Australian Government
Department of Industry, Science, Energy and Resources

STATE OF **HYDROGEN**

2021

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MESSAGE FROM THE MINISTER

In 2019, Australian energy ministers shared our vision for a clean, innovative, safe and competitive Australian hydrogen industry that is a major global player by 2030 through the release of the National Hydrogen Strategy.

Aligned with the adaptive approach to the strategy, energy ministers committed to regular reporting on the progress of Australia's hydrogen industry. I am pleased to release the inaugural State of Hydrogen report where we recognise the collaborative effort of industry and Australian governments in advancing our clean hydrogen sector. The report shows the great success of this effort to date, particularly in the areas of project scale, investment and export potential.

As 1 of 6 priority low emissions technologies under Australia's Technology Investment Roadmap, clean hydrogen is critical to Australia's technology-led approach to reducing emissions while creating jobs and achieving economic growth. The Australian Government has so far committed over $1 billion to clean hydrogen, and this scale of investment is gaining increasing global attention, cementing Australia's role as a world leader.

Widespread global adoption of clean hydrogen will require sustained effort to mitigate the 3 biggest barriers facing industry globally – not just in Australia – including building demand, achieving low-cost hydrogen production at scale and reducing delivery costs.

Like any nascent industry there will be challenges, and it is to be expected that demand-side indicators have slower progress than the supply side. It will take time to lower costs and to build export supply chains. Australian governments are next focusing on how to build up Australia's demand for hydrogen products, with the strategy laying out the pathway to achieve our vision.

All levels of the government in Australia are undertaking the early actions identified in the National Hydrogen Strategy to capitalise on our nation's natural resources and expertise and provide certainty for industry. For example, energy ministers have agreed to an expedited process to allow hydrogen and biogases to be brought within the existing regulatory framework for natural gas.

The National Hydrogen Strategy identifies hydrogen hubs as an effective means to create demand, build scale and reduce production costs by co-locating producers, exporters and users. The Australian Government is delivering on this action and investing $464 million to develop up to 7 hydrogen hubs in regional Australia. These Clean Hydrogen Industrial Hubs will create economies of scale and support the existing industrial infrastructure and workforces in these regions.

These hubs also offer an opportunity to showcase key trading partners' technologies, with collaboration on research and development essential to building a global hydrogen industry.

The Australian Government is supporting this through our commitment of $565.8 million to international technology partnerships through the 2021–22 Budget. Five new low emissions technology partnerships have been announced to date, with Singapore, Germany, Japan, the United Kingdom and the Republic of Korea. These partnerships complement bilateral cooperation on hydrogen with the United States, as well as Australia's involvement in multinational bodies.

Building a successful hydrogen industry for Australia can only be done through a genuine partnership between governments, industry, investors, researchers and our community. As this report shows, Australia's clean hydrogen potential is undeniable. I would like to extend my thanks to the cooperation from industry, state and territory governments and international governments that has seen the Australian hydrogen industry set the pace for this global momentum.

The Hon Angus Taylor MP
Minister for Energy and Emissions Reduction

Three Sisters, Katoomba NSW. Image attribution: Gettyimages mollypix

STATE OF HYDROGEN AT A GLANCE

Purpose of this report

To track Australia's progress against global developments, Australian governments have committed to publishing an annual State of Hydrogen report. This report explains how we measure the progress of Australia's hydrogen industry and provides a snapshot of industry's progress.

Australia's hydrogen opportunity

Clean hydrogen is gaining increasing attention as a clean fuel to decarbonise economies. It is a flexible, safe, transportable and storable fuel that produces no carbon emissions when used.

Hydrogen can be used:

- to power vehicles
- to generate heat and electricity
- as an industrial chemical feedstock for products such as ammonia and steel
- to globally trade clean energy.

Australia has all the ingredients needed to be a major hydrogen producer and exporter, including:

- abundant and cheap renewable energy resources
- geological storage resources
- a proven track record as an energy exporter.

Australia's National Hydrogen Strategy supports all production pathways and technologies that are capable of producing clean hydrogen. Clean hydrogen is hydrogen produced using renewable energy or using fossil fuels with substantial carbon capture and storage (CCS). This gives our emerging hydrogen industry flexibility to pursue the pathways that best meet customer preferences as global markets emerge.

Global trends and opportunities

Australian energy ministers share a vision for a clean, innovative, safe and competitive hydrogen industry that benefits all Australians and is a major global player by 2030.

Australia's National Hydrogen Strategy provides a framework for governments and industry to work together to build Australia's hydrogen industry. It starts with 57 nationally coordinated government actions.

The strategy takes an adaptive approach, ensuring Australia's hydrogen industry can scale up quickly without over-committing in an industry that is still maturing. To do this, we will keep a close eye on the international hydrogen industry to ensure our actions keep pace with the rest of the world.

Since we released our strategy in 2019, the global hydrogen industry has developed in line with our most optimistic estimates for growth. Many countries have released hydrogen or low emissions strategies, with hydrogen a central part of plans to reach net zero and move to low-carbon fuels.

Australia's small but rapidly growing hydrogen industry can take advantage of this global momentum. If our current pipeline of clean hydrogen projects is completed on time, Australia could be one of the world's largest hydrogen suppliers by 2030.

Governments will continue to work with industry to overcome any barriers to development. This work focuses on 3 areas:

- building demand
- achieving low-cost hydrogen production at scale
- reducing hydrogen delivery costs.

Following global momentum, the Australian hydrogen industry has seen substantial developments in 2020 and 2021.

The Department of Industry, Science, Energy and Resources engaged KPMG to compare the Australian industry with global developments. KPMG assessed where Australia is likely to be in 2025 and 2030 against each of the 13 industry development signals outlined in Chapter 6 of the National Hydrogen Strategy (Table 1). For each signal, KPMG rated the industry's development as either:

- advancing quickly
- advancing
- advancing slowly.

Table 1: Overview of Australia's progress across the industry development signals

INDUSTRY DEVELOPMENT SIGNAL	2025 PACE	2030 PACE	CURRENT STATUS
Investment	Advancing quickly	Advancing	• Private sector investment is growing with committed investment exceeding A$1.6 billion. • Public sector investment reached $1.27 billion in June 2021.
Project scale	Advancing quickly	Advancing quickly	• Project announcements indicate scale could reach over 100 MW by 2025. • Gigawatt-scale projects have been announced and are expected to start operating in the second half of the decade. However, a final investment decision on these projects has not been made.
Cost-competitiveness	Advancing quickly	Advancing	• Clean hydrogen costs are expected to decline to between A$2 and A$4 by 2030.[1]
Australia's exports	Advancing	Advancing	• Investment is being directed to hydrogen supply chains. Front end engineering and design studies are underway. • Supply chains still require development for Australia to be a major global supplier. • To support supply chain development, supply chain studies are underway with international partners like HySupply. • The government has supported hydrogen hubs to stimulate demand and produce clean hydrogen for domestic and export markets.
Chemical feedstock	Advancing quickly	Advancing quickly	• Projects to use clean hydrogen in existing facilities have been announced. • Current announcements account for 20% of total electrolyser capacity.
Steel making	Advancing slowly	Advancing slowly	• Limited activity in this area. However, several announcements from steel producers indicate an intent in this sector. • Clean steel is a priority technology under Australia's Technology Investment Roadmap.
Electricity grid support	Advancing slowly	Advancing slowly	• Limited trials are underway to test whether hydrogen can provide frequency control ancillary services (FCAS).
Mining and off-grid	Advancing	Advancing slowly	• A few projects are exploring hydrogen for microgrid applications. However, there are no plans for either small-scale or wide-scale rollout at this stage. Fortescue and ATCO are exploring hydrogen mobility at a mine site. • $103.6 million in government funding has supported microgrid pilots and deployment.
Power generation*	Advancing quickly	Advancing	• Two new hydrogen-ready gas generators reached final investment decision in New South Wales: Snowy Hydro's 660 MW Kurri Kurri gas generator and Energy Australia's 316 MW Tallawarra B gas generator. Additional projects are also in the pipeline, specifically AIP's Port Kembla gas generator.
Light transport	Advancing slowly	Advancing slowly	• Limited deployments or infrastructure to support hydrogen use in light transport. • Four refuelling stations and approximately 30 vehicles are in operation. Some additional projects are targeting operations in 2025. • The Australian Government has launched its Future Fuels Fund to take advantage of opportunities offered by electric, hydrogen and bio-fuelled vehicles. This includes support for electric vehicle refuelling infrastructure, including hydrogen fuel cell vehicles.
Heavy transport	Advancing slowly	Advancing slowly	• Hyzon Motors and Fortescue Metals are collaborating on hydrogen-powered buses for mining applications. • The Australian Government's Future Fuels Fund and Freight Productivity Program will support further heavy transport uptake.
Gas networks	Advancing	Advancing	• Activity is underway to trial hydrogen blending. Nine projects are expected to be operational by 2025. • Gas networks are targeting 100% hydrogen in regions of the network by 2030. • Australian Governments have agreed to national gas regulatory framework amendments to bring hydrogen, bio-methane and other renewable gas blends within its scope. Reforms are expected to initially focus on gases and blends that can be used in existing natural gas appliances.
Industrial heat	Advancing	Advancing	• Limited activity. However, Grange Resources (Tasmania) Pty Ltd is undertaking a feasibility study looking at hydrogen for industrial heat.

*Note: *Power generation refers to global progress as the indicator explicitly relates to international electricity demand*
Source: Adapted from KPMG analysis, June 2021.

[1] Analysis from CSIRO National Hydrogen Roadmap (2018), IEA cost data, SA hydrogen export study and ANU Green hydrogen cost report (2020).

This assessment shows that Australia is progressing well on:

- activities that will support efficient scale-up of the industry by 2030
- the supply-side factors that will let Australia meet increasing demand for hydrogen.

As is to be anticipated as a new industry develops, progress has been slower on demand-side indicators. This is expected given the early state of the industry and the higher cost of clean hydrogen compared to chemicals and fuels currently being used.

Many of hydrogen's expected future uses (such as hydrogen blending in gas networks and fuels for vehicles) have only recently begun trials. Like any new industry, it will take some time to build export supply chains and deliver activities to help scale up the industry. For some uses of hydrogen, it will also take time for demand for hydrogen to build. Progress is expected to be slow at first, but will increase as costs decrease and markets increasingly adopt new technologies. This is a natural part of industry development globally, but will be accelerated through government support.

For example, use of hydrogen for transport applications is dependent on uptake of hydrogen vehicles by consumers. These vehicles are currently expensive, as the technology is new, but are expected to come down in cost over time as technologies continue to improve and production volumes increase. Use of hydrogen will increase in line with uptake of vehicles by consumers. Similarly, large industrial users of hydrogen, such as existing ammonia producers, may not switch to using clean hydrogen until their existing production plants reach their end of their asset lives.

The Australian Government is helping industry to accelerate these demand-side indicators through a variety of funding programs discussed later in this report. For example, through the Australian Renewable Energy Agency, the Australian Government is funding Yara Pilbara Fertilisers and ENGIE Renewables to develop a 10 MW electrolyser project to produce renewable hydrogen at Yara's existing ammonia facility in Karratha, Western Australia. This project will see clean hydrogen used to make clean ammonia for global export. Projects like these, and the Australian Government's $464 million Clean Hydrogen Industrial Hubs program, will help drive the costs of hydrogen down faster, which will increase demand and improve these indictors.

Government actions

All levels of government are delivering the strategy and taking early actions to overcome barriers facing the industry. So far, the Australian Government has:

- built international relationships, including partnership agreements with Germany, Singapore, Japan, Republic of Korea and the United Kingdom to build hydrogen supply chains and advance technology research
- developed a proposed approach for a domestic hydrogen Guarantee of Origin scheme and helped shape the design of an international methodology
- announced hydrogen funding programs, including $464 million for the 'Activating a Regional Hydrogen Industry: Clean Hydrogen Industrial Hubs' program
- invested over $300 million to support development of carbon capture and storage (CCS) and carbon capture, use and storage (CCUS) projects
- awarded over $100 million to three 10 MW hydrogen electrolyser projects through the Australian Renewable Energy Agency (ARENA)
- fostered industry innovation, collaboration and knowledge sharing
- provided more than $300 million in funding for research, development and demonstration activities.

Direct Australian Government support for the hydrogen industry is now over $1.2 billion.

State and territory governments are helping develop the industry by implementing the National Hydrogen Strategy and their own hydrogen strategies. Together, the federal, state and territory governments have:

- started a review of legal and regulatory frameworks
- agreed to amend the national gas regulatory framework
- started the National Hydrogen Infrastructure Assessment
- commenced work on industry development, including skills and training
- supported analysis to understand community attitudes towards hydrogen.

State and territory governments are undertaking activities to support the hydrogen industry in their jurisdictions, including:

- announcing funding for pilots, trials and demonstrations
- engaging with communities
- committing funding for hydrogen hubs
- supporting industry development
- participating in regional hydrogen technology clusters in partnership with National Energy Resources Australia (NERA)
- supporting trials for hydrogen vehicles and blending hydrogen into gas networks.

Australia is progressing well towards the vision in the strategy. But we will need to remain ambitious to keep pace with the global hydrogen industry's rapid development.

Hydrogen hubs

To keep our position as an industry leader, Australia needs to quickly develop end-to-end hydrogen supply chains. We need to increase domestic demand for hydrogen to help our industry scale up and reach our potential as a major supplier.

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. Hubs will also create efficiencies by leveraging and supporting the existing industrial capabilities and workforces in relevant regions. Hubs will stimulate innovation and increase workforce skills development, as well as support other existing industrial sectors in these regions to lower both emissions and costs in doing business.

Demonstrating hydrogen hubs will develop domestic demand and provide the revenue certainty needed for large-scale supply. Hubs could take advantage of co-investment with:

- state and territory governments
- the private sector
- international governments.

The Australian Government has opened the $464 million 'Activating a Regional Hydrogen Industry: Clean Hydrogen Industrial Hubs' program to fund up to 7 hydrogen hubs. State and territory governments have backed this approach by providing funding to develop hydrogen hubs in their jurisdictions.

Hubs will help us scale up the industry as we work towards the Technology Investment Roadmap's goal of hydrogen production for under $2 per kilogram.

International partnerships

Strengthening our international relationships is equally important for building the industry. Australia's federal, state and territory governments are building international partnerships with other governments and private companies.

The Australian Government has committed $565.8 million through the 2021–22 federal Budget to develop international partnerships on low emissions technology. The Special Adviser to the Australian Government on Low Emissions Technology, Dr Alan Finkel AO, is playing a key role in brokering these partnerships.

These international partnerships will help develop Australia's clean hydrogen industry by:

- advancing the goals of the government's Technology Investment Roadmap
- driving investment in Australian-based projects and helping deploy low emissions technologies and energy
- accelerating supply chain growth, including for clean hydrogen
- fostering international collaboration on the development of practical low emissions technology pathways.

As a priority technology identified in the government's first Low Emissions Technology Statement, these partnerships are expected to support development of the clean hydrogen industry.

In 2021 the Australian Government announced 5 new international partnerships:

- Australia and Germany will work together under a new Hydrogen Accord. The accord includes several new initiatives to accelerate the development of a hydrogen industry. Australia will contribute $50 million and Germany €50 million
- Australia and Singapore will establish a $30 million partnership to accelerate deployment of low emissions fuels and technologies (like clean hydrogen) in maritime and port operations
- The Japan–Australia Partnership on Decarbonisation through Technology will increase our shared focus on priority low emissions technologies, including clean fuel ammonia and clean hydrogen
- The Republic of Korea and Australia will work together to drive increased adoption of low and zero emissions technologies
- Australia and the United Kingdom have agreed to collaborate on research and development across technologies crucial to decarbonising the global economy, including clean hydrogen.

State and territory governments are also building international partnerships to support projects in their regions:

- the South Australian Government signed a memorandum of understanding to investigate clean hydrogen exports with the Port of Rotterdam in the Netherlands
- Tasmania is exploring ways to collaborate and cooperate with international partners
- the Victorian Government is a partnering with the Australian Government, the Japanese Government and Australian and Japanese industry to develop the $500 million Hydrogen Energy Supply Chain project in the Latrobe Valley.

Other activities

Governments will continue working on other activities to help the industry flourish. Priorities for the coming year include:

- accelerating pilots, trials and demonstrations of hydrogen technologies
- continuing to develop an international approach to hydrogen certification, moving from design to trialling hydrogen certification methodologies on real projects
- ensuring a fit-for purpose regulatory environment by implementing findings from current reviews of legal and regulatory barriers for the industry
- identifying the industry's future infrastructure needs by considering findings from the infrastructure assessment
- progressing the Victorian and Australian Governments' CarbonNet project to establish a multi-user CCS hub in Gippsland.

Success will rely on industry, governments, researchers and the community working together. If we get this right, we can realise our vision to establish a new clean hydrogen export industry in Australia. Clean hydrogen exports could directly support 16,000 jobs, plus an additional 13,000 from related construction work, by 2050. Australian hydrogen production for export and domestic use could generate more than $50 billion in additional GDP by 2050.

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1 AUSTRALIA'S PATHWAY FOR A CLEAN HYDROGEN FUTURE

Australia's National Hydrogen Strategy takes an adaptive approach, requiring frequent assessment of the industry to ensure its actions are aligned with international progress.

PURPOSE OF THE STATE OF HYDROGEN REPORT

To track Australia's progress against global developments, Australian governments have committed to publishing an annual State of Hydrogen report. This report monitors and tracks the measures of success and industry development signals outlined in the National Hydrogen Strategy.

Australia's National Hydrogen Strategy supports all production pathways and technologies that are capable of producing clean hydrogen. Clean hydrogen is hydrogen produced using renewable energy or using fossil fuels with substantial carbon capture and storage (CCS). This gives our emerging hydrogen industry flexibility to pursue the pathways that best meet customer preferences as global markets emerge.

While the industry has already made progress against many of these measures and signals, others will become more relevant as the industry matures. This report sets out our approach to measuring progress and gives a snapshot of where we are up to.

Thirteen industry development signals are defined in the strategy to indicate whether aspects of the hydrogen industry are advancing quickly or slowly by 2025 and 2030. These industry development signals are:

- investment
- project scale
- cost-competitiveness
- Australia's exports
- chemical feedstock
- electricity grid support
- mining and off-grid
- heavy transport
- light transport
- gas networks
- electricity generation
- steel making
- industrial heat.

The strategy also outlined measures of success across 3 categories. These measures will guide decision-making as the strategy is implemented.

1. Australia has a clean, innovative, safe and competitive hydrogen industry
   - Clean:
     - Carbon intensity of the Australian hydrogen production meets community, customer and consumer expectation and is decreasing over time
     - Australia has a robust certification scheme that is internationally accepted
   - Innovative:
     - Australia is regarded as having a highly innovative hydrogen industry and a supportive research and development environment
     - The sustainability of water use for Australian hydrogen production continues to improve
   - Safe:
     - Australia has an excellent hydrogen-related safety track record
   - Competitive:
     - Australian hydrogen is cost-competitive domestically and internationally
     - Australia has a 'hydrogen-ready' workforce that is responsive to industry's needs.
2. Australia's hydrogen industry benefits all Australians
   - Jobs and prosperity:
     - Hydrogen is providing economic benefits and jobs
   - Supported communities:
     - Benefits are flowing back to communities where hydrogen industries are located
   - Domestic use:
     - The cost of clean hydrogen continues to decrease in part due to technology developments and in part due to scale achieved in the development of a hydrogen export industry
     - Hydrogen production and use is integrated into energy market structures.

3. Australia is a major global player
    - Hydrogen exports:
        - Australia is among the top 3 exporters of hydrogen to Asian markets
    - Investor confidence:
        - Australia is seen as a destination of choice for international investors in hydrogen
        - Australia has major offtake or supply chain agreements in place with importing countries
    - Hydrogen capability:
        - Australia has demonstrated hydrogen capability in all links of the supply chain.

How we track progress

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 then commissioned KPMG to analyse the Australian and global hydrogen industries using CSIRO's data framework. Using the information available in 2021, the industry was assessed against each of the 13 development signals to determine whether each development signal is:

- advancing quickly
- advancing
- advancing slowly.

Definitions

In this report:

- 'hydrogen' means hydrogen and its derivatives, such as ammonia
- 'clean hydrogen', means hydrogen produced with either:
    - renewable energy
    - fossil fuels with substantial carbon capture and storage (CCS)
- 'high-carbon hydrogen' means hydrogen produced from fossil fuels without CCS.

Australia's hydrogen opportunity

Hydrogen is a versatile and clean fuel that produces no carbon emissions when used. It has been identified as an important technology to reduce global emissions by many countries including Australia, the United States, Germany, Japan and Korea.

Hydrogen is a flexible, safe, transportable and storable fuel. It is currently used:

- for oil refining
- in chemical and fertiliser production
- as an industrial chemical feedstock for products such as ammonia and steel.

Emerging uses for hydrogen include:

- powering vehicles
- generating heat
- trading clean energy between countries.

The main methods used to produce hydrogen in Australia are:

- electrolysis (extracting hydrogen from water using electricity)
- thermochemical reactions using coal (coal gasification) or natural gas (steam methane reforming).

Approximately 87 million tonnes of high-carbon hydrogen was produced globally in 2020.[2] Carbon emissions from thermochemical production using fossil fuels can be greatly reduced by capturing and storing the carbon emissions.

Producing hydrogen from electrolysis powered by renewable electricity does not create any carbon emissions.

[2] International Energy Agency (IEA), Net Zero by 2050—A Roadmap for the Global Energy Sector, May 2021.

Australia has abundant renewable energy resources. The National Hydrogen Strategy estimates that Australia has 262,000 square kilometres of land that is highly suitable for hydrogen production using renewable electricity. This is about 3% of Australia's total land area and is larger than the average European Union nation. This amount of land could theoretically support tens of thousands of gigawatts of renewable energy projects.

Australia also has substantial resources of coal, both black and brown. The most significant black coal resources are located in the Bowen and Surat basins (Queensland) and the Sydney basin (New South Wales). Coal is Australia's largest commodity export, with our annual thermal and metallurgical coal exports worth more than $40 billion, mainly to Japan, India, the European Union, the Republic of Korea and Taiwan. Economic demonstrated resources (EDR) of black coal are adequate for about 90 years at current rates of production.[3]

Australia's brown coal resources are located mostly in the Gippsland Basin in Victoria, where it is used for electricity production. At current rates of production, there are nearly 500 years of brown coal resources remaining.[4]

Australia's gas reserves include large conventional gas resources located mostly in the Carnarvon, Browse and Bonaparte basins off the northwest coast, with smaller resources in the Gippsland Basin (offshore Victoria) and the onshore Cooper–Eromanga Basin in South Australia. EDR of conventional gas are adequate at current levels of production for around 60 years.[5]

Substantial resources of coal seam gas (CSG) are associated with the major coal basins of eastern Australia. CSG resources are being rapidly increased by exploration, with significant economic demonstrated resources of CSG now identified in the Bowen, Surat and Sydney basins.

Australia has extensive geological sites for carbon capture and storage (CCS). In the near term, the best CCS opportunities are:

- the Carnarvon Basin
- offshore Western Australia (the site of one of the world's largest carbon capture and storage projects on Barrow Island)
- the Gippsland Basin, in offshore Victoria (site of the CarbonNet project)
- onshore regions near the Cooper Basin (Queensland and South Australia) and Surat Basin (Queensland).

Australia also has a long-standing track record as a trusted global energy exporter. This means we are well placed to produce clean hydrogen at a large scale. We can use Australian-made clean hydrogen to help decarbonise our own economy, as well as supply it to other countries.

Australia's goal is to be a major supplier of clean hydrogen by 2030. This could see the Australian hydrogen industry reach the scale of our current liquefied natural gas (LNG) industry. The value of our LNG exports in the 2019–20 financial year totalled $48 billion, 16% of Australia's total resource and energy exports.[6]

Realising this opportunity for hydrogen could provide enormous growth in domestic manufacturing. It would also create ongoing jobs in project financing, management, operation and maintenance.

Areas for action

For the Australian hydrogen industry to realise this opportunity, we need to keep taking action in 3 main areas:

Building domestic demand

The National Hydrogen Strategy identifies that building domestic demand for hydrogen is important to help the Australian industry achieve export scale.

Increasing domestic demand for hydrogen could unlock new industries to drive economic growth. It could also reduce emissions in hard-to-abate areas of the economy.

Low-cost hydrogen production at scale

Clean hydrogen is currently more expensive than conventional fuels for most end-use applications. Production costs need to fall before clean hydrogen can compete with these fuels on price.

Efficiencies of scale and lower electricity and gas costs will play a significant role in reducing the cost of producing hydrogen.

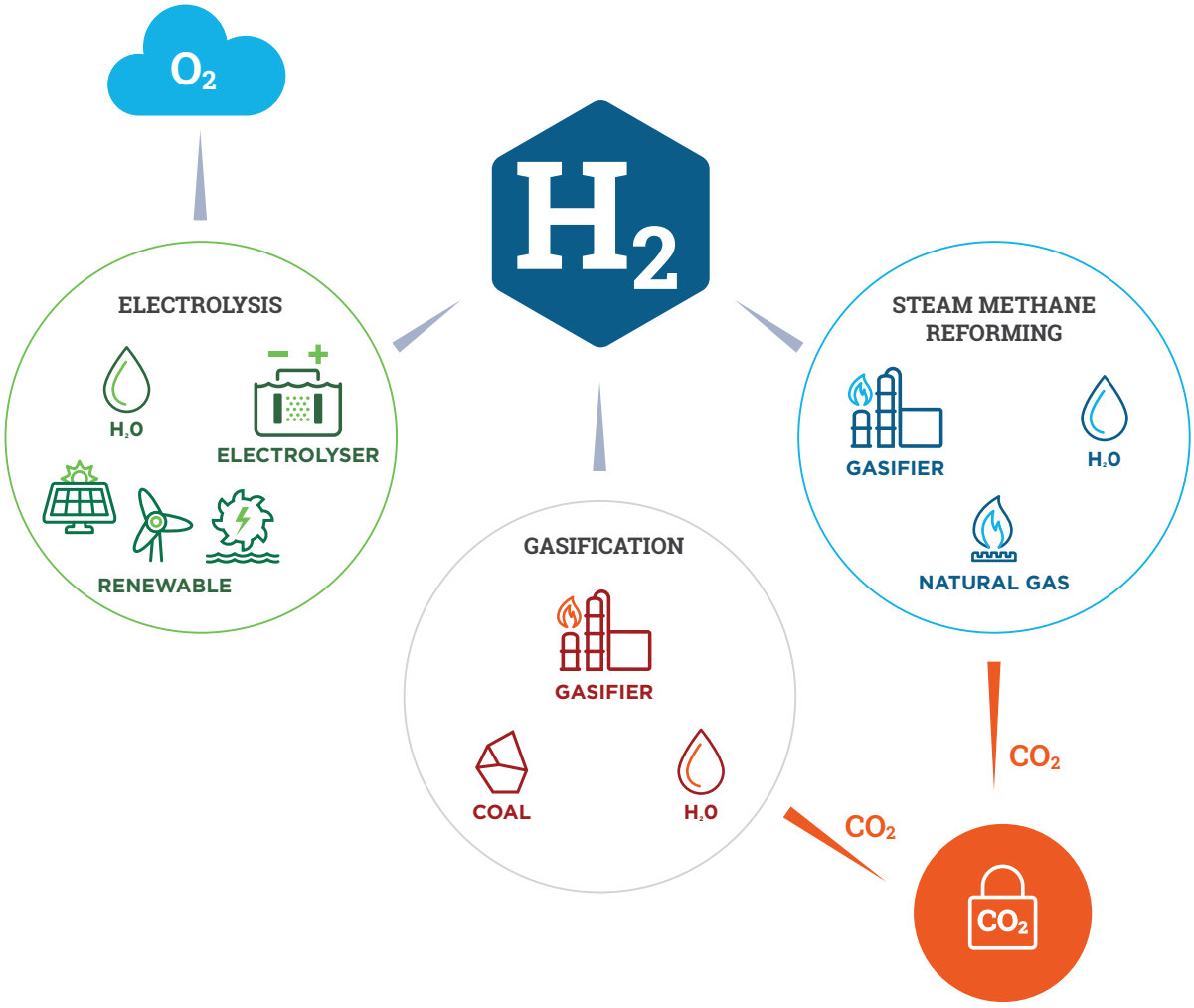
3 Geoscience Australia, Energy Overview, September 2021.
4 Geoscience Australia, Energy Overview, September 2021.
5 Geoscience Australia, Energy Overview, September 2021.
6 Office of the Chief Economist, Resources and Energy Quarterly, March 2021.

Reducing hydrogen delivery costs

Australia's Technology Investment Roadmap sets a stretch goal for hydrogen production of under $2 per kilogram – the point where hydrogen becomes competitive with conventional fuels. Compressing, storing and transporting hydrogen could add up to $2 per kilogram to the cost of hydrogen.[7]

To build a hydrogen export industry, the costs of hydrogen storage and transport need to fall. This will reduce the cost of hydrogen delivered to domestic and international consumers.

Figure 1 Production pathways for clean hydrogen



[7] Advisian, Australian hydrogen market study, May 2021.

Australia's National Hydrogen Strategy

To take advantage of the hydrogen opportunity, Australia's governments worked together to develop Australia's National Hydrogen Strategy in 2019. One of the world's first hydrogen strategies, it provides a framework for governments and industry to work together to build Australia's hydrogen industry.

The strategy describes a vision of a clean, innovative, safe and competitive industry – an industry that benefits all Australians and where Australia is a major global player by 2030.

The strategy enables choice of clean hydrogen production technologies, supporting all production pathways that can create clean hydrogen.

While renewables are essential for decarbonising industries, there is growing recognition that carbon capture and storage (CCS) also needs to play a role. CCS can be used to reduce emissions from industrial processes that cannot be decarbonised with renewables alone. It can drastically reduce the emissions from cement production and fugitive emissions from liquefied natural gas.

Large international organisations such as the United Nations Framework Convention on Climate Change (UNFCCC) and the International Energy Agency (IEA) recognise that achieving many net zero ambitions will be difficult without CCS.

The Australian Government has provided over $300 million help develop CCS and carbon capture, use and storage (CCUS) hubs and technologies, and also has developed an Emissions Reduction Fund method to credit abatement from new CCS projects.

The National Hydrogen Strategy includes 57 nationally coordinated government actions. These actions are the first steps Australia needs to make to capture its hydrogen opportunity. They are grouped into themes:

- national coordination
- developing production capacity, supported by local demand
- responsive regulation
- international engagement
- innovation, research and development
- skills and workforce development
- building community confidence.

A stretch goal for hydrogen

The Australian Government released its first Low Emissions Technology Statement under the Technology Investment Roadmap in September 2020. The statement provides an approach to quickly deploy low emissions technologies with the highest abatement and economic potential for Australia.

The statement sets economic stretch goals for priority low emissions technologies. These stretch goals will help priority technologies reach economic parity with existing technologies and enable wide-scale uptake.

Clean hydrogen is identified as a priority technology under the Technology Investment Roadmap. Its economic stretch goal is a production cost under $2 per kilogram of hydrogen. This is the cost where hydrogen becomes competitive with conventional fuels.

An adaptive approach

Australia's natural advantages are not enough to create a successful hydrogen industry. We also need to ensure the scale and timing of Australia's industry development aligns with international market growth.

The National Hydrogen Strategy takes an adaptive approach to industry development. It lets Australia scale up quickly as the hydrogen market grows, but doesn't overcommit to an industry that is still maturing. This means taking action now, but accepting that we need to keep refining what we do as markets and technologies change.

Figure 2: Adaptive approach to industry development

The adaptive approach has 2 main phases:

- Foundations and demonstrations (2020 to 2025). This phase focuses on creating, testing and demonstrating supply chains, as well as building capability
- Large-scale market activation (2025 to 2030). This phase builds on and broadens the work in the first phase. It focuses on scaling up the industry and developing markets to underpin it.

2 HYDROGEN INDUSTRY DEVELOPMENT

A purpose of this report is to compare Australia's hydrogen industry with the industry development signals set out in the National Hydrogen Strategy.

The indicators cover both supply-side and demand-side sectors. They look at domestic and international progress from 2020 to 2025 and from 2025 to 2030.

Australia's progress is assessed in the context of our 2030 goal to be a major supplier in the global clean hydrogen industry.

Global hydrogen industry development

Australia was one of the first countries to publish a strategy outlining a path to clean hydrogen industry growth.

Other governments have followed, releasing strategies and announcing commitments to develop their own hydrogen industries. Ten countries and the European Union released hydrogen strategies in 2020 and the first half of 2021.

Countries have different focuses for their hydrogen strategies. Resource-rich countries such as Australia, Chile, Canada and Saudi Arabia are focusing on establishing export industries for clean hydrogen. Resource-poor countries with ambitious net zero emission targets, such as Japan and South Korea, want to import clean hydrogen to provide a source of clean energy.

Global trade is an important part of most hydrogen strategies, regardless of whether they focus on imports or exports. Nations are already building relationships to enable future large-scale hydrogen supply. Already 18 memorandums of understanding (MoUs) have been signed for clean hydrogen export.[8]

These MoUs are usually between regions targeting export (such as South America, Saudi Arabia and Australia) and potential import markets, mostly in Asia and Europe. They establish the trading relationships and supply chains to benefit both nations.

ATCO's hydrogen fuelled Toyota Mirai. Image attribution: ATCO.

[8] KPMG analysis of government and private media announcements.

Investment and supply

Global investment in hydrogen demonstrates the momentum of the industry. At the end of 2020, total global investment in clean hydrogen projects that have reached financial decision was estimated at US$38 billion (A$54 billion). Another US$45 billion (A$64 billion) was committed to projects in the planning phase.[9] According to the International Energy Agency (IEA),[10] investment has already delivered over 400 operational projects.

Governments are rapidly developing their hydrogen industries by supplementing their strategies with significant funding. Demand for Australian clean hydrogen could increase if our export markets make large funding commitments to develop hydrogen demand in their regions.

To help the hydrogen industry grow, a lot of early investment has gone towards research, development and demonstration (RD&D). In the last 5 years, OECD counties have invested A$3.8 billion in hydrogen and fuel cells RD&D. This represents 2.1% of total global RD&D investment, up from 1.1% 5 years ago.[11]

This early investment in RD&D has helped technologies mature and become commercially viable for early movers in the industry. It has addressed initial production barriers and let public and private spending expand beyond RD&D.

Hydrogen is also one of the largest growth areas for venture capital funding, indicating a growing interest in scaling up the sector.[12]

Private industries are shifting to hydrogen as countries start transitioning to low-carbon fuels. Some of the world's largest organisations, from oil and gas giants to technology companies, are announcing interests in or commitments to invest in hydrogen. Large-scale projects have already been announced in Europe, Saudi Arabia, Australia and the United States.

Global production of clean hydrogen is low, at around 390,000 tonnes a year. However, the strong ambitions of governments and private industries have produced an exponential increase in the number of announced projects. Clean hydrogen project pipelines suggest that global supply could grow to about 17 Mt by 2030.[13]

Supply costs

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

In the short term, hydrogen from coal or gas with carbon capture and storage is expected to cost less than renewable hydrogen in most parts of the world.[14] These production methods use mature technologies for hydrogen production, so costs are expected to remain relatively stable. There are fewer estimates for the cost of hydrogen from fossil fuels with carbon capture and storage than for the cost of hydrogen from renewables, with the global average around $2.90 per kilogram[15]

Gas prices affect the cost of hydrogen produced from natural gas with carbon capture and storage. Australia, the United States, the United Kingdom and Russia all have access to natural gas and options for carbon capture and storage, which lowers estimated production costs.

The cost of hydrogen produced from electrolysis is currently over $5 per kilogram.[16] The main cost drivers are capital costs and electricity costs. Renewable hydrogen production costs could fall below $2 per kilogram after 2030 if electrolysers and renewable energy become cheap enough.[17,18]

In 2020 the average size of operating electrolysers around the world was approximately 1.1 MW. In early 2021, the 20 MW Air Liquide Plant in Canada commenced operation with a 4-module polymer electrolyte membrane (PEM) electrolyser. The largest single stack electrolyser project is the 10 MW Fukushima Hydrogen Energy Research Field in Japan.

Australia's largest operating electrolyser is the 1.25 MW project at Hydrogen Park in South Australia. The Australian Government has funded 3 electrolyser projects of 10 MW each, which are expected to be operational in the near future.

Electrolyser size is expected to keep increasing. This will likely unlock a 50-fold increase in total renewable hydrogen production in the next 5 years. It could also reduce electrolyser costs by up to 75%[19].

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9 Hydrogen Council, Hydrogen Insights 2021, February 2021.
10 IEA, Hydrogen Project Database FY21Q1, 202013.
11 IEA, "RD&D Budget." IEA Energy Technology RD&D Statistics (database), accessed April 7, 2021, in 2019 values.
12 IEA, Energy Technology Perspectives 2020, 2020.
13 KPMG analysis of the IEA and HyResource hydrogen project databases.
14 IEA, The Future of Hydrogen, June 2019.
15 IEA, Hydrogen Tracking Report, June 2020.
16 Hydrogen Council and McKinsey & Company (2021) Hydrogen Insights Report January 2021.
17 Deloitte, Investing in hydrogen: Ready, set, set zero, November 2020.
18 Advisian, Australian hydrogen market study, May 2021.
19 ReCharge News, Nel to slash cost of electrolysers by 75%, with green hydrogen at same price as fossil H2 by 2025, January 2021 and ReCharge News, Green hydrogen: ITM Power's new gigafactory will cut costs of electrolysers by almost 40%, January 2021.

Demand

The growth in clean hydrogen supply will be driven by a growing demand for clean hydrogen.

Applications for using hydrogen are increasing, particularly in importing countries where hydrogen is a major part of emission reduction strategies. Some of these countries have set targets for using hydrogen in specific applications.

When and where hydrogen will become cost competitive for particular applications depends on:

- the cost of alternatives
- existing technology and markets for using hydrogen.

Industrial applications

Ammonia is expected to become one of the largest sources of demand for clean hydrogen. Using clean hydrogen in place of high-carbon hydrogen to meet existing demand for ammonia is a key opportunity for the industry.

Ammonia made from clean hydrogen can also be used to reduce emissions from electricity production. It can be blended with coal to reduce the amount burned to produce each megawatt-hour of electricity. Countries are considering using clean ammonia to lower emissions from co-fired coal generation plants. For example, Japan has an ambitious target to increase ammonia use in existing coal plants to 20% by 2030.

Clean hydrogen for chemical feedstock is currently at demonstration and pilot scale, with approximately 38 projects focused on chemical production operating around the world.[20]

The first quarter of 2021 saw numerous announcements on using hydrogen for steel making. Some of the world's largest steel producers (HBIS[21], ArcelorMittal[22], JFE Steels and BHP[23]) have announced decarbonisation plans and targets to reduce emissions over the next 30 years.

In June 2021, SSAB, LKAB and Vattenfall commenced operations at the world's first hydrogen-reduced sponge iron pilot plant. The HYBRIT plant in Luleå, Sweden, has tested the production of sponge iron, demonstrating that clean hydrogen gas can be used instead of coal or coke to reduce iron ore.[24]

The use of hydrogen for industrial applications will accelerate over the next decade. An additional 30 projects are due to start around the world by 2025.[25]

Transport

Using clean hydrogen in transport is part of many countries' decarbonisation goals. It is a particular focus for countries with large automobile manufacturing sectors such as Japan and South Korea.

The United States and China deployed the most hydrogen fuel cell electric vehicles (FCEV) in 2019. However Japan, Korea and the Netherlands are also expected to be leading producers in the coming years.

Hydrogen technologies are well advanced for some transport applications. The difference in cost compared to other fuels is small, however new infrastructure will be needed for refuelling. Hydrogen-powered fuel cells have already been developed for many forms of transport, including cars, trucks, buses, trains, ferries and forklifts.

Hydrogen-powered vehicles currently cost more than battery electric vehicles. But they have 2 main advantages over battery vehicles: faster refuelling times and the ability to travel longer distances with larger loads before refuelling.

Road transport

Heavy transport applications such as line haul and back-to-base are the most economical to convert to hydrogen. These vehicles need a lot of diesel for long-distance travel, which will make hydrogen-powered alternatives more affordable as clean hydrogen becomes cheaper. Transitioning heavy vehicle fleets to hydrogen first will reduce capital costs quickly through economies of scale. However, this will depend on sufficient demand.

General Motors, Honda, Hyundai, Hyzon, Kenworth and Toyota are manufacturing or planning to manufacture medium and heavy hydrogen fuel cell trucks.

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20 KPMG, Hydrogen State of the Nation, June 2021.
21 HBIS Group, HBIS Announces its Low-carbon & Green Development Action Plan, 12 March 2021.
22 ArcelorMittal, ArcelorMittal launches XCarb™, signalling its commitment to producing carbon neutral steel, 17 March 2021.
23 JFE Steel Corporation, FE Steels and BHP to address decarbonization in steelmaking process, 10 February 2021.
24 https://www.ssab.com/news/2021/06/hybrit-ssab-lkab-and-vattenfall-first-in-the-world-with-hydrogenreduced-sponge-iron.
25 KPMG analysis of IEA Project Database FY21Q1 supplemented with large scale announcements to April 2021.

Hydrogen for light passenger vehicles may not become cost competitive with existing technologies for some time. This is due to:

- high upfront costs
- competition with electric vehicles
- a need for significant new infrastructure.

The IEA expect global hydrogen demand from road transport to exceed 1.6 Mt per year in 2030. By 2050 road transport will likely consume more hydrogen than any other sector, at 66.5 Mt per year.[26] This will be driven by:

- changing regulatory requirements in many countries
- the expectation that hydrogen will be cheaper than diesel for buses, trains, trucks and SUVs by 2030.27

By 2030, there could be more than 10,500 FCEV refuelling stations supporting 4.5 million on-road FCEVs globally.[28]

Shipping

Cargo and container ships currently produce a significant proportion of global emissions.

Reducing emissions in the shipping sector is a priority for the International Maritime Organisation. The organisation has a goal to halve emissions by 2050 compared to 2008 levels.[29]

This is driving innovation in alternative marine fuels. Clean ammonia is a potential source of low-emissions maritime fuel, particularly for vessels that spend a long time at sea, such as cargo ships.

Gas networks

Forty projects around the world are blending hydrogen into natural gas networks. These projects are all small, with fewer than 1,000 connected buildings.[30]

The use of hydrogen in gas networks is developing quickly, with the biggest advances in countries where gas is used mostly for heating.

The United Kingdom, the Netherlands, Australia and the United States have several demonstration projects. These pilots are testing blends of 5% to 20% hydrogen as well as 100% hydrogen.

Electricity

Hydrogen can be used to generate electricity and support the power grid. Countries with more limited resources, such as Japan and the Republic of Korea, have large targets for using hydrogen for baseload power via hydrogen turbines and ammonia co-firing in coal-fired power plants. Three new Australian gas generators have announced plans to install hydrogen-ready gas turbines at their plants.

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

Australia's industry development

The Australian hydrogen industry has followed global momentum and seen substantial developments in 2020 and 2021.

To compare the Australian industry with global developments, an assessment was completed on where Australia is likely to be in 2025 against each of the 13 indicators in the National Hydrogen Strategy.

Each of the 13 indicators was rated as either:

- advancing slowly
- advancing quickly
- advancing.

[26] IEA, Hydrogen, June 2020.
[27] Hydrogen Council, 2020.
[28] Hydrogen Council, Hydrogen Insights, 2021.
[29] International Maritime Organisation, IMO Action to Reduce Greenhouse Gas Emissions.
[30] IEA, Hydrogen Project Database FY21Q1, 2020.

Table1: Overview of Australia's progress across the industry development signals

INDUSTRY DEVELOPMENT SIGNAL	2025 PACE	2030 PACE	CURRENT STATUS
Investment	Advancing quickly	Advancing	• Private sector investment is growing with committed investment exceeding A$1.6 billion. • Public sector investment reached $1.27 billion in June 2021.
Project scale	Advancing quickly	Advancing quickly	• Project announcements indicate scale could reach over 100 MW by 2025. • Gigawatt-scale projects have been announced and are expected to start operating in the second half of the decade. However, a final investment decision on these projects has not been made. • Gigawatt-scale projects have been announced and are expected to start operating in the second half of the decade. However, a final investment decision on these projects has not been made.
Cost-competitiveness	Advancing quickly	Advancing	• Gigawatt-scale projects have been announced and are expected to start operating in the second half of the decade. However, a final investment decision on these projects has not been made.Clean hydrogen costs are expected to decline to between A$2 and A$4 by 2030.[31]
Australia's exports	Advancing	Advancing	• Investment is being directed to hydrogen supply chains. Front end engineering and design studies are underway. • Supply chains still require development for Australia to be a major global supplier. • To support supply chain development, supply chain studies are underway with international partners like HySupply. • The government has supported hydrogen hubs to stimulate demand and produce clean hydrogen for domestic and export markets.
Chemical feedstock	Advancing quickly	Advancing quickly	• Projects to use clean hydrogen in existing facilities have been announced. • Current announcements account for 20% of total electrolyser capacity.
Steel making	Advancing slowly	Advancing slowly	• Limited activity in this area. However, several announcements from steel producers indicate an intent in this sector. • Clean steel is a priority technology under Australia's Technology Investment Roadmap.
Electricity grid support	Advancing slowly	Advancing slowly	• Limited trials are underway to test whether hydrogen can provide frequency control ancillary services (FCAS).
Mining and off-grid	Advancing	Advancing slowly	• A few projects are exploring hydrogen for microgrid applications. However, there are no plans for either small-scale or wide-scale rollout at this stage. Fortescue and ATCO are exploring hydrogen mobility at a mine site. • $103.6 million in government funding has supported microgrid pilots and deployment.
Power generation*	Advancing quickly	Advancing	• Two new hydrogen-ready gas generators reached final investment decision in New South Wales: Snowy Hydro's 660 MW Kurri Kurri gas generator and Energy Australia's 316 MW Tallawarra B gas generator. Additional projects are also in the pipeline, specifically AIP's Port Kembla gas generator.
Light transport	Advancing slowly	Advancing slowly	• Limited deployments or infrastructure to support hydrogen use in light transport. • Four refuelling stations and approximately 30 vehicles are in operation. Some additional projects are targeting operations in 2025. • The Australian Government has launched its Future Fuels Fund to take advantage of opportunities offered by electric, hydrogen and bio-fuelled vehicles. This includes support for electric vehicle refuelling infrastructure, including hydrogen fuel cell vehicles.
Heavy transport	Advancing slowly	Advancing slowly	• Hyzon Motors and Fortescue Metals are collaborating on hydrogen-powered buses for mining applications. • The Australian Government's Future Fuels Fund and Freight Productivity Program will support further heavy transport uptake.
Gas networks	Advancing	Advancing	• Activity is underway to trial hydrogen blending. Nine projects are expected to be operational by 2025. • Gas networks are targeting 100% hydrogen in regions of the network by 2030. • Australian Governments have agreed to national gas regulatory framework amendments to bring hydrogen, bio-methane and other renewable gas blends within its scope. Reforms are expected to initially focus on gases and blends that can be used in existing natural gas appliances.
Industrial heat	Advancing	Advancing	• Limited activity. However, Grange Resources (Tasmania) Pty Ltd are undertaking a feasibility study looking at hydrogen for industrial heat.

*Note: *Power generation refers to global progress as the indicator explicitly relates to international electricity demand*
Source: KPMG analysis, June 2021.

This assessment shows that Australia is progressing well on:

- the indicators that will support efficient scale-up of the industry by 2030
- the supply-side factors that will let Australia meet increasing demand for hydrogen.

[31] Analysis from CSIRO National Hydrogen Roadmap (2018), IEA cost data, SA hydrogen export study and ANU Green hydrogen cost report (2020).

As is to be anticipated as a new industry develops, progress has been slower on demand-side indicators. This is expected given the early state of the industry and the higher cost of clean hydrogen compared to chemicals and fuels currently being used.

Many of hydrogen's expected future uses (such as hydrogen blending in gas networks and fuels for vehicles) have only recently begun trials. Like any new industry, it will take some time to build export supply chains and deliver activities to help scale up the industry. For some uses of hydrogen, it will also take time for demand for hydrogen to build. Progress will be slow at first, but will increase as costs decrease and markets increasingly adopt new technologies. This is a natural part of industry development and will be accelerated through government support.

For example, use of hydrogen for transport applications is dependent on uptake of hydrogen vehicles by consumers. These vehicles are currently expensive as the technology is new, but are expected to come down in cost over time, as technologies continue to improve and production volumes increase. Use of hydrogen will increase in line with uptake of vehicles by consumers. Similarly, large industrial users of hydrogen, such as existing ammonia producers, may not switch to using clean hydrogen until their existing hydrogen production plants reach their end of their asset lives.

The Australian Government is helping industry to accelerate these demand-side indicators through a variety of funding programs discussed later in this report. For example, through the Australian Renewable Energy Agency, the Australian Government is funding Yara Pilbara Fertilisers and ENGIE Renewables to develop a 10 MW electrolyser project to produce renewable hydrogen at Yara's existing ammonia facility in Karratha, Western Australia. This project will see clean hydrogen used to make clean ammonia for global export. Projects like these, and the Australian Government's $464 million Clean Hydrogen Industrial Hubs program, will help drive the costs of hydrogen down faster, which will increase demand and improve these indictors.

As highlighted in the National Hydrogen Strategy, hydrogen hubs will grow Australian demand in the next few years as the Clean Hydrogen Industrial Hubs program is rolled out. Bringing hydrogen users together will also:

- reduce infrastructure costs
- focus innovation efforts
- develop and share workforce skills.

Locating hydrogen hubs at export sites will provide access to international demand, which is expected to be a large source of offtake for many hydrogen projects.

Investment and supply

Investment in the Australian hydrogen industry has increased since the release of the National Hydrogen Strategy. This is largely due to government spending to support the strategy's pathway and priorities.

At the end of June 2021, Australian Government support directly targeting the hydrogen industry was over $1 billion. State and territory governments had committed another $325 million specifically for hydrogen.[32]

Government investment is targeted at:

- research, development and demonstration (RD&D) projects
- early enabling actions
- developing hydrogen hubs as demand sources and as part of export supply chains.

This targeted investment will help the Australian clean hydrogen industry scale up and meet expected global demand by 2030. It is a useful and necessary early step to establish the industry in Australia.

Like the rest of the world, Australia currently produces a small amount of clean hydrogen – 55 tonnes in 2020.[33]

The industry is expected to grow significantly. In June 2021, Australia had the world's largest pipeline of announced hydrogen projects. If all these projects are completed Australia could be one of the world's largest hydrogen producers by 2030.

Production costs

In 2025 the cost of producing clean hydrogen in Australia is expected to be between A$2.30 and A$5 per kilogram, depending on the production method. In 2030 it will cost an estimated A$2 to A$4 per kilogram[34]. These are some of the cheapest estimates in the world.

Bringing the cost of clean hydrogen below $2 a kilogram (the stretch goal under the Technology Investment Roadmap) will require:

- cheaper and more abundant clean energy
- significant development and deployment of technologies such as electrolysers.

Electrolysers and other clean hydrogen production technologies are still at an early stage of scaling up. Australian projects could increase demand for these technologies, which would help reduce costs.

Shipping hydrogen

Hydrogen cannot be shipped as a gas. To transport it, the gas must be either:

- liquefied
- converted to ammonia or some other low emissions product (for example, clean steel)
- bound to a liquid organic hydrogen carrier.

The best carrier will depend on how the hydrogen is used. Liquid hydrogen has a lower energy density than ammonia, which means less hydrogen can be carried per ship. However, it doesn't require any cracking to convert back to gaseous hydrogen. This makes liquid hydrogen best for end uses that require liquid or high-purity hydrogen.

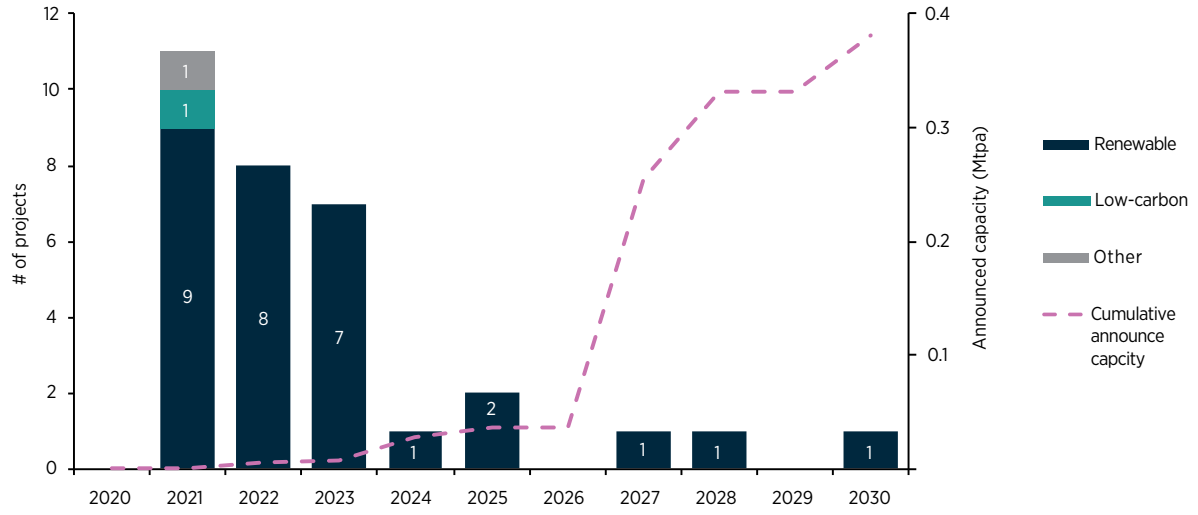
Shipping hydrogen as ammonia is easy, but converting to ammonia and back into hydrogen is energy intensive and adds cost. This means shipping as ammonia will likely be the best option only if ammonia is needed for the end use.[35]

Australia is developing both ammonia and liquefied hydrogen supply chain projects:

- Yara Pilbara and ENGIE are working together on a plant for renewable ammonia production
- The Hydrogen Energy Supply Chain (HESC) project aims to deliver liquefied hydrogen from Victoria's Latrobe Valley to Japan.

[32] https://research.csiro.au/hyresource/a-short-report-on-hydrogen-industry-policy-initiatives-and-the-status-of-hydrogen-projects-may-2021/.
[33] KPMG analysis of CSIRO HyResource project list and individual project analysis.
[34] Analysis from CSIRO National Hydrogen Roadmap (2018), IEA cost data, SA hydrogen export study and ANU Green hydrogen cost report (2020).
[35] Hydrogen Council, Hydrogen Insights Report February 2021.

Figure 3: Announced Australian projects by year of operation and output (2019 to 2030)[36]



Despite these encouraging early signs, Australia's project pipeline is made up of a small number of very large projects (Figure 3). The activities of the next few years will determine if these projects can be delivered.

To deliver these projects on time, Australian governments must keep working together to create a productive regulatory environment supported by necessary infrastructure. This work is already underway. Delivery also depends on technology advancements across the supply chain reducing production costs.

International partnerships

Australia is developing international partnerships to establish ourselves as a preferred supplier of hydrogen.

Since 2018, federal and state governments have entered into various international agreements on hydrogen. These include agreements with Republic of Korea, Japan, Singapore and Germany, all of which are expected to be net importers of hydrogen.[37] These agreements will:

- share industry knowledge
- reduce technology costs
- explore the development of international hydrogen supply chains.

Growing our already strong international relationships in this area will position Australia as a partner of choice for exporting low emissions energy, including clean hydrogen.

In 2021, the Australian Government announced new partnerships with Germany, Singapore, Japan, Republic of Korea and the United Kingdom.

Australia and Germany will work together on a series of new initiatives to accelerate the development of a hydrogen industry under a new Hydrogen Accord. The accord builds on Australia's existing collaboration with Germany on low emissions technologies including hydrogen, with a 2-year supply chain study between the 2 countries already underway.

Australia and Singapore will establish a $30 million partnership to accelerate deployment of low emissions fuels and technologies (like clean hydrogen) in maritime and port operations.

The Japan–Australia Partnership on Decarbonisation through Technology will increase our shared focus on priority low emissions technologies, including clean fuel ammonia and clean hydrogen.

The Republic of Korea and Australia will work together to drive increased adoption of low and zero emissions technologies.

Australia and the United Kingdom have agreed to collaborate on research and development across technologies crucial to decarbonising the global economy, including clean hydrogen.

The private sector is also building international partnerships. Some of Australia's largest organisations have signed memorandums of understanding (MoUs) with supply chain partners. These MoUs will secure trade routes for hydrogen and other low-carbon exports, including low-carbon steel.

For example, Origin Energy has signed an MoU with POSCO, one of Korea's largest steelmakers and trading and resource companies. The companies will cooperate to produce and supply renewable hydrogen to Korea[38].

[36] KPMG Analysis of HyResource project database as at September 2020, supplemented by additional research to fill data gaps where possible.
[37] Hydrogen Council, Hydrogen Insights, 2021.
[38] https://fuelcellsworks.com/news/origin-energy-and-posco-to-cooperate-on-green-hydrogen/.

Demand

Australia's most developed areas of hydrogen demand are:

- ammonia production, where clean hydrogen can replace the existing use of high-carbon hydrogen
- blending into gas networks.

Other areas where hydrogen is likely to become cost-competitive early are:

- heavy transport
- remote power generation
- mining vehicles.

Hydrogen for industrial applications and heating is unlikely to reach cost parity with existing fuels anywhere in the world before 2030.

Battery electric vehicles may be more cost competitive for passenger cars such as urban vehicles and mid-range vehicles. However, customer preferences will drive the choice of vehicle.[39]

Clean ammonia

The largest current use for hydrogen in Australia is as a chemical feedstock for ammonia production.

This ammonia is used to manufacture products such as:

- fertilisers
- industrial chemicals
- explosives
- plastics.

Clean ammonia is also the most developed application for clean hydrogen in Australia. Clean ammonia could also be used to export clean hydrogen and as a new type of fuel for shipping.

Nine clean ammonia production projects are being developed in Australia.[40] These projects range from small-scale pilot and demonstration studies to large-scale developments. Some of the larger projects will produce ammonia for export.

For example, the Australian Government, through ARENA, is providing up to $42.5 million to Engie Renewables Australia for a 10 MW electrolyser project. The project will produce renewable hydrogen at Yara Pilbara Fertilisers' ammonia facility in Karratha, Western Australia.

Clean steel

Clean steel is a great opportunity for Australia thanks to our extensive iron ore resources and competitive advantage in producing hydrogen. Low emissions steel and aluminium are priority technologies under the Technology Investment Roadmap because of their economic and emissions reduction benefits.

Clean steel production in Australia is at an early stage. However, Fortescue Metals, Rio Tinto and GFG Alliance have all made recent announcements on clean steel. In 2021, Fortescue began constructing a pilot low emissions steel plant alongside a commercial renewable power plant in the Pilbara in WA.

[39] Hydrogen Council, Hydrogen Insights Report, February 2021.
[40] KPMG, Hydrogen State of the Nation, June 2021.

Electricity

Hydrogen could provide long-duration storage for firming Australia's electricity grid. It could also help decarbonise power generation in remote areas of Australia.

Using hydrogen for power generation can facilitate sector coupling. For example, hydrogen production and use will more closely link the electricity grid, the gas distribution network and the infrastructure supplying fuel for vehicles. This will see multiple sectors benefit from a rapidly growing clean hydrogen industry.

Like most of the world, hydrogen for electricity is in its early stages in Australia. However, 8 trials with grid-support components are being developed. For example:

- Horizon Power is developing 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[41]
- Three new Australia gas generators have announced plans to install hydrogen-ready gas turbines at their plants (including the Hunter Power Project, Tallawarra B and Port Kembla gas generator), with the Australian Government announcing a $24.9 million to support new gas generators to be hydrogen-ready.

The use of hydrogen for mining and off-grid applications is currently limited in Australia and around the world. However, several major mining companies, including Australian companies, are exploring hydrogen-related opportunities.

Transport

Transport shows promise as an early use for hydrogen, particularly line-haul and back-to-base vehicles. However, hydrogen for transport is at an early stage in Australia. Various challenges need to be overcome to make hydrogen in transport a reality.

Refuelling infrastructure needs to be deployed, vehicles need to become cheaper and more widely available, and we need low-cost hydrogen supply. Consumer choice will also play an important role in deciding which vehicle technologies become popular.

The uptake of hydrogen fuel cell vehicles is dependent on the rollout of hydrogen refuelling stations. However, Hyundai and Toyota have introduced their hydrogen fuel cell vehicles to the Australian market for fleets and early adopters, with special arrangements being made for refuelling. The government's Future Fuels Fund will also consider funding for hydrogen refuelling infrastructure across Australia.

Twelve Australian projects in development will focus on hydrogen use in transport. Another 12 projects have potential for hydrogen transport along with other uses. Fifteen of these 24 projects are scheduled to start operating before 2025.

Most of these projects focus on developing refuelling infrastructure:[42]

- In March 2021, ActewAGL opened Australia's first public hydrogen refuelling station in Canberra. The station will service a fleet of 20 Hyundai Nexos being trialled by the ACT Government
- Toyota Australia is converting its decommissioned car manufacturing plant in Altona into a renewable energy hub. The hub will produce renewable hydrogen for use in both transport and stationary applications. The project has received $3.07 million in funding from the Australian Government and is expected to be fully operational in 2021.

To date, the Australian Government has provided around $1.4 billion to support low and zero emissions vehicle technologies, including for hydrogen-fuelled vehicles.

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

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

Hydrogen hubs will provide an opportunity to bring vehicle manufacturers, hydrogen producers and fuel suppliers together, particularly for back-to-base applications. Hubs will provide a platform to coordinate rollout and share risks.

41 HyResource project database.
42 KPMG analysis of HyResource project database.

Gas networks

Hydrogen can be used in Australia's gas networks for residential, commercial and industrial applications. Using existing gas infrastructure could:

- maximise the use of this critical infrastructure
- reduce costs for end users by lowering capital costs for transport.

Australia's activities in this area are beginning to outpace other countries. Three projects are already testing the blending of hydrogen into gas networks, and 11 more are under development.

One of the most advanced projects is AGIG's Hydrogen Park South Australia in Adelaide. The project has been supplying 700 houses with 5% blended hydrogen since May 2021.

Figure 4: Current hydrogen blending projects in Australia[43]

Clean Energy Innovation Hub
Demonstration of gas blending on a small scale to a display home, studying home appliance performance at various H2 blending rates.

Dampier to Bunbury Natural Gas Pipeline
Feasibility study examining the compatibility of the transmission pipeline with blended hydrogen.

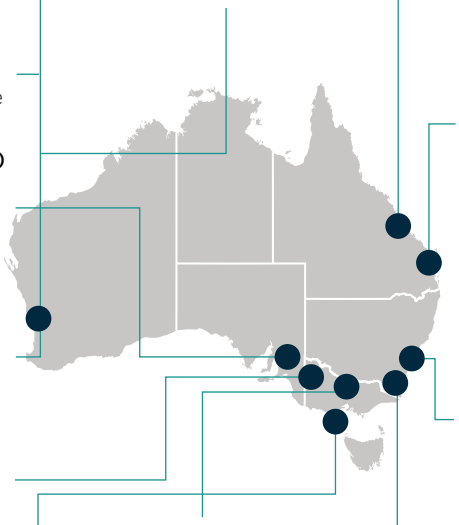
Hydrogen Park South Australia (HyPSA)
HyPSA is an innovative project that will produce renewable hydrogen to be blended with natural gas to be supplied to nearby homes via the existing gas networks.

Murchison Renewable Hydrogen
Alongside hydrogen export, the facility is anticipated to blend hydrogen into natural gas pipeline connecting Dampier and Bunbury.

Australian Hydrogen Centre
Centre Assessing feasibility of hydrogen blending into gas networks of VIC/SA regional towns.

Portland Green Hydrogen Project
Wind or solar powered hydrogen production facility near Portland in Victoria for export and gas blending.

Clean Energy Innovation Park
Feasibility study examining potential for a commercial hydrogen production facility for end use in gas networks, transport and industry.



Hydrogen Park Murray Valley
Regional town hydrogen blending initiative, testing up to 10% blended hydrogen to decarbonise gas supply in Albury (NSW) and Wodonga (VIC).

AGN Hydrogen Park Gladstone
Australia's first renewable hydrogen production facility plant will deliver up to 10% blended hydrogen across the city's residential, small, commercial and industrial customer base.

APA Renewable Methane Demonstration Project
Demonstration end-to-end hydrogen system including electrolysis from solar power, fuel cell power and injection into gas networks.

Utilitas-Recarbon Organic Waste to H_2
Repurposing of a wastewater treatment plant into an industrial park focussing on production of renewable natural gas and hydrogen for blending into local gas networks.

Jemena Western Sydney Green Gas Project
Project is exploring a power to gas pilot on their gas network, complemented by a refuelling station. Injecting expected to begin in early 2021.

Hydrogen Test Facility – ACT Gas Network
Demonstration gas blending project to enhance understanding of the impact of blending hydrogen into the gas network supplying the ACT and Queanbeyan (NSW).

ARENA's Renewable Hydrogen Deployment Funding Round is funding 2 gas blending projects:

- $28.7 million for a 10 MW electrolyser for gas blending at ATCO's Clean Energy Innovation Park in Warradarge, Western Australia
- $32.1 million for a 10 MW electrolyser for gas blending at AGIG's Murray Valley Hydrogen Park in Wodonga, Victoria.

Several of these small pilot projects are also exploring how hydrogen could be integrated into the electricity system. For example, ATCO's Clean Energy Innovation Hub uses solar-powered electrolysis to produce hydrogen that is stored and injected into a micro-grid as a blended fuel. Although small, this trial shows how different uses of hydrogen can be intelligently combined and optimised.

Energy ministers have agreed to an expedited process to allow hydrogen and biogases to be brought within the existing regulatory framework for natural gas, which will allow for more industry development.

Supporting further progress

Australia has made a promising start on the pathway set out in the National Hydrogen Strategy. Continuing this pace is crucial for Australia to remain a world leader in hydrogen.

The rest of this report describes the actions of Australian governments since the strategy was released, as well as future opportunities for Australia.

[43] KPMG, Hydrogen State of the Nation, June 2021.

Wind farm, Blayney, NSW. Image attribution: Gettyimages Andrew Merry

3 GOVERNMENT ACTIONS TO ADVANCE THE INDUSTRY

Governments in Australia are working on activities to implement the National Hydrogen Strategy. Activities are delivered either by the Australian Government, by state and territory governments, or by the Australian Government and state and territory governments together.

Australian Government activities

Supporting research, pilots, trials and demonstrations

Pilots, trials and demonstrations are essential for new industries to evolve. The Australian Government is helping the industry develop demonstration and pilot hydrogen projects through a wide variety of initiatives. Australian Government funding for hydrogen includes:

- $1.78 billion through the Australian Renewable Energy Agency (ARENA)[44]
- $300 million through the Clean Energy Finance Corporation (CEFC)
- $464 million through the Activating a Regional Hydrogen Industry: Clean Hydrogen Industrial Hubs program
- Over $300 million to develop carbon capture, use and storage (CCUS) projects and hubs, and advance technologies.

Hydrogen research, knowledge sharing and collaboration is supported by work at:

- CSIRO
- Geoscience Australia
- National Energy Resources Australia (NERA), an industry growth centre funded by the Australian Government.

Hydrogen also features in a number of cooperative research centres (CRCs) including:

- Future Fuels CRC
- Blue Economy CRC
- RACE for 2030 CRC
- Future Energy Exports CRC
- Heavy Industry Low-Carbon Transition CRC

The Australian Research Council (ARC) has also provided around $33 million in grants for hydrogen research.

Activating a Regional Hydrogen Industry: Clean Hydrogen Industrial Hubs program

The National Hydrogen Strategy identifies hydrogen hubs as the best way for the Australian industry to achieve scale.

Hydrogen hubs are regions where multiple hydrogen producers, user and potential exporters are colocated. This minimises the cost of infrastructure such as powerlines, pipelines, storage tanks and refuelling stations.

The hub model will also build domestic demand by:

- supporting economies of scale to deliver hydrogen to end users
- sharing early movers' risk across sectors.

Hydrogen hubs will create economies of scale to drive down costs of production, unlocking further demand for hydrogen as costs fall. Hubs will also create efficiencies by leveraging and supporting the existing industrial capabilities and workforces in relevant regions. Hubs will stimulate innovation and increase workforce skills development, as well as support other existing industrial sectors in these regions to lower both emissions and costs in doing business.

The Australian Government has announced $464 million from 2021–22 over 5 years for the Activating a Regional Hydrogen Industry: Clean Hydrogen Industrial Hubs program. This includes funding to support the early design works of hydrogen hubs, of which an estimated $30 million is available for Hydrogen Hub Development and Design Grants.

The Australian Government will provide over $300 million to fund carbon capture, use and storage (CCUS) projects and advance technologies. This includes establishing CCUS hubs near high-emitting industrial areas. CCUS hubs may complement the hydrogen hubs by enabling the production of clean hydrogen from fossil fuels with CCS. The government has also developed an Emissions Reduction Fund method to credit abatement from new CCS projects.

[44] ARENA has committed over $160 million to hydrogen projects, and has $1.62 billion available to support the next generation of energy technologies.

Regional hydrogen technology clusters

In February 2021, NERA announced a $1.85 million investment in 13 regional hydrogen technology clusters across all Australian states and territories.

The clusters will accelerate and optimise the development of hydrogen technology and expertise in Australia. The clusters also benefit from state and territory government funding and industry financial support.

ARENA unlocking hydrogen potential in research and development

In 2018, ARENA, on behalf of the Australian Government, set out to turn the potential of renewable hydrogen into a productive industry. ARENA awarded $22.1 million in funding to 16 hydrogen-related research teams across 9 universities and research institutions.

This work aims to unlock innovations at each point of the hydrogen export and supply chain, including production, energy carriers and end use.

Two and half years on, the projects are showing some remarkable results.

Hydrogen research – ammonia from renewables ($913,000 grant)

One project set out to produce ammonia from renewable energy at ambient temperatures and pressures. The project is led by Monash University in collaboration with the University of Wollongong.

The process uses renewable energy to power an electrolyser that splits water into hydrogen and oxygen. Hydrogen can also be sourced from the atmospheric nitrogen using an air separation unit. This hydrogen can then be converted to ammonia using a non-Haber-Bosch process.

The team has achieved their milestones to date. They are also improving the performance of producing ammonia from atmospheric nitrogen at ambient conditions.

Reversible storage of hydrogen in carbons ($805,000 grant)

RMIT University is developing a system to store and transport renewable hydrogen in a dry carbon-based powder or slurry.

This would be cheaper to manage than liquid hydrogen, allowing more hydrogen to be exported. The technology is environmentally friendly and does not produce any emissions.

Testing of the novel 'proton flow reactor' system shows it can recover 60% of the hydrogen stored in the 'wet to dry' electrodes created for the project.

Hydrogen from efficient solar ($1.72 million grant)

Researchers from the Australian National University (ANU) set out to simplify the process of converting solar energy into hydrogen.

Existing systems use separate solar and electrolyser technologies, but ANU is developing an integrated solar hydrogen cell. This will boost efficiency and reduce infrastructure costs by eliminating the need for transmission lines, inverters and electrolysers.

The team has demonstrated efficiencies of 16% using perovskite-silicon tandem cells and low-cost catalysts. Their work has received international recognition, including being named a global top 10 innovation by the Innovation for Cool Earth Forum (ICEF) in 2020.

For a full list of hydrogen projects funded by ARENA, visit arena.gov.au/renewable-energy/hydrogen.

ARENA Renewable Hydrogen Deployment Funding Round

Reducing the cost of renewable hydrogen will be vital to achieving the potential of the technology. Achieving the Australian Government's target of $2 per kilogram of hydrogen will require cost reductions across the supply chain.

To support this, ARENA has conditionally approved $103.3 million towards 3 commercial-scale renewable hydrogen projects as part of its Renewable Hydrogen Deployment Funding Round.

Engie Renewables, ATCO Australia and Australian Gas Networks (AGIG) were selected to install 10 MW electrolysers at sites in Western Australia and Victoria. These 10 MW electrolysers would match the biggest built in the world so far, such as the REFHYNE project in Germany[45] and the Fukushima Hydrogen Energy Research Field at Namie town in Fukushima.[46]

Engie's project will use renewable hydrogen to produce ammonia at the Yara Pilbara Fertilisers site. ATCO's and AGIG's projects will use renewable energy to produce renewable hydrogen for gas blending into existing natural gas pipelines.

Australia's hydrogen industry is in its infancy. The lessons learned from these projects will help shape our hydrogen economy and support commercial-scale renewable hydrogen deployment in future.

CEFC Advancing Hydrogen Fund

The CEFC has made up to $300 million available to support the growth of the Australian hydrogen industry.

The Advancing Hydrogen Fund focuses on projects that align with the National Hydrogen Strategy. It includes projects with financial support from state or territory governments.

Eligible projects will:

- advance hydrogen production
- develop export and domestic hydrogen supply chains, including infrastructure for hydrogen export
- establish hydrogen hubs
- help build domestic demand for hydrogen.

[45] European Commission: Clean Refinery Hydrogen for Europe, accessed September 2021.
[46] Toshiba Energy Systems Press Release, accessed September 2021.

Mapping Australia's Hydrogen Future – the Hydrogen Economic Fairways Tool

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-financial analysis of future large-scale hydrogen projects. It assesses the quality of energy resources required to produce hydrogen, such as:

- wind
- solar
- concentrated solar power
- hybrid wind and solar
- fossil fuels with carbon capture and storage.

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.

Geoscience Australia and Monash University are building an updated version of HEFT through the Australian Government's Exploring for the Future program. The new version will add energy inputs for renewable hydrogen production, including hydropower, pumped hydro, and hybrid wind and hydro. It will also include underground options for large-scale hydrogen storage such as salt and depleted gas reservoirs.

You can access HEFT through Geoscience Australia's hydrogen data portal at AusH2.ga.gov.au. The portal has over 7,000 additional geospatial datasets (including Geoscience Australia's newly released renewable energy capacity factor maps).

Hydrogen Energy Supply Chain Project

The $500 million Hydrogen Energy Supply Chain (HESC) Project is a world-first collaboration involving Japanese and Australian industry and the Victorian, Australian and Japanese Governments.

The project will safely produce and transport clean liquid hydrogen from the Larrobe Valley in Victoria to Kobe in Japan. This will be the first time that liquefied hydrogen has been transported between 2 continents.

The pilot will develop a complete hydrogen supply chain by:

- creating hydrogen gas by gasifying Latrobe Valley brown coal
- transporting it to the Port of Hastings to be converted into liquid hydrogen
- shipping it to Kobe.

The Australian facilities commenced operations in March 2021. The first shipment of hydrogen from Australia to Japan is expected to occur between October 2021 and March 2022.

The decision to progress to a commercialisation phase, which will produce clean hydrogen from coal with CCS, will be made after the pilot project is completed. A commercial HESC could reduce greenhouse gas emissions by 1.8 million tonnes a year and would require carbon capture and storage to store CO_2 emissions. The Victorian and Commonwealth's CarbonNet project is developing a multi-user CCS hub network in Gippsland as a key enabler of new decarbonised industries, including clean hydrogen production.

Carbon capture, use and storage (CCUS)

Ongoing investments in CCUS are critical to reducing the costs of clean hydrogen produced from steam methane reforming and coal gasification. These cost reductions are needed for a competitive clean hydrogen industry in Australia.

The Australian Government will provide over $300 million to:

- fund carbon CCUS projects
- help establish CCUS hubs near high-emitting industrial areas
- support research, development and commercialisation efforts.

This includes establishing a $250 million CCUS Hubs and Technologies Program. The program will fund demonstration and commercial-scale CCUS projects and hubs, as well as accelerate the development of CO_2 utilisation technologies with export potential.

The government will also develop a National CCUS Technology Emissions Abatement Strategy. This strategy will:

- signal government priorities for CCUS
- improve policy frameworks
- guide coordination to deploy CCUS hubs.

This new funding builds on the $50 million CCUS Development Fund announced in the 2020–21 Budget. The CCUS Development Fund supports pilot and pre-commercial CCUS projects. Grant recipients were announced in June 2021.

The government has also announced the development of an Emissions Reduction Fund method to credit abatement from new CCS projects.

Hydrogen-ready generators

The Australian Government is providing $24.9 million for hydrogen-ready turbines and associated infrastructure in new gas generators.

The first gas generator to receive funding under this program is EnergyAustralia's 316 MW Tallawarra B dual fuel capable power station, currently under development in New South Wales. The government will provide $5 million to complement support being provided by New South Wales to support the plant being made hydrogen ready.

The Australian Government has also committed up to $600 million for Snowy Hydro Limited to construct a 660 MW open cycle gas turbine at Kurri Kurri in the Hunter Valley, which will be hydrogen-ready.

Hydrogen-ready turbines can use natural gas and clean hydrogen in varying blends. A number of gas manufacturers are already manufacturing and selling these turbines around the world.

Demonstrating hydrogen-ready turbines in Australia will prove their technical capability and enable their use around the world. This will increase the demand for Australian clean hydrogen domestically and internationally and ensure these generators remain commercially competitive.

Future Fuels Strategy and Future Fuels Fund

In November 2021 the Australian Government released the first national Future Fuels and Vehicles Strategy, which is backed by an expanded $250 million Future Fuels Fund investment.

This technology-led strategy will see the government work with industry to:

- enhance consumer choice
- create jobs
- reduce emissions in Australia's transport sector.

The strategy also puts practical action behind the Low Emissions Technology Statement 2021 priority for enabling infrastructure. Public electric vehicle charging and hydrogen refuelling infrastructure is a priority for investment under the Future Fuels Fund.

The Future Fuels Fund will support the assessment of deployment needs and opportunities to roll out hydrogen refuelling infrastructure to meet demand. The fund will also support demonstration of hydrogen refuelling stations for hydrogen hubs, major freight routes and passenger road corridors in Australia.

Hydrogen research collaborations and knowledge sharing

The Department of Industry, Science, Energy and Resources and CSIRO have established the Australian Hydrogen Researcher Network.

The network brings together stakeholders from across Australia's hydrogen research and development community. It identifies research gaps and enables collaborative research to help develop Australia's hydrogen industry.

The network will deliver the department's $5 million researcher mobility and research collaborations program, with CSIRO as a partner.

CSIRO Hydrogen Industry Mission

CSIRO's Hydrogen Industry Mission will help achieve the National Hydrogen Strategy's vision of a globally competitive Australian hydrogen industry.

Through research, development and demonstration (RD&D) partnerships and projects, the mission will help:

- increase demand for hydrogen
- drive down hydrogen costs
- create jobs
- achieve lower emissions energy systems.

Formally launched on 26 May 2021, the mission is founded on CSIRO's existing long-term research capability and effort in hydrogen energy RD&D.

Hydrogen knowledge centre

One important mission initiative is developing a Hydrogen Knowledge Centre as a national resource for industry, government and the research community.

The knowledge centre will highlight developments in Australia's hydrogen industry and provide tools and resources for new entrants to the industry. The first module, HyResource, was launched in September 2020 with NERA, the Future Fuels Cooperative Research Centre and the Australian Hydrogen Council.

Feasibility and strategy studies

The mission will provide analysis and independent advice on hydrogen opportunities to government, industry and the community.

CSIRO has already made contributions including:

- the 2018 National Hydrogen Roadmap
- hydrogen cost modelling and barrier analysis for the National Hydrogen Strategy
- a report (with long-term partner Boeing) on the contribution that clean hydrogen-based technologies can make to emissions reduction in the aviation sector.

Demonstration projects

The mission is developing demonstration projects that validate hydrogen value chains and reduce risks for enabling technologies.

One example is the hydrogen refuelling station and hydrogen technology demonstration facility at the Victorian Hydrogen Hub. Located at CSIRO's Clayton campus in Melbourne, the project is a collaboration with Swinburne University of Technology and the Victorian Government.

Enabling science and technology solutions

The mission is working with partners to deliver enabling science and technology solutions and socio-economic analysis to help the hydrogen industry scale up.

This includes CSIRO's Hydrogen Energy Systems Future Science Platform. It also includes a major partnership with Fortescue Metals Group focusing on the development and commercialisation of new hydrogen technologies.

Hydrogen Industry Mission partners

CSIRO and its partners will invest more than $68 million in the development of Australia's industry-relevant hydrogen RD&D capabilities.

As Australia's national science agency, CSIRO is in a unique position to bring research, government and industry together.

Hydrogen Industry Mission partners include:

- Department of Industry, Science, Energy and Resources
- ARENA
- Fortescue Metals Group
- Swinburne University
- Victorian Government
- Future Fuels CRC
- NERA
- Australian Hydrogen Council
- other collaborators such as Toyota, Hyundai and Boeing.

International engagement

As countries look to decarbonise their economies, the Australian Government is working closely with trading and strategic partners to deliver on our commitments and goals.

The Special Adviser to the Australian Government on Low Emissions Technology, Dr Alan Finkel, plays a key role in brokering international low emissions technology partnerships. These partnerships will deliver projects that advance the goals of the Technology Investment Roadmap, including clean hydrogen.

The Australian Government committed $565.8 million to international partnerships through the 2021–22 federal Budget. Partnerships will use a co-investment model, recognising the different roles that export and import markets play in the industry.

These partnerships will build on existing collaboration with strategic trading partners including Germany, Japan, Korea, Singapore, the United States and the United Kingdom.

Bilateral engagement

Bilateral agreements are crucial to making Australia a hydrogen partner of choice. They can include commitments to:

- promote trade and investment
- prove the feasibility of supply chains
- build technical collaborations to support research and development.

Japan

Australia signed the Joint Statement of Cooperation on Hydrogen and Fuel Cells with Japan in January 2020. This builds on our countries' collaboration on the HESC pilot project.

In June 2021 the Australian and Japanese Governments announced a new partnership. The Japan–Australia Partnership on Decarbonisation through Technology will increase our shared focus on priority low emissions technologies, including clean fuel ammonia and clean hydrogen.

Germany

In September 2020, Australia and Germany signed a joint declaration of intent to study the feasibility of a supply chain for renewable hydrogen. Known as HySupply, the feasibility study started in December 2020. A consortium led by the University of New South Wales, Deloitte and Baringa Partners are the Australian partners for the study.

In June 2021 the Australian and German governments announced a series of new initiatives to accelerate the development of a hydrogen industry under a new Hydrogen Accord.

Under the accord, Australia and Germany will:

- establish HyGATE, the German-Australian Hydrogen Innovation and Technology Incubator. HyGATE will co-fund pilot, trial, demonstration and research projects along the renewable hydrogen supply chain. Australia will contribute $50 million and Germany €50 million
- facilitate industry-to-industry cooperation on demonstration projects in Australian hydrogen hubs
- explore options to export renewable hydrogen and ammonia from Australia to Germany.

Korea

Australia signed a letter of intent with the Republic of Korea on 27 September 2019. The countries agreed to develop a hydrogen action plan and cooperate on hydrogen development.

A new low and zero emissions partnership with the Republic of Korea was signed on 31 October 2021. This partnership will support research on hydrogen supply chains between the countries.

Singapore

Australia and Singapore developed a Memorandum of Understanding on Low Emissions Technologies, which includes cooperation on hydrogen. The memorandum was signed by Australia's Minister for Energy and Emissions Reduction on 26 October 2020.

In June 2021 the Australian Government announced a new $30 million partnership with Singapore. This partnership will accelerate the deployment of low emissions fuels and technologies (like clean hydrogen) in maritime and port operations. The partnership recognises Singapore's role as a major shipping hub and Australia's ambition to be a leader in the use of clean hydrogen and clean ammonia.

Each country will commit up to $10 million over 5 years to fund industry-led pilot and demonstration projects. Industry is expected to provide at least $10 million of additional investment.

Multilateral engagement

Australia is engaging in international forums to:

- shape the rules for hydrogen trade and investment
- share best practices for RD&D and community engagement
- encourage private sector investment.

Our influence in these forums ensures Australian hydrogen will be accepted around the world.

Australia led the Mission Innovation Renewable and Clean Hydrogen Challenge along with Germany and the European Commission. We are co-leading a new Mission Innovation initiative on hydrogen with Chile, the European Union, Saudi Arabia, the United States of America and the United Kingdom. The initiative will speed up clean hydrogen innovation to achieve performance breakthroughs and lower costs.

Australia is a member of the Center for Hydrogen Safety, a global non-profit dedicated to promoting hydrogen safety and best practices. This is informing the development of domestic skills and training for the hydrogen industry.

Other multilateral forums on hydrogen Australia is part of include:

- G20 energy ministers meetings
- G20 working groups on climate sustainability and energy transition
- International Partnership for Hydrogen and Fuel Cells in the Economy
- Clean Energy Ministerial Hydrogen Initiative.

Austrade support for the hydrogen industry

Austrade is helping position Australia as a reliable producer of clean hydrogen to meet future global demand. It is attracting international project developers and technology providers to develop the global hydrogen industry with Australian partners.

This includes:

- engaging with foreign governments and industry to promote Australia as a preferred partner to supply hydrogen
- helping connect Australian projects with investors, leading to offtake agreements
- promoting Australia to global energy companies, technology companies and fund managers as a place to invest
- building a global hydrogen industry with long-term economic opportunities for Australians.

Austrade helped Kawasaki Heavy Industries and its partners launch the $496 million Hydrogen Energy Supply Chain (HESC) pilot project in Victoria's Latrobe Valley. Austrade provided assistance including:

- coordinating meetings with Australian Government ministers
- providing advice on Australian Government funding programs
- intergovernmental coordination.

Austrade introduced Origin Energy to POSCO, one of South Korea's biggest steelmakers. The companies are investigating exports of renewable hydrogen made in Tasmania and Queensland.

Austrade introduced Stanwell Corporation to Japanese company Iwatani and Singapore's Keppel DC. The companies are developing Gladstone's green hydrogen export hub.

Hydrogen Guarantee of Origin scheme

Australia's National Hydrogen Strategy identified a Guarantee of Origin or certification scheme for hydrogen as an early priority.

A Guarantee of Origin scheme will offer transparency to consumers on how and where the hydrogen they choose to buy is produced. This includes identifying the energy source and technology used to produce it, as well as associated carbon emissions. The scheme is a vital step towards global trade in this new clean energy.

The Australian Government is developing the Guarantee of Origin scheme for hydrogen. In June 2021 the Department of Industry, Science, Energy and Resources released a discussion paper outlining the proposed design of a domestic hydrogen Guarantee of Origin scheme.

The department is taking a lead role in the Production Analysis Taskforce of the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE). The taskforce is developing a methodology to determine the greenhouse gas emissions of different hydrogen production pathways. The proposed scheme aligns with Australia's requirements and our work through IPHE.

The Australian Government has announced $9.7 million to support trials of the Guarantee of Origin scheme in Australia. We are to conduct these trials with the Clean Energy Regulator.

Activities delivered jointly by governments

Australia's federal, state and territory governments are working together on activities under the National Hydrogen Strategy.

The Hydrogen Project Team is a group of federal and state and territory officials that shares information across jurisdictions and oversees these joint projects.

National Hydrogen Infrastructure Assessment

The Australian Government is leading a National Hydrogen Infrastructure Assessment in consultation with the states and territories. It is due for completion by 2022.

This assessment will:

- consider the infrastructure needs, availability and gaps in hydrogen supply chains across Australia
- support future decisions to invest in hydrogen
- be an essential step in developing hydrogen hubs
- help enable hydrogen export.

Hydrogen gas reforms

On 20 August 2021, Energy Ministers agreed that the national gas regulatory framework should be amended to bring hydrogen, bio-methane and other renewable gas blends within its scope. This will include amendments to:

- the National Gas Law (NGL), the National Gas Regulations, the National Gas Rules (NGR), procedures and other subordinate instruments made under the NGL and/or NGR
- the National Energy Retail Law (NERL), the National Energy Retail Regulations and the National Energy Retail Rules (NERR).

Jurisdictional officials, the Australian Energy Market Commission (AEMC) and the Australian Energy Market Operator (AEMO) have each been tasked with progressing different aspects of the reforms.

Officials will identify and develop amendments to the NGL, NERL and regulations, the AEMC will identify and develop amendments to the NGR and NERR, and AEMO will identify and develop amendments to the procedures and other AEMO-made instruments required for settlement and metering in the facilitated and regulated retail gas markets.

Energy Ministers agreed to an expedited process to complete these reforms. A draft legislative package is to be presented to Ministers for approval by mid-2022 and draft rules in the latter half of 2022.

Hydrogen gas review

The Australian Government is also undertaking work to complete the review of hydrogen in gas networks under Action 3.12 of the National Hydrogen Strategy.

This included a review of the National Gas Law, which informed Energy Ministers' decision to expedite these amendments.

The review also is also considering:

- options for a framework to set and update the volume of hydrogen that can be blended in gas networks
- the economics of blending and the eventual use of 100% hydrogen in Australian gas networks.

Legal frameworks review

The Australian Government is reviewing legal frameworks and standards relevant to hydrogen industry development and safety.

The review will determine:

- if existing regulatory frameworks will enable industry development and ensure safety
- any amendments required to ensure appropriate regulation.

We are working with states and territories to coordinate this review and develop a work program for the required regulatory reforms.

Skills and training

South Australian members of the Hydrogen Project Team are leading work on skills, training and emergency services for hydrogen industry development. This project will support future development of nationally consistent training materials and guidelines for producing, handling, using and transporting hydrogen. It will use resources available through Australia's membership of the US-based Center for Hydrogen Safety.

In 2020, the Australian Government made a commitment to subsidise Australian emergency services workers to participate in hands-on training courses from the Center for Hydrogen Safety. These courses could not be delivered as planned due to the COVID-19 pandemic. The Australian Government is working with the Australasian Fire and Emergency Services Authorities Council on how to best deliver this and other training to emergency services workers.

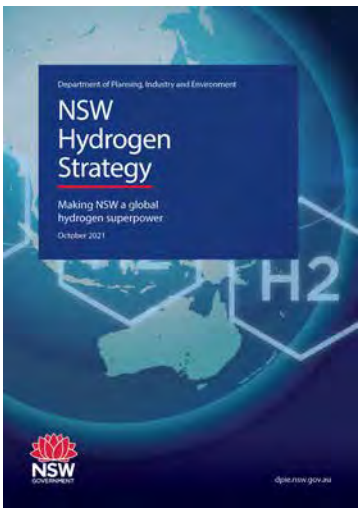
Community engagement

Engaging the community is vital to developing a hydrogen industry that benefits all Australians. Tasmanian members of the Hydrogen Project Team are laying the groundwork for a community education program that will provide clear and accessible information about the risks, benefits and safe use of hydrogen. The program will also support best-practice for community engagement with an interjurisdictional communications and engagement working group overseeing this work stream.

STATE AND TERRITORY GOVERNMENT ACTIVITIES

New South Wales

The NSW Hydrogen Strategy



In October 2021, the NSW Government released the NSW Hydrogen Strategy, the State's bold vision and pathway to enable NSW to be a global first mover in the hydrogen industry, with ambitious policies that capitalise on NSW's natural strengths.

The policies set out in the Strategy aim to:

- reduce the cost of green hydrogen by $5.80 per kg in the next decade to reach under $2.80 per kg
- provide up to **$3 billion** of incentives to support industry development to deliver NSW's 2030 stretch targets of 110,000 tonnes of green hydrogen production per annum and 10,000 hydrogen heavy vehicles.

A total of 60 key actions will be implemented under the Strategy, which will enable industry development and drive rapid scale. In addition to delivering an already committed $70 million to develop the State's hydrogen hubs in the Illawarra and the Hunter regions, the Strategy includes:

- exemptions for green hydrogen production from government scheme charges
- a 90% exemption from electricity network charges for green hydrogen producers who connect to parts of the network with spare capacity
- a hydrogen refuelling station network to be rolled out across the State.

Hydrogen hubs

A key action of the NSW Hydrogen Strategy is the development of hydrogen hubs, initially in the Hunter and Illawarra regions. NSW has committed at least $70 million to the hydrogen hub initiative, which is targeting opening for expressions of interest in late October 2021.

The hydrogen hub initiative focuses on developing new demand and scaling up hydrogen production for multiple end uses, particularly heavy transport and industrial sectors. The initiative also enables other uses of hydrogen such as gas blending, export and electricity.

In addition, the initiative aims to foster collaboration and connections between larger, more developed projects and potential new hydrogen consumers. The NSW Government has launched a platform to drive collaboration between stakeholders and accelerate the growth of NSW's green hydrogen industry.

Net Zero Industry and Innovation program

The $750 million Net Zero Industry and Innovation Program is the NSW Government's plan to support and partner with industry to reduce emissions and help NSW businesses prosper in a low carbon world. There are 3 areas of funding, all of which are available to hydrogen projects:

- $380 million to help existing industries transition to low-emissions alternatives
- $175 million to set up new low-carbon industries such as green hydrogen
- $195 million to research and develop new clean technologies.

Tallawarra B – Australia's first green hydrogen and gas power plant

In May 2021 the NSW Government announced it would provide $78 million in funding to support development of EnergyAustralia's Tallawarra B 316 MW open cycle gas turbine. The Commonwealth also committed to provide $5 million in additional funding to support the plant being hydrogenready. The plant will be Australia's first dual-fuel power plant using both green hydrogen and gas.

Under the funding agreement, EnergyAustralia will offer to buy green hydrogen equivalent to over 5% of the plant's fuel use (about 200 tonnes of green hydrogen per year) from 2025. EnergyAustralia will offset direct carbon emissions from the plant over its operational life. EnergyAustralia will also invest in engineering studies investigating if the plant can be upgraded to use more green hydrogen in future.

Australia's first hydrogen refueller for heavy transport.

Coregas is the largest Australian owned gases company. It is helping develop Australia's hydrogen transport sector by investing in refuelling infrastructure at its Port Kembla industrial gas plant.

Coregas received funding through the NSW Government's Port Kembla Community Investment Fund to build a hydrogen refuelling station at its Port Kembla site. The refueller will be able to dispense 450 kg of fuel cell–quality hydrogen per day at 350 bar pressure.

This project will:

- deploy Australia's first fleet of hydrogen fuel cell trucks
- improve the environmental footprint of transport in the region
- show that fuel cell vehicles are commercially viable for Australian fleets
- showcase the technology's potential to improve energy security, create jobs and investment, and decarbonise the transport sector.

The hydrogen refueller is expected to be operational by mid-2022. Hydrogen will be sourced from Coregas's adjacent hydrogen production facility, which produces hydrogen from natural gas. This will reduce emissions by approximately 50% compared to the diesel trucks currently in use. Emissions could be eliminated entirely once the refueller is supplied with renewable hydrogen.

The project is a key step in building on the existing hydrogen ecosystem in Port Kembla and the Illawarra–Shoalhaven area. This area has the potential to become a thriving domestic and export hydrogen hub.

Port Kembla Gas Terminal. Image attribution: Squadron Energy

Victoria

The Victorian Government launched its Renewable Hydrogen Industry Development Plan in February 2021, establishing a blueprint for an emerging renewable hydrogen industry in Victoria.

Over the next 2 years Victoria will scale up, skill up and build a strong supply chain to foster a renewable hydrogen economy. This will stimulate investment, employment, innovation and economic growth, as well as support Victoria's clean energy transition.

Accelerating Victoria's Hydrogen Industry Program

The Victorian Government announced the Accelerating Victoria's Hydrogen Industry Program to support policy development, industry development and research. The program includes funding for 2 competitive grant programs:

- The $6.2 million Renewable Hydrogen Commercialisation Pathways Fund to support renewable hydrogen pilots, trials, and demonstrations in Victoria
- The $1 million Renewable Hydrogen Business Ready Fund, to support Victorian businesses to take the first steps to transition to renewable hydrogen through business cases and feasibility studies.

Regional hydrogen technology clusters

The Victorian Government has partnered with National Energy Resources Australia (NERA) to co-fund regional hydrogen technology clusters in:

- Gippsland
- Greater Geelong
- the Mallee
- Clayton, Melbourne.

A Victorian Hydrogen Cluster Network will support the growth and coordination of these clusters.

Gas blending studies

The Victorian Government is a founding member of the Australian Hydrogen Centre, which is supporting a series of feasibility studies examining hydrogen blending in the natural gas network.

The centre's regional towns report will investigate the feasibility of a 10% hydrogen blend in Ballarat and Wodonga. The centre will also investigate a 10% state-wide hydrogen blend and a 100% hydrogen network.

Hydrogen Park Murray Valley

On 5 May 2021, the Australian Government, through ARENA, committed $32.1 million from its Renewable Hydrogen Deployment Fund to a hydrogen park at Murray Valley.

Led by Australian Gas Infrastructure Group and ENGIE, the project will develop a 10 MW electrolyser at North East Water's wastewater treatment plant in Wodonga. The Victorian Government is working with the project proponents to progress the proposal.

Zero Emissions Vehicle (ZEV) Roadmap

In May 2021, the Victorian Government launched its Zero Emissions Vehicle (ZEV) Roadmap. The roadmap is supported by a $100 million support package to fast track the transition to battery and hydrogen-powered electric vehicles.

Several programs in the ZEV support package are open to hydrogen:

- $46 million for Australia's first public ZEV subsidy program. The program will help Victorian residents and businesses purchase new ZEVs, including hydrogen fuel cell electric vehicles
- $20 million for a ZEV public transport bus trial. The government wants all public transport bus purchases to be ZEVs from 2025
- $10 million to replace the Victorian Government fleet with ZEVs
- $5 million to establish a ZEV innovation fund for the commercial sector.

Victorian Hydrogen Hub

Through the Victorian Higher Education State Investment Fund, the Victorian Government is providing $10 million for the Victorian Hydrogen Hub (VH2). The project is led by Swinburne University of Technology in partnership with CSIRO and Germany's ARENA 2036.

VH2 will:

- support sustainable manufacturing practices
- enable storage of clean energy from renewable sources
- help create a sustainable future by testing, trialling and demonstrating new and emerging hydrogen technologies.

The project includes funding for:

- a hydrogen refuelling station at CSIRO's Clayton campus
- implementation of a Victorian Hydrogen Industry Capability Program
- large-scale hydrogen engagement programs to generate active partnerships with Victorian industry.

Hycel Technology Hub

The Victorian Government is providing $9 million to Deakin University's Hycel Technology Hub through the Victorian Higher Education State Investment Fund.

The Hycel Technology Hub will develop and manufacture hydrogen fuel technology with a focus on transport, heavy vehicles and industry applications.

As part of the project, Deakin University aims to transition its Warrnambool campus from gas to hydrogen. It also aims to convert the Warrnambool Bus Lines fleet to clean energy.

Zero Emissions Energy Laboratory

The Victorian Government is providing $4.7 million to the University of Melbourne's Zero Emissions Energy (ZEE) Lab through the Victorian Higher Education State Investment Fund.

Located in the Melbourne Connect Precinct, the lab will see Melbourne University work with industry to develop a range of clean energy products across the hydrogen and solar fields.

The ZEE Lab will focus on creating new products and innovations for the commercial market, including new methods for hydrogen gas processing and fuel systems.

Hydrogen testbed and training precinct. Image attribution: Deakin University.

Other government funding

Eligible renewable hydrogen projects may be supported through the second round of the Victorian Government's Energy Innovation Fund. Hydrogen projects were also eligible for the now-closed Business Recovery Energy Efficiency Fund.

Queensland

On 30 May 2019, the Queensland Government released the Queensland Hydrogen Industry Strategy 2019–2024. The strategy is a 5-year plan to grow a sustainable hydrogen industry that:

- supports renewable resources
- creates jobs
- strengthens our economy.

The strategy includes 17 actions across 5 focus areas. It will allow Queensland to take advantage of emerging domestic and international renewable hydrogen opportunities.

The Queensland Government has already invested over $60 million to support the development of the hydrogen industry. This includes:

- support for industry development activities
- investment in education, training and skills to provide a pathway to the highly skilled jobs of the future
- financial assistance for private sector projects through the Hydrogen Industry Development Fund.

The skills and training portion of this funding includes:

- $20 million towards a Queensland Apprenticeships Centre, which will include a Hydrogen Training Centre of Excellence
- $10.6 million towards a hydrogen and renewable energy training facility in Townsville
- $2 million to upgrade training facilities at Gladstone State High School to prepare students for jobs in the hydrogen industry
- $23 million towards the Pinkenba Renewable Energy Training Facility.

Major Projects

Fortescue Future Industries

Queensland was selected for one of the world's largest hydrogen-equipment manufacturing facilities in a partnership between the Queensland Government and Fortescue Future Industries in Gladstone. Stage one of the multi-stage project will establish Australia's first multi-gigawatt-scale electrolyser factory, with an initial capacity of 2 GW per year.

Stanwell Corporation

Stanwell Corporation and Iwatani Corporation of Japan have secured a land site west of Gladstone for a proposed 3 GW hydrogen export facility. Japanese companies Kawasaki Heavy Industries, Kansai Electric Power Company and Marubeni, and Australian energy infrastructure business APA Group, have joined the consortium with Stanwell and Iwatani.

CS Energy

CS Energy, in partnership with IHI Corporation Japan, is undertaking a feasibility study to establish a hydrogen demonstration plant next to the Kogan Creek Power Station near Chinchilla.

The project concept includes co-location of a:

- 2 MW solar farm which will provide behind-the-meter power to the hydrogen plant
- 2 MW battery
- 1 MW hydrogen electrolyser
- hydrogen fuel cell producing up to 50,000 kg of hydrogen a year.

Edify Energy

Townsville City Council formally approved the first development application over land within the Lansdown Eco-Industrial Precinct (46 kilometres south of Townsville) by Edify Energy.

Edify Energy proposes to build and operate a renewable hydrogen production facility as well as a behind-the-meter solar photovoltaic and battery storage facility at the precinct.

A memorandum of understanding was also signed between Edify Energy and the Port of Townsville to explore exporting hydrogen at the port.

Queensland Hydrogen Investor Toolkit

In May 2020 the Queensland Government released the Queensland Hydrogen Investor Toolkit as part of the strategy.

This toolkit gives investors intending to develop hydrogen projects in Queensland an overview of planning and other regulatory approvals.

Hydrogen vehicle trial

Queensland is supporting industry in the state with a 3-year trial of hydrogen fuel cell vehicles in its fleet. Five Hyundai Nexos will be part of the government fleet by the end of 2021.

This commitment was important in gas company BOC's decision to develop its $4.18 million end-to-end renewable hydrogen project in Queensland.

The project will supply BOC's industrial customers with renewable hydrogen and create Queensland's first permanent hydrogen vehicle refuelling station. This will replace the brown hydrogen currently transported from BOC's production facility in Victoria.

Ministerial appointments

In November 2020, Queensland appointed a Minister for Energy, Renewables and Hydrogen and an Assistant Minister for Hydrogen Development.

In March 2021, the Minister appointed an expert taskforce to fast track a sustainable hydrogen supply chain and accelerate the growth of the hydrogen industry in Queensland.[47]

Hydrogen Industry Development Fund

The $15 million Hydrogen Industry Development Fund was announced in 2019 as part of the Queensland Hydrogen Industry Strategy.

After significant interest in the fund, the government committed another $10 million in late 2020 for a second funding round. The second round will focus on projects related to transport and integrating hydrogen into wastewater treatment plants.

The first round of the Hydrogen Industry Development invested in 4 renewable hydrogen projects.

Australian Gas Networks – Hydrogen Park Gladstone

The Queensland government will contribute up to $1.78 million to the Australian Gas Networks (AGN) gas injection project.

This project is the first in Australia to blend renewable hydrogen into a gas network with residential, commercial and industrial customers.

AGN will partner with Central Queensland University to create educational, training and research opportunities for local workers.

Sun Metals – SunHQ

Sun Metals will receive funding of up to $5 million to build North Queensland's first renewable hydrogen facility and heavy vehicle refuelling station. The SunHQ project will be located at Sun Metals' zinc refinery in Townsville.

Renewable hydrogen from SunHQ will be used for a range of applications. This includes 5 hydrogen fuel cell electric prime-movers in the Sun Metals fleet that operates between the refinery and the Port of Townsville.

Spicers Retreats – Scenic Rim Trail ecotourism demonstration using low pressure hydrogen

The Queensland Government will provide up to $943,000 to Spicers Retreats to build a renewable hydrogen plant. The project will demonstrate low-pressure hydride remote power systems at eco-camps on the Spicers Retreats Scenic Rim Trail.

The University of Queensland – Renewable hydrogen-powered intercampus public transport

The Queensland Government will contribute up to $4.8 million to the University of Queensland's $16.2 million project to replace 2 diesel-powered intercampus buses. The buses will be replaced with hydrogen fuel cell electric buses, creating a sustainable transport solution for staff and students.

The intercampus shuttles make the 162-kilometre round trip between Gatton and St Lucia 4 times a day, 5 days a week.

[47] https://statements.qld.gov.au/statements/91665.

Western Australia

In July 2019 the Western Australian Government released the Western Australian Renewable Hydrogen Strategy

The strategy sets out 4 priority strategic focus areas:

- export
- remote applications
- hydrogen blending in natural gas networks
- transport.

Goals to 2030 include:

- WA's market share in global hydrogen exports is similar to its share in LNG today
- WA's gas pipelines and networks contain up to 10% renewable hydrogen blend
- Renewable hydrogen is used in mining haulage vehicles
- Renewable hydrogen is a large fuel source for transportation in regional WA.

In March 2021, Western Australia appointed the state's first Minister for Hydrogen Industry.

To date, the WA Government has allocated around $90 million to support the establishment of the renewable hydrogen industry in Western Australia.

Already 10 feasibility studies and 5 capital works projects have been supported through the Western Australian Renewable Hydrogen Fund (see case study of Horizon Power's Denham Hydrogen Demonstration Plant) delivering demand stimulation and project activation. A series of public knowledge sharing reports have been developed from completed feasibility studies.

The state government is also developing hydrogen hubs in the Mid-West and Pilbara regions, including a $47.5 million commitment to upgrade infrastructure in the Oakajee Strategic Industrial area in the Mid-West.

In October 2021, the state government opened $10 million of funding opportunities through the Hydrogen Fuelled Transport Program. The program is aimed at stimulating local demand for green hydrogen and to kick start take-up of hydrogen-fuelled commercial vehicles. Projects will be assessed in the first quarter of 2022.

The Western Australian Government is currently working with private sector proponents on more than 6 gigawatt scale production sites. Many of these have been granted special project lead agency status and/or special access arrangement, and are on tenure pathways. More land tenure options for proponents are being developed.

The Western Australian Government is also investigating opportunities in upstream and downstream manufacturing including:

- using hydrogen in the Collie area for the production of green products such as green aluminium and green cement
- supporting research into the viability of local environmentally sustainable production of green products including aluminium, cement and green steel, and have made a $1 million allocation to support this work
- building components required for renewable hydrogen projects such as electrolysers and wind turbines. $10 million is committed towards wind turbine manufacturing. This includes the development of a full feasibility study which is likely to be completed in mid-2022.

The state government is also delivering regulatory work to address potential barriers to industry:

- A gas blending study will consider the technical, economic and regulatory impacts of hydrogen on the distributed gas network
- Development of a supply chain model for large scale hydrogen exports
- Investigating potential hydrogen storage locations, to assist with large scale export.

More broadly, the WA Government has committed funding to stimulate local demand for renewable hydrogen, to support the establishment of local manufacturing, and to drive international investment attraction for renewable hydrogen through:

- $206 million for renewable energy initiatives
- $118 million to invest in future climate related initiatives
- $100 million for a New Industries Fund
- $50 million Industrial Land Fund to help unlock strategic industrial sites.

Horizon Power's Denham Hydrogen Demonstration Plant

Horizon Power is developing a hydrogen demonstration plant in Denham, Western Australia. It will be Australia's first project testing the technical capability of hydrogen as a power source in remote microgrids.

Denham's power supply assets are approaching the end of their useful life. So Horizon Power used the opportunity to upgrade Denham's existing diesel power station to support more renewable energy and green hydrogen.

The project received $2.6 million funding from the Australian Government as part of ARENA's Advancing Renewables Program. The Western Australian Government provided another $5.7 million (including $1 million from the Renewable Hydrogen Fund) as part of its WA Recovery Plan.

The demonstration plant will use solar and renewable hydrogen generation and storage to provide 526 MWh of renewable energy every year. This is equivalent to the energy needed to power 100 homes.

The project will reduce Denham's reliance on diesel power, lowering carbon emissions and helping preserve the region's pristine World Heritage coastline.

The hydrogen plant will consist of:

- a 704 kW solar farm
- a 348 kW electrolyser
- hydrogen compression and storage
- a 100 kW fuel cell.

Horizon Power will further increase the renewable energy produced in Denham by building another 640 kW solar farm alongside the hydrogen plant's solar farm.

The project will let Horizon Power explore if hydrogen can be used in other regional microgrid power systems across Western Australia. It will also help advance hydrogen development across Australia.

Compressed hydrogen storage tank and gas blending pipes at ATCO's Clean Energy Innovation Hub in Jandakot. Image attribution: ATCO.

South Australia

South Australia is accelerating the hydrogen economy, having released its Hydrogen Roadmap in September 2017. This was followed by South Australia's Hydrogen Action Plan in September 2019 and the Hydrogen Export Modelling Tool and Prospectus in October 2020.

South Australia's strong renewable energy sector will underpin its hydrogen economy. The state is well placed to be a major producer and exporter of clean hydrogen thanks to its:

- cheap renewable energy
- extensive natural gas and carbon capture and storage resources
- supportive regulatory regime.

South Australia has a $20 billion development pipeline of renewable generation projects and is at the forefront of the international transition to variable renewable energy.

Hydrogen funding

South Australia has already awarded around $40 million in grants and loans to 3 megawatt-scale hydrogen projects:

- Australian Gas Networks (AGN) HyP SA – AGN (part of Australian Gas Infrastructure Group) recently launched its $14.5 million demonstration project at the Tonsley Innovation District in Adelaide's southern suburbs (see case study below)
- The Hydrogen Utility (H2U) Eyre Peninsula Gateway – H2U is developing a worldleading $240 million hydrogen project near Whyalla. The project will boast a 75 MW electrolyser, which can produce enough hydrogen to make 40,000 tonnes of ammonia each year
- Neoen Australia Hydrogen Superhub – Neoen is investigating constructing a renewable hydrogen production facility powered by its Crystal Brook Energy Park.

Port Bonython infrastructure

South Australia's Hydrogen Export Modelling Tool has identified Port Bonython as a prospective hydrogen hub that can export clean hydrogen to national and global markets.

Infrastructure investment in Port Bonython so far includes a $37 million upgrade of the Port Bonython jetty.

International engagement

In July 2019, South Australia joined the Japanese-led Green Ammonia Consortium.

In March 2021, the state signed a memorandum of understanding to investigate clean hydrogen exports to the Port of Rotterdam in the Netherlands.

South Australia will continue engaging with international parties on project development and technology adoption.

Legislative reform

In 2021 the *South Australian Petroleum and Geothermal Energy Act 2000* was amended to allow hydrogen and its derivatives to be transported though pipelines. Further potential changes will enable green hydrogen the same efficient regulatory framework afforded to the oil and gas industry.

Hydrogen Park South Australia (HyP SA)

Located just south of Adelaide in the Tonsley Innovation District, HyP SA was officially opened on 19 May 2021.

Supported by a $4.9 million grant from the South Australia Government, the $14.5 million project houses Australia's largest electrolyser. The 1.25 MW electrolyser is powered by solar and wind energy and produces renewable hydrogen.

HyP SA's parent company, Australian Gas Networks, is blending approximately 5% renewable hydrogen into its natural gas network to supply more than 700 homes. They are some of the first homes in the world to use renewable gas from a mains network.

Australian Gas Networks – Hydrogen Park South Australia (HyP SA). Image attribution: Australian Gas Infrastructure Group.

Tasmania

The Tasmanian Renewable Hydrogen Action Plan was released on 2 March 2020. It has 4 pillars covering 25 actions.

Tasmanian Renewable Hydrogen Industry Development Funding Program

The Tasmanian Government's 2020–21 Budget included $50 million to implement the Tasmanian Renewable Hydrogen Industry Development Funding Program. The funding will support feasibility studies and infrastructure project proposals.

$2.6 million from the first funding round will be used to support 4 feasibility studies:

- Origin Energy is looking at developing a large-scale green hydrogen and ammonia plant
- ABEL Energy will investigate deploying a 100 MW electrolyser plant to produce green hydrogen and methanol
- Grange Resources will explore using hydrogen to replace natural gas for industrial heating.

Also announced was Fortescue Future Industries' potential development of a 250 MW hydrogen and green ammonia production facility.

Industry activation study

Tasmania has completed an industry activation study. This study investigated offtake opportunities to support the first phase of hydrogen production in Tasmania. An overview of the outcomes of the study, including funding towards a hydrogen fuel cell bus trial, is available on the Renewables Tasmania website. This and other initial demonstration projects will help provide a pathway to large-scale production projects.

International engagement

Tasmania is exploring areas for collaboration and cooperation with key international partners.

The state will sign memorandums of understanding where there is mutual benefit for:

- research, development and demonstration
- innovative and advanced manufacturing technologies
- future export.

Bell Bay hydrogen production hub

The Tasmanian Government is developing a proposal for a green hydrogen export hub at Bell Bay, a key industrial hub.

The government has announced another $200,000 to support the hydrogen technology cluster led by Bell Bay Advanced Manufacturing Zone. This funding will contribute to community engagement on hydrogen and link emerging industry participants with skills development.

H2TAS

The H2TAS project, led by Woodside Energy and Countrywide Renewable Energy, was not successful through ARENA's Hydrogen Funding Round. However, Woodside is still committed to the 10 MW project.

The Tasmanian Government has signed a memorandum of understanding with Woodside to support the project proposal.

Blue Economy CRC – development of an offshore hydrogen microgrid

The Blue Economy Cooperative Research Centre (CRC) is working with Optimal Group, Macquarie Group and University of Tasmania to develop an offshore hydrogen microgrid in Tasmania.

The demonstration project will be one of the first hydrogen microgrids in the world to be installed offshore. It will contribute to the CRC's research as part of a multipurpose zone to develop the blue economy.

The CRC will bring the aquaculture and renewable energy sectors together for the first time. This will address the challenges of offshore food and energy production by taking advantage of co-location, vertical integration, infrastructure and shared services.

Phase 1 of the project involves testing the hydrogen microgrid onshore while connected to the grid and Tasmania's abundant renewable energy resources.

A 700 kW electrolyser from ITM Power will be installed in early 2022, making it the first industrial-scale hydrogen production source in Tasmania.

The Tasmanian Government is working with the Blue Economy CRC to determine how the hydrogen produced during Phase 1 can be used to support an early-stage hydrogen demonstration project. Following onshore testing, the microgrid will be deployed offshore. This phase will enable world-leading research into using hydrogen offshore to firm microgrids that are not suited to direct grid connection.

The microgrid technology can be co-located with renewable generation. Hydrogen generation can provide backup storage and grid firming at times of low power generation. Meanwhile, oxygen produced in the electrolysis process benefits associated aquaculture activities.

The development of the offshore hydrogen microgrid builds upon current R&D in the Blue Economy CRC including:

- hydrogen storage and distribution
- offshore/high energy sustainable hybrid power systems
- DC microgrids for offshore applications.

Gordan Dam, Tasmania. Image attribution: Gettyimages Steve Daggar Photography.

Australian Capital Territory

Zero emissions vehicles

In April 2018, the ACT Government released its Transition to Zero Emissions Vehicles Action Plan 2018–21.[48]

The plan will accelerate the use of zero-emissions vehicles, including:

- battery electric vehicles
- hydrogen fuel cell vehicles
- electric bikes.

The plan calls for all newly leased ACT Government fleet passenger vehicles to be zero-emissions vehicles (where fit for purpose) from the 2020–21 financial year.

The ACT Government offers a stamp duty exemption for new zero-emissions vehicles, including hydrogen fuel cell vehicles. It also waives registration fees on newly registered zero-emissions vehicles for the first 2 years of registration. These initiatives are aimed at encouraging more Canberrans to purchase zero-emissions vehicles.

Natural gas transition

In September 2019, the ACT Government released the ACT Climate Change Strategy 2019–25.[49] The strategy outlines how the ACT will reduce its greenhouse gas emissions beyond the 100% renewable electricity generation target achieved in 2020.

One action in the strategy is developing a plan for zero emissions from natural gas use by 2045. The transition plan will be released by 2024, letting the ACT Government develop a policy that:

- accounts for potential developments in zero emissions technologies and green alternatives to natural gas (including biogas and hydrogen)
- phases out fossil fuel gas in the ACT by 2045
- supports energy grid stability
- supports vulnerable households.

Funding support for a renewable hydrogen knowledge economy

The ACT is well positioned to play a role in the renewable hydrogen knowledge economy. The ACT Government's renewables reverse auctions and Renewable Energy Innovation Fund have supported several cutting-edge renewable hydrogen research, development, and demonstration activities.

These activities demonstrate the ACT's commitment to achieving a net zero emissions economy while supporting economic development in Australia's renewable hydrogen knowledge economy for the future.

[48] ACT Government, ACT's Transition to Zero Emissions Vehicles Action Plan 2018–2152.
[49] ACT Government, ACT Climate Change Strategy 2019–25.

Hydrogen projects in the Australian Capital Territory

Australia's first publicly available hydrogen refuelling station

The ACT Government delivered Australia's first public hydrogen refuelling station in partnership with Neoen, Hyundai, ActewAGL and SG Fleet.

The refuelling station was officially launched on 26 March 2021. The project also saw 20 hydrogen fuel cell vehicles integrated into the ACT Government fleet.

This pilot project will give Canberra-based industry and researchers firsthand insights into hydrogen refuelling operating models, transport supply chains and consumer refuelling patterns.

The project came out of the ACT Government's reverse auctions to achieve 100% renewable electricity.

Australian Capital Territory Refuelling Station. Image attribution: ACT Government

Evoenergy hydrogen test facility

Evoenergy and Canberra Institute of Technology (CIT) have partnered to build a hydrogen test facility at CIT Fyshwick. Opened in December 2018, it is Australia's first facility testing 100% hydrogen on existing materials, equipment and work practices in preparation for hydrogen use in gas networks.

CIT has also used the facility to train gas-fitting students in piping and appliance installation for hydrogen, as well as for ongoing training of apprentices.

The Australian National University (ANU) has used the facility for undergraduate projects and is now incorporating it into further materials and hydrogen research.

Hydrogen research and development

The ANU is partnering with research and industry stakeholders in various hydrogen research and educational activities.

Through the ACT's 100% renewables reverse auction, Global Power Generation Australia is supporting a 20-year investment worth $1.5 million. The funding will help boost Australia's hydrogen economy and power new hydrogen research.

ANU researchers have demonstrated unprecedented solar-to-hydrogen conversion efficiency. The technology has been voted a top 10 innovation with the potential to transform society by a distinguished forum established by the Japanese Government.

Through the ARC Linkage funding, the ANU is developing the liquid organic hydrogen storage, together with a regulatory study on removing barriers to commercialise the technology in future.

The ANU's Zero-Carbon Energy for the Asia-Pacific Grand Challenge is undertaking research on hydrogen fuels and hydrogen certification.

ACT Renewable Hydrogen Technology Cluster

In February 2021, Canberra became one of the 13 regional hydrogen clusters across the country to receive seed funding from National Energy Resources Australia's $1.85m investment.

The ACT Renewable Hydrogen Cluster will work closely with industry and government on:

- renewable hydrogen technology development
- policy pilots
- coordinated hydrogen education and training.

Northern Territory

The Northern Territory Renewable Hydrogen Strategy was released in July 2020. The strategy outlines the Northern Territory's approach of:

- taking advantage of current and emerging opportunities
- playing to its strengths
- adapting its approach as technology and market conditions evolve.

Renewable remote power

The Northern Territory Government is seeking to partner with external investors to advance renewable energy in remote areas.

This includes developing a framework for external investment to supply renewable energy to the Northern Territory's 72 remote communities. The framework will target on average 70% renewables and the use of innovative technologies like renewable hydrogen. Current work is mapping the best renewables pathway for each community based on:

- existing energy assets
- community aspirations
- electricity demand
- predicted growth.

In addition, the Aqua Aerem renewable hydrogen pilot project uses innovative technology to capture water from the atmosphere, securing a clean and sustainable water source to produce renewable hydrogen. The next stage of the project will produce renewable hydrogen for blending in gas generators at Tennant Creek.

Renewable Hydrogen Master Plan

The Northern Territory Renewable Hydrogen Master Plan is being developed to:

- identify foundation actions to reduce risk for investment in renewable hydrogen
- provide an adaptive pathway to guide future growth and industry development
- provide a framework for an export-scale renewable hydrogen industry in the Northern Territory
- focus on the enabling activities needed to secure external investment and ensure benefits are accessible to all Territorians.

Middle Arm Sustainable Development Precinct, Darwin

The Northern Territory Government is transforming Darwin's Middle Arm Peninsula into a globally competitive sustainable development precinct. The precinct will focus on:

- low emission petrochemicals
- renewable hydrogen
- carbon capture, use and storage
- minerals processing.

Middle Arm will support a large-scale hydrogen export industry and other advanced gasbased and critical minerals manufacturing projects.

Development of the precinct is being accelerated by:

- mapping the industrial ecologies that will create the greatest value
- performing project finance assessments including demand analysis, revenue forecasting and economic benefit models
- supporting ecosystem readiness through precinct master planning
- supporting investment decisions by identifying the right partners, funding and incentive opportunities
- delivering service level supports to welcome investment and demonstrate the Northern Territory is prepared, engaged and ready to support the development of Middle Arm
- leading commercial activation to enable downstream investment.

The outcomes of these planning activities will be detailed in the Middle Arm Sustainable Development Precinct Masterplan, expected to be released in 2022.

Uterne solar power station near Alice Springs. Image attribution: Gettyimages Christopher Groenhout

4 NEXT STEPS

The National Hydrogen Strategy sets out the pathway to develop Australia's hydrogen industry.

Early activities are already helping the industry grow, and we will build on this foundation. Ongoing collaborative and coordinated effort is required to take these activities to the next level and give the industry the best chance of success.

Australia's emerging and promising hydrogen industry is off to a good start. We are keeping pace with other fast-moving countries as the global industry emerges. To keep up with potential international competition, Australia must continue to build on the work already underway and keep implementing the adaptive pathway set out in the strategy.

Accelerating enabling activities

Becoming a major hydrogen exporter relies on building international partnerships and reducing costs across the supply chain.

Future activities will build on work that is currently underway. Australian Government priorities for coming years include the following measures that will help to drive down the cost of hydrogen production towards the $2/kg goal:

- continuing to engage internationally to build export relationships
- building domestic demand for hydrogen by implementing the Activating a Regional Hydrogen Industry Program and state and territory hydrogen hubs programs
- continuing to contribute to international efforts to design an international methodology for hydrogen certification. This includes trialling hydrogen certification methodologies on real-world projects and using the results to inform domestic and international methodologies.

The federal, state and territory governments will collectively focus on:

- implementing a program of legal and regulatory reform, informed by the current review of legal frameworks
- reforming National Gas Laws to accommodate gas blending in distribution networks
- completing the National Hydrogen Infrastructure Assessment and considering its findings
- enhancing and expanding community engagement, particularly for hydrogen hubs development
- continuing work around industry development, including skills and training
- implementing funding programs to demonstrate applications across the hydrogen supply chain.

These crucial activities will help create an investment environment in which the Australian industry can move from ambition to achievement. The accelerated growth of the industry will be vital in driving down production costs and further developing end-use technologies to build demand.

Continuing international engagement

The Australian Government will continue engaging with other countries to build export relationships and capture market share.

The work of the Special Adviser to the Australian Government on Low Emissions Technologies is enhancing these relationships by co-investing in research and demonstration projects with international partners. These projects will prove technology, demonstrate supply chains and foster innovation and collaboration.

International partnerships will drive investment in Australian projects and accelerate the development of practical technologies. They will help secure international offtake for Australian hydrogen to reduce costs in energy carriers and exports and bridge the gap in delivered costs.

State governments are also collaborating with international partners:

- The South Australian Government signed a memorandum of understanding to investigate green hydrogen exports to the Port of Rotterdam in the Netherlands
- Tasmania is exploring areas for collaboration and cooperation with key international partners.

Building domestic demand for hydrogen

While export markets are emerging, Australia needs to keep building domestic demand for hydrogen. This will help the industry achieve scale, which is critical for bringing costs down and becoming a globally competitive supplier.

Creating domestic demand remains a challenge, but is also a large opportunity. Reaching the Technology Investment Roadmap's stretch goal of hydrogen production for $2 a kilogram will allow hydrogen to become competitive with some alternative fuels. Some applications for hydrogen will become economically viable sooner than others, and these present opportunities for early adoption.

Industry is acting thanks to government support. Demonstration projects are underway or being developed for most major uses of hydrogen. Ammonia production is the most mature, and progress is also being made on trials to blend hydrogen into gas.

There are opportunities for governments and industry to develop more end-use applications. This includes using hydrogen to develop a clean steel industry – another priority technology of the Technology Investment Roadmap. Although clean steel is not expected to reach cost parity until after 2030, Australia's mineral resources offer an opportunity for domestic clean steel manufacturing.

The federal, state and territory governments are responding with significant support to help the hydrogen industry develop. This includes the Australian Government's $464 million in funding for hydrogen hubs and pilot, trial and demonstration projects.

Hydrogen hubs will significantly boost clean hydrogen demand for a range of applications. Colocating hydrogen users, producers and exporters in hubs will:

- create economies of scale for larger hydrogen supply chains
- provide opportunities for shared infrastructure
- create focal points for innovation and skills development.

In addition, the Australian Government's Future Fuels Strategy and Fund will support the rollout of hydrogen refuelling stations, enabling greater use of hydrogen in transport applications.

Future areas of work

Work has started on most of the actions identified in the National Hydrogen Strategy. However, some actions rely on current actions being completed, while others will need to wait until the industry is more developed. Areas of work that will be commencing in coming years are outlined below.

Energy market reforms

In the medium term, electricity and gas costs are the biggest driver of if and when we will bring hydrogen production costs under $2.

The choice of on-grid or off-grid hydrogen production will depend on how close to end users the hydrogen can be produced, as well as strategic application of sector coupling. Future energy market planning and reforms need to consider both on-grid and off-grid applications. Governments are doing substantial work to reduce costs, including designing the post-2025 energy market.

The National Hydrogen Strategy recommends reviewing energy market reforms in 2024 to improve the integration of hydrogen into energy markets and ensure it is cost effective. By 2024, the review will be able to draw on the results of pilots, trials and demonstration projects.

Energy security

Domestic hydrogen production and use could improve Australia's energy security where hydrogen is stored in pipelines or dedicated storage. Security benefits may include:

- better integration of variable wind and solar generation into the electricity supply
- improved electricity system resilience to generation and transmission disturbances
- a more diverse energy supply
- less reliance on fuel imports.

To capture these benefits, Australian governments will examine the role of hydrogen in energy security by 2025.

Infrastructure

The National Hydrogen Infrastructure Assessment is currently underway. It will:

- identify infrastructure needs for the emerging industry
- prompt a need to consider, fund and develop common infrastructure in an efficient and cost-effective way
- consider the inputs from other relevant sector assessments, including the National Gas Infrastructure Plan.

The assessment will be repeated at least once every 5 years to highlight future infrastructure needs for competitive hydrogen supply chains. Governments will need to consider how to implement the findings of the infrastructure assessment.

Skills and training

The South Australian Government and the Department of Education, Skills and Employment are developing nationally consistent training materials and guidelines for producing, transporting and using hydrogen. These materials and guidelines will be the first step towards a robust framework of skills and training activities that support a hydrogen-ready workforce.

From 2025 to 2030, Australian governments will work with industry to:

- establish clear pathways between hydrogen-related education and training and hydrogen-related employment
- ensure industry reference committees review, update and develop units of competency and qualifications as hydrogen becomes more relevant to industry training packages.

Collaboration will deliver the vision in the strategy

Australian energy ministers share a vision for a clean, innovative, safe and competitive hydrogen industry that benefits all Australians and is a major global player by 2030. The National Hydrogen Strategy provides a framework for Australian governments and industry to work together to build Australia's hydrogen industry and achieve that vision.

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 and the broader community to take advantage of these opportunities. Future areas for mutual collaboration include:

- removing barriers identified by legal frameworks and gas networks reviews
- coordinated infrastructure investment between governments and industry to deliver on infrastructure review findings
- accelerating hydrogen skills development and training to build domestic capability and provide jobs for Australians
- building hydrogen hubs to concentrate investment and create domestic demand and export opportunities
- working with communities to build public trust and confidence around hydrogen. Public trust is vital for any new industry or technology.

As projects move from planning to development, more community engagement will be needed, particularly in areas with regional hydrogen hubs and infrastructure. This will ensure that regional Australians directly benefit from the growth of the hydrogen industry in their area.

We are on track to deliver the National Hydrogen Strategy's vision. The rapid global growth of hydrogen means we must continue with our collaborated and coordinated effort. We look forward to meeting this challenge and reinforcing Australia's position as a world leader in hydrogen.