world's largest electrolysers and renewable ammonia plants in the world.

There are also green shoots for zero carbon hydrogen related manufacturing with the first hydrogen buses, ferries, and small planes being made. (See Transport Sector Section). Developing these manufacturing sectors can have positive spill over manufacturing effects increasing investment in manufacturing of technologies critical to these new industries. For instance, the investment by Fortescue Future Industries in their Gladstone electrolyser[38] manufacturing plant, in partnership with the Queensland Government, will deliver Australia's first multi-gigawatt-scale electrolyser factory, with an initial capacity of 2 gigawatts (GW) per annum, and create 300 direct jobs.

The Western Australian (WA) Government have created the WA Government Electrolyser Manufacturing Initiative, with funding approved for industry partners to undertake a study to inform feasibility of establishing electrolyser manufacturing capability with local manufacture, assembly, and maintenance of electrolysers in Western Australia.

The Australian and State Government $926 million investment in hydrogen hubs will also aid manufacture key common use infrastructure to unlock strategic industrial areas and support in enabling the pipeline of potential renewable hydrogen projects.

The Hydrogen Technology Cluster Australia (H2TCA) network, established by NERA in partnership with state and territory governments also supports the development of domestic manufacturing and accelerating regional economic diversification. The national network of 17 regional hydrogen technology clusters across all states and territories connects over 550 organisations spanning the hydrogen value chain and adjacent industries, creating vital linkages between SMEs, large corporations, NGOs, state and local governments and more than 20 research and training institutions.

The scale of investment in renewable energy to underpin decarbonisation of the national grid and Australia's industrial sector, plus the emerging hydrogen industry will create a big opportunity to locally manufacture content for the renewable energy sector, creating new jobs and opportunities for workers. To help capture these job opportunities,

- The NSW Government is establishing a $250 million Renewable Manufacturing Fund. This Fund will make strategic co-investments with the private sector to establish and expand local supply chains for renewable energy content.
- The Victorian Government has announced $19.9 million to support manufacturers to build their capability, invest in renewable energy and low-carbon component manufacturing and help workers transition to advanced manufacturing jobs. This fund sits within the $120 million Victorian Industry Fund. Within its Manufacturing Statement 'Made in Victoria 2030' zero and low emission technologies including hydrogen is one of five manufacturing priority areas.

37 Grattan institute, 'Start with Steel', page 30, May 2020
38 Fortescue Future Industries – Media Release

Box 1. Australia's green iron and steel opportunity

As the world's largest iron ore producer, Australia can play a major role in transitioning steelmaking to a net-zero emissions industry (currently around seven per cent of global emissions). This is because Australia exports almost 900 million tonnes of iron ore each year, but only makes 5.5 million tonnes of steel. There is potential to establish a new onshore iron ore processing industry, utilising renewable energy and hydrogen.

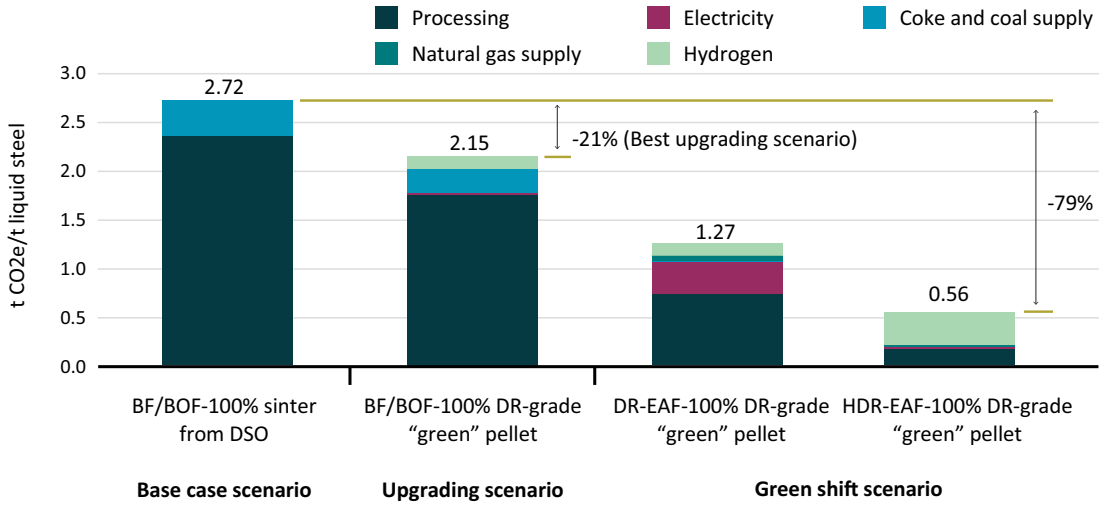
Green iron could become a new green hydrogen derivative, which can reduce global emissions significantly while creating new high-quality jobs in Australia and attracting increased national revenue and international investment.

By cooperating with our major customers, Australia can support the emergence of a global low and zero emission steel industry.

CSIRO's commissioned analysis suggests that onshore processing in Australia can contribute up to a 21 per cent emissions reduction from *existing* blast furnace-based steelmaking and enable the development of Direct Reduction steelmaking on a large scale which can result in further emissions reduction to a total of 79 per cent. In addition, Australia could capture some of this iron ore reduction market on shore.

Results suggest Australia has an economic opportunity to firstly develop the beneficiation and processing technologies for onshore processing of ore, followed by development of iron making in Australia. By 2050 a hydrogen-driven iron making industry in Australia feeding Electric Arc Furnace steelmaking in Japan and Korea is a globally competitive scenario.

Modelling on the economic benefits out to 2040 and 2050 by Accenture and the Grattan Institute finds significant economic potential from developing the green iron and steel manufacturing opportunity. Accenture's modelling found that the potential development of green iron and steel sector in Australia could create $35.3 billion in exports, $20.1 billion in direct and indirect value add and create up to approximately 111,000 direct and indirect jobs by 2040.



Chapter 2

An Assessment of the Australian Hydrogen Industry

Australia's National Hydrogen Strategy 2019[39] outlines an adaptive approach, requiring frequent assessment of the industry to ensure its actions are aligned with international progress. The Strategy identified 57 initial actions that would support industry growth (Appendix 1).

How we track progress

To track Australia's progress against global developments, Australian governments committed to publishing an annual State of Hydrogen report. Thirteen industry development signals are defined in the strategy to indicate progress of the hydrogen industry over two-time horizons (2025 and 2030)[40].

In 2020, the Department of Industry, Science, Energy and Resources commissioned CSIRO to develop a data framework to facilitate consistent, repeatable measurement of hydrogen industry progress.

The Department commissioned an independent assessment of the Australian and global hydrogen industries using CSIRO's data framework in 2021. In 2022, this independent analysis was conducted by Deloitte[41], which considered each of the 13 development signals to determine whether each signal is either Advancing Quickly, Advancing or Advancing Slowly.

Table 3: Independent Assessment of progress against Industry development signals (Deloitte, 2022[42]).

	2021 Assessment		2022 Assessment	
Industry Development Signal	**2025 Pace**	**2030 Pace**	**2025 Pace**	**2030 Pace**
Investment	Advancing Quickly	Advancing	Advancing	Advancing
Project Scale	Advancing Quickly	Advancing Quickly	Advancing	Advancing
Cost-competitiveness	Advancing	Advancing	Advancing	Advancing
Australia's exports	Advancing	Advancing	Advancing	Advancing
Chemical feedstock	Advancing Quickly	Advancing Quickly	Advancing Quickly	Advancing
Electricity grid support	Advancing slowly	Advancing slowly	Advancing	Advancing slowly
Mining and off-grid	Advancing	Advancing slowly	Advancing	Advancing slowly
Heavy transport	Advancing slowly	Advancing slowly	Advancing slowly	Advancing slowly
Light transport	Advancing slowly	Advancing slowly	Advancing slowly	Advancing slowly
Gas networks	Advancing	Advancing	Advancing	Advancing slowly
Electricity generation	Advancing Quickly	Advancing	Advancing Quickly	Advancing Quickly
Steel and iron making	Advancing slowly	Advancing slowly	Advancing slowly	Advancing slowly
Industrial heat	Advancing	Advancing	Advancing slowly	Advancing slowly

39 Commonwealth Government (2019) National Hydrogen Strategy - www.dcceew.gov.au/energy/publications/australias-national-hydrogen-strategy

40 The signals identified in the National Hydrogen Strategy. For access to the National Hydrogen Strategy see - Commonwealth Government (2019) National Hydrogen Strategy - www.dcceew.gov.au/energy/publications/australias-national-hydrogen-strategy

41 Deloitte (2022) Hydrogen Market Analysis and Comparison. Deloitte

42 Deloitte (2022) Hydrogen Market Analysis and Comparison. Deloitte

Areas where hydrogen is advancing quickly

Hydrogen as a chemical feedstock

This year's assessment shows that Australia is progressing well at enabling the use of hydrogen as a chemical feedstock.

There are currently 45 Australian projects planning to use hydrogen as a chemical feedstock for both domestic and export markets Six projects have moved beyond 'under development' status, and 23 involve ammonia production and have a combined announced capacity of 4.86 Mt per annum. A further three involve methanol production with a combined announced capacity of 0.02 Mt per annum. A single project is dedicated to exporting methylcyclohexane (MCH) as a hydrogen carrier.

Hydrogen for ammonia manufacturing

The Australian domestic demand for hydrogen through ammonia is diverse and significant. Ammonia is an important chemical feedstock for both industry and agriculture. Hydrogen is used primarily as a chemical feedstock for ammonia and to a lesser degree used to refine oil and gas. Ammonia is used in the production of nitrogen-based fertilisers, ammonium nitrate explosives for mining, sodium cyanide in nickel processing and in plastics.

- Australia's current annual fossil fuel-based hydrogen production is approximately 500,000 tonnes.
- Approximately 80 per cent of all fossil fuel-based hydrogen producers are associated with ammonia production with the remaining 20 per cent associated with crude oil refining.
- Western Australia produces approximately 200,000 tonnes per year.
- Queensland has the largest number (5) of fossil fuel-based hydrogen producers of ammonia.

Table 4: Total Grey Hydrogen Producers

Name of operation/project	Operator	Location	Annual production (kt)	Sector
Yara Pilbara Nitrates	Yara	WA	141	Ammonia
CSBP Kwinana	Wesfarmers	WA	56.5	Ammonia
Phosphate Hill	Incitec Pivot	QLD	35.5	Ammonia
Dyno Ammonium	Dyno Nobel	QLD	37	Ammonia
Moura Ammonium Nitrate	QNP	QLD	18.5	Ammonia
Gibson Island	Incitec Pivot	QLD	53	Ammonia
BOC	BOC	QLD	0.35	Oil/Gas
Kooragang Island	Orica	NSW	79.5	Ammonia
CoreGas	Wesfarmers	NSW	1.2	Oil/Gas
BOC	BOC	VIC	20	Oil/Gas
Geelong Refinery	Viva	VIC	52	Oil/Gas
Total			**494.277**	

Many off the 23 renewable-based ammonia production projects being planned in Australia are small-scale pilots but some of the larger projects will produce ammonia for export.

- **Yuri Clean Ammonia Project, Pilbara, Western Australia** - The Australian Government, through ARENA, is providing up to $47.5 million and the WA Government is providing $2 million to Engie Renewables Australia for an $87 million hydrogen project. In an important milestone for the Australian hydrogen industry, the project proponents announced a final investment decision in September 2022. The project will deliver the first 10 MW electrolyser in Australia and will use renewable electricity to supply hydrogen to Yara's liquid ammonia facility in Karratha from 2024.
- **Fortescue Future Industries (FFI) Gibson Island Renewable Ammonia Project** - FFI is undertaking a technical and cost benefit feasibility study on investing in the integration of renewable energy and a new electrolyser into this existing ammonia plant. The project aims to be entirely powered by renewable energy through a power purchase agreement (PPA). If built, the Gibson Island facility on Brisbane River would constitute one of the world's largest electrolysers and renewable ammonia plants in the world. The Australian Government, through ARENA, is providing up to $13.7 million to support the development work being undertaken[43].
- **The Australian Renewable Energy Hub** (formerly Asian Renewable Energy Hub) - has commenced preparatory works for potentially the world's largest renewable ammonia facility in the Pilbara region of Western Australia.
- **Western Green Energy Hub** – this project based in south-east Western Australia could produce over 3 million tonnes of renewable-based hydrogen or around 20 million tonnes of (renewable-based) ammonia for export.

Chemical feedstock – methanol manufacturing

Hydrogen can also be used as a feedstock to make methanol. There is interest in methanol as a hydrogen carrier because it is a stable liquid, which can be transported in large volumes using conventional petroleum shipping tankers without the need for cooling. This makes it cost efficient compared to compressed and liquefied hydrogen. Notable developments in Australia include:

- **ABEL Energy Bell Bay Powerfuels Project**[44] - ABEL Energy is developing a large-scale, 120-160 MW, renewable hydrogen and hybrid e-methanol facility at the Bell Bay Advanced Manufacturing Zone in Tasmania. Feasibility work for this development is being supported by the Tasmanian Government. The project would deploy biomass gasification of plantation forestry residues in conjunction with water electrolysis to produce 200-300 ktpa of green methanol. Direct capture of CO_2 from the atmosphere is also under assessment.
- **Green Springs Project**[45] - Climate Impact Capital Limited (CIC) is reportedly progressing development of a 10 GW (off-grid) renewable hydrogen production facility and associated chemical production (methanol, kerosene, fuel ammonia) in the Western Davenport region of the Northern Territory. A feasibility study is complete and the Front-End Engineering and Design (FEED) terms have been drafted.
- **HIF Carbon Neutral eFuels Manufacturing Facility**[46] - HIF Global is developing a large-scale synthetic eFuels production facility to be located near the town of Burnie in Tasmania. The plant at full-scale would include 250 MW of electrolysis capacity to produce hydrogen from renewable energy sources and direct air capture of the necessary carbon dioxide. At full capacity the facility could be expected to produce up to 100 million litres of carbon neutral eFuels per annum (equivalent to around 260,000 tonnes of avoided CO_2 emissions per annum). HIF Global is targeting construction to start in 2024 with operations following in 2026.

43 ARENA – Gibson Island Renewable Ammonia Project Feed Study at https://arena.gov.au/projects/gibson-island-renewable-ammonia-project-feed-study
44 HyResource – ABEL Energy Bell Bay Powerfuels Project at https://research.csiro.au/hyresource/abel-energy-bell-bay-powerfuels-project
45 HyResouece – Green Springs Project at https://research.csiro.au/hyresource/green-springs-project
46 HyResource - HIF Carbon Neutral eFuels Manufacturing Facility at https://research.csiro.au/hyresource/hif-carbon-neutral-efuels-manufacturing-facility

- **Methanol synthesis using renewable hydrogen**[47] - HAMR Energy and Bingo Industries, with the support of the Victorian Government is conducting a feasibility study into the use of carbon feedstock from unrecyclable waste combined with renewable hydrogen can support a restart of methanol manufacturing in Victoria

Electricity generation

Hydrogen and ammonia can be combusted in thermal power plants, providing a potential option to decarbonise the existing fossil-fuel based power generation sector. Although limited in scale and commercial availability, companies such as GE have developed hydrogen fired generators that can take blended fuel up to 100 per cent hydrogen and are working on ammonia co-firing. However, the quality of Australia's solar and wind resources makes it unlikely that hydrogen and/or ammonia combustion will be solely used for base load generation capacity in fossil fuel fired power stations in Australia.

However, countries without the same renewable generation capacity will not have the same option for transitioning their existing fossil-fuel based electricity generation.

Japan's power utilities are taking a lead in co-firing ammonia in both coal- and gas-fired power plants. JERA is trialling the co-firing of ammonia with coal, with ammonia making up 20 per cent of the fuel mix. The same company has also announced plans to increase the use of ammonia to 50 per cent of the fuel mix by 2028[48].

The South Korean government also has plans to commercialise ammonia co-firing and China has reportedly demonstrated co-firing 35 per cent ammonia with coal[49].

The supply chains associated with supporting hydrogen fired generations are complex but are being closely examined. In April 2022, a Victorian-based world-first pilot project to export liquid hydrogen from Victoria to Japan was successfully completed[50].

In addition, hydrogen can be used in the future to support domestic electricity generation and grid stability. This is being advanced (see Electricity Grid Support section below) in projects in NSW, and WA.

47 HyResouce - Methanol synthesis using renewable hydrogen at https://research.csiro.au/hyresource/methanol-synthesis-utilising-renewable-hydrogen
48 Jera Targets 50 per cent Green Ammonia Coal Co-Firing at www.ammoniaenergy.org/articles/jera-targets-50-ammonia-coal-co-firing-by-2030
49 Chinese Firm Uses Ammonia for Coal Fired Power in Unit Bid Cut at www.scmp.com/news/china/science/article/3164951/chinese-energy-firm-uses-ammonia-coal-fired-power-unit-bid-cut
50 Hydrogen Energy Supply Chain (HESC) Project at www.hydrogenenergysupplychain.com

Areas where hydrogen is advancing

Investment

Based on public announcements, as of December 2022 Australia has a total of 106 active planned or operational hydrogen projects (Appendix 6) with 64 announced since the 2021 State of Hydrogen Report. In total, these hydrogen and ammonia projects are estimated to leverage investment capital of over $230-300 billion (Appendices 6 and 7).

The Table below points to more than twenty projects that are either operational or have reached a final investment decision, which is higher than the equivalent rate cited by the IEA (4 per cent)[51].

However, Figure 7 illustrates that in Australia most majority of projects have either not reached FID or been translated into an operational project. A significant portion of the projects yet to achieve FID have been undergoing development and financial restructuring for the past 2-3 years and are pending feasible financing solutions. To address this, Governments are investing in hydrogen industry hubs, providing economic incentives and investing in research and development to bring down the costs of hydrogen production, as outlined in sections below.

Table 5: Australian hydrogen projects in operation or past FID[52].

Project Name	Size of project (electrolyser capacity MW)	State
Operating		
Hydrogen Park South Australia	1.25	SA
Jemena Western Sydney Green Gas Project	0.5	NSW
Clean Energy Innovation Hub (CEIH)	0.26	WA
Toyota Ecopark Hydrogen Demonstration (Toyota Hydrogen Centre)	0.25	VIC
Sir Samuel Griffith Centre	0.16	QLD
ActewAGL Hydrogen Refuelling Station	0.075	ACT
Hydrogen Test Facility - ACT Gas Network	0.00125	ACT
Horizon Power Hazer Commercial Demonstration Plant		WA
Denham Hydrogen Demonstration Plant	0.348	WA
Hydrogen Refuelling Station Project	0.26 (using CEIH electrolyser)	WA
Under construction (achieved FID)		
Yuri Renewable Hydrogen to Ammonia Project	10	WA
Viva Geelong New Energies Service Station Project	2.5	VIC
Christmas Creek Renewable Hydrogen Mobility Project	1.4	WA
SunHQ Hydrogen Hub	1	QLD
Blue Economy CRC offshore hydrogen microgrid project[53]	0.7	TAS
Kogan Creek Renewable Hydrogen Demonstration Plant	0.7	QLD
Hydrogen Fuels Australia Truganina HRS	0.432	VIC
BOC Renewable Hydrogen Production and Refuelling Project	0.22	QLD
APA Renewable Methane Demonstration Project	0.005	QLD
Coregas Port Kembla Hydrogen Refuelling Facility		NSW
Swinburne University of Technology Victorian Hydrogen Hub - CSIRO Hydrogen Refuelling Station		VIC
Tallawarra B Dual Fuel Capable Gas/Hydrogen Power Plant		NSW

51 IEA (2022) Global Hydrogen Review (p72)
52 HyResource, 2022 - https://research.csiro.au/hyresource/category/projects/industry
53 HyResearch, 2022 - https://research.csiro.au/hyresearch/dc-microgrids-for-offshore-applications

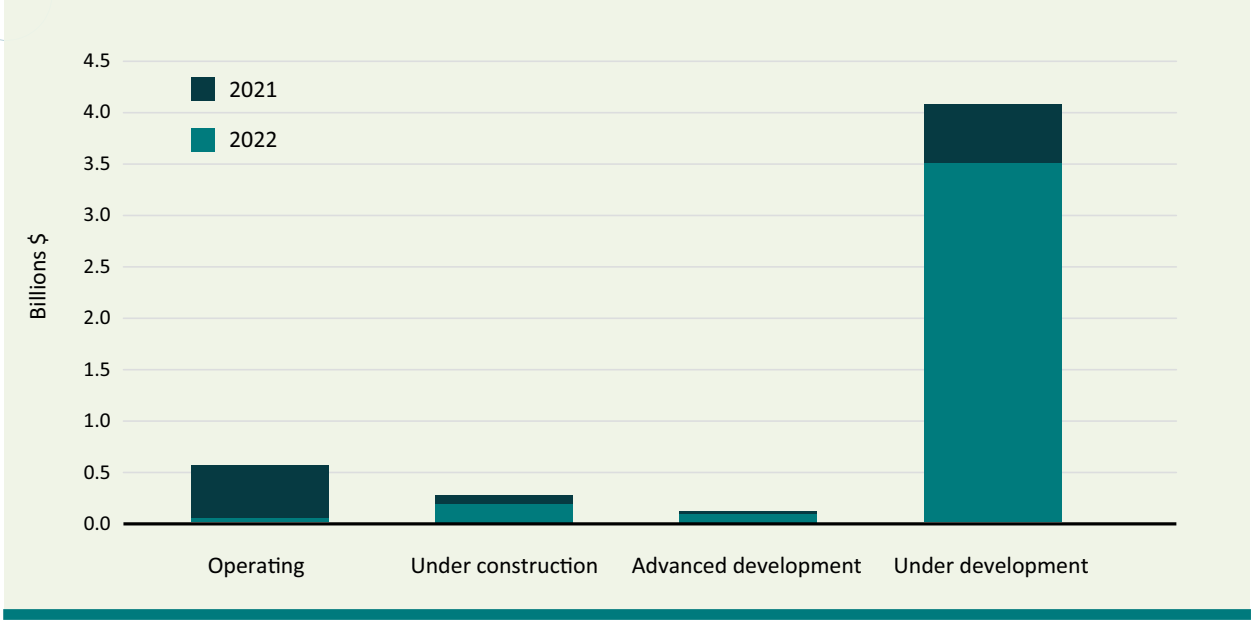


Figure 7: Estimated cumulative value of Australian hydrogen projects.

Table 6: Australian government hydrogen investment as at December 2022[54]

Jurisdiction	Committed hydrogen specific support (AUD)	Announced hydrogen eligible support (AUD)
Commonwealth	$1,589,377,972	$27,057,000,000
ACT	$130,000	$12,000,000
NSW	$3,264,100,000	$1,300,000,000
NT	$5,000,000	$2,000,000
QLD	$169,950,000	$4,500,000,000
SA	$682,090,000	$150,000,000
TAS	$280,200,000	$4,600,000
VIC	$97,735,000	$2,168,800,000
WA	$170,000,000	-
TOTAL	**$6,250,671,637 $6.3 billion**	**$35,198,400,000 $35.2 billion**

Appendix 2 contains summarises of government investment and policy support for hydrogen industry growth. Overall, Commonwealth, States and Territories have committed significant funding towards hydrogen industry development through project, infrastructure, policy and R&D funding.

54 HyResource (2023) – funding page. Proper link to come when live

Project scale

Australia's ambitions to become a global hydrogen super-power requires rapid development of industrial scale hydrogen production. Hydrogen hubs are regions where various producers, users and potential exporters of hydrogen across industrial, transport, export and energy markets are co-located. Hydrogen hubs will create economies of scale to drive down costs of production, unlocking further demand for hydrogen as costs fall.

Hydrogen Hubs are currently being established with the support of several Australian governments. In total federal and state funding is resulting in around a billion dollars investment in hydrogen hubs..

The Australian Government is providing $526 million towards the establishment of eight hydrogen hubs through the 'Regional Hydrogen Hubs' program and other commitments, including nine feasibility studies in support of potential future hydrogen hubs.

Table 7: Government Support for Hydrogen Hubs

State Government	Financial support	Hydrogen hub initiative details
New South Wales	$150,000,000	The NSW hydrogen hub initiative will support the development of hubs focusing on the Illawarra and Hunter regions. Four shortlisted projects are in the Hunter, four in the Illawarra and two in regional NSW. The NSW Government is currently assessing applications.
Northern Territory	MoU	The Northern Territory Government and international renewable energy company, Total Eren, have signed a MoU to develop a new green hydrogen project in Darwin.
Queensland	$15,000,000	$15 million was awarded under the Queensland Government's $4.5 billion Renewable Energy and Hydrogen Jobs Fund to progress the Front-End Engineering and Design (FEED) study planned for the Stanwell consortium CQ-H2 project. $15 million was committed to supercharge renewable hydrogen hubs in the state as part of the Queensland Energy and Jobs Plan.
South Australia	$67,000,000	$37 million invested to upgrade the Port Bonython jetty. $30 million committed towards the development of the Port Bonython Hydrogen Hub.
Tasmania	$230,000,000	The Tasmanian Green Hydrogen Hub will deliver common user infrastructure and domestic market activation to establish an export-scale hydrogen industry at Bell Bay. This investment will have matching support from the Tasmanian Government, its businesses and proponents.
Western Australia	$124,500,000	The WA Government will match the Australian Government's funding for the Pilbara Hydrogen Hub committing an additional $70 million towards the hub. $54.5 million to kick-start development of the Oakajee Strategic Industrial Area as a renewable hydrogen hub for the state's Mid-west region. $300,000 was awarded under Round 2 of the WA Government's Renewable Hydrogen Fund for a feasibility study for the H2 Kwinana project. Additional funding of $2.2 million is being provided to support hub development
Commonwealth	$526,000,000	Establishment of eight hydrogen hubs through the 'Regional Hydrogen Hubs' program and other commitments
TOTAL	**$1.02 billion**	

Kwinana Hydrogen Hub

The Australian Government has provided up to[55] and Australian governments have committed to provide up to $70 million each to establish a hydrogen hub at BP Australia's existing industrial area in Kwinana. The hub will include the construction of an electrolyser, hydrogen storage facilities and the upgrades to existing on-site infrastructure to support a range of uses such as transport fuels, and ammonia production. Funding agreements are currently under negotiation.

Hunter Valley Hydrogen Hub

The Australian government has committed to provide up to $82 million to develop a hydrogen hub in the Hunter Valley. This includes up to $41 million towards Origin Energy Future Fuels to deliver a 55 MW electrolyser, hydrogen storage facilities, a 2 MW fuel cell for hydrogen generated power and tube tailer filling bays in the same region. Most of the hydrogen produced will be blended into the natural gas network and delivered to Orica's ammonia production facility at Kooragang Island. Three hydrogen refuelling stations will also be built at customer locations across the region to fuel hydrogen trucks and buses.

The Hunter region may also benefit from the NSW government commitment of up to $150 million in grant funding to support the development of hubs across NSW focusing on the Illawarra and Hunter regions[56].

Pilbara Hydrogen Hub

The Australian government has provided $70 million towards the establishment of the Pilbara Hydrogen Hub, with a further $70 million to be provided by the Western Australian government[57]. The project is led by the Western Australian Government and focuses on common-user infrastructure, skills development and future expansion works required to grow the hub. The hub comprises a hydrogen pipeline system with a transfer capacity equivalent to 2–5 GW of renewable energy, the facilitation of vocational and university-level training, the upgrade of key infrastructure at Lumsden Point (Port Hedland).

Port Bonython Hydrogen Hub

The South Australian Government and industry partners are developing a hydrogen hub based on common-user infrastructure at Port Bonython to support hydrogen export projects. The project includes three focus areas: jetty and associated works at the state-owned port; construction of hydrogen storage systems; and transmission, electrical and substation infrastructure upgrades. The Australian government has provided $70 million towards the project, alongside a $37 million commitment from the South Australian government towards the upgrade of the existing Port Bonython jetty[58] and a further $30 million towards the development of the hub itself[59]. The project aims to achieve production from industry partners of a combined total portfolio of 1.2 million tonnes per annum of hydrogen by 2030, evolving with an estimated combined capital expenditure of up to $35.2 billion.[60]

55 HyResource – Kwinana – Hydrogen https://research.csiro.au/hyresource/h2kwinana

56 NSW Government – Hydrogen Hubs at www.energysaver.nsw.gov.au/reducing-emissions-nsw/net-zero-industry-and-innovation/hydrogen-hubs

57 Premier Mark McGowan (2021) Media Release - $117.5 million to progress two renewable hydrogen hubs www.mediastatements.wa.gov.au/Pages/McGowan/2021/11/117-point-5-million-dollars-to-progress-two-renewable-hydrogen-hubs.aspx

58 Government of South Australia – Energy and Mining Web Portal - Port Bonython export hub, details at www.energymining.sa.gov.au/industry/modern-energy/hydrogen-in-south-australia/port-bonython-export-hub

59 Government of South Australia - Hydrogen Jobs Plan - Powering New Jobs and Industry, details at www.statebudget.sa.gov.au/our-budget/jobs-and-economy/hydrogen

60 Source Department of Treasury and Finance SA

Bell Bay Hydrogen Hub

The Tasmanian Government is developing a hydrogen hub at Bell Bay based around common-user infrastructure including improvements to water infrastructure to facilitate increased water supply, transmission network upgrades, and port works comprising upgrades to berths, road access, pipeline corridors and fire emergency infrastructure. The Australian government is providing $70 million towards the establishment of the hub which will be added to by $230 million by the Tasmanian government, its businesses and proponents[61].

The hydrogen produced from the Tasmanian Green Hydrogen Hub will be used for ammonia and methanol production and export, as well as numerous domestic market activation trials in sectors such as agriculture, gas blending, heavy industry, transport, marine and maritime, and for remote power generation including in Antarctica.

Central Queensland Hydrogen Hub

The Australian government has committed $69.2 million towards the establishment of a hydrogen hub at Gladstone. In addition, the hub will be supported by the Queensland government ($30 million). The state government provided the Stanwell consortium with $15 million to progress the CQ-H2 Renewable Hydrogen project Front End Engineering and Design study[62] and an additional $15 million was provided to coordinate and further plan for renewable hydrogen hubs in key locations across the state including Central Queensland as part of the Queensland Energy and Jobs Plan[63].

Mid-West Hydrogen Hub

The Western Australian government has so far announced $54.5 million in support for development of Western Australia's Mid-West renewable hydrogen hub, targeting the Oakajee Strategic Industrial Area (SIA) for the hub's development. The Mid-West is attracting international interest for its renewable hydrogen potential and government support for the project will help to create regional jobs for the state[64,65].

Darwin H2 Hub

In August 2022, the Northern Territory government and international renewable energy company, Total Eren, signed a Memorandum of Understanding (MoU) to develop the Darwin H2 Hub. This renewable hydrogen hub will be based in Darwin in the Northern Territory and is planned to **c**omprise of at least 2 GW of solar PV generation that will power a 1 GW electrolyser. Total annual hydrogen production from the facility is anticipated at more than 80,000 tonnes. The Darwin H2 Hub will target production for both domestic uses and export, creating construction and ongoing jobs for the Territory[66].

Port Kembla Hydrogen Hub

The NSW government is providing up to $150 million for the development of two hydrogen hubs in the Illawarra and Hunter regions to support the establishment and growth of hydrogen industries across the state. Hydrogen hub development at Port Kembla in the Illawarra region has been targeted by the NSW government as it can benefit from the existing energy and related industries, associated infrastructure, and skills in the area. Port Kembla also hosts export scale steel and mining industries, representing additional off-take opportunities for the regional hub to decarbonise these hard-to-abate sectors[67].

61 Guy Barnett, Minister for Energy (2021) Tasmania's green hydrogen feasibility study findings, details at www.premier.tas.gov.au/site_resources_2015/additional_releases/tasmanias-green-hydrogen-feasibility-study-findings

62 The Honourable Dr Steven Miles (2022) Queensland Government funding fast-tracks Gladstone hydrogen hub. Details at https://statements.qld.gov.au/statements/95489

63 Queensland Government (2022) Queensland Energy and Jobs Plan at https://media.epw.qld.gov.au/files/Queensland_Energy_and_Jobs_Plan.pdf

64 Government of Western Australia Government (2021) A $61.5 million dollar boost for WA renewable hydrogen industry. At www.mediastatements.wa.gov.au/Pages/McGowan/2021/09/61-point-5-million-dollar-boost-for-WAs-renewable-hydrogen-industry.aspx

65 Government of Western Australian (2022) $5.5 million boost for Mid West Hydrogen Hub at www.mediastatements.wa.gov.au/Pages/McGowan/2022/10/5-5-million-dollar-boost-for-Mid-West-Hydrogen-Hub.aspx

66 Northern Territory Government (2022) Creating Territory Jobs through Hydrogen and Renewables at www.miragenews.com/creating-territory-jobs-through-hydrogen-and-836664

67 HyResource, 2022 – Port Kembla Hydrogen Hub at https://research.csiro.au/hyresource/port-kembla-hydrogen-hub

Townsville Green Hydrogen Hub

The Australian Government has committed to provide up to $70 million to establish a green Hydrogen Hub in the Townsville region of Queensland. This investment will further support the development of Australia's green hydrogen industry, assisting Australia to achieve its emission reduction goals while continuing to grow local industries and support the transition to low-cost green energy.

The rise of gigawatt scale projects in Australia

The private sector is also leading the way in pushing hydrogen project scale and ambition in Australia. Of particular significance is the positive final investment decision (FID) taken in September 2022 for Yuri SPV's 10 MW Yuri Renewable Hydrogen to Ammonia Project located in the Pilbara region of Western Australia.

Gigawatt scale project ambition is also on the rise in Australia. There are 11-gigawatt scale hydrogen projects in Australia's project pipeline, with nine announced (either new projects or existing projects with increased ambition) (Appendices 6 and 7) since the release of the 2021 State of Hydrogen report[68]:

- 10 GW Green Springs Project, NT
- 8 GW Desert Bloom Hydrogen, NT
- 4GW Cape Hardy Green Hydrogen Hub, SA[69]
- 3 GW Central Queensland Hydrogen Project (CQ-H2), QLD
- 3 GW H2-Hub Gladstone, QLD
- 3 GW Murchison Hydrogen Renewables Project, WA
- 2 GW Hunter Energy Hub, NSW
- 1 GW Edify Green Hydrogen Project, QLD
- *50 GW Western Green Energy Hub, WA
- *26 GW Australian Renewable Energy Hub, WA (formerly Asian Renewable Energy Hub)
- *8 GW HyEnergy Project, WA

*GW capacity relates to scale of anticipated renewable energy production rather than the electrolyser capacity.

These projects, however, are in the early stages of development and it is unclear how many will proceed to FID and then into operation. Feasibility studies and learnings from these projects will be important to Australia's emerging large scale hydrogen industry as they will provide a foundation to future hydrogen projects at gigawatt scale.

Cost-competitiveness

Although rated as Advancing in this year's assessment, this reflects a downgrade from the previous State of Hydrogen report. Global supply chain issues partly due to geopolitical instability in Europe, rising global demand for vital cleantech such as solar PVs and electrolysers has resulted in higher costs for key elements of clean hydrogen projects in 2022 compared to 2021. The mid-tier rating also reflects the lack of progress to lift the percentage of FID for commencing projects of scale. Currently, at this early stage of development of the clean hydrogen industry in Australia, costs of clean hydrogen production vary depending on the scale and size of project as well as how close production is to where the clean hydrogen will be used. For instance,

- Public data from the ActewAGL Hydrogen Refuelling Station indicates that hydrogen is priced at an uncompetitive AU$10-15/kg[70]. Although this cost is closely related to the small scale of the electrolyser (75kW), it is reflective of high national production costs given that, of the eight operating electrolysers on the HyResource list, only one exceeds 1 MW capacity.
- Feasibility studies continue to be released on Australian projects, with a pre-feasibility study released by Frontier Energy Limited for their Bristol Springs Project. Although largely theoretical at this stage, Frontier Energy estimates that the project could achieve a total cost of AU$2.83 per kilogram of hydrogen, inclusive of cost reduction attributed to net power sales from the site[71].

68 HyResource, 2022 - https://research.csiro.au/hyresource/category/projects/industry

69 Iron Road, 'Cape Hardy Green Hydrogen EOI Attracts Multi-Billion Dollar Indicative Proposals' (15 November 2022), https://wcsecure.weblink.com.au/pdf/IRD/02597990.pdf

70 J. Narayan, 'First Public Hydrogen Refuelling Station Set to Power Government Vehicles' (29 March 2021), www.drive.com.au/news/first-public-hydrogen-refuelling-station-set-to-power-government-vehicles

71 Frontier Energy Ltd, 'Pre-Feasibility Study Outlines Low-Cost Green Hydrogen Production' (4 August 2022), https://wcsecure.weblink.com.au/pdf/FHE/02549649.pdf

Options to improve cost competitiveness

In addition to increasing scale, global analysis suggests that key factors to reduce the costs of hydrogen include ongoing improvements in energy conversion efficiency of both electrolysers and renewable electricity (Figure 9). Reducing the cost of hydrogen storage will also be important for processes requiring a consistent supply, such as ammonia production.

Deloitte's analysis observed that Fortescue Future Industries' construction of the world's largest electrolyser facility in Gladstone will likely drive down the cost of electrolysers. The IEA Global Hydrogen Review in 2022 found that Australia would contribute the bulk of new electrolyser capacity from 2028-2030 globally.

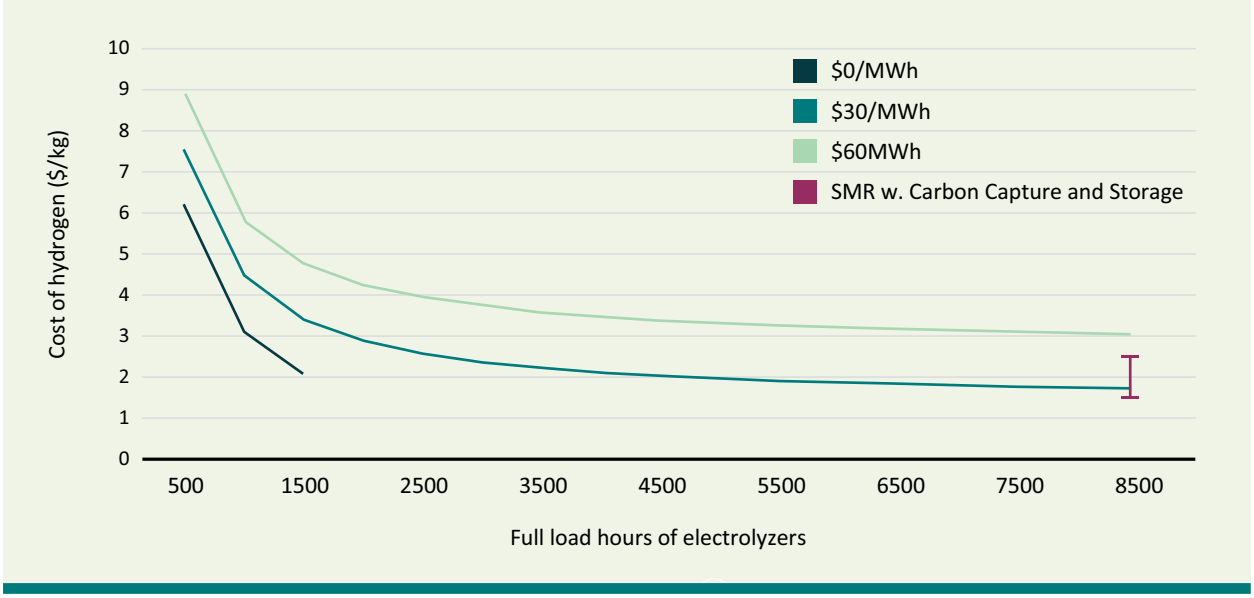


Figure 8: Costs of hydrogen as a function of utilization factor of alkaline electrolysers for various electricity prices. (IEA, 2022)[72]

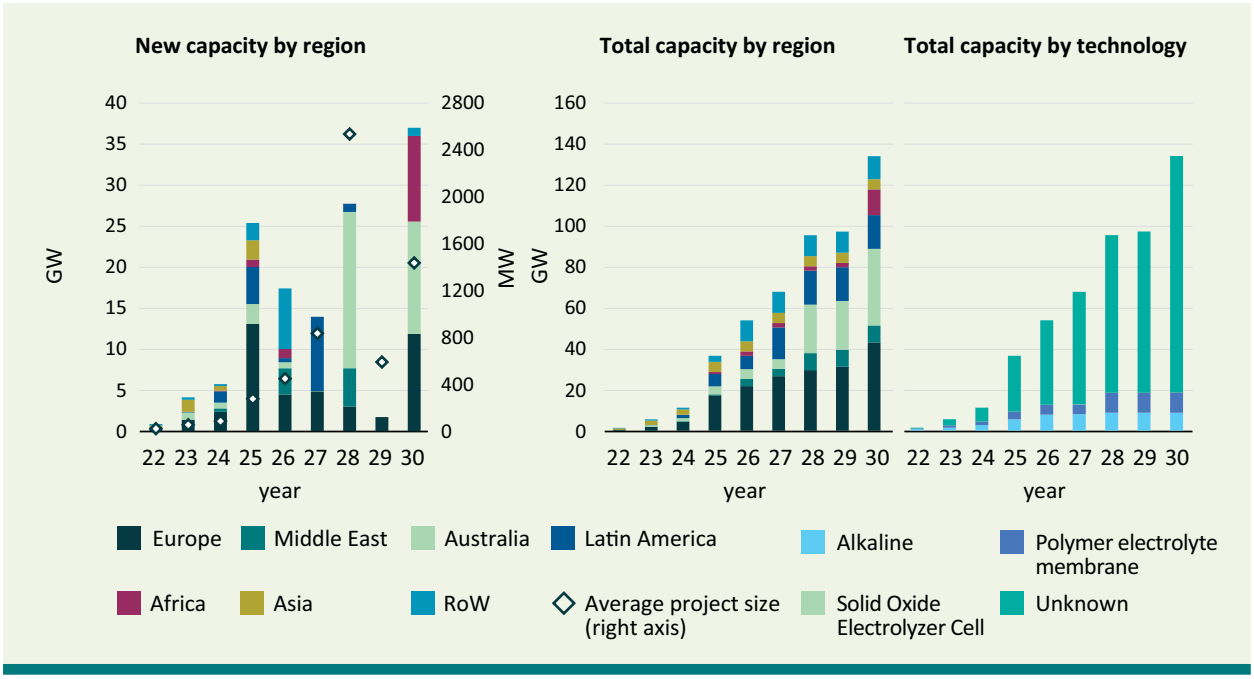


Figure 9: Electrolyser capacity by region and type based on project pipeline to 2030 (Source: IEA, 2022)[73]

72 IEA (2019) The Future of Hydrogen. IEA. Paris. P47https://iea.blob.core.windows.net/assets/9e3a3493-b9a6-4b7d-b499-7ca48e357561/The_Future_of_Hydrogen.pdf
73 IEA (2022) Global Hydrogen Review. IEA. Paris.

There is potential to improve the energy efficiency of electrolysers and thereby significantly reduce both capital and operational expenditure of hydrogen projects. For instance, Hysata is an Australian electrolyser research and development company that has developed an electrolyser capable of 95 per cent system efficiency (requiring only 41.5 kWh/kg of hydrogen), compared with 75 per cent system efficiency for other electrolyser designs.

The improvement in efficiency is anticipated to enable a hydrogen production cost well below AU$2/kg[74]. Hysata is planning to build an electrolyser facility capable of manufacturing 1 GW of electrolysers per annum by 2025. However, Hysata has not yet undertaken large-scale system trials. The Australian Government has supported the development of Hysata technology through funding from ARENA[75] and the CEFC[76], alongside the NSW Government[77].

Ongoing efficiency improvements in generation technology are likely to contribute to further falls in renewable energy and hydrogen production costs. For instance, 5B is an Australian firm that makes prefabricated solar PV modular structures that are built and pre-wired in a factory and then can be deployed rapidly and safely at scale. Assisted by ARENA funding, 5B is focused on lowering costs via greater automation of assembly and deployment. 5B aims to reduce the total capital cost of delivering a complete solar farm from AUD$0.88/W to AUD$0.56/W by the end of the ARENA project, towards a target of AUD$0.29/W by 2030. The pre-fabrication and greater automation of installation has enabled 5B to achieve a record for speed of installation in May 2022 of 110kW per person per day. This is 10 times faster than conventional solutions.

Although in its early stages of development, Australia's offshore wind industry has massive potential, with the IEA observing, "*Using offshore wind generation for electrolysis is another option to provide hydrogen at relatively high full load hours and high utilisation rates for further synthesis steps in regions with good resource conditions*"[78].

The cost competitiveness of hydrogen production will likely benefit from the Australian Government's actions to modernise the Australian electricity grid. This initiative includes achieving 82 per cent renewable electricity by 2030 through the $20 Billion Rewiring the Nation initiative. The scaling of transmission line capacity for renewable electricity projects will lead to the costs of large-scale utility renewable energy projects continuing to fall over time.

Uncertainty regarding regulation and standards of new equipment, such as electrolysers, can also create risks for new investment. Australian governments are working together to establish a clear and certain regulatory pathway for the development of hydrogen projects.

74 Hysata, 'Hysata's Electrolyser Breaks Efficiency Records' (16 March 2022)
75 ARENAWIRE – Australian R&D Puts Low-Cost Hydrogen Within Reach at https://arena.gov.au/blog/australian-rd-puts-low-cost-hydrogen-within-reach/
76 CEFC (2022) Media Release – CEFC Increases Hysata Investment to Advance Green Hydrogen at www.cefc.com.au/media/media-release/cefc-increases-hysata-investment-to-advance-green-hydrogen
77 NSW Government (2022) Clean technology research and development set to take off at - www.nsw.gov.au/media-releases/clean-tech-research-development
78 IEA (2022) Global Hydrogen Review. P96

Electricity grid support

This year's assessment shows that Australia is progressing well on using hydrogen for electricity grid support, while acknowledging that batteries and pumped-hydro technologies are currently being favoured for electricity grid support services. Several trials with hydrogen grid support components are being developed, including the following examples[79]:

- Horizon Power has commissioned a hydrogen demonstration plant in the small coastal town of Denham. The plant will provide renewable energy for a microgrid power station.
- The Clean Energy Innovation Hub in Perth operates a microgrid hybrid energy system that produces, stores and uses hydrogen. This includes blending hydrogen with natural gas and using it to generate power. [80]
- In 2021, it was announced that Snowy Hydro's 660 MW Kurri Kurri gas generator and Energy Australia's 316 MW Tallawarra B gas generator were being developed to be hydrogen-ready once operational. It is anticipated that these facilities will operate on natural gas or a natural gas/hydrogen blend on commissioning. The final configuration of the project once deployed may require additional investment to support various (up to 100 per cent) hydrogen blending levels.
- The South Australian Government has committed to the development of the Whyalla Hydrogen Power Station, which is expected to be operational by 2025. This will include a 200 MW generation unit, 250 MW electrolyser and associated hydrogen storage facility at an estimated cost of $593 million. The plant will be world leading in terms of supporting grid stability and demand balancing when complete.

The Western Australian Government is also doing significant work in this sector. The WA Government are developing a new Renewable Hydrogen Target which could incentivise 'green hydrogen' used to generate electricity in the South West Interconnected System (SWIS)[81].

International collaboration

Australia is working closely with international partners to develop a global hydrogen export industry. Since 2018-2020 the Australian Government has developed and established bilateral MoU partnerships with South Korea, Japan and Singapore on clean hydrogen and since 2021 the Australian Government has established seven international clean energy partnerships, with Singapore, Japan, Germany, the United Kingdom, the Republic of Korea, India, and the United States, all of which feature cooperation on hydrogen. The hydrogen aspects of these partnerships focus on:

- attracting investment and trade
- building supply chains and increasing scale and
- advancing research, development and deployment.

Australia and India signed the Letter of Intent on New and Renewable Energy Technology during the fourth India-Australia Energy Dialogue in February 2022. The collaboration focusses on tangible actions and projects including the manufacture and deployment of electrolysers. Australia and the United States signed the Australia – United States Net Zero Technology Acceleration Partnership at the Sydney Energy Forum in July 2022. The partnership includes a focus on developing and deploying hydrogen applications in mining and heavy vehicles, cooperation on hydrogen certification, and hydrogen hubs development.

Other developments and initiatives under the international clean energy partnerships include:

- The launch of the German-Australian Hydrogen Innovation and Technology Incubator (HyGATE) with funding of up to A$50 million from Australia and up to €50 million from Germany to support real-world projects along the hydrogen supply chain.
- The Hydrogen Energy Supply Chain (HESC) Pilot Project completing a world-first demonstration of a liquefied hydrogen supply chain from Australia to Japan (Box 2)[82].

79 Deloitte (2022) Hydrogen Market Analysis and Comparison. Deloitte.
80 HyResource project database
81 Government of Western Australia, 'A Renewable Hydrogen Target for Western Australia, www.wa.gov.au/government/document-collections/renewable-hydrogen-target-western-australia
82 CSIRO, 'Hydrogen Energy Supply Chain (HESC) – Pilot Project' (June 2022)

BOX 2. World-first liquid hydrogen export

In April 2022, a Victorian-based world-first pilot project to export liquid hydrogen from Victoria to Japan was successfully completed. The project was a collaboration involving the Japanese Government, Australian Government, Victorian Government, and supported by Japanese and Victorian industry.

The pilot established a new hydrogen supply chain in Victoria produced from brown coal and a mixture of biomass, which was then transported to the Port of Hastings for liquefaction, before being loaded onto the purpose-built vessel known as the 'Suiso Frontier' at the Port of Hastings. The liquid hydrogen was then shipped to the Port of Kobe in Japan. This is the first time that liquefied hydrogen has been exported from one continent to another. The Hydrogen Energy Supply Chain pilot project provided Victoria with a first mover advantage in developing a hydrogen supply chain, removed regulatory barriers, provided a focus for investment in new engineering and technical expertise, created knowledge transfer, and built an understanding of hydrogen as a fuel across the economy.

Figure 10: Purpose built vessel known as the 'Suiso Frontier' carrying hydrogen between Australia and Japan.

CSIRO has contributed towards international engagement efforts through the $5 million Hydrogen RD&D International Collaboration Program. CSIRO have led hydrogen research delegations under the program to France, Germany, the United Kingdom, the US and Japan.

Alongside its bilateral work, Australia is also playing a leading role in multilateral cooperation around hydrogen. The most notable is through our lead role in the International Partnership for Hydrogen and Fuel Cells in the Economy's (IPHE) work on greenhouse gas accounting methodologies for hydrogen production and supply chains.

The accounting framework is being trialled domestically by the Clean Energy Regulator in co-design with the Australian industry. The results of the trial are assisting the Australian Government to design an internationally aligned Guarantee of Origin scheme for hydrogen and other low emission products. The approach of using the IPHE framework could potentially be adopted worldwide, as a common emissions accounting system to underpin the various standards and definitions for hydrogen.

Australia is also co-leading the Clean Hydrogen Mission (CHMI) under Mission Innovation. CHMI is a multi-government initiative to support activities that increase the cost-competitiveness of hydrogen through RD&D activities.

The states and territories are also closely engaged with potential trading partners through the following initiatives:

- South Australia[83], Tasmania[84], Queensland[85] and Western Australia[86] have all signed MoUs with the Dutch Port of Rotterdam to collaborate on opportunities to develop a hydrogen export supply chain.
- The Northern Territory Government has signed a MoU with an international renewable energy company, Total Eren, to develop a new green hydrogen project – the Darwin H2 Hub[87].
- The South Australian Government has signed multiple Statements of Cooperation with several Australian and Japanese companies to accelerate the development of the hydrogen industry in South Australia[88].

The Australian private sector also continued to build international partnership momentum. Several of Australia's largest organisations signing memorandums of understanding (MoUs) with supply chain partners. For example, Fortescue Future Industries (FFI) and E.ON, one of Europe's largest operators of energy networks and energy, signed a MoU to deliver up to five million tonnes per annum of green renewable hydrogen to Europe by 2030.

Mining and off-grid

Many mines in Australia operate off-grid using diesel generators or natural gas to produce electricity. Hydrogen could soon be sufficiently affordable to provide a viable alternative. In its market study to the Clean Energy Finance Corporation, Advisian noted that the hydrogen production, storage and power generation cycle approaches parity with battery / diesel hybrid systems in remote power service[89]. This application could provide opportunities for the mining sector to consider synergies with hydrogen powered heavy vehicles.

Fourteen mining and off-grid projects have been announced that are primarily connected to moderate scale renewables (0.3-0.6 MW systems). Seven off-grid projects are operational or under construction, with two of these coming online since the 2021 assessment. Australian projects progressing in 2022 include:

- The Denham Hydrogen Demonstration Plant, Western Australia which has been commissioned and is anticipated to become fully operational in early 2023 with a 348 kW PEM electrolyser and 100 kW fuel cell.

83 Port of Rotterdam, 'Feasibility Study on Export of South Australian Green Hydrogen to Rotterdam, (23 March 2021), www.portofrotterdam.com/en/news-and-press-releases/feasibility-study-export-south-australian-green-hydrogen-rotterdam

84 Tasmanian Government, 'Tasmania and Port of Rotterdam Sign Green Hydrogen MOU' (28 December 2021), www.premier.tas.gov.au/site_resources_2015/additional_releases/tasmania_and_port_of_rotterdam_sign_green_hydrogen_mou

85 Queensland Government, 'Queensland Signs Hydrogen Agreement with Massive European Port' (11 May 2022), https://statements.qld.gov.au/statements/95128

86 Government of Western Australia, 'WA and Port of Rotterdam to Collaborate on Renewable Hydrogen' (30 November 2021), www.mediastatements.wa.gov.au/Pages/McGowan/2021/11/WA-and-Port-of-Rotterdam-to-collaborate-on-renewable-hydrogen.aspx

87 Northern Territory Government, 'Creating Territory Jobs Through Hydrogen and Renewables', https://cmc.nt.gov.au/news/2022/creating-territory-jobs-through-hydrogen-and-renewables

88 Government of South Australia, 'Heavyweights Sign Hydrogen Statement of Cooperation', (11 October 2022), www.energymining.sa.gov.au/home/news/latest/heavyweights-sign-hydrogen-statement-of-cooperation

89 CEFC, 'The Australian Hydrogen Market Study' (24 May 2021), www.cefc.com.au/insights/market-reports/the-australian-hydrogen-market-study

- Phase 1 of Ark Energy's SunHQ Hydrogen Hub that moved into construction in 2022. The project seeks to produce green hydrogen using electricity from the Sun Metals solar farm that will be used to refuel a fleet of ultra-heavy duty Hyzon hydrogen trucks for use at the Sun Metals zinc refinery. Fortescue is seeking to replace its fleet of diesel coaches at the Christmas Creek iron ore mine with a fleet of hydrogen fuel cell coaches. This project is under construction and expected to commence operation in 2022. The site will use two 700 kW PEM electrolysers and include a BOC supplied refuelling station at an anticipated cost of $32 million, with $2 million of WA Government support.
- Australian companies such as LAVO and H2X Global are advancing fuel cell generator technologies for smaller scale off-grid uses.

Integrating hydrogen into the gas networks

The use of hydrogen in gas networks is developing, but there has been limited progress in terms of projects reaching a Final Investment Decision since last year. There is also uncertainty regarding some large-scale projects that have spent a further year in development, driving a downgrade of this metric compared to the last State of Hydrogen report.

A total of 16 hydrogen projects targeting gas blending have been announced, representing an increase of 2 projects since 2021. Both of these new projects are in Western Australia. Of the 16 projects, 4 are operational (Clean Energy Innovation Hub, Hydrogen Park South Australia, Hydrogen Test Facility – ACT Gas Network and Western Sydney Green Gas Project) and have a combined annual hydrogen production capacity of 286 tonnes.

Notable projects which have either commenced operations or entered advanced development and are approaching FID since the 2021 assessment include:

- The Western Sydney Green Gas Project, which commenced grid injection operations in November 2021. It has an electrolyser capacity of 0.5 MW, producing approximately 88 tonnes of hydrogen per annum.
- The Clean Energy Innovation Park is in advanced development in Perth in Western Australia and is targeting a 10 MW electrolyser to produce 4 tonnes of hydrogen per day. This project is awaiting FID.
- The Hydrogen Park Murray Valley is also in the advanced development stage and targeting a 10 MW electrolyser to supply 10 per cent of Albury and Wodonga's volumetric gas supply. The project is awaiting FID and was awarded $32.1 million in 2021 in conditional ARENA funding.
- In Western Australia, ATCO commenced Hydrogen blending into gas networks supported by $2 million State government funding.

In addition, there techno-economic studies are being finalised by Australian Hydrogen Centre with ARENA funding for 10% and 100% hydrogen injection by 2030 and 2050 respectively into state wide gas network in Victoria and South Australia. As part of the National Hydrogen Strategy, Australian Governments are also undertaking a study to explore the economics of hydrogen blending in Australian gas networks and potential conversion to 100% hydrogen.

In October 2022, Australian governments through Energy Ministers have agreed to reform the National Gas Law (NGL) and National Energy Retail Law (NERL), regulations and subordinate instruments to bring hydrogen, biomethane and other renewable gases, including blended gas, within the scope of the national gas regulatory framework. The reforms aim to provide regulatory certainty to support investment in innovative projects and foster the development of a competitive and cost-efficient hydrogen and renewable gas industry.

Areas where the industry is advancing slowly

Transport

The National Hydrogen Strategy[90] identifies several early opportunities for hydrogen vehicles:

- 'back to base' transport applications such as fleet vehicles and metropolitan public transport
- freight transport
- industrial users such as ports or remote industrial sites.

Hydrogen transport is seen as an early offtake opportunity to both stimulate hydrogen demand and decarbonise hard-to-abate aspects of the transport sector, such as heavy vehicles and shipping. Due to the high cost and immaturity of the sector, hydrogen transport has required government support to de-risk investments and kick-start hydrogen transport uptake.

Australian public funding for hydrogen transport totals $357 million with the Australian Government contributing $132 million and State and Territory governments $225 million to the sector's development (as of October 2022).

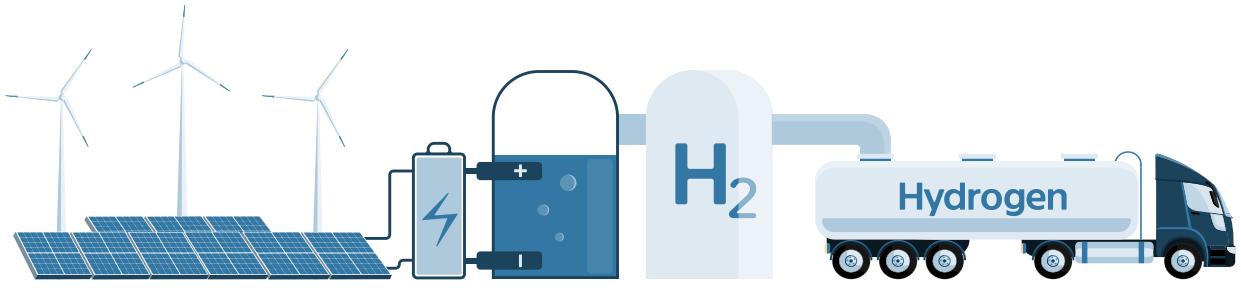
The Australian Government has committed up to $80 million to the development of hydrogen transport refuelling infrastructure through the ARENA Future Fuels funding program (Hydrogen Highways). ARENA and the Clean Energy Finance Corporation have also supported ARK Energy Corporation to operate five purpose-built hydrogen fuel cell heavy trucks to transport zinc ore from Townsville Port in Queensland to the Sun Metals Refinery, where they will refuel with green hydrogen produced on site, before taking zinc ingots back to the port in a 30 km clean energy round trip. [91] Additional Australian Government funding for transport has been contributed through the ARENA Advancing Renewables program and the Australia-Singapore Low Emissions Technologies for Maritime and Port Operations initiative. Table 8 summarises State and Territory investment for hydrogen transport.

90 Commonwealth Government (2019) National Hydrogen Strategy - www.dcceew.gov.au/energy/publications/australias-national-hydrogen-strategy

91 CEFC, 'CEFC Hydrogen Investment Fuels World's Heaviest Fuel Cell Electric Trucks', (8 November 2021), www.cefc.com.au/media/media-release/cefc-hydrogen-investment-fuels-world-s-heaviest-fuel-cell-electric-trucks

Table 8: State and Territory Government investment towards enabling hydrogen transport.

State Government	Financial support	Hydrogen transport initiative details
Matching State contributions to *Driving the Nation: Hydrogen Highways*	$60,000,000	Exclusive of NSW and Victoria as they been accounted for under the Hume Hydrogen Highways initiative ($20 million), the Federal Government's Hydrogen Highways initiative will make available up to $60 million to remaining States and Territories on a matching basis.
New South Wales	$10,000,000	The Hume Hydrogen Highway initiative is a joint grant initiative between the NSW and Victorian Governments to support the deployment of an Australian-first hydrogen refuelling network for line-haul freight along the Hume Highway. The objective is to kick-start decarbonisation of the heavy transport industry, with a minimum of 4 refuelling stations and 25 hydrogen-powered trucks.
	$15,000,000	Total $25 million for regional trials in new and emerging technologies, including $15 million for hydrogen fuel cell electric buses.
	$600,000	State-first trial of hydrogen-powered electric buses on the state's Central Coast.
Queensland	$28,900,000	Under the $4.5 billion Queensland Renewable Energy and Hydrogen Jobs Fund to support the Kogan Renewable Hydrogen Demonstration Plant near Chinchilla backing CS Energy for the demonstration plant and a heavy hydrogen vehicle refueller network.
	$19,200,000	Under the $35 million Hydrogen Industry Development Fund (HIDF) for hydrogen transport related projects including: • $5 million for SunHQ to trial up to five hydrogen fuel cell electric trucks in the Sun Metals fleet • $5 million towards the construction of a Sealink hydrogen passenger ferry capable of carrying up to 200 passengers at speeds of 20 knots (37 km/hr) • $2.7 million for the GH2BUS project to supply fuel for the trial of two hydrogen fuel cell electric coaches on its mine transport and school bus contracted routes • $1.5 million for Transdev to trial two hydrogen fuel cell electric buses on the existing TransLink public transport network at Redland Bay • $5 million for the Hydrogen Mobility Project to support Aurizon trial four hydrogen fuel cell electric trucks in its fleet with installation of a high capacity refueller at the Stuart Freight Terminal suitable for heavy vehicles.
	TBC	Hume Hydrogen Highway initiative (tri-state MoU between NSW, Victoria and Queensland to build an East Coast Renewable Hydrogen Refuelling Network).
	TBC	Committed to a trial of five hydrogen powered Fuel Cell Electric Vehicles (FCEV) in the Queensland Government fleet.
Tasmania	$12,300,000	Approved under the Tasmanian Renewable Hydrogen Industry Development Funding Program to support the trial of three hydrogen fuel cell electric buses (FCEB) in Hobart, for up to three years.



State Government	Financial support	Hydrogen transport initiative details
Victoria	$46,000,000	Australia's first public Zero Emissions Vehicle (ZEV) subsidy program which will support Victorian residents and businesses to purchase new ZEVs including hydrogen FCEVs.
	$10,000,000	The Hume Hydrogen Highway initiative is a joint grant initiative between the NSW and Victorian Governments to support the deployment of an Australian-first hydrogen refuelling network for line-haul freight along the Hume Highway. The objective is to kick-start decarbonisation of the heavy transport industry, with a minimum of 4 refuelling stations and 25 hydrogen-powered trucks.
	$10,000,000	Fund the replacement of the Victorian Government Fleet with ZEVs that may include hydrogen FCEVs.
	$2,800,000	Under the $6.6 million Renewable Hydrogen Commercialisation Pathways Fund towards: • $1.8 million for Volgren Australia's Manufacturing and Commercialisation of Hydrogen Buses Project to develop two hydrogen fuel cell electric buses for demonstration, trial and commercialisation. • $1 million for Viva Energy towards its New Energies Service Station Project to develop a hydrogen refuelling station.
	$150,000	Under the $608,665 Renewable Hydrogen Business Ready Fund for Electromotiv's Green Hydrogen Coach Trial to conduct a feasibility study for installing hydrogen refuelling infrastructure at bus depots in Victoria for (long-range) V/Line routes.
Western Australia	$10,000,000	Hydrogen Fuelled Transport Program to accelerate the uptake of hydrogen fuelled transport and stimulate local production of renewable hydrogen.
	$5,400,000	Under the $15 million Renewable Hydrogen Fund to support hydrogen transport related projects including: • $2 million for FMG H2's renewable hydrogen mobility project in the Pilbara which will produce solar hydrogen for transport at Fortescue's Christmas Creek iron ore mine • $1 million towards ATCO's hydrogen refueller project in Jandakot that will develop, deploy and operate the first green hydrogen refuelling station in WA. • $250,000 for the Renewable Hydrogen Transport Hub in the City of Mandurah feasibility study for a hydrogen refuelling infrastructure hub. • $149,000 for the City of Cockburn project to determine the feasibility for solar hydrogen production for waste collection and light vehicle fleets.
TOTAL	**$230,850,000**	

Heavy transport

Heavy transport shows promise as an early use for hydrogen, particularly line-haul and back-to-base bus and truck vehicles. Below is a summary of some of the projects occurring[92]:

- Australia has several committed projects that will trial hydrogen fuel cell buses. Foton Mobility will be delivering the first fuel cell electric buses in Australia, which will be added to the Transit Systems fleet of sustainable green transport solutions. [93]
- The NSW Government in partnership with ARCC and Red Bus will be trialling the state's first fuel cell electric bus. The results will be compared with battery electric bus trials.
- Emerald Coaches are planning to trial fuel cell electric buses powered with green hydrogen to transport mine workers and students in the Bowen Basin[94].
- Transdev will trial two fuel cell electric buses in Redland Bay with the buses manufactured by Australian bus builder, Volgren in partnership with European manufacturer, Wrightbus. The Victorian Government is also supporting a project with Volgren Australia to develop two renewable hydrogen fuel cell electric buses in Dandenong[95]. The Victorian Government is conducting a $20 million Zero Emissions Bus Trial, including two hydrogen fuel cell buses to operate from its Footscray depot from March 2023.
- The Western Australian government has invested $10 million in Woodside's hydrogen heavy transport and refueller @H2Perth Project that will deploy 10 hydrogen fuelled heavy vehicles for back to base operations by end 2024.

The Australian Government, through ARENA, has also provided up to $22.8 million in support to Viva Energy to develop the Geelong New Energies Services Station. Servicing all hydrogen heavy truck types - The new hydrogen refuelling station from the Geelong New Energies Service Station project will be providing dedicated hydrogen fuel to heavy transport. The Geelong project will provide fuel to:

- Toll Group – two hydrogen-powered prime movers deployed for the delivery of liquid fuels from Viva Energy's Geelong Refinery.
- ComfortDelGro Corporation Australia – two hydrogen-powered buses for use on Geelong's city commuter bus routes.
- Cleanaway – two hydrogen-powered waste management vehicles for municipal waste collection in the Greater Geelong region.
- Barwon Water – one hydrogen-powered prime mover to aid recycling of organic waste.

Light transport

The NSW Government has set a stretch goal of getting 10,000 hydrogen fuel cell vehicles on NSW roads and 100 refuelling stations by 2030. Lack of hydrogen refuelling infrastructure in Australia has prevented companies from purchasing hydrogen fuel cell forklift trucks in the numbers seen in the USA. The significant investment in hydrogen refuelling stations outlined above, is designed to enable a range of hydrogen fuel cell light vehicles to be used in Australia.

92 Deloitte (2022) Hydrogen Market Analysis and Comparison. Deloitte.
93 Australasian Bus and Coach, 'Foton Hydrogen City Buses Arrive for Transit Systems Australia, (19 August 2022), www.busnews.com.au/industry-news/2208/foton-hydrogen-city-buses-arrive-for-transit-systems-australia
94 Queensland Government, 'Hydrogen to Fuel Emerald Buses for Miners and School Kids' (20 April 2022), https://statements.qld.gov.au/statements/94999
95 The Driven, 'Victorian Government Backs Volgren to Build Two Hydrogen Buses' (30 March 2022), https://thedriven.io/2022/03/30/victorian-government-backs-volgren-to-build-two-hydrogen-buses

Investing in hydrogen refuelling infrastructure

The uptake of hydrogen fuel cell vehicles is dependent on the roll out of hydrogen refuelling stations. Currently, Australia has two fixed operating hydrogen refuelling stations:

- Toyota Australia commenced operations of its commercial hydrogen refuelling facility at its former car factory in Altona (Victoria) in November 2021. The Hydrogen Centre project is the second phase of the Altona site transformation and includes an on-site 87 kW solar PV system (in conjunction with an existing 500 kW array with grid back-up) and a 250 kW electrolyser that will produce at least 60 kg of hydrogen per day. This will fuel hydrogen powered vehicles, such as fuel cell forklifts at the Altona site warehouse and FCEVs.
- In March 2021, ActewAGL opened a public hydrogen refuelling station in Canberra, and services 20 Hyundai Nexo hydrogen fuel cell electric vehicles (FCEVs) operated by the ACT Government, and a small number of private FCEVs.
- In December 2022, ATCO Jandakot Hydrogen Refueller started refuelling hydrogen cars in Western Australia, operated by ATCO, FFI and WA Police in Western Australia

There are a further nine refuelling station projects currently under construction and seven under development that target a range of transport end-use applications, such as refuelling for freight and mining trucks, buses, and passenger vehicles and ferries. The refuelling stations under construction are[96]:

- Hydrogen Fuels Australia Truganina
- ATCO and Fortescue Metal Group's Hydrogen Refueller Station Project
- Kogan Creek Renewable Hydrogen Demonstration Plant
- Port Kembla Hydrogen Refuelling Facility
- BOC Renewable Hydrogen Production and Refuelling Project
- SunHQ Hydrogen Hub
- Swinburne University of Technology Victorian Hydrogen Hub - CSIRO Hydrogen Refuelling Station
- Christmas Creek Renewable Hydrogen Mobility Project.
- The Geelong New Energies Service Station Project. The project includes a 2.5 MW electrolyser and will be capable of generating more than 1,000 kilograms of renewable hydrogen per day, powering a fleet of at least 15 hydrogen fuel cell heavy vehicles.

Hydrogen fuelled transport initiatives in Western Australia

In August 2021, the Western Australian Government announced an initial $10 million to accelerate the uptake of hydrogen fuelled transport as part of the $61.5 million announced in the 2021-22 State Budget to drive renewable hydrogen development and demand stimulation.

The purpose of the initial Expression of Interest Stage was to understand the market's risk appetite, preferred delivery model and price point for Hydrogen at the bowser. The State was able through this process to assess a number of hydrogen fuelled transport applications, which would be deployed in Western Australia and identify potential projects that could be co-funded by Government with the objectives of:

- aggregating demand for local renewable hydrogen
- accelerating the uptake of hydrogen fuelled vehicles
- encouraging the deployment of hydrogen refuelling infrastructure and
- increasing skills, capacity and knowledge relevant to renewable hydrogen technologies in WA's transport sector, and/or other related industries.

Under this process, Woodside was awarded the full $10 million grant for its Hydrogen Refueller project at its H2Perth site that will establish a renewable hydrogen production, storage and refuelling facility as well as deploy up to 10 heavy hydrogen vehicles for commercial operations such as concrete agitator trucks, waste collection trucks and prime movers replacing incumbent diesel vehicles. The commissioning of this back to base type operation is planned for mid-2024.

96 Deloitte (2022) Hydrogen Market Analysis and Comparison. Deloitte.

BOX 3. Hydrogen highways

In March 2022, the New South Wales, Victoria and Queensland governments announced a landmark tri-state collaboration on a renewable hydrogen refuelling network for heavy transport and logistics along Australia's eastern seaboard. The first program being delivered under this agreement is the Hume Hydrogen Highway initiative by the NSW and Victorian Governments.

Initially, the Victorian and New South Wales Governments are investing $10 million each for the Hume Hydrogen Highway initiative[97]. The Hume Hydrogen Highway is a joint grant initiative that supports the design and delivery of the at least four refuelling stations. This includes 25 hydrogen-powered line-haul heavy freight vehicles along the Hume Hydrogen Highway between Melbourne and Sydney - Australia's busiest freight corridor.

The Federal Government will also work with the States and Territories to roll out Hydrogen Highways nationally, matching the funding already committed by New South Wales and Victoria ($20 million) and making the same amount available to other jurisdictions on a matching basis (up to $60 million)[98]. Based on a recent agreement between New South Wales, Victoria and Queensland, the investment could deliver an extra 16 hydrogen refuelling stations on Australia's busiest freight routes.

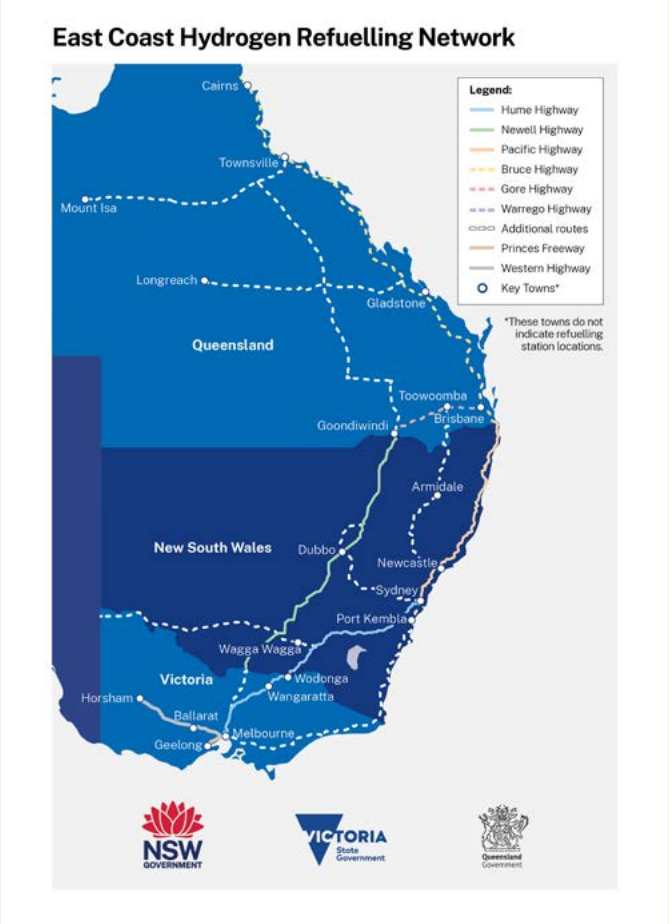


Figure 11: East Coast Hydrogen Refuelling Network (Source, NSW, Victoria and Queensland Governments, 2022[99]).

97 NSW government, 'Delivering the renewable Hume Hydrogen Highway' (July 2022)
98 Australian Labor Party, 'Driving the Nation' (2022)
99 NSW Government (2022) Hydrogen Refuelling Network Funding at www.energy.nsw.gov.au/business-and-industry/programs-grants-and-schemes/hydrogen-refuelling-network-funding

Shipping and aviation

There is a range of hydrogen related shipping and aviation projects supported by the Commonwealth and state governments, and industry:

- The Australia-Singapore Low Emissions Technologies for Maritime and Port Operations initiative (total $10 million from Australia ($9.4 million Commonwealth, $600,000 from CSIRO), $10 million leveraged from industry aims to accelerate deployment of low emissions fuels and technologies like hydrogen to reduce emissions in maritime and port operations. CSIRO is administering the program.
- $10 million towards the 'The Innovations in Sustainable Aviation Fuels (SAF) Production and Deployment at Scale Project' which is focused on the production, compression and storage of hydrogen and synthesis of SAF from hydrogen and CO_2.
- $5 million under the $35 million Hydrogen Industry Development Fund (HIDF) for the construction of a Sealink hydrogen passenger ferry capable of carrying up to 200 passengers at speeds of 20 knots (37 km/hr).
- In November 2020, H2X Marine – the boat-building unit of the fledgling automotive manufacturer – announced a partnership with Queensland-based shipbuilding specialist WildCat Marine to manufacture a range of hydrogen-fuelled passenger ferries for industrial and commercial use.
- In 2021 Fortescue Future Industries (FFI) revealed plans to convert its vessel MMA Leveque to run on green ammonia by the end of 2022 to speed up the firm's decarbonisation path.
- CSIRO, in partnership with Boeing, has analysed in detail and published publicly in their report entitled "Opportunities for hydrogen in commercial aviation', the potential for using hydrogen in aviation fuels to assist decarbonisation and the steps needed to enable this transition[100].

BOX 4: Bunkering and transport of ammonia from the Pilbara

In 2022, Yara Clean Ammonia and Pilbara Ports Authority (PPA) signed a Collaboration Agreement to jointly facilitate the uptake of ammonia as a marine fuel in the Pilbara region in Western Australia. The purpose of the agreement is to jointly assess the potential ammonia demand and required bunker infrastructure, leveraging off the existing ammonia production facility of Yara Pilbara and its ammonia potential in the region. The agreement will also ensure safe ammonia bunker operations within PPA ports through collaborative safety analysis and the creation of transparent ammonia bunkering guidelines.

Assessing, planning and progressing the required bunker infrastructure and safe ammonia bunker guidelines will accelerate the effective uptake of ammonia as a fuel, and will be a major step towards making shipping fossil-fuel free. The joint assessment is planned to take approximately one year.[101]

100 CSIRO, www.csiro.au/en/news/news-releases/2020/five-year-runway-to-hydrogen-power-in-airports

101 Pilbara Ports Authority, 'Pilbara Region Moves Towards Ammonia Bunkering', (28 July 2022), www.pilbaraports.com.au/about-ppa/news,-media-and-statistics/news/2022/july/pilbara-region-moves-towards-ammonia-bunkering

Green steel making

The leadership of Australian governments and industry is encouraging investment in the hydrogen supply chain that are expected to contribute to lowering hydrogen costs and revitalising Australia's manufacturing sector.

Although this year's independent assessment suggests Australia is Advancing Slowly compared to some leading nations, there is strong interest in establishing low emissions onshore iron ore processing from major Australian iron ore companies and in decarbonising steel plants in Australia. This includes work co-funded by ARENA being led by Bluescope Steel[102] to undertake low emissions steel feasibility analysis, and by Calix, who are leading a low emission steel feasibility study and pilot[103] . Additional support is occurring through the Heavy Industry Low-Carbon Transition (HILT) CRC.

BHP, the world's third largest iron ore producer announced an investment in Verdagy's hydrogen electrolyser technology to assist BHP decarbonise its operations.[104]

Rio Tinto has signed an agreement with German steel manufacturer Salgitter Group to investigate the use of Rio's iron ore products in Salzgitter's green steel project in Germany. The project aims to progressively switch from using fossil fuels to hydrogen in its steel production.[105]

Fortescue Metals Industry Group, the fourth largest iron ore producer in the world, has announced an intention to be carbon neutral by 2030, by focussing on hydrogen to power its iron ore operations, and the production of green iron and steel as an export commodity. The company has announced plans for building Australia's first green steel pilot plant in the Pilbara, committing AUD$9.6 billion over four years.

Australia's largest steelmaker, BlueScope, signed a Memorandum of Understanding (MOU) with Rio Tinto to explore options for low-emissions iron and steelmaking at the Port Kembla Steelworks in New South Wales. The agreement includes a feasibility study for a hydrogen direct reduction and iron smelter.

Australian governments have also recognised the importance of hydrogen's impact on the iron and steel industry, including the South Australian Government's $593 million commitment to collocate a 200 MW hydrogen plant on the GFG Whyalla Steelworks. Collocating the hydrogen plant and consuming it in the steelmaking process will simplify the hydrogen value chain, and address complexities in transport and conversion.[106] On 24 August GFG began producing high quality magnetite pellets to support its proposed direct reduced iron (DRI) plant.[107]

Industrial heat

In many heavy industries heat or process steam is required at medium to high temperatures that is challenging to be generated by renewable energy and heat pumps. In such situations, hydrogen can replace natural gas for industrial process heat or steam systems. Hydrogen has not yet been deployed for any applications of industrial heating beyond natural gas grid injection within Australia. Similarly, there are very limited international examples of hydrogen being used solely for industrial heat production and use.

102 ARENA – Investigating Low Emission Steel Production at Port Kembla at https://arena.gov.au/news/investigating-low-emissions-steel-production-at-port-kembla
103 ARENA – New Iron Reduction Technology Targeting Low Emission Steel https://arena.gov.au/news/new-iron-reduction-technology-targets-low-emissions-steel
104 2022 BHP Ventures: https://www.b hp.com/sustainability/climate-change/reducing-our-operational-emissions
105 Sazgitter AG, 'Green Light for Green Steel' (13 July 2022), www.salzgitter-ag.com/en/newsroom/press-releases/details/green-light-for-green-steel-19904.html
106 Australian Financial Review, 'Sanjeev Gupta may get a $593m Hydrogen Plant Next to his Steelworks', (2 March2022), www.afr.com/companies/energy/sanjeev-gupta-may-get-a-593m-hydrogen-plant-next-to-his-steelworks-20220302-p5a0w6
107 GFG Alliance, 'Our Whyalla Journey', https://gfgalliancewhyalla.com/our-journey

In 2022, Grange Resources completed a Renewable Hydrogen Study into the use of hydrogen as a replacement for natural gas for industrial heating purposes at the Port Latta pelletising plant in Tasmania. The study concluded that the use of hydrogen would be technically feasible, but no investment decision has been reached[108]. This has been supported through the Commonwealth funded HILT CRC, which is also working to help Alcoa, FFI, Rio Tinto, Liberty and Adbri decarbonise through partly decarbonising industrial heat processes. Alcoa is the operator of three of Australia's six alumina refineries and is pursuing the alternative pathway of electrification over hydrogen for generating the industrial heat necessary for calcination. The Alcoa Renewable Powered Electric Calcination Pilot was announced in April 2022 and aims to demonstrate the technical and commercial feasibility of electric calcinators.[109]

The first stage of the project will include the study, engineering and testing of technologies whilst the second stage will include the detailed design, construction and pilot testing at Alcoa's Pinjarra Alumina refinery in Western Australia. The project is anticipated to cost $19.7 million. The project has received $8.6 million from ARENA and $1.3 million from WA Government's Clean Energy Future Fund.

ARENA and Rio Tinto each committed $0.58 million to study the feasibility of using hydrogen at Rio Tinto's Yarwun refinery in Gladstone, Queensland. This complements a separate Rio Tinto partnership with Sumitomo to construct a pilot hydrogen plant to supply the Yarwun refinery as well as other industrial users in Gladstone.[110]

The $1.2 million study, funded equally by ARENA and Rio Tinto, will comprise two distinct work packages:

- Simulating the calcination process using a lab scale reactor at Rio Tinto's Bundoora Technical Development Centre in Melbourne, Victoria.
- Preliminary engineering and design study conducted at Rio Tinto Yarwun to understand the construction and operational requirements of a potential demonstration project at the refinery.

The study will see an improved understanding of the potential for renewable hydrogen to be used in the alumina refining process and the scope of development works required to implement hydrogen fuelled calcination technology at an existing alumina refinery.

The Advancing Slowly rating this year reflects the lack of progress against the apparent optimism of early feasibility studies considered in the previous State of Hydrogen report.

108 Grange Resources Limited, 'Annual Report 2021' (2022)
109 ARENA, 'World-First Pilot to Electrify Calcination in Alumina Refining' (12 April 2022), https://arena.gov.au/news/world-first-pilot-to-electrify-calcination-in-alumina-refining
110 Rio Tinto (2022) Could Hydrogen Help Reduce Emissions? www.riotinto.com/en/news/stories/could-hydrogen-help-reduce-emissions

Chapter 3

Foundations for Australia's hydrogen industry development

The establishment of hydrogen as a significant industry sector in Australia requires the adaptation of existing oversight measures and the creation of new ones. This chapter provide some commentary on the pace of these measures as distinct from the specific metrics considered above.

Providing regulatory certainty for investors and proponents

The 2019 National Hydrogen Strategy[111] points to the importance of ensuring regulation is hydrogen ready to enable the development of the new hydrogen industry. Australian governments have been conducting a coordinated review of Australia's legal frameworks to assure hydrogen safety, industry development and national consistency.

This review is nearing completion with resulting actions likely to focus on potential barriers and regulatory inefficiencies across a range of hydrogen supply chain sectors. Areas of focus have included:

- National consistency in the regulation of hydrogen production - The regulation of a hydrogen production facility provides the opportunity for streamlined and transparent hydrogen specific safety regulation in a large-scale production environment.
- National consistency in hydrogen refuelling station safety - Regulators do not currently have consistent or agreed standards for the equipment, storage and dispensing of hydrogen in a hydrogen refuelling station. Existing regulatory frameworks for petrol stations, and/or major hazard facilities are not adapted to the specific safety issues associated with hydrogen. Consideration has been given to other countries use of specific hydrogen refuelling national laws and safety codes.
- Prioritised reforms in the transport sector (vehicles and vessels) - Regulators do not currently have agreed standards for the certification of vehicles and vessels against safety standards for hydrogen fuel cells and carrying hydrogen as a cargo. This is forcing the use of 'novel' regulatory compliance processes, which have associated costs.
- National consistency for hydrogen industry appliances - There are different regulatory approval processes in each state and territory for appliances that are central to the growth of the hydrogen industry (for example electrolysers, mobile fuel cells).

Regulation of pipelines infrastructure

Following completion of a review into the national gas regulatory framework and a detailed consultation process, Australian governments have agreed to reform the National Gas Law (NGL) and National Energy Retail Law (NERL), regulations and subordinate instruments to bring hydrogen, biomethane and other renewable gases within the scope of the national gas regulatory framework. These reforms provide a nationally consistent approach to the economic regulation of pipeline infrastructure to better support the development of a competitive and efficient hydrogen and renewable gas industry.

These reforms will support efficient investment in new renewable gas pipelines and gives confidence that future shippers will be given fair terms by having third party access provisions for renewable gas pipelines. In parallel, the Australian Energy Market Commission has developed amendments to the National Gas Rules and National Energy Retail Rules for agreement by Energy Ministers. The reforms are anticipated to take come into effect in 2023.

111 Commonwealth Government (2019) National Hydrogen Strategy - https://www.dcceew.gov.au/energy/publications/australias-national-hydrogen-strategy

Hydrogen guarantee of origin

Australia's National Hydrogen Strategy[112] identified a guarantee of origin or certification scheme for hydrogen as an early priority.

The Australian Government is developing a Guarantee of Origin (GO) scheme which consists of a product-based emissions accounting framework and a mechanism for tracking renewable electricity. It will initially cover hydrogen, hydrogen energy carriers and renewable electricity. However, over time new products such as metals, biofuels and other materials could also be incorporated.

The GO scheme is intended to provide greater transparency to both domestic and international consumers on where and how the hydrogen they choose to buy is produced. The scheme has been developed to be internationally aligned and integrate with existing and emerging domestic schemes. Domestically, this includes industry-led and state and territory schemes that could use information from the GO scheme to provide brandings, certifications, categorisations or incentives for "green" or carbon neutral products.

To support international trade, it is critical that the emissions accounting approach of the scheme is aligned with international approaches. To ensure this alignment with regards to hydrogen, the Australian Government is an active participant in the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), to develop internationally agreed carbon accounting methodologies. The IPHE has released two working papers covering methodologies for hydrogen production and hydrogen energy carriers, the proposed scheme closely aligns with this work.

International outreach also extends beyond the IPHE to our main energy trading partners. The Department has been working closely with partners to ensure acceptance of the GO Scheme to facilitate trade of Australian hydrogen to export markets.

The Australian Government announced $2.2 million in 2022-23 towards developing and consulting on design and draft legislation for the GO scheme. This is in addition to the previously announced $9.7 million to support trials of the Guarantee of Origin scheme in Australia. The Department conducted consultation paper on the GO scheme in late 2022 through to early 2023 in which the proposed scheme design was outlined.

Translating skills and training needs into a hydrogen workforce

Australian governments recognise that it is critical to prepare and have a hydrogen ready workforce or else skills shortages will be a brake on the development of an Australian hydrogen industry. In addition to hydrogen specific skills, the usual cross-section of engineers, electricians, and trades people to build supporting infrastructure will be needed.

As such, several projects to equip a future workforce with the necessary skills and training have progressed in 2022 (see below). The subsequent creation of these materials and guidelines will create progress towards a robust framework of skills and training activities that support a hydrogen-ready workforce.

Emergency responders training analysis

The Australasian Fire and Emergency Service Authorities Council Ltd (AFAC) conducted a study to determine the requirements for the domestic training of Australian first responders in dealing with hydrogen emergencies. Noting the relevance of existing work in the US or Europe, Australian governments established a group to progress the development of training material and a sustainable funding model. The report is publicly available on the AFAC website.[113]

112 Commonwealth Government (2019) National Hydrogen Strategy - www.dcceew.gov.au/energy/publications/australias-national-hydrogen-strategy

113 National Council for Fire and Emergency Services, 'National Hydrogen Strategy – AFAC Emergency Responders Training Analysis' (29 March 2022), www.afac.com.au/insight/doctrine/article/current/national-hydrogen-strategy---afac-emergency-responders-training-analysis

Hydrogen skills and training mapping

PwC was engaged to help Australian governments build an understanding of the workforce needed to support a safe and effective hydrogen economy. Across six key supply chain areas it sought to identify the type and number of job roles that will be needed, the hydrogen specific capabilities (skills and knowledge) these job will require to undertake hydrogen related activities, and whether these capabilities were catered for within the existing education and training system. The report[114] has been provided to the newly established industry skills and training cluster[115] to aid the development of education and training packages. Additional hydrogen skills, training and workforce work includes:

- *Victorian Hydrogen Skills Roadmap* - The Victorian Government is providing $10 million towards the Victorian Hydrogen Hub, which is being led by Swinburne University of Technology in partnership with CSIRO and Germany's ARENA 2036. The hub includes a hydrogen refuelling station at CSIRO's Clayton campus, the implementation of a Victorian Hydrogen Industry Capability Program and large-scale hydrogen engagement programs to generate active partnerships with Victorian industry. In 2022, it released the Hydrogen Skills Roadmap detailing the jobs impacted and skills required.[116]
- *Queensland Hydrogen Industry Workforce Development Roadmap 2022–2023* - The Queensland Government has developed the Hydrogen Industry Workforce Development Roadmap 2022–2023[117] to prepare Queenslanders to take part in hydrogen opportunities and ensure the industry can access the workers it needs. The roadmap sets out a range of short, medium, and long-term actions to deliver a strong and adaptable workforce for a safe and thriving Queensland hydrogen industry.
- *NSW Hydrogen Strategy* - The NSW Government has committed to providing strategic policy direction, access to resources and information developed through its hydrogen strategy initiatives[118]. Where required, it will explore options to provide financial support to training institutions to expand hydrogen related units of competency and implementation of training programs. The NSW Government has also committed to foster partnerships between industry, universities and vocational education and training providers.

Supporting hydrogen research and development

Since 2017, the Australian public and private sectors have invested more than $570 million into hydrogen research and development (R&D) and demonstration projects. Over the past year there has been a notable increase in R&D funding from the private sector as seen in Figure 12. New R&D projects that progressed in 2022 include:

- The New Energies Service Station Geelong Demonstration Project developed by Viva Energy to demonstrate hydrogen refuelling for heavy fuel cell electric vehicles.
- The Innovations in Sustainable Aviation Fuels (SAF) Production and Deployment at Scale Project which is focused on the production, compression and storage of hydrogen and synthesis of SAF from hydrogen and CO_2.
- Other new projects and facilities in R&D include the Hunter Hydrogen Research and Innovation Facility (HyRIF), Hunter Node of the New South Wales Decarbonisation Hub and the AMMONIAC project.

The Australian Government has also supported CSIRO and the Australian Hydrogen Research Network[119] to create the HyResearch web portal[120], which reports on all aspects of Australian research and development through the entire hydrogen supply chain.

114 Australian Industry and Skills Committee, 'Developing Australia's Hydrogen Workforce', (20 December 2022), www.aisc.net.au/hub/developing-australias-hydrogen-workforce
115 Australian Government Department of Employment and Workplace Relations, 'Skills Reform', www.skillsreform.gov.au/faqs/industry-engagement-faq
116 Swinburne University of Technology, 'Hydrogen Skills Roadmap' (September 2022), https://commons.swinburne.edu.au/file/80f8414f-5646-4d6b-ac77-b2038857ea7a/1/swinburne_hydrogen_report.pdf
117 Queensland Government, 'Hydrogen Industry Workforce Development Roadmap 2022-2032', (20 July 2022), www.epw.qld.gov.au/about/initiatives/hydrogen/training
118 NSW Government, 'NSW Hydrogen Strategy', (October 2021), www.energy.nsw.gov.au/nsw-plans-and-progress/government-strategies-and-frameworks/nsw-hydrogen-strategy
119 https://research.csiro.au/hyresource
120 https://research.csiro.au/hyresearch/#maincont

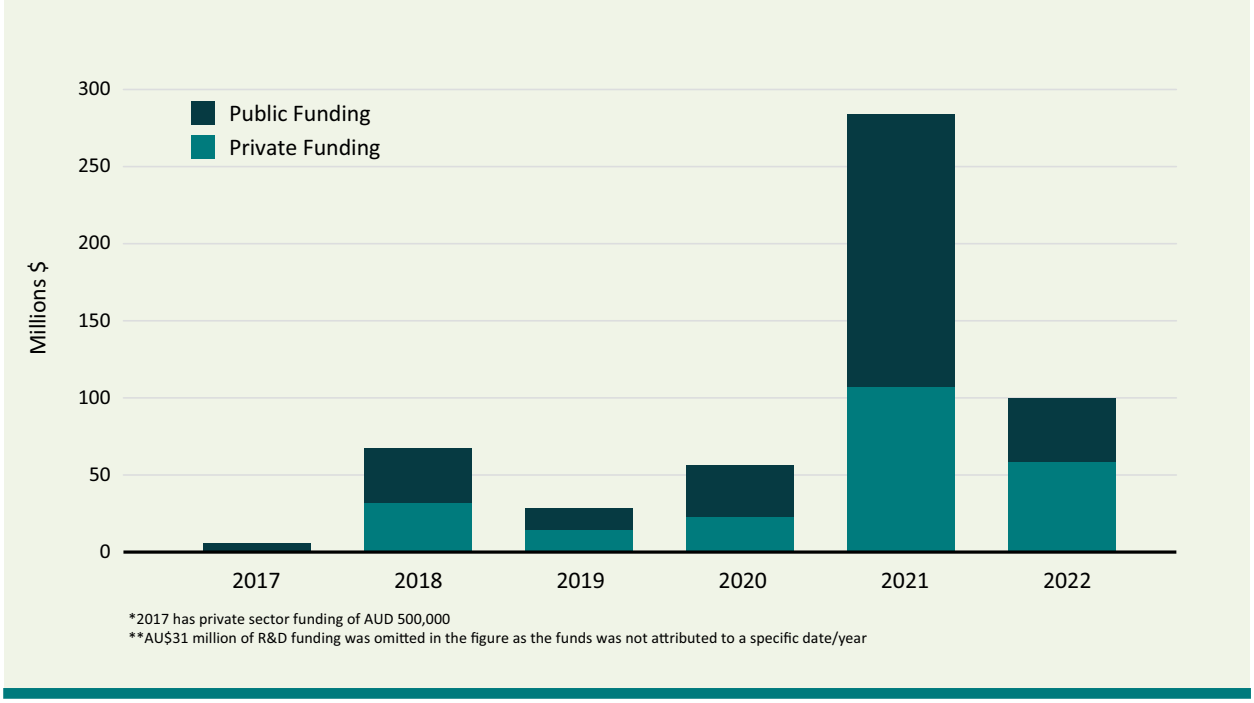


Figure 12: Funding directed to Hydrogen Research and Development (2017-2022)[121]

Exploring for naturally occurring hydrogen

Hydrogen can be naturally produced by various geological processes with research currently underway to understand its potential as a resource. Australia is one of the most prospective locations for natural hydrogen due to our ancient geology and potentially suitable hydrogen traps. Geoscience Australia[122] and CSIRO[123] are currently running research programs, including field exploration activities, to understand the potential of naturally occurring hydrogen in Australia.

South Australia is currently the primary focus for natural hydrogen exploration with some 30 per cent of the state now subject to actual or potential exploration permit[124]. The Northern Territory has active exploration for naturally occurring hydrogen[125] and Mt Kitty was considered one of Australia's first native hydrogen finds with a relatively high 11.5% hydrogen concentration.

121 Data for 2017 includes approximately $500,000 in funding from the private sector. $31 million in funding to hydrogen R&D that could not be attributed to a particular year has been omitted.
122 Geoscience Australia, 'Australia's Future Energy Resources', www.eftf.ga.gov.au/australias-future-energy-resources
123 CSIRO, 'Natural Hydrogen Exploration', https://research.csiro.au/hydrogenfsp/our-research/projects/natural-hydrogen-exploration
124 On 11 February 2021 the Petroleum and Geothermal Energy Regulations 2013 was amended to declare hydrogen, hydrogen compounds and by-products of hydrogen production related substances under the Petroleum and Geothermal Energy Act 2000
125 H2 Bulletin, 17 May 2022, www.h2bulletin.com/central-petroleum-explores-helium-and-hydrogen

Analysis and planning to ensure sustainable water usage

The Australian Government, in collaboration with the Australian Hydrogen Council, released the Water for Hydrogen Technical report[126] via the National Hydrogen Council in 2022. The water paper was written to better understand the considerations and potential design requirements regarding the supply and treatment of water for the production of hydrogen and conversion of hydrogen carriers in Australia.[127] The report analyses potential water requirements, potential sources and treatment options of water through the hydrogen industry supply chain.

The report found that the Australian hydrogen industry's use of water is currently very low, but will be significant if Australia becomes a major global producer of hydrogen. For example, the figures could grow to 500-1000 GL a year for ambitious hydrogen production (export and domestic use) by 2050. By way of context, in the financial year 2020-2021 the biggest users of water in Australia were the agricultural sector (7100 GL), households (1800 GL), the mining sector (1300 GL) and manufacturing (500 GL

As the Australian hydrogen industry grows, it is expected that these needs will mostly be met by recycled water or desalinated water, rather than high quality surface or drinking water. Where desalinated water is used planning and management to ensure the brine produced is disposed of in ways that do not harm local freshwater or marine ecosystems will be important.

It is important for both planners and developers of large hydrogen production facilities to consider how their water choices and wastewater management best align with local cultural and environmental considerations, as well as existing water planning to meet the needs of other users.

Results from the Water for Hydrogen technical paper are publicly available and intended to inform policy and to develop communications materials, progress communications with stakeholders and support the wider industry to better engage with the topic.

State and Territory Governments have also been undertaking water availability and infrastructure assessments to inform planning to pro-actively ensure secure and sustainable water supplies. For instance, the Queensland Government has undertaken studies and published reports to understand any potential water constraints and provide pre-emptive solutions to industry. A detailed assessment of the infrastructure capacity currently available to support hydrogen production and export at 14 regional Queensland ports has been completed.

Gaining community acceptance of hydrogen

Survey results released by the Future Fuels CRC in August 2021 found widespread public support for producing and using hydrogen both in Australia and for export, and that awareness about hydrogen is growing[128]. Localised responses will be important to understand, be they regional or suburban communities or indigenous communities.

A 2021 study by The20 and OMD Marketing Intelligence for the Tasmanian Government found a low familiarity with hydrogen among the general population[129]. Hydrogen was not broadly understood to be an environmentally sustainable energy source. The study also found growing public discussions of hydrogen associated with Government announcements, though the discussions included scepticism about how hydrogen will be used.

126 ARUP (2022) Water for Hydrogen - Technical Pape. Department of Climate Change, Energy, the Environment and Water. https://h2council.com.au/uploads/Arup-Technical-paper-Water-for-Hydrogen-report-14-Nov-22_FINAL.pdf#asset:111108

127 ARUP (2022) Water for Hydrogen - Technical Pape. Department of Climate Change, Energy, the Environment and Water. https://h2council.com.au/uploads/Arup-Technical-paper-Water-for-Hydrogen-report-14-Nov-22_FINAL.pdf#asset:111108

128 Future Fuels CRC, 'Public Perceptions of Hydrogen, 2021 National Survey Results', (June 2021), www.futurefuelscrc.com/wp-content/uploads/FFCRC_RP2.1-02_Public-perceptions-of-hydrogen_National-survey-report_June2021Final.pdf

129 The20 and OMD Marketing Intelligence (2021) Hydrogen – Building Community Knowledge and Engagement on Hydrogen.

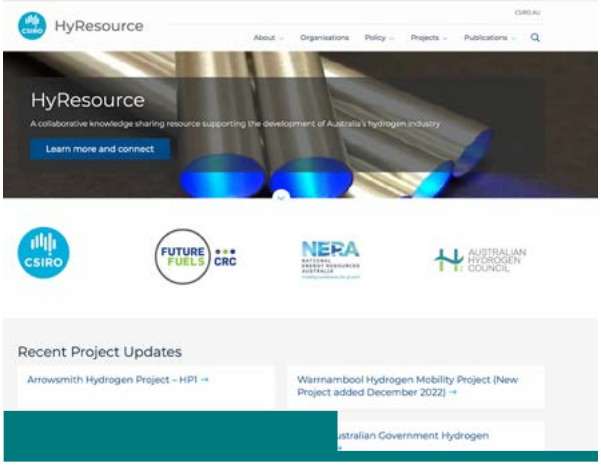
Better informing the market and the community

HyResource – managed by CSIRO

CSIRO has created a one stop shop Hydrogen Knowledge Centre as a national resource for industry, government, and the research community. The knowledge centre highlights developments in Australia's hydrogen industry and provide tools and resources for new entrants to the industry. The first module, HyResource[130], was launched in September 2020 with NERA, the Future Fuels Cooperative Research Centre, and the Australian Hydrogen Council.

The Australian Government has also funded CSIRO and the Australian Hydrogen Research Network to create the HyResearch web portal[131]. It is a tool to help researchers, decision-makers and stakeholders more broadly access Australian hydrogen related R&D information via an easy-to-navigate platform. The portal aims to also facilitate connections and collaborations, domestically and internationally. It features over 250 hydrogen research projects to date.

CSIRO also hosts an online educational resource for the Australian Hydrogen Industry (Hylearning)[132]. A collaboration between Australian governments and the Australian Hydrogen Council has provided an extensive repository of questions and answers for the site, and a resource for the broader community to access trusted and validated information.



Hydrogen Economic Fairways Tool (HEFT)

Geoscience Australia, in collaboration with Monash University, has developed a tool mapping the economic viability of hydrogen operations across Australia. The Hydrogen Economic Fairways Tool (HEFT) helps policymakers and investors make decisions about the location of new infrastructure and the development of hydrogen hubs. The tool conducts detailed geospatial-economic analysis of future large-scale hydrogen projects. It assesses the quality of energy resources required to produce hydrogen. HEFT also assesses rail and road transportation infrastructure, pipelines to export ports and ready access to water.

Preliminary results show that economically viable regions for hydrogen production are located across Australia. All states and territories have regions with high potential.

The interactive tool lets users explore economic relationships within the hydrogen supply chain and determine the variables that will drive the cost of hydrogen production in Australia.

130 https://research.csiro.au/hyresource
131 https://research.csiro.au/hyresearch/#maincont
132 https://research.csiro.au/hylearning

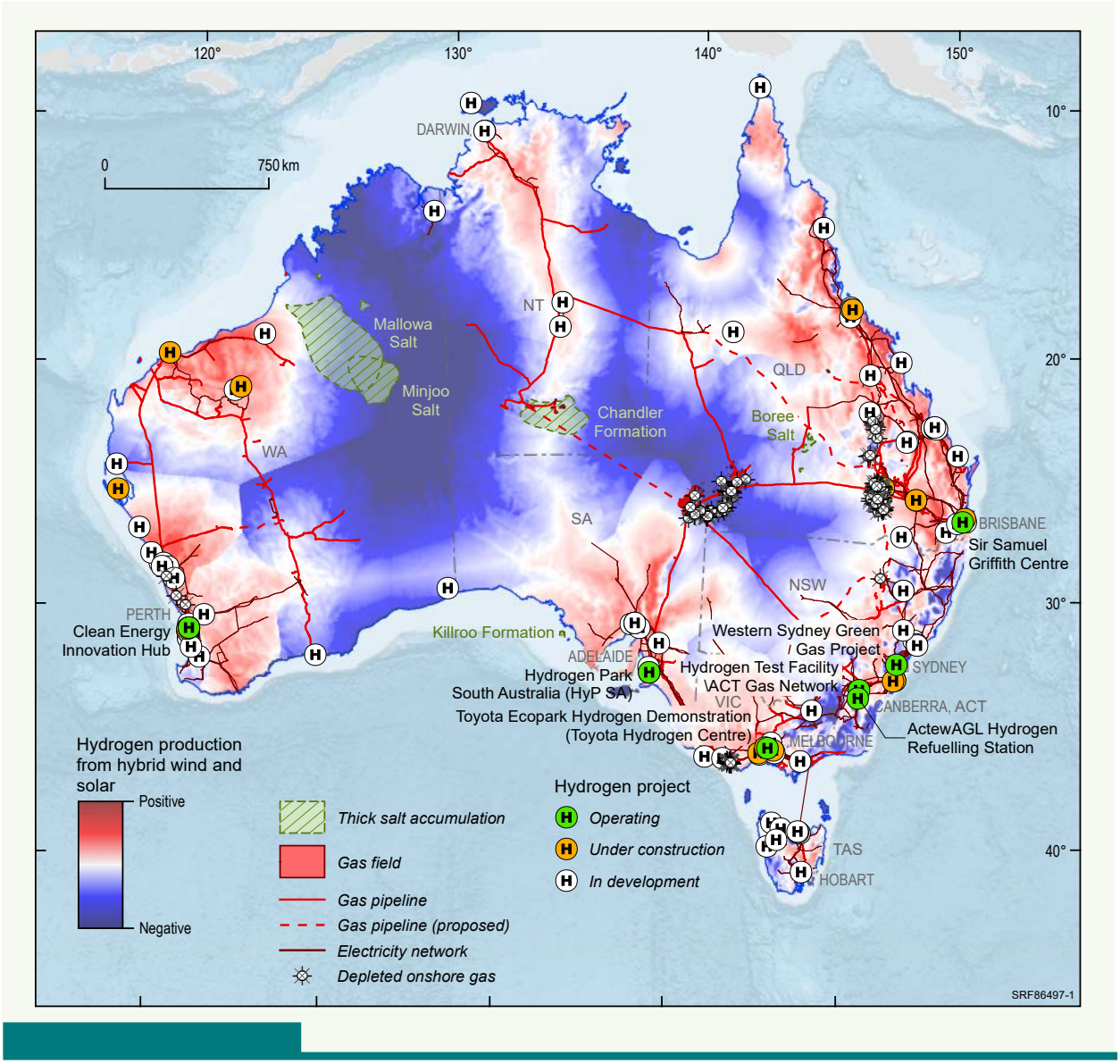


Figure 13: Economically favourable locations for hydrogen production in 2030 are shown in red (based on specific input parameters). Current hydrogen projects (shown as colour coded circles on the map) are predominately located in highly prospective 'red' regions indicating the alignment of the HEFT modelling with real world data (Geoscience Australia, 2022).

Large scale hydrogen storage in Australia's underground salt accumulations

Geoscience Australia is mapping underground salt accumulations across Australia and developing techniques to find new salt prospects. Internationally, large scale storage of commercially produced hydrogen (from unabated fossil fuels) often occurs in underground salt (halite) caverns. Australia appears well placed to develop its own salt resources for underground hydrogen storage with several well-suited sites already discovered.

Strategic studies

There is a need for participants in the hydrogen sector to gain a clearer understanding of issues relating to hydrogen. Since the last State of Hydrogen report, there have been some important reports that have helped to map out infrastructure needs, sustainable water requirements and hydrogen export potential. A selection of public reports led by the Commonwealth, state and territories, and industry are listed below (Appendix 5)

BOX 4: Where is Australia's prospective salt accumulations for underground hydrogen storage?

Australia is an ancient continent featuring thick salt accumulations dating back approximately 800 million years, to the time before the emergence of the first animals. These ancient salts are mainly distributed in a broad band across the centre of Australia (Figure 16) , but "younger" salts (approximately 400 million years old) have been intersected by drilling in the Canning Basin in north-western Western Australia and Adavale Basin in central Queensland. Salt in this part of Australia is over half a kilometre thick, almost two kilometres underground. Except for the Maka Sarakham salt in Thailand, Australia possesses the only know thick and extensive salt accumulations in the South East Asian – Pacific region.

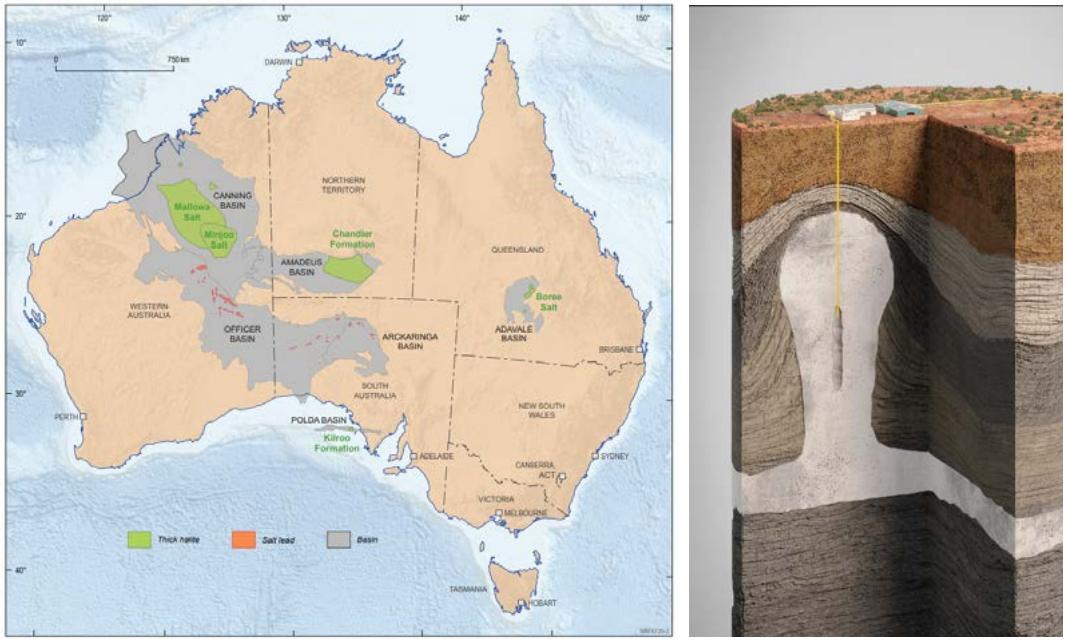


Figure 14: (a) Known thick (>100 metres) underground accumulations of salt (halite) in Australia potentially suitable for large scale hydrogen storage. (b) Example of how underground salt caverns can be used to store hydrogen gas (Geoscience Australia, 2022).

Chapter 4

Global hydrogen industry development

Projected global demand for hydrogen and ammonia by 2030 has doubled in the last year, due to geo-strategic developments in Europe leading to increased national renewable hydrogen demand targets.

In addition, the relatively high 2022 international gas prices have resulted in a significant closing of the hydrogen and ammonia green premium this year. In many parts of the world in 2022, it was potentially cheaper to manufacture green ammonia than fossil fuel-based ammonia.

The IEA has reported that 2022 is the year that hydrogen moved to centre stage in global energy and climate policy. The IEA World Energy Outlook report found "*The cost advantages of mature clean energy technologies and the prospects for new ones, such as low-emissions hydrogen, are boosted by the Inflation Reduction Act in the United States, Europe's increased push for clean energy, and other major new policies.*" And "*Investment in low-emissions gases, such as hydrogen, is set to rise sharply in the coming years…to reach over 30 million tonnes (Mt) per year in 2030. Much of this is produced close to the point of use, but there is growing momentum behind international trade in hydrogen and hydrogen-based fuels*."[133]

New hydrogen strategies and increased ambition

Australia was one of the first countries to publish a hydrogen strategy and a further 30 countries have subsequently followed, including 9 strategies published in 2022 alone. A further 7 governments have released draft strategies or announced they are in development including the United States.

Over a quarter of these known strategies are export oriented and include at least eight countries that could be considered competitors.

Research by CSIRO, shown in Figure 13, has identified the priority end-uses for hydrogen for each of the world's leading hydrogen nations, outlined in their respective strategies. Resource-rich countries such as Australia, Chile, Canada, and Saudi Arabia are working to create new export industries for hydrogen, with increased demand providing new opportunities for these exporting nations. By comparison, resource-poor countries with net zero emission targets, such as Japan and South Korea, are seeking to be largely importers of hydrogen and its derivatives. Countries like the United States that have financially incentivised hydrogen production are poised to initially support this market.

2022 also saw many countries with existing national hydrogen strategies ratchet up their ambition and hydrogen specific targets[134]. For instance, in March 2022, the European Commission published the REPowerEU plan to significantly reduce consumption of fossil fuels in the European Union in the wake of Russia's invasion of Ukraine. The plan aims to produce 10 Mt/year of renewable hydrogen and a further 10 Mt/year to be imported by 2030, a doubling of previous targets.

National government targets also focussed on electrolyser capacities, whereby the 2021 global target of 74 GW significantly increased to 145-190 GW as of late 2022 (see Appendix 3).

133 IEA (2022) World Energy Outlook 2022. IEA. Paris
134 IEA (2022) Global Hydrogen Review. IEA. Paris

International hydrogen trade

Bilateral agreements

Nations are building relationships to enable future large-scale hydrogen supply and demand, with many bilateral agreements in place. Major global hydrogen export partnerships, based on established export agreements are shown in Figure 14.

Hydrogen trade agreements are usually made between regions targeting export, such as South America, Saudi Arabia and Australia, and potential import markets, mostly in Asia and Europe. Specific ports are also establishing agreements with cities and countries, most notably the Port of Rotterdam in the Netherlands. The establishment of these trade relationships and supply chains benefits all parties and is stimulating global supply and demand.

There has also been an increase in hydrogen trade agreements in response to the global energy crisis triggered by the Russian invasion of Ukraine. Australian company Fortescue Future Industries, for instance, has signed an agreement with European utility E.ON to deliver up to 5 Mt H2/year by 2030[135]. Similarly, Fortescue signed a MoU with Covestro, a German materials manufacturer, to deliver 0.1 Mt H2/year starting from 2024 to several of its operations, including in Europe. Fortescue and Italian-based Enel Green Power (EGP) have also signed a partnership to jointly explore green hydrogen value chain developments in Australia[136].

Expected hydrogen exports

It is estimated that 12 Mt of low-emissions hydrogen could be exported per year, mainly from Latin America followed by Australia, Europe, Africa/Middle East, and the USA, by 2030. This is based solely on the export-oriented projects announced to date. Of the 12 Mt H2 per year flagged for export, 2.4 Mt per year is planned to become operational by 2026[137].

Hydrogen investment

Despite the proliferation of national strategies and bilateral agreements, low-emissions hydrogen production was less than 1 Mt in 2021. Almost all this production was based on fossil fuels with carbon capture use and storage. Although only 35 kt of hydrogen was produced via electrolysis, this represented an increase of almost 20 per cent compared to 2020. Similarly, more than 200 MW of installed electrolyser capacity was added to the global mix in the last year bringing the total global operational capacity above 500 MW[138]. The IEA hydrogen project tracker shows the current electrolyser deployment pipeline could result in 134-240 GW capacity being operational by 2030. This is a significant increase to the projection made in the 2021 IEA Global Hydrogen Review (54-91 GW in the same timeframe).

Continued global investment in hydrogen demonstrated the momentum of the industry, with 1,583 hydrogen projects delivered since 2000 and annual production projected to reach 24 Mt by 2030[139].

Investment in research to lower costs

To help the hydrogen industry grow significant investment has gone towards hydrogen Research, Development and Deployment (RD&D). In the last five years OECD counties have invested $3.8 billion in hydrogen and fuel cell RD&D. This represents 2.1 per cent of total global RD&D investment, up from 1.1 per cent five years ago[140]. This early investment in RD&D has helped technologies mature and become more viable for early movers in the industry. It has addressed initial production barriers and let public and private spending expand beyond RD&D.

135 IEA (2022) Global Hydrogen Review (pg167)
136 H2 View, 'FFI, Enel Partner to Explore Green Hydrogen Opportunities in Latin America and Australia', (2 November 2022), www.h2-view.com/story/ffi-enel-partner-to-explore-green-hydrogen-opportunities-in-latin-america-and-australia
137 IEA (2022) Global Hydrogen Review (pg 162)
138 IEA (2022) Global Hydrogen Review (pg71)
139 IEA (2022) Hydrogen Project Database FY2022
140 IEA (2022) "RD&D Budget." IEA Energy Technology RD&D Statistics (database), accessed April 7, 2021, in 2019 values

Hydrogen is also one of the largest growth areas for venture capital funding, indicating a growing interest in scaling up the sector[141]. According to the IEA, "*hydrogen accounted for about 10 per cent of all early-stage VC investments in clean energy start-ups [in 2021], compared with 5 per cent in 2020, suggesting increasing appetite for hydrogen start-ups.*"[142]

In addition to this progress, in November 2021, the Breakthrough Agenda was launched at the World Leaders Summit at COP26. This agenda saw a commitment from 44 countries, including Australia, USA, and the European Union, to cooperate on lowering clean-tech costs and making it accessible worldwide before 2030. Hydrogen was chosen as one of four breakthrough technology focus areas. Additionally, in May 2022, the G7 launched a Hydrogen Action Pact to focus on scaling, at lowest cost, low emissions hydrogen technology development[143].

In the private sector new partnerships have been formed to develop first-of-a-kind hydrogen enabling technologies. For example, KHI and Airbus signed a MoU to develop a hydrogen supply chain for aviation, including the development of hydrogen hubs in airports[144].

These developments evidence the increasing global recognition of hydrogen to play a key role in decarbonising hard-to-abate sectors.

Investment in larger electrolysers to lower costs

The cost of an installed electrolyser is in the range of USD 1400-1 770 per kilowatt (kW)[145]. Electrolyser costs are forecast to become cheaper due to the need for larger systems to fulfil increased global hydrogen ambition, innovation in system design, and scaling of manufacturing. The IEA finds, based on the "*Current pipeline of projects under construction and planned would reduce the capital cost of electrolysers by 60-64 per cent by 2025, and 68-72 per cent by 2030 (USD 440-500/kW). With an installed capacity of 725 GW globally by 2030, (this is likely to achieve) a cost reduction of 78-82 per cent and resulting in electrolyser costs slightly above of USD 300/kW.*"[146]

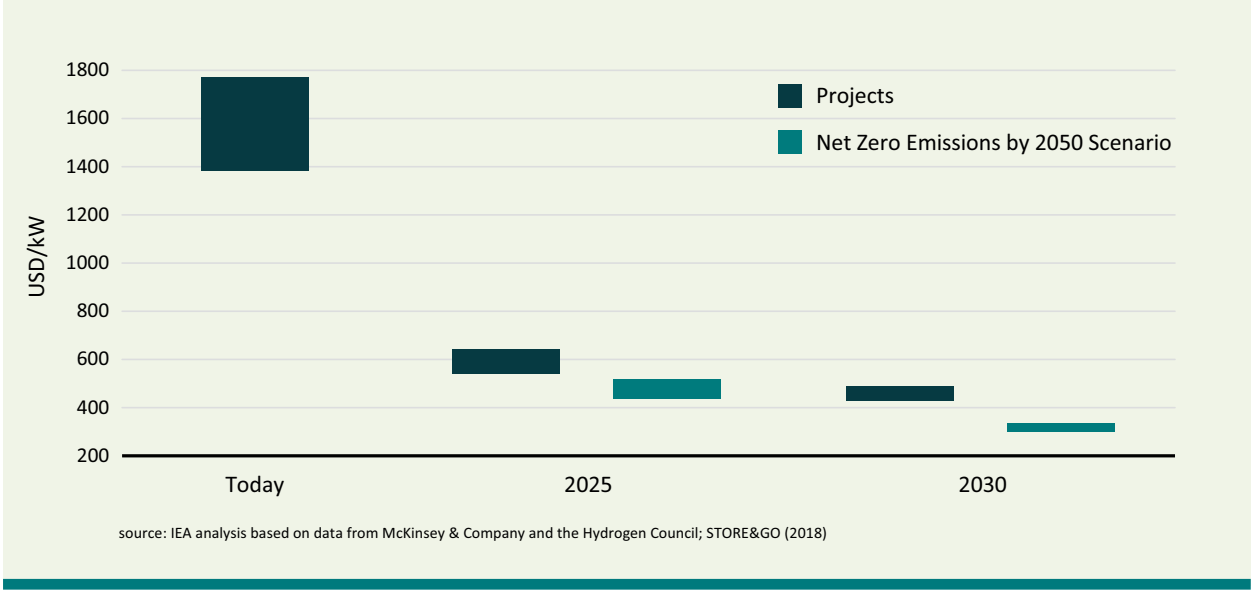


Figure 15: Evolution of electrolyser capital costs based on project pipeline and in the Net Zero Emissions by 2050 Scenario, 2025, and 2030. (Source. IEA (2022)).

141 IEA (2020) Energy Technology Perspectives 2020, IEA. Paris.
142 IEA (2022) Global Hydrogen Review (p223)
143 IEA (2022) Global Hydrogen Review (p206)
144 IEA (2022) Global Hydrogen Review (p206)
145 IEA (2022) Global Hydrogen Review (p82-82)
146 IEA (2022) Global Hydrogen Review (p82-83)

Most of the world's current supply of electrolysers are manufactured in Europe and North Asia with a combined market share of over 65 per cent. While electrolysers are projected to decrease in price, they rely on specific critical resources. Alkaline electrolyser manufacturing uses resources, such as nickel, which are generally abundant within Australia and the surrounding Indo -Pacific region. Current state-of-the-art alkaline designs require approximately 800 tonnes of nickel per year[147]. Fortescue Future Industries is current building the world's largest alkaline electrolyser plant in Gladstone, Queensland, with an initial capacity of 2GW per annum.

Another dominant electrolyser type, PEM electrolysers, are constrained to more scarce critical resource components. This includes anodes made of platinum and more specifically iridium, which is predominantly mined in South Africa, Russia, and Zimbabwe, and is not produced within Australia and the Indo-Pacific region. While PEM electrolysers are more expensive to manufacture compared to alkaline electrolysers, they are much more efficient. The type of electrolyser used may impact the direction and scale of hydrogen projects in Australia, especially if are constraints to supply.

Electrolyser manufacturing capacity sits at nearly 8 GW per year and based on industry announcements it could exceed 60 GW per year by 2030. As Australia hosts the world's largest pipeline of hydrogen projects, by 2030, Australia is expected to make up 28 per cent of the global announced electrolyser capacity[148]. This potentially puts the Australian hydrogen industry in a strong position given its vast project pipeline. However, the impact of substantial industry support policies in some countries may have a negative impact on Australian industry's ability to secure affordable electrolysers.

Providing investor certainty through standards, regulations, and certification

Globally, the quality and appropriateness of standards, regulations and certification of the hydrogen industry is varied. Most jurisdictions with significant hydrogen ambitions have developed comprehensive standards and a regulatory scheme with respect to the hydrogen industry (5). For example, the EU-funded CertifHy initiative developed a certification system that is being used in voluntary markets and may be adopted for use in regulatory compliance in the future. Additionally, South Korea has stated plans to establish a Clean Hydrogen Certification System and Country of Origin Verification System by 2024[149].

However, there are also international efforts that could assist nations in this regard, including:

- The International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)[150] is an international government-to-government forum to develop a mutually agreed methodology for determining the greenhouse gas (GHG) emissions of hydrogen production, which could be used as a seed document to develop a standard[151] through the International Organization for Standardisation (ISO). As discussed in Chapter 3, Australia is developing a Guarantee of Origin Certification scheme based on this methodology.
- The ISO is developing a Draft Technical Specification to measure the GHG emissions intensity of hydrogen production, aiming for publication in 2024[152]. This draft specification could serve as a key common reference for the market in the interim before a draft International Standard and finalised ISO standard are completed in coming years. To address this issue, countries could develop internationally harmonised regulations for the emissions intensity of hydrogen production and other process and production methods.

147 International Energy Agency, 'The role of Critical Minerals in Clean Energy Transitions' (May 2021)
148 IEA (2022) Global Hydrogen Review. 2022
149 IEA (2022) Global Hydrogen Review. IEA. Paris
150 www.iphe.net
151 IEA (2022) Global Hydrogen Review. P13
152 IEA (2022) Global Hydrogen Review. P209

Shoring up hydrogen supply

Lowering supply costs through government incentives

Early RD&D funding for hydrogen production will drive innovation and economies of scale. As a result, the costs of producing hydrogen are expected to fall significantly over the next decade.

The cost of hydrogen produced from electrolysis is currently over USD 5/kg H2[153]. The main cost drivers are capital costs and renewable electricity costs. Renewable hydrogen production costs could fall below USD $2/kg H2 after 2030 if electrolysers and renewable energy costs reduce as predicted[154,155].

In 2022, a range of nations committed to hydrogen production economic incentives that significantly lower the supply cost of hydrogen, namely the USA, Germany, the UK, the EU, and Canada. However, Egypt has also committed USD$40 billion towards implementation of its hydrogen industry strategy.

- **The United States of America** – is leading on using tax credits to lower the production cost of hydrogen. The *Inflation Reduction Act (IRA)* provides for hydrogen production tax credits worth up to US$3.00/kg. The credits are available for hydrogen produced at a qualifying facility during the facility's first 10 years of operation[156]. This funding package is in addition to the *Infrastructure, Investment and Jobs Act* that provides up to US$7 billion in funding for hydrogen hubs.
- **Germany** – is leading on cost for difference economic incentives. The German Federal Ministry for Economic Affairs and Climate Action (BMWK) is providing €900 million to fund a reverse auction-based mechanism that will secure long term supply contracts and short-term sales contracts (H2Global)[157]. The German government will provide grant funding to compensate the intermediary for the difference between supply prices (construction and transport) and demand prices[158].
- **United Kingdom -** In October 2021, the British government's 'Net Zero Strategy' confirmed that up to £100 million would be awarded to up to 250 MW of green hydrogen projects through 'Hydrogen Business Model' (HBM) contracts. Like the German mechanism, the HBM would provide a 'contract for difference' subsidy through a combination of price support and volume support based on the difference between a 'strike price' (to enable producers to cover costs) and a 'reference price' (the higher of the sales price received by the producer and the natural gas price)[159].
- **Canada -** Canada's 2022 budget introduced the technology investment tax credit scheme. The Canadian Government has announced that it will offer at least a 40 per cent investment tax credit for low emission hydrogen projects in response to the USA IRA[160].

New South Wales, Australia - Domestically, the NSW Government has done significant work on legislated Australian-first schemes to bring down the cost of hydrogen production. By combining revenue from certificates generated under the state's Renewable Fuel Scheme and electricity charge concessions, green hydrogen producers are expected to be able to achieve over $2 per kilo in cost reductions.

153 Hydrogen Council and McKinsey & Company (2021) Hydrogen Insights Report January 2021 and Boston Consulting Group (2020) Executive Perspectives – The US Inflation Reduction Act, https://media-publications.bcg.com/BCG-Executive-Perspectives-US-Inflation-Reduction-Act-16August2022.pdf

154 Deloitte, Investing in hydrogen: Ready, set, set zero, November 2020

155 Advisian, Australian hydrogen market study, May 2021

156 Boston Consulting Group (2020) Executive Perspectives – The US Inflation Reduction Act, https://media-publications.bcg.com/BCG-Executive-Perspectives-US-Inflation-Reduction-Act-16August2022.pdf

157 German Ministry of Economic Affairs and Climate Action (2021) Media Release - €900 million for H2Global hydrogen project Minister Habeck: Launch of hydrogen economy market ramp-up at www.bmwk.de/Redaktion/EN/Pressemitteilungen/2021/12/20211223-900-million-euro-for-h2global-hydrogen-project.html

158 German Ministry of Economic Affairs and Climate Action (2021) Implementation of the National Hydrogen Strategy at www.bmwk.de/Redaktion/EN/Publikationen/Energie/report-of-the-federal-government-on-the-implementation-of-the-national-hydrogen-strategy.pdf?__blob=publicationFile&v=2

159 UK Government (2022) Department of Business, Energy and Industrial Strategy. Hydrogen. *Hydrogen Business Model and Net Zero Hydrogen Fund: Electrolytic Allocation Round 2022. www.gov.uk/government/publications/hydrogen-business-model-and-net-zero-hydrogen-fund-electrolytic-allocation-round-2022*

160 Klevstrand, A (2022) Canada to introduce 40 per cent hydrogen tax credit as fears mount it will be 'left behind' by US IRA. Hydrogen Insight at www.hydrogeninsight.com/policy/canada-to-introduce-40-hydrogen-tax-credit-as-fears-mount-it-will-be-left-behind-by-us-ira/2-1-1346684

Building hydrogen demand

Ammonia projects are rapidly expanding

Ammonia production is the largest consumer of hydrogen globally with the industry using around 50 per cent of global production. Ammonia has many uses, most importantly as a feedstock in the production of agricultural fertilisers for farming. Agricultural uses of ammonia will remain essential to provide for the world's growing population, with a forecasted increase of 44 Mt of fertiliser required by 2050[161].

Low emissions ammonia production is of particular importance, as current ammonia production from fossil fuels is responsible for 1.8 per cent of global carbon dioxide emissions and 33 per cent of global chemical scope 1 emissions[116]. Delivering clean ammonia at scale, however, is economically challenging. For example, green ammonia production requires large amounts of renewable electricity, with the production of 580–830 Mt of green ammonia requiring 100–150 Mt of green hydrogen, which in turn requires 3,700–7,100 TWh of renewable electricity to be produced[116]. The price parity between grey and green ammonia production, however, is closing.

2022 saw an increased interest in green ammonia production, as fossil fuel-based ammonia prices rose significantly due to Russia's invasion of Ukraine. In March 2022, grey hydrogen production reached a levelised cost of $US6.71/kg in Europe, the Middle East and Africa compared to an estimated cost of $US4.84-6.68/kg for renewable hydrogen production[116]. There are now several large-scale green ammonia projects under development globally (excluding Australia).

Two examples are summarised below:

- Construction has completed on a 20 MW PEM electrolyser to supply 3,000 tonnes of renewable hydrogen per annum to Fertiberia (an ammonia and fertiliser manufacturer) in Puertollano, Spain. The total project cost of €150 million includes a 100 MW solar PV plant and a 20 MWh lithium-ion battery.
- Construction of a 60 MW integrated green hydrogen and ammonia plant for company Unigel has commenced in Bahia, Brazil. The facility will produce 10,000 tonnes per annum of green hydrogen and 60,000 tonnes per annum of green ammonia. The project has received a US$120 million investment. The project is anticipated to commence operations at the end of 2023.

Additional large-scale ammonia projects (>10 MW) are under development globally, with projects with clear investment decisions emerging in South America, Europe, and China. This is evident in Figure 26.

Methanol projects on the rise

Methanol as a clean fuel is simpler, safer to store and hosts a higher energy density than ammonia. European Energy is active in this space developing two e-methanol production facilities in Denmark (whereby the 'e' in e-methanol means electricity used in production). One facility is to be built in Kassø with Siemens Energy contracted to supply and commission a 50 MW PEM electrolyser. The e-methanol produced will be supplied to Maersk and Circle K, with production anticipated to commence in the second half of 2023. European Energy's second e-methanol project is to be in the Port of Aabenraa and will produce 17 kt per annum hydrogen[162]. Other international e-methanol projects include the Vicat Montalieu-Vercieu cement plant in France (57 kt hydrogen capacity)[163] and the Vordingborg Biofuels project in Denmark (19 kt hydrogen capacity).[164]

161 Mission Possible Partnership (2022) Ammonia Transitions Strategy, September. Making Net-Zero Ammonia Possible: *An Industry-backed, 1.5c –aligned transition strategy* at https://missionpossiblepartnership.org/wp-content/uploads/2022/09/Making-1.5-Aligned-Ammonia-possible.pdf

162 European Energy (2022) Media Release - Siemens Energy secures electrolyzer order from European Energy for world`s first large-scale e-Methanol project. European Energy.

163 L'Usine Nouvelle, www.usinenouvelle.com/article/vicat-investit-dans-sa-cimenterie-de-montalieu-vercieu-pour-reduire-l-usage-d-energies-fossiles.N1162162

164 Baltic Transport Journal, 'Vordingborg to House a Green Biofuel Factory', (15 June 2021), https://baltictransportjournal.com/index.php?id=1729

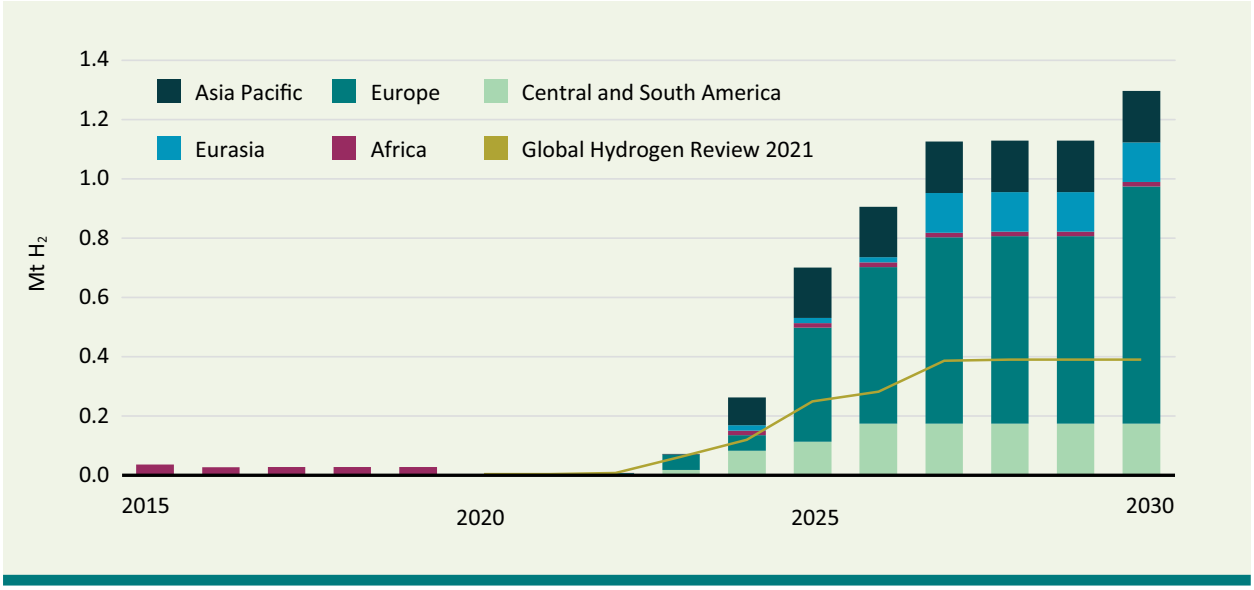


Figure 16: Operational and planned low emission hydrogen production capacity for ammonia by technology and region. (2015-2030) (Source. IEA, 2022[165])

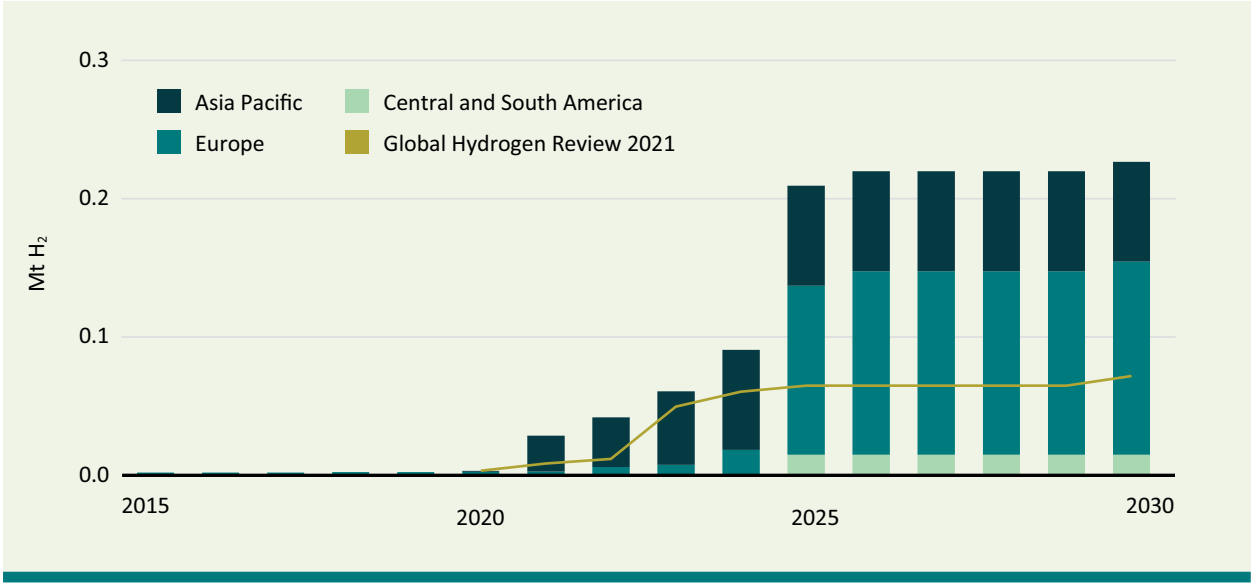


Figure 17: Operational and planned low emission hydrogen production capacity for methanol, by technology and region (2015-2030). (Source: IEA, 2022[166]).

In cumulative impact of the various tax credits available under the US Inflation Reduction Act may provide a significant stimulus to the emergence of new methanol projects in the coming year. However, current planned blue hydrogen projects located in North America are set to deliver an additional 0.3 Mt of low emissions hydrogen for methanol production by 2030 (Figure 18).

The CCUS portion of these projects, however, are highly dependent on the outcome of key projects including the national gas and CCUS Lake Charles Methanol project in Louisiana (United States) and the national gas and CCUS Nauticol Blue Methanol project in Alberta (Canada)[167].

165 IEA (2022) Global Hydrogen Review. IEA. Paris
166 IEA (2022) Global Hydrogen Review. IEA. Paris
167 IEA (2022) Global Hydrogen Review. IEA. Paris

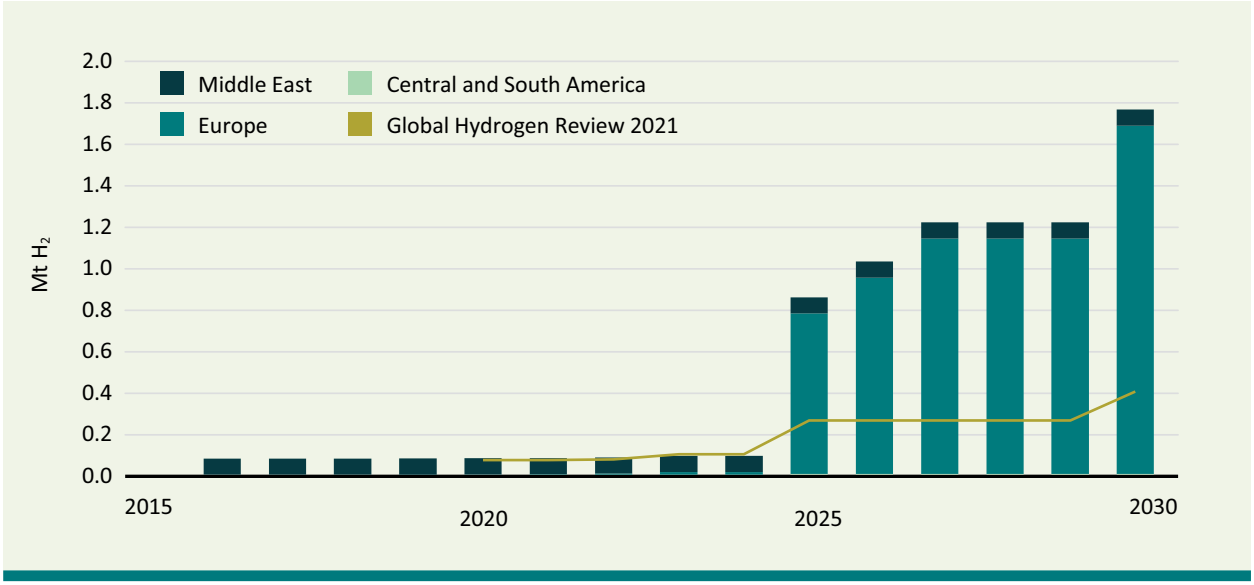


Figure 18: Planned low emission hydrogen production capacity for low emission steel, by region (2015-2030). (Source: IEA, 2022[168]).

Industrial applications – iron and steel

There are numerous hydrogen-based steel making pilot projects and trials occurring globally. For instance:

- In March 2022, Shanghai University and Changli Xingguo Precise Machine Parts Co in China completed testing of a hydrogen-enriched smelting blast furnace that utilises hydrogen to reduce coal coke consumption by over 10 per cent, while at the same time increasing the output of iron production by 13 per cent[169].
- In Sweden, H2 Green Steel is planning the construction of a €2.5 million hydrogen powered steel plant that is anticipated to produce 2.5 million tonnes of steel per annum by 2026.[170] H2 Green Steel has reportedly pre-sold 60 per cent of the initial green steel production volumes and has been successful in securing around €300 million in equity to progress the project[171].
- In August 2021, the HYBRIT partnership between SSAB, LKAB and Vattenfall announced the production of the world's first fossil fuel free steel, with delivery to the Volvo Group. The facility is in Lulea in Sweden and is targeting industrial scale production by 2026.[172]

The use of hydrogen for industrial applications will accelerate over the next decade with an additional 30 projects due to start around the world by 2025. The EU Steel industry have announced plans to transition the entire sector to zero emissions by initially focussing on improving existing process efficiencies and eventual replacement of blast furnace technology to be 100 per cent hydrogen by 2040.

168 IEA (2022) Global Hydrogen Review. IEA. Paris
169 Global Times, 'China Counts on New Technology to Decarbonize Steel Production' (31 March 2022) www.globaltimes.cn/page/202203/1257298.shtml cited in Deloitte (2022) Hydrogen Market Analysis and Comparison. Deloitte
170 H2 Green Steel, 'H2 Green Steel Starts Preparing Boden-site for Construction' (25 July 2022), www.h2greensteel.com/latestnews/h2-green-steel-starts-preparing-boden-site-for-construction
171 H2 Green Steel, 'H2 Green Steel Completes EUR 190 Million Funding Round' (29 August 2022), www.h2greensteel.com/latestnews/h2-green-steel-completes-190-million-funding-round
172 143. SSAB, 'The World's First Fossil-Free Steel Ready for Delivery' (18 August 2021), www.ssab.com/en/news/2021/08/the-worlds-first-fossilfree-steel-ready-for-delivery

Road transport

The uptake of hydrogen fuelled vehicles is increasing globally. By the end of 2021, the global hydrogen fuel cell electric vehicle (FCEV) stock was above 51,000, up from about 33,000 in 2020. As a result, the number of hydrogen refuelling stations has steadily increased over the past few years to just over 700[173]. China is on track to have 50,000 FCEVs alone by 2025[174].

Light vehicles

Using hydrogen for light transport is part of many countries' decarbonisation goals. An increasing amount of car manufacturers and brands are conducting prototype testing of passenger FCEVs with Honda, Toyota, Citroën, Peugeot, and Opel all expected to make light FCEVs available in 2023.

The use of hydrogen is also well established in the forklift truck market and in 2022, more than 50,000 hydrogen fuel cell forklifts (or similar) were in service in the United States. This was an increase of about 10,000 from the previous year. Walmart also recently signed an agreement to provide renewable hydrogen to fuel their fleet of as many as 9,500 hydrogen fuel cell forklifts.[175]

Heavy vehicles

Heavy FCEVs are the most viable options to compete with diesel powered vehicles due to their long-range capabilities and similarities in required infrastructure, such as refuelling stations. Transitioning heavy vehicle fleets to hydrogen is challenging due to high capital costs, however, prices are anticipated to rapidly decrease through economies of scale.

Many countries are targeting heavy FCEVs to decarbonise their heavy vehicle industries. Some leading countries and projects include:

- China is the global leader in producing hydrogen fuel cell buses and trucks, with a reported total of over 8000 vehicles deployed.
- In Germany, Wrightbus will be supplying up to 60 fuel cell buses to the city of Cologne, while Solaris will be providing up to a further 20 fuel cell buses with delivery expected in 2023. Additionally, Hyundai, together with seven German companies in logistics, manufacturing, and retail aim to put 27 fuel cell trucks into fleet service.
- The United Kingdom's West Midlands will deploy 124 new fuel cell electric buses adding to their existing fleet of 20 fuel cell electric buses.
- The South Korean government are purchasing 624 fuel cell electric buses.
- In Japan, Isuzu, Toyota, Hino and CJPT have announced they will develop light-duty fuel cell electric trucks for market release in 2023. Additionally, Toyota and Kenworth have jointly developed fuel cell electric heavy-duty trucks for the United States market.
- French company Alstom is pursuing hydrogen powered rail transport in Europe with the company conducting trials of its Corodia Lint hydrogen train in Austria, France, the Netherlands, and Sweden. Following successful trials, Germany has ordered a total of 41 trains to replace its diesel-powered trains[176].

173 IEA (2022) Global Hydrogen Review p47

174 China Daily, 'Nation Poised to Become Global Leader in Hydrogen Vehicle Industry', (29 August 2022), www.chinadaily.com.cn/a/202208/29/WS630c19c8a310fd2b29e74b4a.html

175 Bloomberg, 'Walmart will run Forklifts on 'Green; Hydrogen in Plug Power Deal', (19 April 2022), www.bloomberg.com/news/articles/2022-04-19/walmart-will-run-forklifts-on-green-hydrogen-in-plug-power-deal

176 Alstom (2022) Press Release Alstom and ENGIE sign a partnership to supply a fuel cell system with renewable hydrogen for use in European rail freight. www.alstom.com/press-releases-news/2022/4/alstom-and-engie-sign-partnership-supply-fuel-cell-system-renewable

Shipping

Cargo and container ships currently produce around 3 per cent of global emissions[177]. Reducing emissions in the shipping sector is a priority for the International Maritime Organisation (IMO), which currently has a goal (under review) to halve its emissions by 2050 compared to 2008 levels[178]. This is driving innovation in alternative marine fuels such as hydrogen, ammonia, and methanol. The Getting to Zero Coalition reports growth in the number of demonstration shipping projects, with 45 hydrogen (small vessels), 40 ammonia (large vessels), and 25 methanol (small and large vessels). Zero emission shipping orders are growing with 66 global orders for ammonia-ready vessels, three for hydrogen-ready vessels and five for methanol-ready vessels placed in the first half of 2021[179].

Methanol has a higher technology readiness level than hydrogen or ammonia technologies for shipping and as a hydrocarbon fuel it has a high energy density that makes it well suited for long-distance vessels. It is actively being pursued by companies including Maersk for large, long-distance container ships. Maersk is developing several strategic partnerships for methanol production for their vessels and has plans to introduce eight, carbon neutral methanol container vessels in 2024[180].

The Norwegian government is also actively working to decarbonise its shipping fleet. Its plan to reduce emissions from domestic shipping by 50 per cent by 2030 has led to a commitment to build five Norwegian hydrogen hubs that will provide the infrastructure to fuel 35-40 ships.

Ports

In addition to preparation to handle the importation of hydrogen many ports are considering the opportunity to use hydrogen fuels for their in-port operations as well as supplying bunker fuels for shipping. At the end of 2021, the world's first hydrogen fuel cell powered mobile crane was deployed at the Port of Shanghai in China.

The Port of Rotterdam in the Netherlands is working towards a large-scale hydrogen network across its port complex. As an existing international shipping hub and containing half of the hydrogen projects in the Netherlands, it is well placed to enable hydrogen production, imports, application, and transport to other countries in Northwest Europe. A layout of hydrogen hubs plans is presented in Figure 23.

Pipelines

There are opportunities and challenges with repurposing infrastructure for the use of hydrogen. Repurposing natural gas pipelines for the transmission of hydrogen can cut investment costs 50-80%, relative to the development of new pipelines. There are projects[181][182] under development to repurpose thousands of kilometres of natural gas pipes to 100% hydrogen. However, practical experience is limited, and significant reconfiguration and adaptation will be necessary to address risks of leakage.

Gas networks

There are 40 projects around the world blending hydrogen into natural gas networks including those listed in Table 9 below. The United Kingdom, the Netherlands, Australia, and the United States each host several gas blending demonstration projects of which these pilots are mostly testing blends of 5-20 per cent hydrogen.

177 Bloomberg, 'Huge Container Ships' Biggest Problem is Emissions (31 March 2021), www.bloomberg.com/opinion/articles/2021-03-30/huge-container-ships-biggest-problem-is-emissions#xj4y7vzkg

178 International Maritime Organisation, IMO Action to Reduce Greenhouse Gas Emissions

179 Global Maritime Forum (2022) Mapping of Zero Emission Pilots and Demonstration Project at www.globalmaritimeforum.org/content/2022/03/Mapping-of-zero-emission-pilots-and-demonstration-projects_third-edition.pdf cited in IEA (2022) Global Hydrogen Review (pg52)

180 Maersk issues first green bond to fund first green methanol vessels, 19 November 2021, www.maersk.com/news/articles/2021/11/19/maersk-issues-first-green-bond-to-fund-first-green-methanol-vessels

181 European Hydrogen Backbone, 'The European Hydrogen Backbone (EHB) Initiative', https://ehb.eu/#:~:text=carbon%20hydrogen%20market.-,Mission,and%20low%2Dcarbon%20hydrogen%20market

182 PV Magazine, 'Netherlands to Build 10 GW National Network for Green Hydrogen', (30 June 2022), www.pv-magazine.com/2022/06/30/netherlands-to-build-10-gw-national-network-for-green-hydrogen/#:~:text=The%20Netherlands%20is%20planning%20a,to%20go%20online%20in%202027.

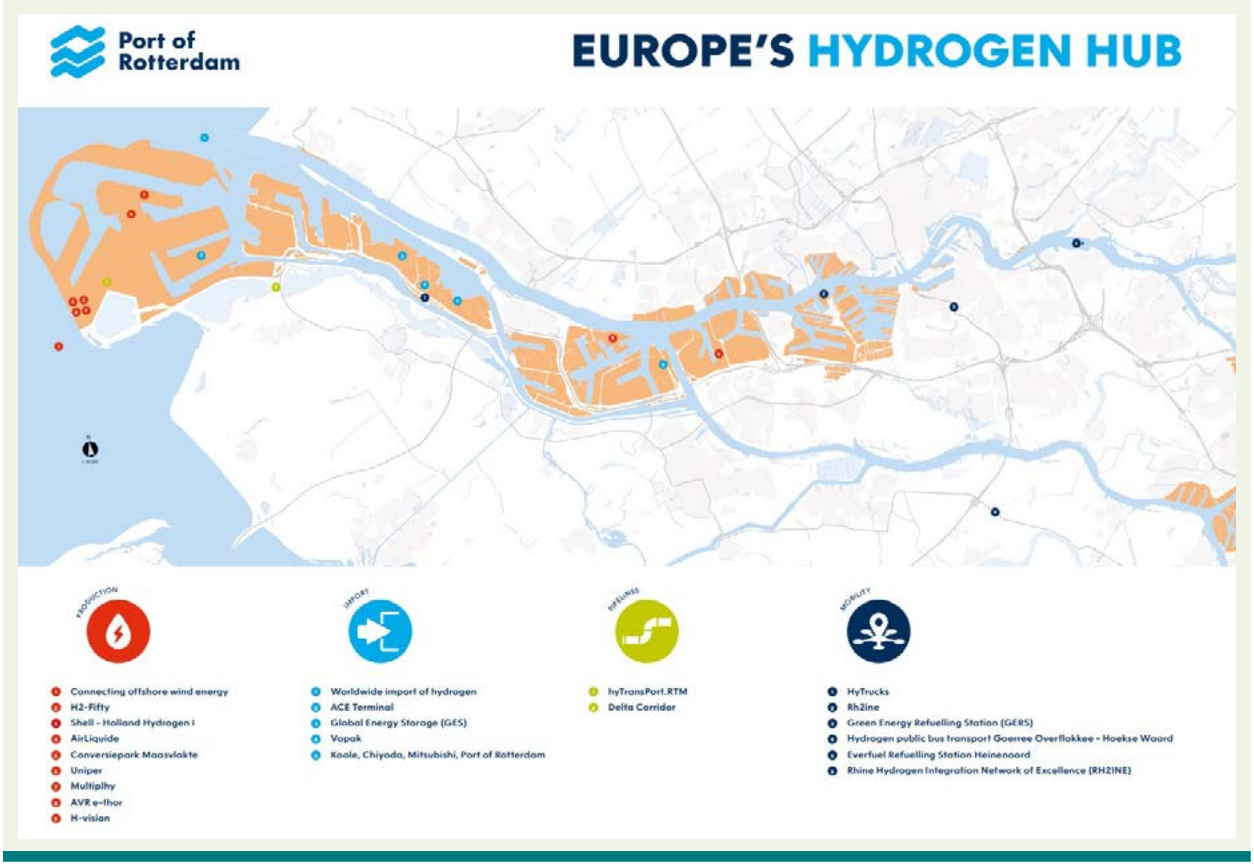


Figure 19: Port of Rotterdam – Europe's Hydrogen Hub

Table 9: Hydrogen blending projects (Source: IEA, 2022[183])

Project Name	Country	Start Year	Blending Volume	Production	Announced Project Size
Enbridge Gas and Cummins Ontario	Canada	2022 (operational)	2 per cent	Electrolysis	3,600 customers
ATCO – Alberta	Canada	2022 (unknown)	5 per cent	Electrolysis	2,100 customers
Gasvalpo Energas-Coquimbo	Chile	2022 (operational)	5-20 per cent	Electrolysis	1,800 customers
Promigas, Surtigas – Heroica	Colombia	2022 (operational)	N/A	Electrolysis	1.6 tonnes per annum
GAIL-Madhya Pradesh	India	2022 (under construction)	2 per cent	Electrolysis	N/A
Green Pipeline Project – Setubal	Portugal	2022 (unknown)	2-20 per cent	Electrolysis	80 customers
HyGrid – Long Island	United States	2022 (unknown)	5-20 per cent	Electrolysis	800 homes

183 IEA (2022) Global Hydrogen Review. IEA. Paris

Electricity

Countries with limited access to natural resources, such as Japan and South Korea, have large targets for using hydrogen for baseload power generation via hydrogen turbines and ammonia co-firing in coal-fired power plants. Co-firing of ammonia has advanced worldwide since 2021, with further trials in Japan, the United States and China underway, including:

- In Japan, JERA and IHI Corporation have undertaken small-volume ammonia co-firing, with larger-volume co-firing (20 per cent of heating value) anticipated to commence in mid to late 2023.
- In 2022 in the United States, 5 per cent (by volume) co-firing of hydrogen with natural gas was demonstrated in Ohio at the 485 MW Long-Ridge Energy Terminal.
- In China it has been reported that China Energy has successfully demonstrated co-firing of 35 per cent ammonia with coal in a 40 MW coal boiler at the Huaneng Yantai coal power plant.

Major turbine manufacturers, such as Siemens and General Electric, have also started to produce and sell 100 per cent hydrogen-ready gas turbines.

Agriculture and Food

The agriculture and food sector has traditionally been a hard to abate sector. Emerging evidence synthesized here suggests hydrogen could assist the decarbonisation of this sector in addition to the other hard to abate sectors covered above.

There is research and development[184] regarding the use of hydrogen in many aspects of agriculture and food production in addition to clean ammonia for fertilisers. For instance, there is research and trials of fuel cells to power heavy farm machinery[185].[186] Japanese multi-national Kubota plans to roll out a mass-produced hydrogen fuel cell tractor in 2025[187]. In Australia, The Victorian Government is funding the Energy Independent Farming (EIF) partnership to trial using hydrogen fuel for farm machinery to replace diesel fuel.[188]

There is also a significant body of research and trials into using hydrogen on farms to power generators instead of diesel[189]. There has been a large amount of research and trials evidencing the effectiveness of the hydrogen molecule in improving the fertility of soils and crops[190]. Australian start-up "HydGene Renewables" is seeking to develop a new way to produce hydrogen on farm[191]. There is also a significant array of start-ups[192] working to pioneer and commercialise the use of hydrogen and methanol as a fuel for precision fermentation to create a new generation of low carbon protein food. CSIRO has a $150 million Future Protein Mission seeking to support $10 billion of alternative protein exports from Australia by 2030. CSIRO states that "*Precision fermentation has emerged as one of the frontrunners for additional sources of protein that could underpin the growth of a sustainable bio-economy in Australia.*"[193] Early results suggest the ability to make food protein using precision fermentation with relatively very low carbon and ecological footprints compared to traditional approaches.[194]

184 Phillips, C and Leachman, J. (2021) The hydrogen fuelled farm of the future. Washington State University https://hydrogen.wsu.edu/2021/08/04/the-hydrogen-fueled-farm-of-the-future

185 NSW Farmers Federation (2022) Hydrogen Fuelled Tractors A Clean Energy Option For Farmers at www.nswfarmers.org.au/NSWFA/Posts/The_Farmer/Tools/Hydrogen_fuelled_tractors_a_clean_energy_option_for_farmers.aspx

186 PV Magazine Australia (2021) Can Hydrogen Bump Diesel To Power Large Scale Agriculture at www.pv-magazine-australia.com/2021/05/10/can-hydrogen-bump-diesel-to-power-large-scale-agriculture

187 Asia Nikkei (2022) Kubota to roll out first fuel cell tractor in 2025, eyeing U.S. and Europe at https://asia.nikkei.com/Spotlight/Environment/Climate-Change/Kubota-to-roll-out-first-fuel-cell-tractor-in-2025-eyeing-U.S.-and-Europe

188 PV Magazine (2021) Could hydrogen replace diesel in large-scale agriculture? www.pv-magazine.com/2021/05/14/could-hydrogen-replace-diesel-in-large-scale-agriculture

189 Fuel Cell Works (2021) hydrogen-fuel-is-shaping-the-future-of-agriculture at https://fuelcellsworks.com/news/hydrogen-fuel-is-shaping-the-future-of-agriculture

190 Zulfiqar, F. Russel, G. Hancock, T., (2021) Molecular hydrogen in agriculture. Planta volume 254, Article number: 56 https://link.springer.com/article/10.1007/s00425-021-03706-0

191 Ag Futures Grow - Low-cost green hydrogen technology for Australian farms, ready for investment at www.growag.com/highlights/article/green-hydrogen-solution-for-australian-agriculture-ready-for-investment

192 American Chemical Society (2020) Can start-ups succeed in making food from the air at - https://cen.acs.org/articles/98/i36/start-ups-succeed-making-food.html and Solar Foods at - https://solarfoods.com

193 CSIRO (2021) https://ecos.csiro.au/whats-brewing-precision-fermentation

194 Labiotech (2022) Protecting our food supply chain with precision fermentation at www.labiotech.eu/in-depth/precision-fermentation-food-supply

The first product using the precision fermentation approach with hydrogen as a fuel has past regulatory requirements and been approved for sale in Singapore[195]. This is increasing investment as shown by the fact that in 2021, over US$435 million in venture capital investment was invested in precision fermentation start-ups[196]. There is growing demand for low carbon alternative protein products with the global market forecast to reach $25 billion by 2030.[197]

Comparison with Australia's progress

Deloitte has evaluated Australia's progress relative to other countries with their assessment listed in Table 10. Overall, Australia tends to be a follower rather than a leader on the global scale.

Deloitte's assessment helps to understand indicators where Australia is marked as doing well, but, when compared to global hydrogen ambition, is not as highly ranked as competing countries. Some further explanation of each metric is provided below.

Table 10: 2022 International comparison of Australia's progress related to global best practice.

Industry Development Signal	2022 International Comparison
Investment	Follower ... Leader
Project Scale	Follower ... Leader
Cost-competitiveness	Follower ... Leader
Australia's exports	Follower ... Leader
Chemical feedstock	Follower ... Leader
Electricity grid support	Follower ... Leader
Mining and off-grid	Follower ... Leader
Heavy transport	Follower ... Leader
Light transport	Follower ... Leader
Gas networks	Follower ... Leader
Electricity generation	Follower ... Leader
Steel and iron making	Follower ... Leader
Industrial heat	Follower ... Leader

195 Solar Foods – Singapore Approves Novel Food for Sale at https://foodmatterslive.com/article/solar-foods-receives-novel-food-approval-solein-singapore/#:~:text=Finland%2Dbased%20foodtech%20company%20Solar,%2C%20the%20start%2Dup%20says.

196 CSIRO (2021) What is Brewing – Precision Fermentation at https://ecos.csiro.au/whats-brewing-precision-fermentation

197 McKinsey – Alternative Proteins – Our Insights at www.mckinsey.com/industries/agriculture/our-insights/alternative-proteins

Investment

In relation to the Investment metric, Australia has a large pipeline of announced hydrogen projects, but it still trails many OECD nations in terms of projects proceeding to deployment. For example, the amount of hydrogen projects with 10 MW or greater electrolyser production that have passed final investment decision is higher in many OECD countries (Figure 2).

Contributing to Australia's is assessment as follower rather than leader is the comparatively high levels of public funding allocated to hydrogen industry development in other countries noted previously. Private investment in other countries is also ahead of Australia (for example Japan and Egypt), or has considerable potential (US). In comparison, private companies in Australia have mostly been unable to impact the hydrogen market or hydrogen innovations on a global scale.

Project scale

Australia's first 10MW project to achieve FID is broadly in line with the global standard in terms of scale. In 2021, the global average electrolyser size was around 5 MW, according to the IEA[198]. However, many progressive hydrogen nations are now exceeding this scale globally with larger projects. In comparison to global competitors, Australia is behind others regarding project scale. Many leading hydrogen nations have operational electrolyser projects of above 50 MW, with some such as China planning to construct hydrogen projects at a scale of 300 MW. An assessment of Australia's cost-competitiveness with international markets is difficult due to the limited quantity of publicly available information and the small amount of low carbon hydrogen produced.

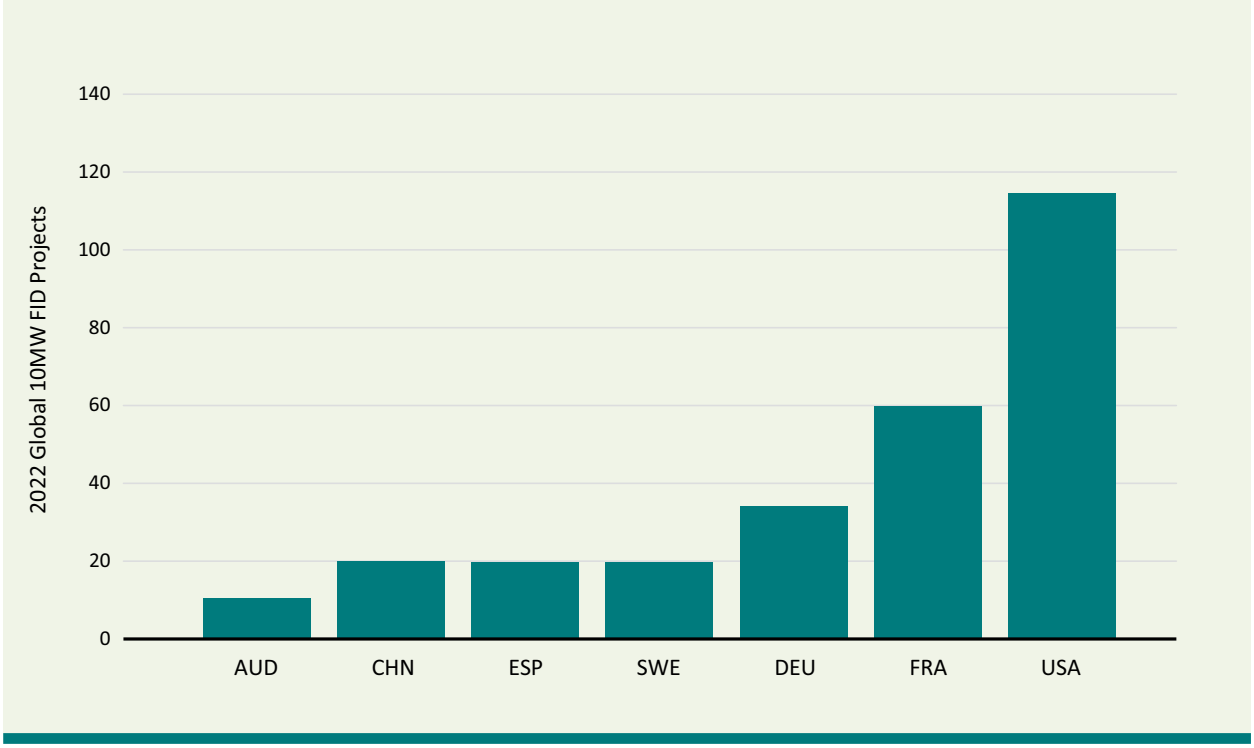


Figure 20: 10MW or Greater Clean Hydrogen FID Approved Projects - Global Comparison.

198 IEA, 'Global Hydrogen Review 2022' (September 2022)

Cost competitiveness

Analysis by the IEA has identified that renewable hydrogen could compete in many regions with fossil fuels due to elevated energy prices emerging following Russia's invasion of the Ukraine. However, the extent to which these price distortions will persist is unclear. Market commentary indicates the US Inflation Reduction Act is set to dramatically improve the economics of low-carbon hydrogen, with varying tax credits available depending upon the emissions intensity of the hydrogen produced and other socioeconomic benefits associated with the project.

Internationally, the pace of regulatory adaption in key future markets, which is required to smooth the process of adopting hydrogen, is moving faster in comparison to Australia.

Australian exports

Australian governments and industry have made efforts in progressing their hydrogen supply chain technology and in launching projects that relate directly to the Australia' Exports metric. Although other nations such as Germany and the Netherlands have invested significantly more hydrogen trade related projects. The construction of a green ammonia plant in addition to the international partnerships formed around technology innovation and hydrogen trade clearly demonstrates Australia's ambition for hydrogen export.

Chemical feedstock

Australia is considered to be behind other key global players with only a single Chemical Feedstock project at 10 MW. Several large-scale projects are under development globally for ammonia and methanol production, as well as refining activities including:

- Construction has been completed on a 20 MW PEM electrolyser in Puertollano, Spain and will supply 3,000 tonnes of renewable hydrogen to Fertiberia (an ammonia and fertiliser manufacturer) per annum.
- Construction in Bahia, Brazil by Unigel has commenced of a 60 MW integrated green hydrogen and ammonia plant. The plant has a planned production capacity of 10,000 tonnes per annum of green hydrogen and 60,000 tonnes per annum of green ammonia and is expected to be operational by the end of 2023.
- Sinopec Energy in China has reportedly commenced construction of a 300 MW electrolyser, with hydrogen produced planned for use in oil refining. This project is expected to enter operation in 2023.

Electricity generations and grid support

The extent to which hydrogen will be used to deliver base load power or serve load balancing, grid firming and ancillary services at an international scale is currently unclear. Projects are likely to be dependent upon comparable economics of the delivered cost of hydrogen in comparison to the installation of variable renewable energy, particularly in potential hydrogen import markets such as Japan and South Korea. For example, Japanese power utilities have demonstrated 100% firing of hydrogen in a 1MW generator that could be used for grid firming. Similarly in Japan in 2022, IHI demonstrated over 100% combustion of liquid ammonia in a 2 MW gas turbine which could be utilised for either generation or grid firming applications.

Australia is considered a relative leader in the use of hydrogen for Electricity Grid Support considering the developments of the 'hydrogen-ready' Tallawarra B and Kurri Kurri projects as early development of the Whyalla project.

Mining and off grid

Australia is generally prioritising battery adoption over hydrogen for Mining and Off-Grid applications, which is like what is happening globally. There is limited international activity for hydrogen use as an off-grid diesel replacement, with some projects in India (by Hygenco and NTPC Limited) and Romania (by Vodafone). This limited global application of hydrogen for mining and off-grid hydrogen use means the scale and quantity of projects within Australia place us as a comparative global leader in the use of the technology.

Transport

Despite the Australian transport projects, and funding announcements described in Chapter 2, other nations have invested significantly more than Australia into heavy hydrogen fuel cell transport with many countries deploying hundreds or thousands of vehicles. The same can be said in relation to light vehicles and in relation to shipping and rail transport.

Gas networks

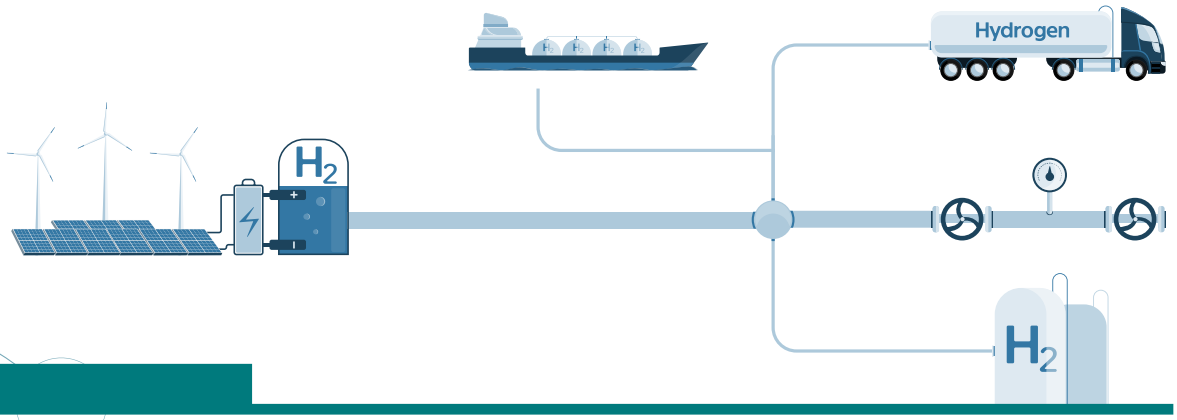
Operational Australian projects as well as projects in the advanced stages of development for gas blending space are similarly placed to other global movers. These include projects which have entered or have been announced to enter operation in Canada, Chile, Colombia, India, Portugal, and the United States in 2022. Europe is more advanced relative to Australia in the planning for repurposing of hydrogen transmission infrastructure, however, these projects are yet to reach financial close.

Steel and iron making

Australia is considered to be behind other countries such as Europe and China in relation to hydrogen use in green steel production. Analysis by the IEA has identified Europe as the major growth location for green steel production. IEA also identifies the GravitHy project in France, Joint Project of Air Liquide and Arcelor Mittal in France, AM Gent H2 Consumption Hub in Belgium and HyDeal Espana project in Spain which have been announced as including the use of hydrogen for steel production. Additionally, public sector investment totalling EUR 723 million has been made by Salzgitter in Germany to convert an existing steelwork.

Industrial heat

There are limited international hydrogen projects dedicated to industrial heat production and use. As such, Australia is neither leading nor following international activities, with alternative technologies for industrial heating such as electrification being considered



Chapter 5

Next steps

Australia has made a promising start on the pathway set out in the National Hydrogen Strategy. Continuing and potentially increasing this pace will be crucial for Australia to be a world leader in hydrogen. Australia will need to move from planning to implementation in a range of areas and consider further measures that will help the Australian industry fulfil its potential, particularly in light of policy developments globally that will have an impact on existing industry development strategies.

Implementation of projects supporting scale

The establishment of hydrogen hubs are a critical element to efficiently activating the hydrogen industry. They will provide centres of activity where there is enabling infrastructure, capacity to scale, foster innovation and synergies among sectors.

Initial steps have now been taken by governments and industry to identify the location of viable hubs as well as proposing both backbone infrastructure and initial sources of hydrogen demand. However, most of these hub elements are yet to confirm their access to funding, or break ground on project delivery. It will be critical for these early steps to be adequately supported in terms of patient funding, and allocation of risk.

The implementation of hydrogen projects, such as the hydrogen hubs, will provide a clearer understanding of associated costs, deployment timelines and potential constraints. The success or failure of early projects will shape the growth trajectory of the sector. As projects emerge that are first of a kind by size or application in Australia, it will be important that learnings continue to be shared.

Securing foreign investment

Australia is reliant on foreign direct investment to facilitate industry growth and development. There is also the prevailing view of market economists that there is no way to meet de-carbonisation commitments without a significant amount of productive foreign investment over an extended period. Given the scale of new renewable energy generation needed to enable the hydrogen industry, and reach renewable electricity generation targets, there are good opportunities for foreign investment that will be aided by appropriate regulations, workforce capability, and incentives.

Delivery of electricity generation projects

The use of hydrogen for electricity for electricity generation provides an alternative to the traditional combustion of fossil fuels. However, with the abundance of renewable electricity production potential, it is unlikely that hydrogen will contribute to base load electricity generation during normal operation. Rather it could provide a means of storing excess renewable generation for times when renewable generation is insufficient to meet medium to long term demand. This usage model is consistent with that envisaged by both the South Australian government proposal for Whyalla, and the Commonwealth government's proposal for Kurri Kurri as well as projects in WA.

These projects are of significant scale and will generate significant hydrogen demand. As with other hydrogen projects of scale it will be important to adequately support the project's progress from plan to implementation.

Implementation of hydrogen ready regulation

A priority for the immediate future will be to provide investor certainty through agreeing to and implementing standards, regulations, and certification. Wherever possible, this should be consistent domestically and internationally to avoid unnecessary confusion and perceived risk for investors and project proponents.

Agreed legislative reforms to extend the national gas regulatory framework to bring hydrogen blends, biomethane and other renewable gases within its scope are expected to come into effect in 2023. State government and industry have continued to invest in trials to test blending. For example, the WA government has invested $2 million in a $2.6 million blending project by ATCO Gas Australia. The Hydrogen Park South Australia will extend their blending project from 700 homes to more than 3000 homes.[199]

Work is continuing on the safe upper limits of hydrogen blending levels and on the economics of hydrogen blending in gas networks, including up to 100 per cent conversion. A range of issues still need to be considered to progress hydrogen blending to higher levels including:

- Residential appliance testing and upgrade requirements.
- Industrial consumer appliance testing and upgrade.
- Supply and distribution networks and facilities conversion requirements
- Transport logistics associated with hydrogen supply.

The relative economics of the domestic use of hydrogen needs to be determined, with considerable efforts already underway to electrify households and industrial processes.

Delivery of supporting infrastructure

The first iteration of the National Hydrogen Infrastructure Assessment is now complete and provides insight into infrastructure options and associated challenges that will be confronted by an expanding hydrogen industry. The eventual scale means that infrastructure constraints are likely without early consideration and no regrets investment. In addition, the necessary infrastructure will need to be partially driven by the specific use cases for hydrogen including use in the electricity and gas networks.

Work to be undertaken under the National Energy Transformation Partnership aims to support the integration and co-ordination of energy and climate policy across Commonwealth, state and territory governments. This will include:

- improving co-ordination of gas and electricity system planning, with gas planning to now encompass hydrogen planning.
- improving the understanding of demand evolution and regional-level scenario planning.

The national assessment will be repeated at least once every 5 years to highlight future infrastructure needs for competitive hydrogen supply chains. The adaptation of this work stream in the context of a newly formed Energy Transition Partnership between all Australian governments needs to be considered.

Translating skills and training needs into a hydrogen workforce

Australia's development of a hydrogen-ready workforce is critical given our scale of ambition. Understanding the extent to which existing qualifications need to be altered and whether entirely new courses are required is an important first step. Beyond that step, the workforce numbers and occupations required will be necessary information to plan for the growth of the sector. Any planning will need to be cognisant of the broader energy transition currently underway, which will also place a large demand for a skilled workforce. In response to this need, in 2022, the Australian Government established Jobs and Skills Australia (JSA) to provide independent advice on current, emerging, and future workforce, skills, and training needs. Part of JSA's new role is to deliver the Government's Skilling the Clean Energy Workforce program and Clean Energy Capacity Study to ensure Australia has the workforce required to build a robust, green economy[200]. Practical action through international collaboration

199 Hydrogen Park SA to be industry supplier | Australian Gas Networks
200 Department of Employment and Workplace Relations – www.dewr.gov.au/newsroom/articles/jobs-and-skills-australia

Australia has been ambitious in establishing bilateral international partnerships and joining multilateral clean energy forums involving a focus on hydrogen. The translation of these partnerships into practical projects and activities will be important in realising the opportunities these partnerships offer. Advancing shared goals internationally is essential to enable the sector to grow at the pace necessary to meet our decarbonisation requirements.

Lowering the cost of hydrogen

Only a limited number of Australian projects have achieved final investment decision (FID). This aligns with the current state of hydrogen globally, with only four per cent of global hydrogen projects having reached FID or being under construction according to the IEA[201].

The Australian, state and territory governments are offering a range of economic incentives to lower the upfront costs of investing and thus also lowering the green premium for producing and using hydrogen (refer Appendix 2). Deloitte note[202] that high fossil-fuel prices are improving the relative economics of renewable hydrogen projects globally, but government support is still required to help project proponents to overcome the hydrogen price gap. Although positive for the development of global hydrogen industry, substantial policy interventions such as the Inflation Reduction Act will have an equally substantial impact on Australia's emerging domestic hydrogen industry.

Deloitte also note that regulatory barriers are important to overcome to help the sector to grow and Australia has yet to enact any new laws, standards or regulations related to developing a new hydrogen industry.

Australian Governments are investing in research, development, and demonstration of innovations to lower renewable and electrolyser costs over time. In addition, the Australian Government is supporting investment in domestic manufacturing of electrolysers to scale their production.

Australian Governments also have policies and announced funding to support further onshoring of manufacturing of key components of other technologies used in hydrogen production and use to improve supply chain security and put downward pressure on costs over time. However, a greater sense of urgency regarding the need to find ways to accelerate our domestic industry's growth has developed over the past year.

Supporting industrial heat uses

This report points to slow progress in the uptake of hydrogen in industrial heat scenarios. Many of Australia's largest greenhouse gas emitters will have to reassess how they will transition away from their use of fossil fuels for industrial heat, as the expected changes to the Safeguard Mechanism are intended to help industry reduce emissions in line with Australia's climate targets.

Increased energy efficiency and electrification will assist in many circumstances, but hydrogen may be the only available option for others, particularly those where there are high heat requirements, such as steel production and non-ferrous metal production.

Taking advantage of global price reductions and ensuring the enactment of domestic cost reduction measures (project scale, incentives, supply chain efficiency), will be critical to enable these potential hydrogen users being able to transition and compete globally.

Commercialising Australian investment in hydrogen R&D

The need to translate research into real world applications remains essential in reducing the cost of hydrogen production. Funding is needed to support research from investigative studies, to applied projects and then to support the transition to commercialise a product. Research and development also has potential to develop new end use applications of hydrogen to assist decarbonisation of other hard to abate sectors such as agriculture, food production and development of new low carbon export products as outlined in this report.

201 IEA (2022) Global Hydrogen Review 2022.
202 Deloitte (2022) Hydrogen Market Analysis and Comparison. Deloitte

Tracking international hydrogen R&D and industry growth

International developments in hydrogen R&D and demonstration in new novel end uses of hydrogen, such as those outlined in Chapter 4 above, can help prove up and de-risk investment in the same new hydrogen use applications here in Australia and thus assist local decarbonisation and local hydrogen industry development. Hence why we will continue to track such global developments in each annual State of Hydrogen report.

Understanding supply chains and addressing bottlenecks

The growth of a nascent industry is complex. There are multiple issues that will need to be understood and responded to as time progresses. A critical element will be supply chains and addressing aspects of the supply chains that is limiting the growth of the sector. This may include consideration of any overdependence on international supply chains, or opportunities for Australia to grow its manufacturing base.

Engaging the community

As hydrogen projects and hubs evolve, the changes may cause concerns in the local communities that need to be understood and considered as the sector grows. Consulting with communities enables the articulation of concerns and identification of responses to address community concerns. For instance, all Governments are committed to working with Traditional Owners and other landholders to build capacity and help negotiate the best outcomes for communities engaging with hydrogen project proponents across Australia. For instance, in July 2022, the Western Australian Government facilitated a forum to bring Traditional Owners together to share information and discuss the opportunity to develop approvals and engagement processes that support free, prior, and informed consent for some of the State's approximately 30 medium and large-scale renewable hydrogen projects, which span from Kununurra in the north, through to the Esperance/Eucla region on the south coast.

For instance, all Governments are committed to engage more in the future with farmers and graziers to identify win-win opportunities. For instance, the Western Australian Government is actively working with Western Australian landholders to develop suitable land tenure models for large scale hydrogen production proponents across Western Australia. This includes stakeholder engagement undertaken through Forums like the Esperance Hydrogen Forum in June 2022.

Additionally, The Western Australian Government has proposed changes to Western Australia's Land Administration Act 1997 (LAA) to introduce a new, more flexible form of land tenure for unallocated Crown and pastoral land, allowing multiple interests to co-exist.

Sharing learnings internationally

The issues facing Australia to implement the energy transition to a zero-emission economy are enormous. International cooperation will be vital to ensure a successful transition. Our researchers, policymakers, regulators, NGOs, industry, and industry associations all need to engage internationally to benefit from the wealth of information being generated overseas. In turn, we should be willing to share information about our successes and failures in progressing towards a net-zero world.

Conclusion

The National Hydrogen Strategy[203] sets out an adaptive pathway to develop Australia's hydrogen industry.

Early activities are helping the industry take early steps but building on this foundation will likely take greater effort given the greater than expected level of action from nations that also have great potential to produce hydrogen.

To keep up with potential international competition, Australia will need to build on the work already underway, and likely accelerate its next steps. This may require a refocus of our priorities to take advantage of what we have learnt since the release of the National Hydrogen Strategy, as well as respond to shifts in the market place.

Ongoing collaborative and coordinated effort will be required to take these activities to the next level and give the industry the best chance of success.

The future for hydrogen is bright and there is immense opportunity for future prosperity. We can work together to build lasting partnerships between industry, investors, researchers, governments, international partnerships and the broader community to take advantage of these opportunities.

203 Commonwealth Government (2019) National Hydrogen Strategy - www.dcceew.gov.au/energy/publications/australias-national-hydrogen-strategy

Appendix 1

Summarised actions from the National Hydrogen Strategy

Adaptive pathway

The adaptive approach is designed to help remove market barriers, efficiently build supply, and demand, and accelerate the global hydrogen cost-competitiveness of Australia's hydrogen industry:

- Maintain an innovative, collaborative and nationally coordinated model of stimulating hydrogen industry development, building demand and enabling supply with a view to Australia being a major global hydrogen player by 2030.
- Pursue opportunities both domestic and international to scale up the industry as part of Australia's pathway to net zero emissions that generates positive environmental and economic outcomes.
- Recognise the role of governments to provide responsive regulation, establish targets and provide financial support mechanisms including through the scale of their procurement activities.
- Acknowledge that jurisdictions will progress specific actions but be transparent with regards to progress, including through the publication of an annual State of Hydrogen report. Encourage regular reviews to refine actions as technologies and markets change.

Community and engagement

- Work with industry and local communities to secure and maintain social licence for the development and continued operation of the hydrogen industry.
- Support best practice community engagement by governments and industry, including through the provision of clear and accessible information to communities about the hydrogen industry.

Existing energy markets

- Coordinate and undertake reviews, trials, and pilots as necessary, to assess the regulatory, economic, social, and safety impacts of integrating hydrogen into existing energy markets.
- Support incentives to facilitate hydrogen integration in the context of hydrogen hubs and best practice regulation.
- Engage energy market bodies to account for the possible effects of hydrogen industry growth in their planning and future reforms and ensure market mechanisms that would constrain the hydrogen industry's development are not applied while the industry is still emerging.
- Apply the adaptive approach to the consideration of these issues through periodic review.

Guarantee of origin

- Lead the design and development of an internationally aligned Guarantee of Origin certification scheme for Australia that traces the carbon intensity of low emissions products across domestic and international supply chains, starting with hydrogen and its derivatives, to create hydrogen markets and unlock trade.
- Ensure the scheme is flexible so that subsequent expansions, such as the guarantee of origin of renewable energy inputs, water consumption and green commodities, are easily accommodated.

Infrastructure

- Regularly review and take necessary action to support Australia's infrastructure needs for competitive hydrogen supply chains that emerge because of the Commonwealth led hydrogen infrastructure assessments.
- These assessments will be undertaken on a regular basis as the industry emerges to ensure priorities for future hydrogen infrastructure needs are up to date.
- Support early-stage domestic demand for hydrogen by prioritising hydrogen fuel infrastructure in the assessment, open access to government infrastructure, and consortium-based approaches to deploying refuelling infrastructure on major freight and passenger road corridors across Australia.

International collaboration

- Support the development of bilateral and multilateral agreements to demonstrate Australia's commitment and capability as a hydrogen partner of choice.
- Work to strengthen collaboration with international partners to improve hydrogen supply chain resilience and intellectual exchange, and to promote hydrogen trade and investment that meets Australia's needs and interests.

Responsive regulation

- Coordinate a comprehensive review of federal, state and territory legislation, regulation, and standards to address barriers and gaps to the development of the hydrogen industry and to assure hydrogen safety.
- Based on consideration of the review, amend existing legislation and regulations or draft new instruments to be hydrogen-ready, nationally consistent and that follow best practice.
- Seek to maximise regulatory certainty for the emerging hydrogen industry to enable a smooth transition from the provision of support to the application of appropriate mechanisms to ensure the community shares the economic benefits.

Training and workforce

- Pursue nationally consistent training materials and guidelines that cover the hydrogen supply chain to ensure a system of automatic mutual recognition across jurisdictions for hydrogen-related occupations under equivalent occupational licences or registration.
- Revise and update hydrogen safety training packages to ensure Australian emergency services are adequately trained to safely manage potential hydrogen emergencies.
- Be proactive in building Australia's net zero workforce, inclusive of hydrogen, to ensure there is sufficient capability in the country to fill future workforce needs.

Appendix 2

Summary of public support for hydrogen

Australian Government Support

ARENA

The Australian Renewable Energy Agency (ARENA) has committed over $190 million in funding to develop Australia's hydrogen industry, including:

- The announcement of ARENA co-funding to three 10 MW electrolyser projects in Australia:
  - $47.5 million to Engie Renewables towards a 10 MW electrolyser project to produce renewable hydrogen in a consortium with Yara Pilbara Fertilisers at the existing ammonia facility in Karratha, Western Australia;
  - Conditionally committed $28.7 million to ATCO Australia towards a 10 MW electrolyser for gas blending at ATCO's Clean Energy Innovation Park in Warradarge, Western Australia; and
  - Conditionally committed $32.1 million to Australia Gas Networks Limited (AGIG) for a 10 MW electrolyser for gas blending at AGIG's Murray Valley Hydrogen Park in Wodonga, Victoria.
- A number of hydrogen transport projects including the Viva Energy New Energies Service Station, Ark Energy SunHQ Renewable Hydrogen Demonstration for Heavy Transport, Toyota Hydrogen EcoPark and BOC renewable hydrogen refuelling station. Feasibility and Front End Engineering and Design work for large scale hydrogen projects including the Gibson Island Renewable Ammonia Project FEED study, Stanwell Gladstone Hydrogen Hub and the Port of Newcastle Hydrogen Hub Feasibility Study.
- $22.1 million in Research and Development funding to Australian universities and research organisations to accelerate the development of a potential renewable energy export supply chain, centred on hydrogen and related carrier materials.
- Further information on ARENA hydrogen projects can be found at: https://arena.gov.au/renewable-energy/hydrogen/

Clean Energy Finance Corporation

Additionally, the Clean Energy Finance Corporation (CEFC) has $300 million available through the Advancing Hydrogen Fund204, to provide debt or equity finance to eligible largescale commercial and industrial projects.

- In the Advancing Hydrogen Fund the CEFC has committed up to $12.5 million to help Ark Energy Corporation produce green hydrogen to power what are expected to be the world's heaviest fuel cell electric trucks.
- CEFC Clean Energy Innovation Fund - first hydrogen related investment in 2021 of $750,000 into Hysata technology), an innovative electrolyser production technology developed at the University of Wollongong. The fund's second investment of $10 million also went to Hysata technology in 2022.

For further information see the CEFC Advancing Hydrogen Fund at www.cefc.com.au/where-we-invest/special-investment-programs/advancing-hydrogen-fund

Clean Energy Regulatory – Hydrogen Method Development

The Clean Energy Regulator under the Emission Reduction Fund (ERF) is progressing the hydrogen method which will credit abatement generated from displacing high emissions fuels with hydrogen in specific circumstances, taking into account emissions from producing the hydrogen. Further details on the progress to develop this new method are listed here - https://www.cleanenergyregulator.gov.au/ERF/Pages/Method%20development%20tracker/Method-development-tracker.aspx#Hydrogen

204 Clean Energy Finance Corporation – Advancing Hydrogen Fund - www.cefc.com.au/where-we-invest/special-investment-programs/advancing-hydrogen-fund

National Reconstruction Fund

The Australian Government has committed for establishing a $15 billion dollar National Reconstruction Fund (NRF)[205]. Within this new fund, up to $3 billion will be allocated to supporting investment in new low carbon energy industries that includes hydrogen electrolysers and fuel switching, and green metals: steel, alumina and aluminium[206]. The fund would operate on similar terms to the Clean Energy Finance Corporation (CEFC). The 2022-2023 October Budget allocated $50 million over two years to establish the framework and institutional mechanisms for the NRF.[207]

Powering the Regions Fund

"The Powering the Regions" $1.9 billion fund, also announced in the October 2022-2023 Australian Government budget[208] supports the decarbonisation of existing emissions intensive industries and creation of new clean energy industries and jobs. This fund supports new jobs and long-term international competitiveness. Hydrogen projects are eligible to apply for co-funding through this fund.

Australian Government - Regional Resilience and Opportunity program – Northern Territory

In the 2022-23 Federal Budget, the Australian Government is delivering on almost $2.5 billion of election commitments for vital infrastructure projects in the Northern Territory. This includes: $1.5 billion in planned equity to support the construction of common user marine infrastructure within the Middle Arm Sustainable Development Precinct[209], providing a pathway to a decarbonised economy by helping emerging clean energy industries. Developing marine infrastructure at Middle Arm will open new export opportunities in Northern Australia for commodities such as green hydrogen and critical minerals, with associated downstream opportunities for onshore processing and low-emission manufacturing.[210]

Australian Government - Regional Resilience and Opportunity program – Western Australia

The Australian Government in the October 2022 budget committed to investing $565 million in enabling infrastructure in the Pilbara to support emerging green industries and technologies in enabling infrastructure in the Pilbara to support emerging green industries and technologies such as hydrogen[211].

205 Australian Government – Joint Media Release – Establishing a $15 Billion National Reconstruction Fund at www.minister.industry.gov.au/ministers/husic/media-releases/establishing-15-billion-national-reconstruction-fund

206 Australian Government – Media Release – National Reconstruction Fund – Diversifying and Transforming Australia's Industry and Economy at www.industry.gov.au/news/national-reconstruction-fund-diversifying-and-transforming-australias-industry-and-economy

207 Australia Industry Group – Media Release – Australia's new National Reconstruction Fund at www.aigroup.com.au/news/blogs/2022/national-reconstruction-fund/

208 Australian Government - Joint Media Release – Delivering Australia's Climate and Energy Transformation at https://minister.dcceew.gov.au/bowen/media-releases/joint-media-release-delivering-australias-climate-and-energy-transformation

209 Australian Government – Media Release – Honouring Our Commitments for Regional Australia at https://minister.infrastructure.gov.au/c-king/media-release/honouring-our-commitments-regional-australia

210 Australian Government – Media Release - $2.5 Billion Infrastructure Boost for Northern Australia https://minister.infrastructure.gov.au/c-king/media-release/25-billion-infrastructure-boost-northern-territory#:~:text=In%20the%202022%2D23%20Federal,projects%20in%20the%20Northern%20Territory.

211 https://minister.infrastructure.gov.au/c-king/media-release/honouring-our-commitments-regional-australia

Rewiring the Nation Initiative.

The Australian Government's "Rewiring the Nation" program seeks to modernise Australia's electricity grid, revitalising traditional industries like steel and aluminium and allow growth in new sectors like hydrogen and battery production. $20 billion in low-cost Government finance seeks to complement and unlock $58 billion of private co-financing. Rewiring the Nation will be implemented through a partnership with the CEFC. This initiative is designed to support the achievement of transitioning the Australian national electricity grid to reliable and dependable 82% renewable electricity capacity by 2030 in line with the Australian Governments 2030 Renewable Energy Target.

This work is critical to supporting decarbonisation of the Australian grid, to help underpin the long-term growth of net zero carbon industries such as the hydrogen industry. The Rewiring the Nation initiative and Australia's 2030 renewable electricity target represent a major public contribution to strategically positioning Australia to be a global leader in net zero emission production of clean hydrogen and derivatives this decade and beyond.

Other relevant domestic policies incentivising decarbonisation

The Renewable Energy Target (RET) provides an example of a policy that has been successful in helping to increase the uptake, and reduce the costs of renewable energy technologies.

- The RET operates through the creation of tradable certificates which establish an incentive for additional generation of electricity from renewable sources.
- Through the scheme, large renewable power stations and the owners of small-scale systems are eligible to create certificates for every megawatt hour of power they generate—creating the 'supply' side of the certificate market.
- Wholesale purchasers of electricity, mainly electricity retailers, buy these certificates to meet their renewable energy obligations—forming the 'demand' side of the certificate market, and creating a reliable revenue stream that is well understood and accepted by developers, investors and financial institutions.
- The RET has helped increase the share of renewable electricity generation in Australian from around 8 per cent in 2011 to 29 per cent in 2021.
- A scheme similar to the RET, for hydrogen, has been advocated at industry forums, to provide the certainty to drive investment in Australia.

Australian Government's Driving the Nation Program

This includes up to $80 million commitment to the Hydrogen Highways Program: a national expansion of hydrogen highways. Up to $80 million will be made available to all States and Territories on a matching basis with funding administered through ARENA's Future Fuels program.

Australian Government's Skilling the Clean Energy Workforce

This includes financial support, assistance and mentoring to 10,000 New Energy Apprenticeships as part of a broader $100 million commitment over 10 years.

Australian Government Support of Regional Hydrogen Hubs Program

Regional Hydrogen Hubs Program discussed in Chapter 2 - Hydrogen Hubs (located in Gladstone, the Hunter Valley, Bell Bay, Port Bonython, Kwinana and the Pilbara) and 8 Development & Design projects announced for funding across regions of Australia ($454 million total). An additional Hydrogen Hub in Townsville, Queensland still to be determined (up to $72 million committed as part of the 2022-23 October Budget).

Funding Research - Australian Research Council (ARC) grants and Commonwealth Research Centres

The ARC's purpose is to grow knowledge and innovation for the benefit of the Australian community through funding the highest quality research, assessing the quality, engagement and impact of research, and providing advice on research matters. The ARC has committed $52 million in clean hydrogen related research and development. The Australian Government also co-funds, Cooperative Research Centres (CRC), four of which fund, as part of their missions, some hydrogen research namely, the Future Energy Exports CRC, the Future Fuels CRC, the Heavy Industry Low-carbon Transition CRC, and the Blue Economy CRC.

For a complete list of all of the Australian Government's funding of hydrogen industry development see HyResource's funding web page[212]at https://research.csiro.au/hyresource/funding.

Australian State and Territory Government Hydrogen Strategies, Plans and Support

Significant Government support for clean hydrogen industry development exists at the State and Territory Government level in Australia. In BOX 5, NSW Government's incentives and how they lower the production cost of hydrogen are featured as an example. Table 11 summarises the strategies, plans and support from the Australian State and Territory's Governments.

212 HyResource (2023) – Commonwealth, State and Territory Government hydrogen industry development related funding page. https://research.csiro.au/hyresource/funding/

BOX 5: NSW Government Clean Hydrogen Economic Incentives

The New South Wales Hydrogen Strategy, released in October 2021, provides more than $3 billion in economic incentives to attract $80 billion in new hydrogen infrastructure investment, including:

- Up to $150 million in grant funding under the New South Wales Hydrogen Hubs Initiative to support the development of hydrogen hubs in the Hunter and Illawarra regions.
- Support for the development of hydrogen refuelling infrastructure along major interstate highways, including $10 million (matching $10 million from the Victorian Government) for the Hume Hydrogen Highway initiative.
- $78 million in funding support for the Tallawarra B power plant to use 200,000 kg of green hydrogen per year from 2025.
- Waiving government charges on hydrogen production and providing a 90% concession to network use of system charges for electrolysers that connect to parts of the of the electricity grid with spare capacity. Combined, the electricity scheme exemptions and network concession are estimated to reduce the cost of producing hydrogen by $2.13 per kg.
- Extending the Energy Security Safeguard to provide financial incentives for green hydrogen, with targets gradually increasing to 67,000 tonnes by 2030.
- Setting a target for the New South Wales Government heavy vehicle fleet to comprise 20 per cent hydrogen vehicles by 2030.
- In total, NSW economic incentives listed in the NSW Hydrogen Strategy and in Figure 21 below, are forecast to lower the cost of clean hydrogen production by an estimated $5.80 per kg to reach NSW Government's stretch target of under $AU2.80 per kg by 2030. Further cost reductions can also be achieved through technology innovations and the falling cost of renewable energy to put NSW within reach of $2 per kg by the end of the decade.

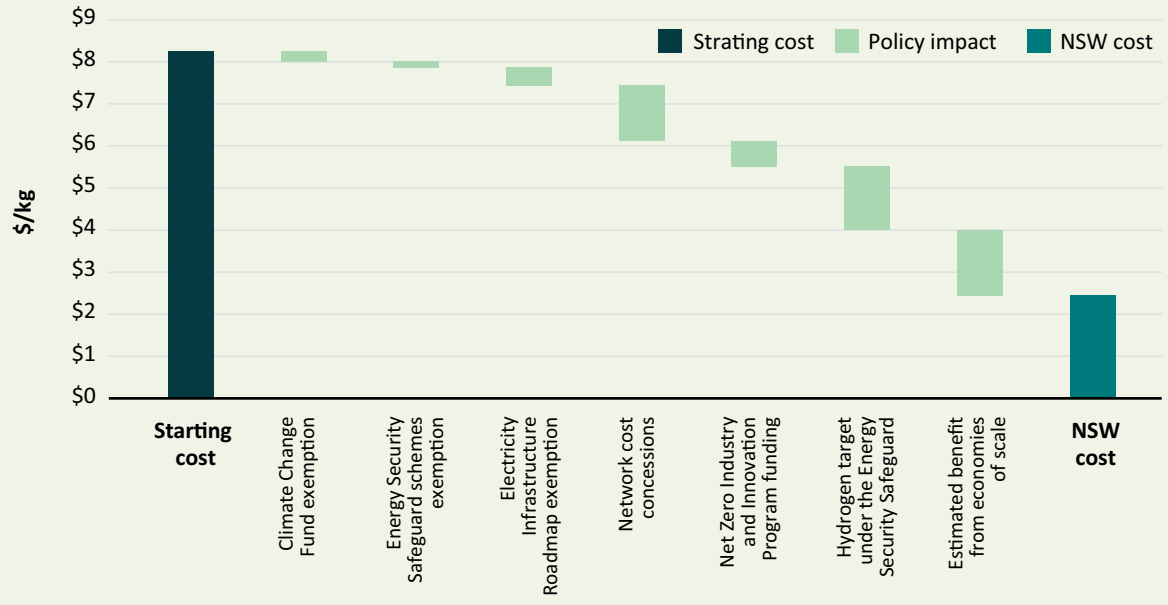


Figure 21: NSW Hydrogen Strategy impact on levelised cost of hydrogen. (Source. NSW Hydrogen Strategy[213])

213 NSW Government - NSW Hydrogen Strategy at https://www.energy.nsw.gov.au/sites/default/files/2022-08/2021_10_NSW_HydrogenStrategy.pdf

Australian State and Territory Government Hydrogen Strategies and/or Plans

Table 11: Summary of Australian state and territory hydrogen strategies, plans and support.

State	Key Strategy	Targets	Key Funding Initiatives	Key Projects	Related Strategies/Programs /Reports
ACT	ACT Transition to Zero Emissions Vehicles Action Plan 2018-21	Goal accelerates the transition to battery-electric and fuel cell vehicles, including shifting to a zero-emissions Government passenger vehicle fleet from 2020.	$12 million Renewable Energy Innovation Fund	• ActewAGL Hydrogen Refuelling Station • Hydrogen Test Facility - ACT Gas Network	ACT Climate Change Strategy 2019-25.
NSW	NSW Hydrogen Strategy (2021)	2030 Stretch Targets: • 110,000 tonnes per annum green hydrogen production • Price target: Under $2.80 per kg • 700 MW electrolyser capacity • 10,000 hydrogen vehicles • 100 refuelling stations • 10 per cent gas network blending	• $3 billion committed to hydrogen incentives through Strategy (includes discounts on network charges and incentives under the Renewable Fuel Scheme - Australia's first legislated hydrogen production target and certificate scheme) • $1.05 billion of hydrogen eligible funding under the Net Zero Industry and Innovation Program • Up to $150 million for hydrogen hubs in the Hunter and Illawarra. • $10 million Hume Highway Initiative (tri-state MoU between NSW, Victoria, and Queensland to build an East Coast Renewable Hydrogen Refuelling Network)	• Port of Newcastle Hydrogen Hub • Hunter Valley Hydrogen Hub (Origin Energy) • Port Kembla Hydrogen Refuelling facility • Tallawarra B Dual Fuel Capable Gas/ Hydrogen Power Plant • Western Sydney Green Gas project • NSW Government Hydrogen Hubs program. 10 shortlisted projects are being assessed and are in the Hunter, Illawarra, and regional NSW	• Net Zero Plan Stage 1: 2020-2030 (2020) • Renewable Fuel Scheme (2022)
NT	Northern Territory Renewable Hydrogen Master Plan (2021)	local industry development, resource management, grow and harness demand, support innovation, and responsive regulation	• $5 million to support the Renewable Hydrogen Master Plan to accelerate and expand the Territory's hydrogen industry • $1 million Remote hydrogen program under the $2 million Renewable Remote Power Program • MoU between the Northern Territory Government and international renewable energy company, Total Eren, to develop a new green hydrogen project in Darwin.	• Desert Bloom Hydrogen Project • Tiwi H2 Project • Darwin H2 Hub • Green Springs Project	Northern Territory Renewable Hydrogen Strategy (superseded by Masterplan)

State	Key Strategy	Targets	Key Funding Initiatives	Key Projects	Related Strategies/Programs /Reports
QLD	Queensland Hydrogen Industry Strategy 2019 -2024 (2019)	2030 vision: • Queensland is at the forefront of renewable hydrogen production in Australia, supplying an established domestic market and export partners with a safe, sustainable, and reliable supply of hydrogen.	• $4.5 billion Queensland Renewable Energy and Hydrogen Jobs Fund • $53.6 million to renewable energy and hydrogen industry training and skills development • $35 million Queensland Hydrogen Industry Development Fund • Queensland Energy and Jobs Plan (2022), including: – Top of up to $4.5 billion of the Queensland Renewable Energy and Hydrogen Jobs Fund (noted above) – $20 million to plan for hydrogen hubs and to build community awareness – Invest in a 200MW hydrogen-ready gas peaking facility – Review of the Queensland Hydrogen Strategy • Tri-state MoU between NSW, Victoria, and Queensland to build an East Coast Renewable Hydrogen Refuelling Network). • Signed an MoU with the Port of Rotterdam to collaborate on opportunities to develop a hydrogen export supply chain.	• Stanwell Consortium Central Queensland Hydrogen Project (CQ-H2) • H2-Hub Gladstone • Green Energy Manufacturing Centre • Gibson Island Green Ammonia Project • Kogan Renewable Hydrogen Demonstration Plant • SunHQ Hydrogen Hub • For further information on publicly announced projects in Queensland please see the interactive mapper.	• Queensland Hydrogen Industry Workforce Development Roadmap (2022) • Queensland Energy and Jobs plan (2022) • Enabling Queensland's Hydrogen production and export opportunities report (2022)

State	Key Strategy	Targets	Key Funding Initiatives	Key Projects	Related Strategies/Programs /Reports
SA	South Australia's Hydrogen Action Plan (2019)	Objective of scaling up renewable hydrogen production for export and domestic consumption and enabling South Australia to become a world-class renewable hydrogen supplier Under the Hydrogen Jobs Plan (2022): • 250MW of electrolysers • 200MW Power Station for generation from hydrogen • Hydrogen storage of 3,600 tonnes of hydrogen	• $593 million through Hydrogen Jobs Fund for a hydrogen power station, electrolyser, and storage facility. • $37 million upgrade of the Port Bonython jetty in preparation for a hydrogen hub. • $30 million for Port Bonython Hydrogen Hub • $18.1 million under the Renewable Technology Fund towards hydrogen projects • Signed a MoU with the Port of Rotterdam to collaborate on opportunities to develop a hydrogen export supply chain.	**Operating** • AGIG HypSA **Advanced development** • H2U EP Gateway Phase 1 at Cultana • Trafigura Port Pirie Green Hydrogen • Marubeni's metal hydride demonstration project at Bolivar • SA Gov't Hydrogen Power Plant **Under development** • AMP Port Bonython • FFI Port Bonython • Santos Port Bonython • Origin Port Bonython • Neoen/Eneos Eyre Peninsula • Neoen/Chiyoda/Mitsubishi Eyre Peninsula • H2U EP Gateway Phase 2 at Port Bonython • AGL Clean Energy Hub Port Adelaide **Concept Phase** • Cape Hardy **Completed studies** • Neoen Crystal Brook **AGIG Australian Hydrogen Centre H2 in gas network study**	• Hydrogen Jobs Plan (2022)
TAS	Tasmanian Renewable Hydrogen Action Plan (2020)	• Commence renewable hydrogen export by 2025-27 • Tasmania to be a significant global producer and exporter of hydrogen by 2030.	• $70 million for the Tasmanian Green Hydrogen Hub • $50 million under the Tasmanian Renewable Hydrogen Industry Development fund, including: – $20 million for projects – $20 million in concessional loans – $10 million in support services • Signed an MoU with the Port of Rotterdam to collaborate on opportunities to develop a hydrogen export supply chain.	• ABEL Energy Bell Bay Powerfuels Project • Tasmanian Green Hydrogen Hub Project (Bell Bay) • Fortescue Green Hydrogen and Ammonia plant • Origin Green Hydrogen and ammonia plant • H2TAS Green Hydrogen and ammonia Plant (Woodside) • LINE Hydrogen George Town Project (October Budget) • Whaleback Energy Park Feasibility study (October Budget)	

State	Key Strategy	Targets	Key Funding Initiatives	Key Projects	Related Strategies/Programs /Reports
VIC	Victorian Renewable Hydrogen Industry Development Plan (2021)	Goal to stimulate investment, employment, innovation, and economic growth, as well as supporting Victoria's clean energy transition.	• AU$2 billion hydrogen eligible funding through the Breakthrough Victoria fund • $52.1 million hydrogen eligible funding under the Energy Innovation Fund (EIF) • $50 million co-investment with the Commonwealth towards the Hydrogen Energy Supply Chain (HESC) project • $10 million Hume Highway Initiative (tri-state MoU between NSW, Victoria, and Queensland to build an East Coast Renewable Hydrogen Refuelling Network) • $10 million Victorian Hydrogen Hub (VH2) • $6.6 million Renewable Hydrogen Commercialisation Pathways Fund • $608,665 Renewable Hydrogen Business Ready Fund	• Australian Hydrogen Centre • Geelong New Energies Service Station project • Hycel Technology Hub - Deakin University • Hydrogen Energy Supply Chain (HESC) project • Hydrogen Park Murray Valley • Toyota Ecopark Hydrogen Demonstration (Toyota Hydrogen Centre)	• $100 million Zero Emissions Vehicle Roadmap (2021) • Gas substitution roadmap (2022)
WA	Western Australian Renewable Hydrogen Strategy and Roadmap (2019)	2030 goals: • WA's market share in global hydrogen exports is like its share in LNG today. • WA's gas pipelines and networks contain up to 10 per cent renewable hydrogen blend. • Renewable hydrogen is used in mining haulage vehicles. • Renewable hydrogen is a large fuel source for transportation in regional WA.	The WA Government has spent a total of $170 million supporting development of the hydrogen industry. This includes all of part of the contributions to the following: • $70 million for the Pilbara Hydrogen Hub • $10 million Hydrogen Fuel Transport Program • $54.5 million for Mid West Hydrogen Hub • $15 million Renewable Hydrogen Fund • $11.5 million to kick-start development of a Mid-west hydrogen hub at the Oakajee Strategic Industrial Area • Signed a MoU with the Port of Rotterdam to collaborate on opportunities to develop a hydrogen export supply chain.	There are more than 30 large scale hydrogen proposals in Western Australia, demonstrating the State is an ideal location and partner for international investment. • Asian Renewable Energy Hub • BP Australia's H2Kwinana Hydrogen Hub • Clean Energy Innovation Park • Denham Hydrogen Demonstration Plant • WA Government's Pilbara Hydrogen Hub • Western Green Energy Hub • Yuri Renewable Hydrogen to Ammonia project	• Western Australia Renewable Hydrogen Investment Prospectus (2022) • Renewable Hydrogen Target being consulted on

Appendix 3

Hydrogen targets worldwide

Table 12: International examples of national hydrogen demand targets.

Country	Aspirational H2 goals / demand	Specific actions & policy mechanisms
European Union	**2030** - 10 million tonnes of green hydrogen imports by 2030	European Commission in 2022 doubled the previous EU renewable hydrogen target to 10 million tonnes of annual domestic production and an additional 10 million tonnes of annual hydrogen imports by 2030.
United Kingdom	**2030** - Doubled their 2030 target to 10 GW clean hydrogen production.	UK aims also to have up to 1GW of electrolytic hydrogen and up to 1GW of carbon capture, usage, and storage (CCUS)-enabled hydrogen operational or in construction by 2025
Japan	**2030** - Japan is targeting to expand ammonia fuel use to 3 million tonnes/year by 2030.	Japan is targeting to expand ammonia fuel use to 3 million tonnes/year by 2030 through establishing co-firing technology at coal-fired power plants and developing a market and supply chain for the alternative fuel, as part of efforts to achieve the country's 2050 decarbonisation goal.
Republic of Korea	**2030** - At least 50 per cent of all coal fired power stations to be green ammonia cocombustion by 2030. Establish World's Best Hydrogen Utilization System • Mobility (cars, trucks, trains, ships, drones, utility etc) • Power (distributed energy production with fuel cells and turbines) Expansion of Stable and Universal Hydrogen Supply System • Production – By-product hydrogen – Hydrogen extraction – Electrolysers running with surplus renewable electricity • Storage and transport – advancement of hydrogen storage methods – Efficient hydrogen transportation system	South Korea's Ministry of Trade, Industry and Energy (MOTIE) announced ammonia coal cocombustion will be operational in over half the country's coal-fired power generating units by 2030. 2018 - 2.6 trillion KRW (22 billion USD) for public/private Hydrogen vehicle industry **Targets by 2040:** • 6.2 million HFCV– 2.9 million domestic market and 3.3 million for export. • 15 GW Utility scale fuel cells – 7 GW for export • 2.1 GW stationary building scale fuel cells Short - medium term: stimulate demand through procurement and subsidies of Korean built HFCV. Replace: • 80,000 taxis • 40,000 busses • 30,000 trucks • Subsidise cost of domestic HFCV to almost 50 per cent • Decreased taxes and road tolls • Subsidise cost of installing and operating refuelling stations **Electricity generation** **Renewable Portfolio Standard policy** • Large energy generators must include renewables, and this includes fuel cells (to 10 per cent by 2022) • under scheme, Fuel Cells are valued double compared to other renewables such as offshore wind

Country	Aspirational H2 goals / demand	Specific actions & policy mechanisms
Netherlands	**2022-2025** • Demonstrate: 500 MW installed electrolyser • Develop hydrogen demand **2026 – 2030** • Scale: 3 – 4 GW installed electrolyser capacity • Connectivity: producers, consumers & large-scale salt cavern storage	• Constructing large scale green ammonia import terminal • 2030, 6 billion Euros: Dutch Hydrogen backbone (100 per cent hydrogen, high-capacity gas network) **Demand:** short term mandate to use hydrogen in manufacture of transport fuels: • 2 PJ in 2023 and 4 PJ in 2024 – stimulating demand for 400 MW renewable hydrogen by 2025 (of the 500 MW target) • 14 per cent blended green aviation fuel by 2030 and 100 per cent by 2050 Increased fuel prices to be subsidised up to 210 million Euros through the SDE++ fund (SDE++ is a 30 billion Euro EU funding source available to the Netherlands) • procurement program by 2025 – 15,000 fuel cell vehicles – 3,000 heavy-duty vehicles – 50 fuelling stations • procurement program by 2030 – 300,000 fuel cell vehicles **Trials:** • Pilot projects convert suburbs to use hydrogen in their reticulated gas network 2020 -2025 (40 homes currently connected to 100 per cent locally produced hydrogen)
Chile	**2025 –** 5 GW electrolyser capacity installed or in development **2028 –** US$1.5 / kg H_2 **2030 –** 25 GW electrolyser capacity	**Targeted domestic markets** **Now to 2028** • Replace imported ammonia with local production using green hydrogen • Replace grey hydrogen with green in refineries • Target long distance and heavy transport **By 2030** • Mining trucks • Medium trucks • Domestic. gas blending (20 per cent) • Export ammonia **Out to 2033** • Hydrogen export • Domestic shipping
India	**2030** - 5 MT green H_2 per annum	Mandatory quotas for green H_2 have been introduced: **2023/2024** • Refineries must supplement 10 per cent and fertiliser manufacturers must supplement 5 per cent total H_2 used with green **2030** • Quota increase to 25 per cent for refineries
Canada		**2020-2030 –** increase FCEV stock from 130 to 50,000 • Clean Fuel standards – reduce emissions intensity of fuels (anticipated to increase demand for H_2)

Appendix 4

Global regulatory reform leaders

South Korea - South Korea passed the *Hydrogen Economy Promotion And Hydrogen Safety Management Act* on 4 February 2020. This is a comprehensive Act, and provides the government with a broad range of powers for the purposes of establishing a hydrogen driven economy. These powers include

- The government is granted explicit powers to regulate:
  - The manufacture or modification, import and of hydrogen equipment.
  - Hydrogen refuelling stations and hydrogen powered transport.
  - Hydrogen safety.

Japan - The Japanese hydrogen industry is regulated through one of several Acts, depending on the use of the hydrogen. Specifically:

- Gas business Act - regulates hydrogen gas, among other gases / gas blends, when supplied via pipelines to meet general demand. This regulation captures includes:
  - coordinating the operation of Gas Businesses
  - ensure public safety and prevent pollution by regulating the construction, maintenance, and operation of Gas Facilities
  - manufacture and sale of Gas Equipment.
- Electricity Business Act – regulates hydrogen when used in electricity production.
- High Pressure Gas Safety Act – regulates hydrogen, and other high-pressure gases, with respect to:
  - production,
  - storage,
  - sale,
  - transportation
  - any other matters related to the handling, consumption, manufacture, and handling of high-pressure gas containers.

The High-Pressure Gas Safety Act, was amended in August and November 2020, to reduce regulation and encourage the development of hydrogen refuelling stations, including:

- Not requiring a person with a supervisor's licence for high-pressure gas production to be appointed responsible for supervising the safe production of high-pressure hydrogen, and
- Enable the operation of hydrogen stations by remote monitoring.

France -The Law-Decree No 2021-167 of 17 February 2021 made some significant changes to the legal framework relating to hydrogen including:

- Definitions of the different types of hydrogen.
- Self-consumption of hydrogen: hydrogen produced and consumed on the same site by one or more producers and one or more consumers who are linked together within a single legal entity, possibly with a storage period.
- The mechanisms of guarantees and traceability to produce renewable and low-carbon hydrogen.
  - The system of guarantees of origin is inspired by the existing mechanisms for electricity from renewable energy sources and biogas. A guarantee of origin is issued for each megawatt-hour produced.
  - A traceability guarantee proves one megawatt-hour of hydrogen with a low-carbon or renewable character, not mixed with another type of hydrogen or gas, has been physically delivered to the buyer or final consumer. A traceability guarantee cannot be sold independently from the corresponding hydrogen.
  - Guarantees of origin of renewable and low-carbon hydrogen from other Member States may be assimilated to French guarantees of origin provided they meet a similar level of requirements. These special provisions for guarantees of origin from other Member States have been applicable since 30 June 2021.

- The public support mechanism for green/low-carbon hydrogen production.
- Hydrogen injection into natural gas networks. The Law-Decree amended articles L. 431-6-4 and L. 432-14 of the Energy Code to extend the obligations of natural gas network operators regarding hydrogen transportation. In this respect, the operators will have to ensure the safety conditions of goods and people, in addition to the proper functioning and balancing of the networks.
- The implementing regulations of the Law-Decree should be published during the course of 2021 to set out the details of this new legal regime.

Additionally, the Mobility Orientation Law of 24 December 2019 provides a framework for refuelling stations for private vehicles, buses, and ships as part of a broader law looking at sustainable alternatives in the mobility sector (hybrids, other alternative fuels and traditional electric vehicles are also covered).

Germany

On 24 July 2021 the German Parliament passed an amendment to the Energy Act which contains new provisions for the regulation of hydrogen networks. The purpose of the amendment to the Energy Act is to gradually build up a hydrogen infrastructure in Germany. These amendments to the Energy Act provide for the following framework conditions:

- Hydrogen is categorised as an independent energy carrier alongside gas. However, this only applies to pure hydrogen pipelines. For the blending of hydrogen into the natural gas network, the existing legal framework continues to apply.
- Definitions of hydrogen networks and hydrogen storage facilities.
- Operators of existing networks and newly constructed networks have a unique and irrevocable right to choose whether they want to be subject to the newly introduced regulation of hydrogen networks or not. Those who choose not to be regulated will not be covered by the requirements regarding network access, tariffs, and unbundling.
- Network operators are required to grant access and connection to their hydrogen networks based on the principle of negotiated network access rather than the standardised natural gas network access contracts.
- Cost-based tariff largely in line with the current legal situation. The conditions and tariffs must be reasonable, non-discriminatory, and transparent.
- Operators of hydrogen networks must carry out separate accounting and bookkeeping for their networks (unbundling of accounts).
- Hydrogen network operators may not construct, operate, or own facilities for the production, storage, or distribution of hydrogen.
- The transfer and continued application of rights of way and easements for gas pipelines also apply to the operation of these pipelines with hydrogen. This is intended to facilitate the transition from gas pipelines to hydrogen.
- Transmission system operators can identify pipelines that could be converted to hydrogen in the framework of the Gas Network Development Plan.

An independent Network Development Plan is to be drawn up for the hydrogen networks. The target year for this is 2035. This rejects the idea of joint network planning with the natural gas network.

Appendix 5

Sample of hydrogen reports of 2022

Table 13: Hydrogen reports related to Australia released on 2022.

Report Title	Report Focus
HySupply: Supply-side Road mapping Exercise	A supply-side investigation for Australia to aid the profiling of the scale and breadth of government and private action required for Australia to build an export value chain for hydrogen/hydrogen derivatives to Germany.
Enabling Queensland's hydrogen production and export opportunities	A state-wide study to better understand Queensland's hydrogen export capacity and the ability for different regions to support a new hydrogen industry. The study also aimed to identify key steps that government needs to take to enable the development of the new industry.
South Australia – Port of Rotterdam: Hydrogen Supply Chain	A pre-feasibility study that shows South Australian hydrogen is expected to be competitive on the future hydrogen market in Rotterdam and could supply up to 10 per cent of Rotterdam's hydrogen requirements in 2050. Rotterdam's hydrogen demand is forecast to reach 18 million tonnes per annum by 2050.
Hydrogen Industry Workforce Development Roadmap 2022-2032	A dedicated workforce development plan aimed at creating a skilled, hydrogen-ready workforce that will support Queensland's exciting and fast-growing hydrogen sector.
Tasmanian Renewable Hydrogen Industry Development fund learnings	The three feasibility studies funded through the $50M Tasmanian Renewable Hydrogen Industry Development Fund (TRHIDF) and knowledge sharing reports from Origin and ABEL Energy
Developing Australia's hydrogen workforce - PWC	Drawing on substantial consultation and research, this report builds an understanding of the workforce needed to support a safe and effective hydrogen economy in Australia in 2030 across six key supply chain areas.
ARENA Knowledge Sharing reports	ARENA's Knowledge Bank is an open-source library of reports, studies, multimedia, and tools that provide guidance and learnings to benefit future renewable energy projects. Samples of ARENA co-funded knowledge sharing reports are listed below.
Port Kembla Steelworks Renewables & Emissions Reduction Study Lessons Learnt 1	This report shares initial lessons learned about procuring biochar in Australia – September 2022
Feasibility study for Wodonga **Feasibility study for Port Adelaide** **Feasibility study for Ballarat**	The Australian Hydrogen Centre commissioned several studies which provide a detailed perspective on the potential role that renewables-based hydrogen could play to help decarbonise regional areas – August 2022
BOC Renewable Hydrogen Production and Refuelling Lessons	This report identifies three key learnings as the project neared the commissioning stage – February 2022
Western Australian Renewable Hydrogen Fund Knowledge Sharing reports.	Public knowledge sharing reports for completed feasibility studies and capital works projects that received grants from the Western Australian Renewable Hydrogen Fund can be found at a dedicated website: Public knowledge sharing reports: WA Renewable Hydrogen Fund (www.wa.gov.au)
City of Cockburn – Green Hydrogen Feasibility Public Knowledge Report.	This report details the methodology and outcomes for the design for an on-site greenfield solar field and green hydrogen plant—which also makes use of existing landfill gas power—for the refuelling of heavy vehicles – April 2022
Dampier to Bunbury Natural Gas Pipeline (DBNGP)	This report was designed to identify a practical pathway to enable hydrogen to be blended into the DBNGP; the study identifies a clear pathway for declaring a pipeline section as suitable for use with hydrogen/natural gas blends – January 2022

Appendix 6

Australia's hydrogen project pipeline (HyResource project database)

Data sourced from the HyResource Industry Projects database (current as of December 2022). Some metrics are missing for some projects as this information has not been publicly reported on in the HyResource database.

NOTE: Two projects listed in Table 1 are not found in the HyResource database and are therefore marked with an * in Table 1. Relevant links to information on these two projects has been included for reference.

HyResource project status definitions:

- **Operating:** the facilities are operated, maintained and modified within regulatory requirements.
- **Under Construction:** a positive FID is made to proceed, remaining detailed engineering is completed, physical construction of facilities begins followed by commissioning of the constructed facilities. Once completed and any regulatory approvals are received, the facilities can move into operations.
- **Advanced development:** the development option is sufficiently defined across all key project parameters (technical, financial, permitting, resourcing, contracting & procurement) for an FID to be made. In this period, it is not uncommon that schedule critical long-lead items may have been ordered.
- **Under development:** covers a range of 'stages' under one definition - projects in concept stage, undertaking initial feasibility studies or initiating FEED studies.

Table 14: Australia's active hydrogen project pipeline. Data current as of December 2022.

	Project Name	State/ Territory	Status (Active Projects)	Estimated Project Cost: Investment Data ($AU)	Anticipated Hydrogen Production Capacity [t/year]	New projects added To Australia's Hydrogen Pipeline (since April 2021)	GW scale projects added To Australia's Hydrogen Pipeline (since April 2021)	Ammonia Export Projects
1	ABEL Energy Bell Bay Powerfuels Project	TAS	Under development		21900			
2	ActewAGL Hydrogen Refuelling Station	ACT	Operating		7.665			
3	APA Renewable Methane Demonstration Project	QLD	Under construction	$ 2,260,000	0.34			
4	Arrowsmith Hydrogen Project - Stage 1	WA	Under development		9125			
5	ATCO Hydrogen Blending Project	WA	Operating	$ 2,600,000		•		
6	Australian Hydrogen Centre	SA/VIC	Under development	$ 4,150,000				
7	Australian Renewable Energy Hub	WA	Under development		1600000			•
8	Bio-Hydrogen Demonstration Plant	QLD	Under development	$ 7,000,000				
9	*Blue Economy CRC offshore hydrogen microgrid project (project listed on HyResearch)	TAS	Under construction			•		
10	Bristol Springs Solar Hydrogen Project	WA	Under development		4500	•		
11	*Cape Hardy Green Hydrogen Hub (not listed on HyResource)	SA	Under development			•	•	
12	Central Queensland Hydrogen Project	QLD	Under development	$ 10,400,000	292000		•	
13	Christmas Creek Renewable Hydrogen Mobility Project	WA	Under construction	$ 32,000,000	65.7			
14	Clean Energy Innovation Hub (CEIH)	WA	Operating	$ 3,530,000	23			
15	Clean Energy Innovation Park (CEIP)	WA	Advanced development	$ 46,000,000	1460			
16	Collie Battery and Hydrogen Industrial Hub Project	WA	Under development			•		
17	Daintree Microgrid Project	QLD	Under development					
18	Darwin H2 Hub	NT	Under development		80000	•		
19	Denham Hydrogen Plant - Operating	WA	Under construction	$ 9,300,000	13			
20	Desert Bloom Hydrogen	NT	Under development	$ 14,333,333,333	410000	•	•	
21	Development of Altona Renewable Hydrogen Plant	VIC	Under development	$ 5,784,000	130	•		
22	Early Production System: MEG-HP1	WA	Under development		1606	•		
23	Edify Green Hydrogen Project	QLD	Under development		150000	•	•	
24	Emerald Coaches Green Hydrogen Mobility Project	QLD	Under development	$ 100,000,000		•		
25	Energys Renewable Hydrogen Production Facility	VIC	Under development	$ 3,350,000		•		
26	Eyre Peninsula Gateway Project - Demonstrator Stage	SA	Under development	$ 240,000,000	10000			•

	Project Name	State/ Territory	Status (Active Projects)	Estimated Project Cost: Investment Data ($AU)	Anticipated Hydrogen Production Capacity [t/year]	New projects added To Australia's Hydrogen Pipeline (since April 2021)	GW scale projects added To Australia's Hydrogen Pipeline (since April 2021)	Ammonia Export Projects
27	Feasibility of Renewable Hydrogen to Decarbonise the Esperance Region in WA	WA	Under development			•		
28	Fortescue Green Hydrogen and Ammonia Plant	TAS	Under development					•
29	Future Energy and Hydrogen Precinct	QLD	Under development			•		
30	Geelong Hydrogen Hub	VIC	Under development			•		•
31	Geelong New Energies Service Station Project	VIC	Under construction	$ 43,300,000	365	•		
32	Geraldton Export-Scale Renewables Investment	WA	Under development	$ 4,420,000	4000			•
33	Gibson Island Green Ammonia Feasibility	QLD	Under development	$ 38,000,000	70000	•		•
34	Goondiwindi Hydrogen	QLD	Under development	$ 15,000,000	1350	•		
35	Great Southern Project	TAS	Under development		5438.5	•		
36	Green Liquid Hydrogen Export Project	QLD	Under development					
37	Green Methanol Feasibility Study	QLD	Under development	$ 150,000,000		•		
38	Green Springs Project	NT	Under development	$ 9,300,000,000		•	•	•
39	H2-Hub Gladstone	QLD	Under development					•
40	H2Kwinana	WA	Under development	$ 252,000,000		•		
41	H2Perth	WA	Under development	$ 1,000,000,000	109500	•		•
42	H2TAS Project	TAS	Under development					•
43	Hay Point Hydrogen Export	QLD	Under development			•		
44	Hazer Commercial Demonstration Plant	WA	Operating	$ 24,000,000	100			
45	HIF Carbon Neutral eFuels Manufacturing Facility	TAS	Under development			•		
46	Hunter Energy Hub	NSW	Under development			•	•	
47	Hunter Hydrogen Hub	NSW	Under development			•		
48	Hunter Valley Hydrogen Hub	NSW	Under development	$ 200,000,000		•		
49	Hybrid PV-Battery-Hydrogen System for Microgrids	WA	Under development					
50	Hydrogen Bell Bay	TAS	Under development		1642.5	•		
51	Hydrogen Brighton Project	TAS	Under development	$ 60,000,000	800	•		
52	Hydrogen Energy Supply Chain – Feasibility Study Phase	VIC	Under development			•		
53	Hydrogen Fuels Australia Truganina HRS	VIC	Under construction		32.85	•		

	Project Name	State/ Territory	Status (Active Projects)	Estimated Project Cost: Investment Data ($AU)	Anticipated Hydrogen Production Capacity [t/year]	New projects added To Australia's Hydrogen Pipeline (since April 2021)	GW scale projects added To Australia's Hydrogen Pipeline (since April 2021)	Ammonia Export Projects
54	Hydrogen Hubs Powering Remote Communities (H2H)	QLD	Under development			•		
55	Hydrogen Mobility Project	QLD	Under development			•		
56	Hydrogen Park Gladstone	QLD	Under development	$ 4,200,000	23.725			
57	Hydrogen Park Murray Valley	VIC	Advanced development	$ 44,000,000				
58	Hydrogen Park South Australia	SA	Operating	$ 14,500,000	175			
59	Hydrogen Portland Project	VIC	Under development		1600			
60	Hydrogen Powered Trains Feasibility Study	QLD	Under development			•		
61	Hydrogen Refueller H2Perth	WA	Under development		85.775	•		
62	Hydrogen Refueller Station Project	WA	Operating					
63	Hydrogen Test Facility - ACT Gas Network	ACT	Operating	$ 600,000				
64	HyEnergy Project	WA	Under development		550000	•	•	
65	Joint Feasibility Study for Creation of a Supply Chain of Low Carbon Ammonia in Western Australia	WA	Under development			•		•
66	Kogan Creek Hydrogen-Ready Gas Peaking Power Station	QLD	Under development			•		
67	Kogan Creek Renewable Hydrogen Demonstration Plant	QLD	Under construction		75	•		
68	Lattice Technology International Joint Development Project	NT	Under development		42000	•		
69	Manilla Solar Phase 2 Hydrogen Energy Storage System	NSW	Under development	$ 7,300,000				
70	Manufacturing and Commercialisation of Hydrogen Buses	VIC	Under development	$ 4,000,000				
71	Melbourne Hydrogen Hub	VIC	Under development		1642.5	•		
72	Methanol Synthesis Utilising Renewable Hydrogen	VIC	Under development	$ 154,451		•		
73	Mid West Clean Energy Project	WA	Under development		40000	•		•
74	Murchison Hydrogen Renewables Project	WA	Under development				•	•
75	Neoen-ENEOS Export Project	SA	Under development			•		
76	Origin Green Hydrogen and ammonia Plant	TAS	Under development	$ 9,200,000				•
77	Parmelia Green Hydrogen Project	WA	Under development			•		
78	Port Bonython Hydrogen Hub	SA	Under development			•		
79	Port Kembla Hydrogen Hub	NSW	Under development					
80	Port Kembla Hydrogen Refuelling Facility	NSW	Under construction			•		

	Project Name	State/ Territory	Status (Active Projects)	Estimated Project Cost: Investment Data ($AU)	Anticipated Hydrogen Production Capacity [t/year]	New projects added To Australia's Hydrogen Pipeline (since April 2021)	GW scale projects added To Australia's Hydrogen Pipeline (since April 2021)	Ammonia Export Projects
81	Port of Newcastle Hydrogen Hub	NSW	Under development	$ 163,000,000		•		
82	Port Pirie Green Hydrogen Project	SA	Under development	$ 755,000,000	36500	•		•
83	Project Haber	WA	Under development		1825	•		
84	Queensland Nitrates Renewable Hydrogen and Ammonia Project	QLD	Under development	$ 3,800,000	3500			
85	Queensland Solar Hydrogen Facility	QLD	Under development		200000			
86	Renewable Hydrogen Hydro-Gen 1	VIC	Under development	$ 32,000,000	700	•		
87	Renewable Hydrogen Production and Refuelling Project	QLD	Under construction	$ 5,540,000	28.8			
88	Rio Tinto Pacific Operations Hydrogen Program	QLD	Under development	$ 1,160,000		•		
89	Sealink Hydrogen Ferry	QLD	Under development	$ 20,600,000		•		
90	Sir Samuel Griffith Centre	QLD	Operating		23.652			
91	South Australian Government Hydrogen Facility	SA	Under development	$ 593,000,000		•		
92	Spicers Retreats Scenic Rim Trial Ecotourism Demonstration	QLD	Under development					
93	Sumitomo Green Hydrogen Production Plant	QLD	Advanced development		300	•		
94	SunHQ Hydrogen Hub	QLD	Under construction	$ 12,970,000	140			
95	Swinburne University of Technology Victorian Hydrogen Hub - CSIRO Hydrogen Refuelling Station	VIC	Under construction	$ 2,300,000	7.3	•		
96	Tallawarra B Dual Fuel Capable Gas/Hydrogen Power Plant	NSW	Under construction		200	•		
97	The Julia Creek Project	QLD	Under development			•		
98	Tiwi H2	NT	Under development		100000	•		
99	Torrens Island Green Hydrogen Hub	SA	Under development			•		
100	Toyota Ecopark Hydrogen Demonstration (Toyota Hydrogen Centre)	VIC	Operating	$ 7,370,000	29.2			
101	Transdev Mobility Trial	QLD	Under development	$ 3,000,000		•		
102	Utilitas-Recarbon Organic Waste to Green Hydrogen Technology	QLD	Under development					
103	Western Green Energy Hub	WA	Under development	$ 100,000,000,000	3500000	•	•	•
104	Western Sydney Green Gas Project	NSW	Operating	$ 15,000,000	88			
105	Whaleback Energy Park	TAS	Under development			•		
106	Yuri Renewable Hydrogen to Ammonia Project	WA	Under construction	$ 87,000,000	640			•
				$ 127,672,121,784	**7253644**	**64**	**9**	**17**

Appendix 7

Australia's major hydrogen project investment pipeline (Department of Industry, Science and Resources 2022 Resources and Energy Major Projects report - Major Hydrogen Projects Database)

The Department of Industry, Science and Resources (DISR) 2022 Resources and Energy Major Projects publication[214] is an annual review of major projects which involve at least $50 million in investment. It finds that as of October 2022, there are 48 announced major hydrogen projects for Australia or 32 more major hydrogen projects than 2021 which represent a pipeline of hydrogen major project investment, of AUD$230 and AUD$302.5[215] billion. This represents a significant increase to the investment pipeline for hydrogen of AUD$133–185 billion from 2021. This analysis draws on extensive experience of the DISR Resources and Energy Major Projects team which has been publishing such analysis on investment costs of major resources and energy projects since 1997.

This DISR 2022 Resources and Energy Major Project analysis and public database below[216] (Appendix 7) complements and uses as a basis the CSIRO managed HyResource database of announced Australian based hydrogen projects[217] (Appendix 6). The CSIRO HyResource database reports on all announced Australian hydrogen projects irrespective of the size of investment where the lead proponent(s) have publicly released their project's investment costings.

To get a complete picture of the Australian clean hydrogen project investment pipeline, the 2022 State of Hydrogen report draws on both the HyResource[218] (Appendix 6) database and the DISR Resources and Energy Major Projects report's database[219]. This is because the DISR database provides robust estimates of the likely cost of the investment for major hydrogen projects, when there's no private sector publicly available costings in the HyResource database.

Using HyResource announce hydrogen project's list or the DISR's Resources and Energy Major Projects major hydrogen projects lists on their own would be incomplete. For instance, the HyResource database only includes 3 of the 11 announced and proposed major Australian gigawatt scale clean hydrogen projects. For instance, the 2022 Resources and Energy Major Projects report approach excludes four of the flagship regional "hydrogen hubs" with a combined estimated worth of nearly AUD$1 billion, which have been classified as hydrogen-related infrastructure by the DISR report.

Combining the data from CSIRO managed HyResource, with the analysis by DISR, results in a total announced pipeline of clean hydrogen investment for Australia, as of 31st of October of 2022, of AUD$231 to AUD$303[220] billion. Throughout this State of Hydrogen report, these figures have been rounded to AUD$230 to AUD$300 billion.

214 DISR(2022) Resources and Energy Major Projects Report www.industry.gov.au/sites/default/files/2022-12/resources-and-energy-major-projects-2022_0.pdf
215 $302.5 is a conservative estimate and the actual upper bound of Hydrogen investment could be higher.
216 DISR(2022) Resources and Energy Major Projects Report – Hydrogen Data and Excel Spreadsheet - www.industry.gov.au/publications/resources-and-energy-major-projects-2022
217 CSIRO (2022) HyResource Hydrogen Project Database - https://research.csiro.au/hyresource/projects/
218 CSIRO (2022) HyResource Hydrogen Projects Database - https://research.csiro.au/hyresource/projects/
219 DISR(2022) Resources and Energy Major Projects Report – Hydrogen Data and Excel Spreadsheet - https://www.industry.gov.au/publications/resources-and-energy-major-projects-2022
220 $303 is a conservative estimate and the upper bound for clean hydrogen investment could be higher.

Table 15: Australia's active hydrogen major project announced investment pipeline as of October 2022. (Source: DISR, 2022[221])

No. of Projects	Project Name	State/ Territory	Status (Active Projects)	Estimated Project Cost: Investment Data ($AU millions)	Anticipated Hydrogen Production Capacity [t/year]
1	ABEL Energy Bell Bay Powerfuels Project	TAS	Feasibility	1000–1499	21900
2	Arrowsmith Hydrogen Project Stage 1	WA	Feasibility	300	9125
3	Australian Renewable Energy Hub	WA	Feasibility	50000	1600000
4	Bristol Springs Solar Hydrogen Project	WA	Feasibility	289	1642500
5	Central Queensland Hydrogen Project	QLD	Feasibility	5,000+	292000
6	Darwin H2 Hub	NT	Publicly_announced	5,000+	80000
7	Desert Bloom Hydrogen (phase 1)	NT	Publicly_announced	700	20000
8	Desert Bloom Hydrogen (phase 2)	NT	Publicly_announced	13600	390000
9	Dyno Nobel Renewable Hydrogen Project	QLD	Feasibility	500–999	9000
10	Early Production System: MEG-HP1	WA	Feasibility	89	1606
11	Edify Green Hydrogen Project	QLD	Publicly_announced	5,000+	150000
12	Eyre Peninsula Gateway Project – Demonstrator Stage	SA	Feasibility	240	10000
13	Fortescue Green Hydrogen and Ammonia Plant	TAS	Publicly_announced	670	250000
14	Geelong Hydrogen Hub	VIC	Publicly_announced	100	
15	Geraldton Export-Scale Renewables Investment	WA	Feasibility	149	4000
16	Gibson Island Green Ammonia Feasibility	QLD	Feasibility	2500–4999	70000
17	Great Southern Project	TAS	Publicly_announced	335	5438.5
18	Green Liquid Hydrogen Export Project	QLD	Publicly_announced	500–999	36000
19	Green Springs Project	NT	Feasibility	5,000+	
20	H2-HubTM Gladstone	QLD	Feasibility	1610	1825000
21	H2Kwinana	WA	Feasibility	252	
22	H2Perth	WA	Publicly_announced	1000	109500
23	H2TAS Project	TAS	Publicly_announced	2500–4999	200000
24	HIF Carbon Neutral eFuels Manufacturing Facility	TAS	Publicly_announced	1500–2499	250
25	Hunter Energy Hub (initial large-scale H2 facility stage)	NSW	Feasibility	1000–1499	
26	Hunter Hydrogen Hub	NSW	Feasibility	200	
27	Hydrogen Bell Bay	TAS	Publicly_announced	77	1642.5
28	Hydrogen Brighton Project	TAS	Publicly_announced	60	800
29	Hydrogen Energy Supply Chain Project (pilot phase)	VIC	Completed	450	
30	HyEnergy Project	WA	Feasibility	5,000+	550000
31	Melbourne Hydrogen Hub	VIC	Publicly_announced	80	1642.5
32	Mid-West Clean Energy Project	WA	Feasibility	1500–2499	40000
33	Murchison Hydrogen Renewables Project	WA	Feasibility	10000	385000
34	Ord Hydrogen	WA	Publicly_announced	50–249	25

221 DISR(2022) Resources and Energy Major Projects Report www.industry.gov.au/sites/default/files/2022-12/resources-and-energy-major-projects-2022_0.pdf and DISR(2022) Resources and Energy Major Projects Report – Hydrogen Data and Excel Spreadsheet - https://www.industry.gov.au/publications/resources-and-energy-major-projects-2022

No. of Projects	Project Name	State/ Territory	Status (Active Projects)	Estimated Project Cost: Investment Data ($AU millions)	Anticipated Hydrogen Production Capacity [t/year]
35	Origin Green Hydrogen and ammonia Plant	TAS	Feasibility	2500–4999	500
36	Port Kembla Hydrogen Hub	NSW	Publicly_announced	224	
37	Port of Newcastle Hydrogen Hub	NSW	Feasibility	163	
38	Port Pirie Green Hydrogen Project (Phase 1)	SA	Feasibility	750	7300
39	Port Pirie Green Hydrogen Project (Remainder)	SA	Publicly_announced	751	29200
40	Portland Renewable Hydrogen Project	VIC	Publicly_announced	85	1600
41	Project Haber	WA	Feasibility	80	1825
42	Queensland Nitrates Renewable Hydrogen and Ammonia Project	QLD	Feasibility	50–249	
43	Queensland Solar Hydrogen Facility	QLD	Publicly_announced	5,000+	200000
44	South Australian Government Hydrogen Facility	SA	Publicly_announced	500–999	1800000
45	Tiwi H2 (initial phase)	NT	Feasibility	2500–4999	50000
46	Tiwi H2 (remainder)	NT	Publicly_announced	1500–2499	50000
47	Western Green Energy Hub	WA	Publicly_announced	100000	3000000
48	Yuri Renewable Hydrogen to Ammonia Project	WA	Committed	87	640
			Total	**AUD$230–303 billion**	**5,100,640 tonnes**

Note – Where figures are not provided for anticipated hydrogen production related to a specific hydrogen project, it is because such figures are not available as of 31st of October 2022.


H2
CO2
O2
H