Australian Government

Department of Climate Change, Energy, the Environment and Water

National Hydrogen Strategy 2024

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Development of this strategy

This strategy was developed by the Department of Climate Change, Energy, the Environment and Water in consultation with:

- States and territories through a working level reference group and a sub-committee of the Energy and Climate Change Ministerial Senior Officials Group.
- Industry stakeholders, including face to face meetings with more than 65 stakeholders and the receipt of 115 submissions to a formal consultation paper released in July 2023.
- A multidisciplinary advisory group (refer Appendix E)

The strategy development was overseen by an interdepartmental Steering Committee comprising senior representatives of the Department of Climate Change, Energy, the Environment and Water, the Department of Industry, Science and Resources, and the Department of Infrastructure, Transport, Regional Development, Communications and the Arts.

National Hydrogen Strategy modelling scenarios were selected to represent a range of pathways to reaching the Australian Government's legislated net zero by 2050 objective. CSIRO modelling of these scenarios adopt a range of assumptions, which are closely aligned with those used to underpin work such as the Australian Industry Energy Transitions Initiative and AEMO's Integrated Systems Plan, which themselves were developed on the basis of the best available information and extensive consultation.

The government is committed to regular review and update of the National Hydrogen Strategy.

Acknowledgement of Country

Our department recognises the First Peoples of this nation and their ongoing connection to culture and country. We acknowledge Aboriginal and Torres Strait Islander Peoples as the Traditional Owners, Custodians and Lore Keepers of the world's oldest living culture and pay respects to their Elders past, and present.

Contents

Minister's foreword

I am pleased to present Australia's 2024 National Hydrogen Strategy.

Hydrogen is central to the Australian Government's vision for a Future Made in Australia.

It is a vital part of the generational economic opportunity presented to Australia to ensure our future prosperity through the net zero transformation.

Australia's renewable energy resources are the envy of the world, and this transformation is underpinned by clean, cheap renewable power. Along with our mature innovation ecosystem, our experience making large export industries, and our record as a stable and trusted trading partner, we have the elements to be a global hydrogen leader.

This revitalised National Hydrogen Strategy is another step towards unlocking Australian hydrogen's world-class potential. The enthusiasm of investors, businesses, communities and workers for hydrogen in Australia gives increasing confidence that we have what is needed to establish a world leading hydrogen industry with bright opportunities ahead. We can decarbonise new and existing manufacturing industries, like green metals and chemicals. We can set up new, large-scale clean exports. And we can bring safe, secure and well-paid jobs to Australians, especially in our regional powerhouses. They have the people and the skills to make sure the places that have powered Australia's prosperity for generations continue to do so through the net zero transformation.

Investors value clarity and a clear plan. That's why, in 2022, we legislated Australia's greenhouse gas emission reduction targets for both the medium and long term. This strategy, which identifies targets and stretch potential for producing and exporting Australian hydrogen, strengthens that clarity. And with the substantial policy and Budget measures delivered by the Australian Government, we have a resounding message to the world: Australia is ready to be a global hydrogen leader.

New policies including the Hydrogen Production Tax Incentive and an expanded Hydrogen Headstart program unequivocally position Australia as one of the best places in the world to make green hydrogen. The challenge is now over to our emerging hydrogen industry to seize the moment.

I thank industry, investors, unions, universities, and others for their extensive input and support in developing Australia's 2024 National Hydrogen Strategy. We invite companies, investors, workers, all levels of government and our communities across the country to take up the challenge and be part of this important opportunity.

The Hon Chris Bowen MP
Minister for Climate Change and Energy

What is hydrogen?

Hydrogen is colourless, tasteless, odourless, non-toxic, and highly combustible

Electrolysers, which use electricity to split water into hydrogen and oxygen, are a critical technology for producing low-emission hydrogen

Approximately 58 kg of hydrogen is required to produce 1 tonne of Direct Reduced Iron

100,000 tonnes of hydrogen per year could fuel two green iron production plants

On a mass basis 1 kg of hydrogen contains as much energy as 2.4 kg of natural gas, however when transported as a gas in a pipeline, hydrogen is about 8.5 times less dense than natural gas

Using hydrogen instead of combusting natural gas avoids the equivalent of 6.2 tonnes of carbon dioxide emissions for every tonne of hydrogen

1 tonne of hydrogen can be used to make around 5.6 tonnes of ammonia, 10 tonnes of urea or 28 tonnes of diammonium phosphate (DAP) fertiliser

Hydrogen's energy can be released as heat through combustion or electricity using hydrogen fuel cell technology where the only by-product is water

1 kg of hydrogen contains as much energy as 3.2 kg of petrol

A hydrogen fuel cell car has travelled 1360 km on road using a single fuel tank containing 5.65 kg of hydrogen

Hydrogen is the most abundant element in the universe

On Earth it is mostly bound to other elements in molecules such as water. When two hydrogen atoms bind to each other it is referred to as hydrogen gas or molecular hydrogen

Executive summary

The 2024 National Hydrogen Strategy provides the framework for Australia to become a global hydrogen leader.[1]

Hydrogen is a critical element of the global energy transition. This transition is well underway. The International Energy Agency (IEA) is both authoritative and clear. The high share of global energy held by fossil fuels is expected to decrease by 2030, for the first time in decades. Under commitments already made, the IEA finds that demand for coal, oil and gas falls by 74%, 43% and 42% in volume, respectively, by 2050.[2] As countries increase their efforts to meet net zero, these falls will be even larger.

Australia's renewable energy advantages mean the nation is well-placed for export and manufacturing opportunities in the energy transformation. For example, the global hydrogen market is forecast to reach US$1.4 trillion in 2050. This includes around US$280 billion of interregional trade.[3] Australia must capture the significant economic opportunities that are becoming available.

Australian hydrogen can be exported as an energy carrier to countries less able to generate renewable electricity. It can also be exported through low-emissions products that have been manufactured locally using hydrogen as a chemical or heat input to the production of green metals, ammonia and low-carbon liquid fuels.

Focusing on large-scale export and manufacturing industries will help bring down the cost of producing renewable hydrogen in Australia. It will also support our national emissions reduction goals. Hydrogen will play a role in decarbonising existing hard-to-abate sectors such as long-haul transport and aviation. It could also potentially support power generation. Under the production targets in this strategy, Australian hydrogen could avoid emissions of between 93 and 186 million tonnes of CO_2 per year by 2050.[4]

Australia already has a globally significant project pipeline of more than 100 projects announced since 2019. The IEA reports that 20% of all announced projects globally are in Australia.[5] This pipeline is larger than for any other single country. It represents approximately half of all export oriented projects announced globally. The pipeline is growing yearly. It is currently valued at $225 billion or more.[6] The pipeline is overwhelmingly focused on renewable hydrogen production as Australia's extensive wind and solar resources provide the foundation for producing low-cost renewable hydrogen (refer Figure ES-1).

However, most projects remain at the feasibilty or engineering stage. Many other countries also have excellent renewable resources. The 2024 National Hydrogen Strategy is tailored to the development of an Australian industry. It accepts that Australia will need to actively compete with other nations to be considered a global hydrogen leader.

While most renewable hydrogen projects will likely be developed off-grid, on-grid projects will provide a flexible source of electricity demand and like batteries, allow electricity to be stored. Both characteristics could support Australia's transition to 82% renewable electricity by 2030, and the ongoing decarbonisation of the electricity system. In addition, having a domestic hydrogen industry will limit Australia's exposure to increases in the cost of natural gas and imported liquid fuels.

The emergence of large-scale off-grid renewables presents a new opportunity for renewable energy generation project developers. This type of project will have the benefits of scale, lower transmission and network connection costs and may not require generation to be firmed prior to supply to a hydrogen production facility.

1 The strategy's primary focus is on developing renewable hydrogen, though many hydrogen industry development activities (such as responsible safety regulation) are relevant to broader 'clean hydrogen' production pathways. The 2019 Strategy defined clean hydrogen as having been produced via electrolysis with renewable energy, or via fossil fuel pathways with substantial carbon capture (greater than 90%). Where hydrogen is created using unabated fossil fuels, this is specified. See also Box 2 regarding hydrogen production pathways.

2 IEA 2023, *World Energy Outlook*. www.iea.org/reports/world-energy-outlook-2023

3 Deloitte 2023, *Green hydrogen: Energizing the path to net zero*. www2.deloitte.com/content/dam/Deloitte/at/Documents/presse/at-deloitte-wasserstoffstudie-2023.pdf. Unless otherwise specified, monetary values in the strategy are expressed in Australian dollars.

4 Assuming annual hydrogen production displaces the emissions from natural gas at a rate of 6.2 million tonnes/CO_2-e for each 1 million tonnes of hydrogen – 2019 National Hydrogen Strategy.

5 IEA 2023, *Global Hydrogen Review*. www.iea.org/reports/global-hydrogen-review-2023

6 DISR 2023, *Resources and energy major projects 2023*. www.industry.gov.au/publications/resources-and-energy-major-projects-2023 Note a revised valuation methodology was used, compared with previous years, that excluded projects that were at an 'Advanced Feasibility' stage. The preceding report from 2022 valued the pipeline at $230 to $303 billion.

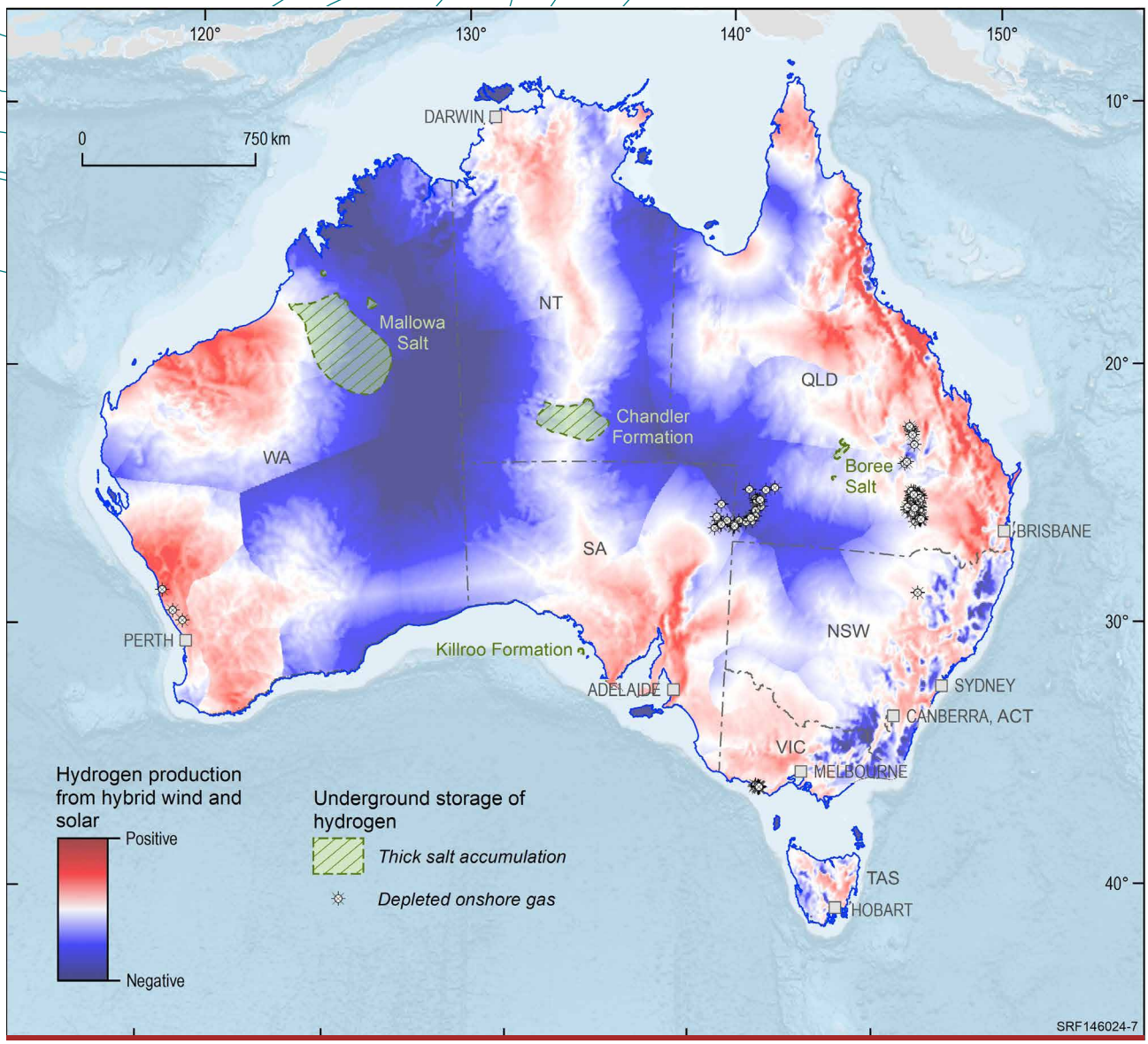


Figure ES.1: Australia's hydrogen production potential

Source: Geoscience Australia.[7]

Large-scale underground hydrogen storage can guard against production and demand fluctuations. Australia's unique geography presents many options for exploring this opportunity. It also provides seasonal storage capability to support our electricity network. This will be important as we transition to a renewables-dominated grid.

Our proximity to Asian and Indo-Pacific markets is an advantage for new hydrogen-based export industries. Our trading partners value our proven track record of stability and reliability.

7 Geoscience Australia 2023, *Australia's hydrogen production potential*. www.ga.gov.au/scientific-topics/energy/resources/hydrogen/australias-hydrogen-production-potential - Current hydrogen projects (shown as colour coded circles on the map) are predominately located in highly prospective 'red' regions indicating the alignment of the HEFT modelling with real world data. The map includes salt accumulations and depleted onshore gas, which represent potential locations for geological hydrogen storage. (Geoscience Australia, 2022).

These widespread development and investment opportunities will offer new job and business prospects across many regional areas of Australia. Australia's renewable hydrogen exports could create tens of thousands of direct and indirect jobs by 2040. These exports could also provide opportunities for existing workers in declining fossil fuel industries to transition to new resource and manufacturing businesses that use hydrogen.[8] Australia's hydrogen industry will also deliver benefits to regional communities in the form of new infrastructure to support the industry to grow.

Renewable hydrogen is a priority industry in the government's $22.7 billion Future Made in Australia plan, through which it is the focus of targeted investment and other assistance. This long-term commitment, combined with the actions, targets, milestones and the monitoring and review framework detailed in this strategy, provides the necessary platform to take the next step to develop a successful Australian hydrogen industry.

Australia's 2024 National Hydrogen Strategy

The 2024 Strategy vision is for a clean, innovative, safe and competitive hydrogen industry that benefits Australia's communities and economy, enables our net zero transition, and positions us as a global hydrogen leader. The strategy identifies 4 objectives. The strategy's objectives are supported by specific actions, targets, collaboration across governments and associated enablers that will underpin their delivery.

Vision

A clean, innovative, safe and competitive hydrogen industry that benefits Australia's communities and economy, enables our net zero transition, and positions us as a global hydrogen leader

Objectives

Supply

Australia's hydrogen industry is globally cost-competitive
(Chapter 2)

Demand

Identify and support the most prospective hydrogen demand sectors
(Chapter 3)

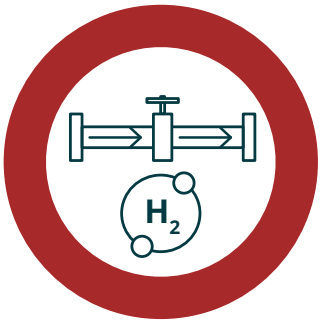
Community benefit

Communities are aware of and realise the benefits of hydrogen
(Chapter 4)

Trade, investment and partnerships

Establish trade at scale and leverage purposeful partnerships
(Chapter 5)

8 Accenture 2021, *Sunshot: Australia's opportunity to create 395,000 clean jobs*. https://assets.nationbuilder.com/climateaction/pages/3147/attachments/original/1660717384/Clean_exports_detailed_report_vf.pdf?1660717384



Objective 1:
Supply - Australia's hydrogen industry is globally cost-competitive

Success against this objective will see Australia produce sufficient volumes of hydrogen at a price that will attract demand from domestic and international buyers.

At this early stage, the cost of renewable hydrogen production is high. The industry is nascent and public investment for early movers will generate learnings to reduce the production cost over time.

The Australian Government will implement significant production support through the Hydrogen Production Tax Incentive and Hydrogen Headstart programs. These will help drive deployment, build experience in the hydrogen and finance sectors with large-scale projects, and help bridge the commercial gap. These are key strategic investments that will deliver on this objective and ensure Australian hydrogen projects are globally cost-competitive.

The strategy also sets a long-term hydrogen target out to 2050, consistent with Australia's net zero emissions target, supported by 5-yearly milestones. These structures will help guide infrastructure planning and provide a long-term signal to investors about the role hydrogen will play in the Australian economy.

Renewable energy is the biggest component of the hydrogen cost stack, so reducing the cost of renewables is essential to building viable Australian hydrogen businesses. Multiple initiatives are now in place to drive cost reductions, including support for innovation to bring through the next generation of technologies, and for renewable energy deployment to deliver economies of scale.

Other actions targeted at hubs and infrastructure, workforce, supply chains and innovation will also reduce project costs and enable the industry to grow.

Chapter 2 of this strategy details the target, milestones and actions. These are summarised below.

2050 production target and milestones

Setting 5-yearly production milestones out to 2050 will provide the trajectory we will need to realise our goal to be a global hydrogen leader, with hydrogen providing both a critical component to our domestic decarbonisation strategy, and enabling new economic opportunities to emerge.

Australia will target producing at least 15 million tonnes of hydrogen annually, with a stretch potential of 30 million tonnes annually, by 2050.

Hydrogen Production Tax Incentive

The $2 per kilogram Hydrogen Production Tax Incentive will provide time-limited, demand-driven production support to eligible producers of renewable hydrogen through Australia's tax system, forming the basis of government support to the sector to 2040.

Hydrogen Headstart

The Hydrogen Headstart program represents an early strategy action to address the current financial gap between the production cost and sale price of renewable hydrogen. It is focussed on industry early-movers with well developed projects.

Future Made in Australia Innovation Fund

Renewable hydrogen is a National Interest Priority industry under a Future Made in Australia. The Future Made in Australia Innovation Fund will fund deployment of innovative technologies and facilities linked directly to priority industries.

Hydrogen Hubs

The Australian Government's existing investment in hydrogen hubs in regional Australia remains an important building block to a large scale hydrogen industry, with expanding linkages to our future clean energy export industries.

ARENA support

The Australian Renewable Energy Agency (ARENA) will continue to play an important role in funding clean energy technology research, development and deployment (RD&D). ARENA will support improvements in hydrogen technologies and projects and renewable energy generation.

Concessional finance

Concessional finance through government special investment vehicles, including the Clean Energy Finance Corporation and the National Reconstruction Fund, will continue to play an important role in enabling large scale projects to proceed, prove new commercial models and provide confidence to capital markets.

Strengthened approval processes

Streamlined and prioritised approvals processes at all levels of government are essential to the development of the clean hydrogen industry and the broader transformation of our economy to meet our 2050 decarbonisation goal.

Infrastructure planning

Working with states and territories to analyse specific infrastructure needs for the hydrogen industry, as well as regular broad-based assessment at a national level to inform infrastructure prioritisation.

Workforce, skills and training

Assuring the availability and safety of a suitably trained workforce will be central to the growth of the hydrogen industry.

Objective 2:
Demand and decarbonisation – Identify and support the most prospective hydrogen demand sectors

Hydrogen has many potential applications, but the strategy focuses on the use-cases that are currently most prospective. These demand sectors are more likely to support the hydrogen sector to scale up, contribute to domestic decarbonisation, and contribute to our economy through large-scale export.

These use-cases align with priority industries in the Future Made in Australia agenda and will create new jobs and opportunities for our country.

Chapter 3 of this strategy details the actions supporting this objective.

Green metals (iron & alumina)

Global demand for green iron and steel is forecast to grow significantly by 2050. Hydrogen can provide a clean source of industrial process heat to the refining of our mineral resources and enable the export of hydrogen embodied green metals, such as iron and alumina.

Ammonia

Clean hydrogen is the only viable pathway to decarbonising current ammonia production, which is essential to manufacture fertilisers and explosives. Ammonia also represents a viable means to transport hydrogen to other countries and will play a role as a fuel in a decarbonising maritime industry.

Long haul transport (heavy road, aviation shipping)

There are good prospects for hydrogen to play a role either directly or indirectly through the production of low-carbon liquid fuels in the decarbonisation of the long-haul road, aviation and shipping sectors.

Power generation & grid support

Internationally, Australian hydrogen can support other countries to reduce emissions from their power sectors and achieve energy security goals. Domestically, the ability to produce hydrogen with excess renewable generation and store this energy for use in peak demand also presents an opportunity for hydrogen to support the increased use of renewables in our electricity grids.

Safeguard Mechanism

The Safeguard Mechanism provides a strong incentive for large industrial companies to decarbonise their operations, including by adopting hydrogen technology.

Objective 3:
Community benefit - Communities are aware of and realise the benefits of hydrogen

A hydrogen industry will provide jobs and economic benefits to Australia. It can help diversify regional economies affected by the global energy transition.

Governments can play a role in developing workforces and ensuring they are sufficiently mobile to address shifting demand across the country. Best practice engagement and responsible conduct by the businesses will ensure that projects gain the social licence required. Governments are also responsible for delivering appropriate infrastructure planning and regulatory frameworks for safety and environmental protection.

The clean energy transition provides an opportunity to reset the historic approach large projects have taken to engage with First Nations people. In addition to direct funding of First Nations communities to improve negotiations, governments can hard-wire the importance of best practice engagement into their funding programs. In this way, governments can encourage industry to partner directly with First Nations communities to develop the industry.

Chapter 4 details the actions supporting this objective.

First Nations benefits sharing

The expansion of the First Nations Renewable Hydrogen Engagement Fund pilot will enable First Nations communities that live near projects supported by the Hydrogen Headstart program to access the due diligence and advisory services needed to support their engagement with hydrogen project developers.

Regional jobs & business opportunities

The Australian Government is establishing a national Net Zero Economy Authority to ensure the workers, industries and communities that have powered Australia for generations can seize the opportunities of Australia's net zero transformation.

Australian Energy Infrastructure Commissioner

The independent Australian Energy Infrastructure Commissioner will promote best practices for industry and government to adopt in regard to the planning and operation of projects.

Voluntary Industry Code of Conduct

Best practice engagement with communities that are near new energy projects can underpin mutually beneficial outcomes. Setting clear expectations of all parties including through a hydrogen industry code of conduct provides an important foundation for these enduring relationships.

Planning for sustainable water use

Water is an essential resource for many communities, particularly in regional Australia. Australian governments will consider principles and actions that will help plan for and manage demands for water, including from hydrogen, in a new National Water Initiative.

Objective 4:
Trade, Investment and Partnerships - Establish trade at scale and leverage purposeful partnerships

Capturing a share of developing international hydrogen markets represents a significant economic opportunity for Australia.

We are well-placed for this opportunity. However, our renewable resources alone will not be enough with other countries also possessing solar and wind resources moving to compete for global hydrogen opportunities. The key to realising significant economic benefit from our hydrogen industry will be establishing large-scale and enduring trade relationships. In parallel, strategic international engagement will help ensure Australia remains competitive in the next phase of global market development.

Chapter 5 details the targets and actions supporting this objective.

2030 export target

A base export target of 0.2 million tonnes of renewable hydrogen per year with a stretch potential of 1.2 million tonnes per year.

Setting an early export target provides a strong signal of Australia's intention to continue supplying energy to the global market. This matches the ambition of some of our existing trade partners who already have 2030 hydrogen targets.

Investment attraction

As a large country with a small population, we will continue to welcome international investment in order to develop new industries like hydrogen. Austrade and NZEA will play active roles in attracting this investment.

Guarantee of Origin expansion

The Guarantee of Origin (GO) is an internationally aligned scheme to measure and verify the emissions intensity of the hydrogen we produce.

The scheme will be both scalable and expandable, enabling similar verification of products produced from hydrogen including green metals and low carbon liquid fuels.

Secure supply chains

We will build on our international clean energy bilateral partnerships and multilateral engagement to secure supply chains for our hydrogen industry.

International partnerships & co-investment

Major international energy companies and investment houses are already participating in Australian hydrogen project development.

International partnerships fulfil a range of functions including knowledge sharing, RD&D collaboration, supply chain development and are the precursor to trade arrangements.

States and territories
Collaboration across governments to capture the hydrogen opportunity

The 2024 National Hydrogen Strategy reflects the deep commitment to developing the Australian hydrogen industry at all levels of government.

Each of Australia's states and territories has ambitious hydrogen initiatives or strategies that leverage local advantages. All are also actively participating in projects coordinated nationally. This includes, for example, providing a nationally consistent regulatory environment for hydrogen projects.

Delivering the National Hydrogen Strategy relies on complementary and consistent actions from the states and territories. They will play an important role in planning and developing new infrastructure, such as for water; while noting the emerging challenges of a changing climate, population growth and increasing water demand. In many cases, jurisdictional governments are also responsible for planning approvals and regulating large projects. All levels of government will need to ensure efficiency in assessing projects to ensure the growth of the hydrogen industry and broader energy transition. State and territory governments have a particularly important role in ensuring the progress of projects as they typically have a more direct relationship with individual communities.

Developing large-scale industrial projects will place considerable demands on Australian workforces. Ensuring the relevant workforces are available and mobile will enhance the efficiency with which they can be deployed.

Regulatory approval improvements

Streamlined state and territory regulatory and planning approval frameworks will provide certainty to business and confidence to communities, as well as complement *Environmental Protection and Biodiversity Conservation Act* (EPBC Act) process reforms.

Safety – best practice regulation

Nationally consistent best practice regulation for safety facilitates both project design and financing decisions by investors. All jurisdictions are developing a consistent national approach through the production of National Codes of Best Practice.

Complementary funding and planning

The states and territories will deliver locally-focused hydrogen industry development funding measures that complement the support provided by the Australian Government. The states and territories will also incorporate growing hydrogen industry needs into their policy planning, for example infrastructure planning.

Hubs & precincts

States and territories have the regulatory and legislative structures in place to establish hubs, zones or precincts that provide an advantageous operating environment for new and existing industries to thrive.

Workforce development

Governments will continue to work together to deliver the training necessary to build the hydrogen workforce. At the same time, it will be important for states and territories to enable the mutual recognition of skills, licences, and registrations across jurisdictional boundaries to enable workers to relocate to new centres of activity as they emerge.

Underpinned by
Regular policy review and broader integration

The Australian Government's long-term hydrogen vision is set in the context of a much larger national energy transformation. The complexity of the transition will require concerted effort, monitoring and adjustment over many years.

Central to this monitoring and adjustment will be the continued publication of an annual State of Hydrogen report. This report is centred on an assessment of progress. This assessment will extend to include reporting against the strategy's targets, and milestones as well as other metrics of interest to a broader range of stakeholder issues, such as water. A more in-depth review will be undertaken at 5-yearly intervals, ahead of Australia's Nationally Determined Contribution under Article 4 of the Paris Agreement being updated.

Capacity Investment Scheme

Support for renewable energy deployment, such as the Capacity Investment Scheme, will help drive down the cost of renewable energy which will in turn drive down the cost of producing hydrogen.

Research, development and innovation

Investments in RD&D through ARENA, CSIRO, Australia's universities and other bodies will support technology advances and breakthroughs in hydrogen and renewable energy, which will help bring through the next generation of technologies, including ultra low-cost solar.

Annual reporting and 5-yearly reviews

The Australian Government will expand the monitoring, benchmarking and public reporting of industry development through the annual State of Hydrogen report.

A regular planned strategy review every 5 years will provide a significant opportunity to work with states, territories and the industry to review progress and refresh our national strategy.

Sectoral decarbonisation plans

The 2024 National Hydrogen Strategy has been developed with a view to Australia achieving net zero emissions by 2050. However, specific plans to achieve that target are being separately developed and will incorporate analysis and actions that have contributed to this strategy.

Carbon leakage review

The current price premium associated with using hydrogen provides some incentive for the import of products with a lower cost but higher emissions intensity.

The Australian Government is reviewing additional policy options to address carbon leakage.

Taking the next step

Our collective actions since Australia's inaugural 2019 Strategy have focused on the early foundations for industry growth. But to date we have lacked the incentives needed to drive economies of scale and build industry experience. The 2024 National Hydrogen Strategy builds on this early work and leans into the adaptive approach it established to refocus on accelerating growth through supporting development at scale. The strategy sets a growth trajectory through production targets and milestones and identifies the most prospective hydrogen use cases that will be the focus for ongoing policy support.

Hydrogen production incentives represent the centrepiece of Australia's revitalised strategy. These will help bridge the commercial gap and enable the sector to achieve scale by supporting early movers and building familiarity within the hydrogen and finance sectors with large scale projects.

The production incentives will also ensure Australian projects remain competitive in a rapidly evolving international policy environment and fill a significant gap in Australia's policy mix. They will help the current pipeline of projects achieve final investment decision and unlock the next wave of investment.

Technologies, markets and the international policy landscape have evolved rapidly in the past 5 years. Australia has many advantages that could be put to work towards becoming a global hydrogen leader, but until now has not had the policy support needed to unlock the hydrogen opportunity and be competitive globally. The Australian Government has responded through this revitalised strategy and the unprecedented support announced through the 2024-25 Budget. The challenge now is for all elements of our emerging hydrogen industry to seize the moment.

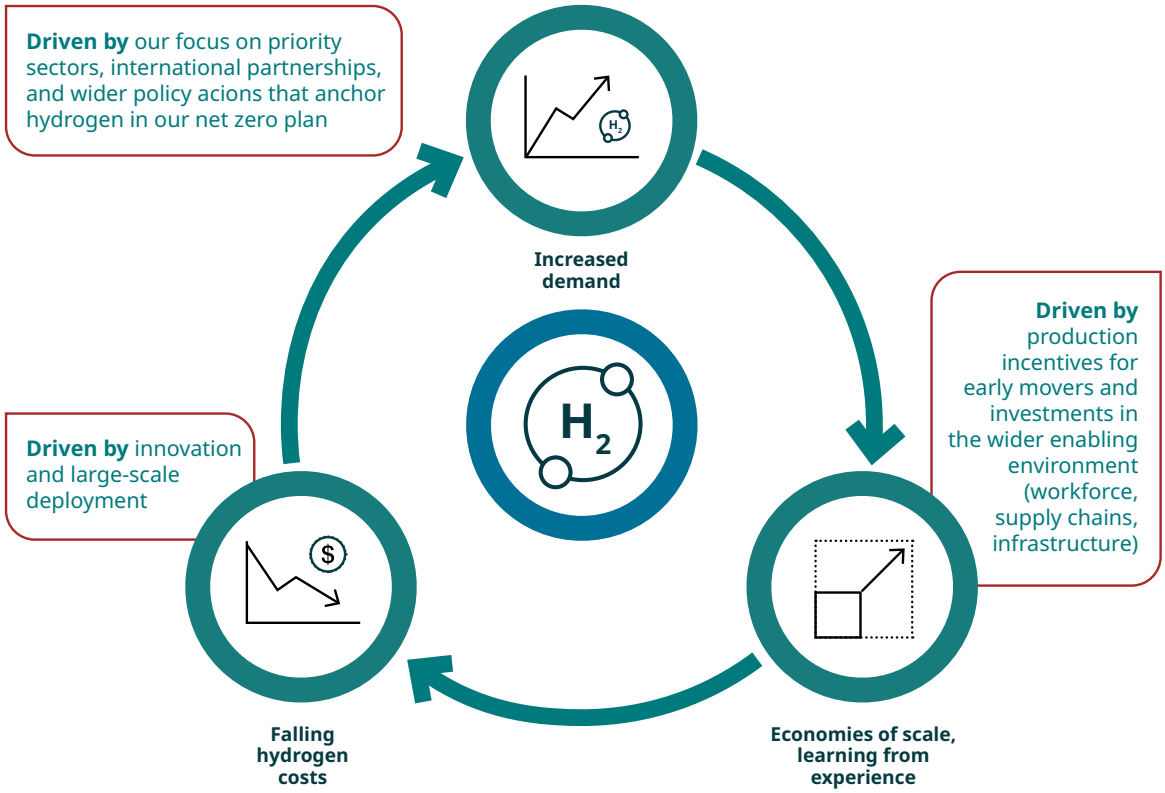


Figure ES.2 **Policy to drive industry development.**

Strategy on a Page

Vision – A clean, innovative, safe and competitive hydrogen industry that benefits Australia's communities and economy, enables our net zero transition, and positions us as a global hydrogen leader

Objectives

Supply

Australia's hydrogen industry is globally cost-competitive

- 2050 production target and milestones
- Hydrogen Production Tax Incentive
- Hydrogen Headstart
- Future Made in Australia Innovation Fund
- Hydrogen Hubs
- ARENA support
- Concessional finance
- Strengthened approval processes
- Infrastructure planning
- Workforce, skills and training

Demand and decarbonisation

Identify and support the most prospective hydrogen demand sectors

- Green metals (iron & alumina)
- Ammonia
- Long haul transport (heavy road, aviation, shipping)
- Power generation & grid support
- Safeguard Mechanism

Community benefit

Communities are aware of and realise the benefits of hydrogen

- First Nations benefits sharing
- Regional jobs & business opportunities
- Australian Energy Infrastructure Commissioner
- Voluntary Industry Code of Conduct
- Planning for sustainable water use

Trade, investment and partnerships

Establish trade at scale and leverage purposeful partnerships

- 2030 export target
- Investment attraction
- Guarantee of Origin expansion
- Secure supply chains
- International partnerships & co-investment

States and territories

Collaboration across governments to capture the hydrogen opportunity

- Regulatory approval improvements
- Safety – best practice regulation
- Complementary funding and planning
- Hubs & precincts
- Workforce development

Underpinned by

Regular policy review and broader integration

- Lower cost renewables Capacity Investment Scheme
- Research, development and innovation
- Annual reporting and 5-yearly reviews
- Sectoral decarbonisation plans
- Carbon leakage review

Australia's National Strategy supporting opportunities across the nation

New South Wales

New South Wales (NSW) combines its natural advantages and extensive industrial infrastructure with world-leading incentives to create a clear pathway to cost-competitive hydrogen and projects of global scale.

The NSW advantage: ready infrastructure and a deep talent pool

NSW is a world-leading location for hydrogen industry development and investment. State infrastructure includes deep water import and export ports, existing ammonia production, Australia's largest integrated steelworks and three major interstate highways. NSW is Australia's most populous state with a large, highly skilled workforce to enable large scale projects. NSW is leveraging its world-class, abundant renewable energy resources by supporting the development of generation and transmission infrastructure for dedicated Renewable Energy Zones.

World-leading policy: $3 billion NSW Hydrogen Strategy

The NSW Hydrogen Strategy is the state's plan to become a global hydrogen superpower. Delivering 60 cross-sectoral actions and providing a clear policy pathway to achieve competitive green hydrogen production, including incentives of up to $5/kg. The strategy includes:

- $1.5 billion in NSW **network charge discounts**
- $1 billion in incentives in the NSW **Renewable Fuel Scheme**
- $109 million awarded for 3 **green hydrogen hubs** in the Hunter, Port Kembla, and Moree
- $25 million for a **Hydrogen Centre of Excellence**
- $10 million to establish **freight refuelling infrastructure**.

These strategy initiatives are designed to drive innovation, support industry growth, and contribute to a large-scale hydrogen industry in the state.

Further NSW support: from innovation to operation

NSW's commitment to a sustainable future is underscored by substantial investments and resources aimed at advancing hydrogen projects from innovative ideas to operational realities. These initiatives represent a strategic push to position NSW as a leader in clean technology, low carbon manufacturing, and renewable energy production, ensuring achievement of our net zero ambitions. Below are the key programs propelling this vision forward:

- Up to $25 million accelerating **Clean Tech Innovation** in NSW.
- Up to $100 million expanding the state's **Low Carbon Product Manufacturing** capacity.
- Up to $150 million to increase local **Renewable Manufacturing**, including electrolysers.

Additionally, comprehensive **Hydrogen regulatory guide and planning resources** are available to streamline the development and implementation of hydrogen projects.

Find out more about the vision and opportunities for hydrogen in NSW at:
www.energy.nsw.gov.au/business-and-industry/ways-get-started-business/hydrogen-nsw

NSW Hydrogen Hubs initiative

The hydrogen hub initiative is a key action under the NSW Hydrogen Strategy, which sets out the NSW Government's plan to develop a green hydrogen industry.

Hydrogen hubs are regions where producers and users of green hydrogen across industrial, transport and energy markets are co-located. The NSW Government is supporting the development of hubs to:

- unlock a green hydrogen industry and workforce to transform NSW regional economies and prepare NSW for the future as global markets decarbonise
- reduce the cost of hydrogen infrastructure development and supply chain costs to make hydrogen commercially competitive with existing fuels
- create new jobs, encourage innovation, improve energy security, and provide businesses with more choices to increase revenue while reducing emissions.

Hydrogen hubs will help NSW shift to a low carbon economy. This supports NSW's plan to cut emissions by 70% by 2035 and achieve net zero by 2050.

NSW is supporting the development of 3 hydrogen hubs to increase the production and availability of green hydrogen across the state. The hydrogen hubs are foundational projects that will help enable the first phase of the NSW Government's plan to become a hydrogen superpower in the region. So far, $109.3 million has been granted to 3 hydrogen hub projects:

- Decarbonizing agriculture with hydrogen: Good Earth Green Hydrogen and Ammonia ("GEGHA") - Hiringa, Sundown Project Co – Moree plains ($35.8 million).
- Zero emissions hydrogen heavy transport: The Illawarra hydrogen technology hub – BOC Limited - Cringila ($28.5 million).
- Decarbonising industry and manufacturing: The Hunter Valley Hydrogen Hub – Origin Future Fuels, Orica – Kooragang Island, Newcastle ($45 million). This project is also supported with a $70 million grant under the Australian Government's Regional Hydrogen Hubs Program.

View onto Kooragang industrial area, Newcastle.

Victoria

Victoria is building the foundations for a thriving renewable hydrogen economy-ensuring the state can capture the benefits of this emerging clean energy source.

Victorian Renewable Hydrogen Industry Development Plan

Victoria has many advantages when it comes to establishing a renewable hydrogen economy. These advantages include:

- renewable energy resources
- renewable carbon sources
- an extensive gas network
- a highly skilled workforce and manufacturing sector
- world class education institutions
- sustainable water sources
- nationally significant transport networks and deepwater ports.

The Victorian Renewable Hydrogen Industry Development Plan sets out a blueprint for how the Victorian Government supports the growth of this emerging high potential sector using these advantages. It sets out how the Victorian Government will drive the development and establish the renewable hydrogen economy in the state through a principles-based approach.

Victoria is focused on supporting high-value hydrogen end uses such as heavy transport, shipping and aviation, industrial decarbonisation, and supporting long-duration energy storage and backup generation.

Hydrogen grants and investments

Breakthrough Victoria

Breakthrough Victoria is an independent investment management company established in 2021, to invest and manage the Victorian Government's landmark $2 billion Breakthrough Victoria Fund.

Over the next 10 years, the fund will invest in five priority sectors:

- Clean Economies
- Advanced Manufacturing
- Digital Technologies
- Agri-food
- Health and Life Sciences

For more information, visit breakthroughvictoria.com

Hycel Technology Hub

Supported by $9 million in Victorian Government funding, Deakin University's Hycel Technology Hub at Deakin University's Warrnambool campus will be a regional hub of expertise for researching, testing, optimising and scaling technologies that use hydrogen, with a focus on mobility applications and the transport sector. The facility will support training, education and social licence to ready the Australian workforce for the hydrogen and clean energy jobs of the future.

Due to be opened in late 2024, Hycel will be a new 4.5 hectare precinct within Deakin University's Warrnambool campus, co-located with South West TAFE. Its location in South-west Victoria is positioned to support the increasing industry activity in this region by supporting skills, training and technology testing to grow the sector.

Renewable Hydrogen Worker Training Centre

The Victorian Government is providing up to $8 million in an open competitive selection process for the delivery of a Renewable Hydrogen Worker Training Centre. The training centre will promote renewable hydrogen workforce development to support the skilled workforce needs of the growing domestic renewable hydrogen industry. This initiative has been boosted by a co-funding commitment of up to $10 million from the Australian Government outlined in the 2024-25 Federal Budget.

Find out more:
www.energy.vic.gov.au/renewable-energy/renewable-hydrogen

Hydrogen Park Murray Valley

Hydrogen Park Murray Valley is a renewable hydrogen production facility that involves the development of a 10 MW electrolyser to produce hydrogen for initial use of gas-blending into the Albury-Wodonga Gas Network. The facility will be located alongside Northeast Water's West Wodonga Wastewater Treatment Plant. Operated by Australian Gas Infrastructure Group (AGIG), the $65.46 million facility will produce renewable hydrogen using renewable electricity purchased from a Victorian wind farm.

The facility has received funding from the Victorian Government ($12.3 million) and ARENA ($36 million) with additional financial backing from the CEFC. Wodonga's strategic location on the Hume Highway, a major road-freight route, also provides access to other end-use markets, particularly heavy-freight.

Toyota Hydrogen Centre

Toyota Australia, with funding assistance from ARENA, commissioned Victoria's first commercial-grade permanent hydrogen production, storage and refuelling facility at its former manufacturing site at Altona in Melbourne's west. Together with the hydrogen production, storage and refuelling facility, the Toyota Hydrogen Centre also incorporates an Education Centre to provide information on the opportunities that exist with the introduction of a hydrogen economy in Australia.

Hydrogen is produced on site by a 200 kW electrolyser that uses electricity to split water into hydrogen and oxygen components and has the capacity to produce up to 80kg of hydrogen per day. Power for the electrolyser is drawn from a combination of an 87 kW solar array, a 100 kW battery storage and mains grid depending on what's available at the time.

Credit: Toyota. Toyota Hydrogen Centre at Altona.

Queensland

The Queensland Government has committed to developing a sustainable hydrogen industry to supply an established domestic market and export partners with a safe, sustainable and reliable supply of hydrogen.

Queensland's close proximity to Asia, established port infrastructure, manufacturing capabilities and renewable energy potential presents an exciting opportunity for world-leading production and export of renewable hydrogen that supports our collective decarbonisation ambitions.

Queensland's renewable hydrogen project pipeline is developing at pace, with more than 60 projects at various stages of development.

The Queensland Hydrogen Industry Strategy and associated initiatives have directed significant Queensland Government resources and funding towards hydrogen and renewable energy industry development activities. These include:

- **Building international partnerships** through actively pursuing international technology partners and promoting investment opportunities. For example, government owned corporations including Stanwell Corporation and CS Energy are progressing projects in partnership with major international investors.
- **Supporting private sector investment** through project facilitation that supports projects to progress technical and commercial studies and development approvals, the $35 million Hydrogen Industry Development Fund and the Queensland Hydrogen Investor Toolkit. In addition, the $4.5 billion Renewable Energy and Hydrogen Jobs Fund enables energy government owned corporations to partner with the private sector to develop both domestic production and use and large-scale export projects.
- **Strategic planning for infrastructure and services** in partnership with the private sector, including the $15 million Supercharging Hydrogen Hubs program, the $8.5 million Abbot Point Activation Initiative and an $8 million desalination detailed business case for Gladstone.
- **Supporting hydrogen research and innovation** through the work of a number of Cooperative Research Centres.
- **Investing in training and skills** through the Hydrogen Industry Workforce Development Roadmap 2022–2032. The Roadmap is the first dedicated workforce development plan for the hydrogen industry and sets a path to achieving a clear vision – a strong and adaptable workforce for a safe and thriving Queensland hydrogen industry.
- **The Hydrogen Safety Code of Practice** which provides a consolidated compliance framework for relevant safety requirements under the *Petroleum and Gas (Production and Safety) Act 2004*.

The Queensland Energy and Jobs Plan further recognises the opportunity renewable hydrogen presents in transforming the energy system, through actions such as:

- **Legislation to support hydrogen development and use**, including passage of the *Gas Supply and Other Legislation (Hydrogen Industry Development) Amendment Act 2023* to provide a clear pathway for a proponent to apply for a pipeline licence for the transmission of hydrogen and hydrogen carriers.
- **Building community awareness** of hydrogen through rolling out a $5 million renewable hydrogen awareness program.
- **Reviewing the Queensland Hydrogen Industry Strategy** to continue to support the sector's growth and contribute to the state's renewable energy targets.

Find out more about the Queensland Energy and Jobs Plan at www.energyandclimate.qld.gov.au

Central Queensland Hydrogen Project (CQ-H2) Case Study

Queensland Government owned corporation and electricity generator Stanwell is leading an international consortium to develop the global-scale Central Queensland Hydrogen (CQ-H2) Project in Gladstone, Central Queensland. Its consortium partners include Japanese foundation partners – Iwatani Corporation and Marubeni – and Singapore's Keppel. The project aims to export renewable hydrogen via its carriers to Japan and Singapore and supply large industrial customers domestically to support local decarbonisation.

The CQ-H2 Project is undertaking its Front-End Engineering Design study with a commitment of $117 million from government and consortium partners, including $20 million from ARENA and $15 million from the Queensland Government.

The project includes a hydrogen production facility, a hydrogen pipeline, a hydrogen liquefaction facility and ship loading facilities at Gladstone Port, and supply of hydrogen to an ammonia production facility. Operations are planned to commence in 2029 and scale up to 800 tonnes per day from the early 2030s.

At its peak, the CQ-H2 Project is expected to support more than 8,900 new jobs. The project will also deliver $17.2 billion in hydrogen exports and $12.4 billion to Queensland's Gross State Product over its 30 year life.

In addition to the CQ-H2 Project, Stanwell is leading the Central Queensland Hydrogen Hub (CQ Hydrogen Hub), which was awarded $69.2 million in funding from the Australian Government under the Regional Hydrogen Hubs Program. The hub consortium partners will match this funding and are working to develop their projects and associated infrastructure to further the renewable hydrogen industry in the Central Queensland region.

Stanwell is also developing a Future Energy Innovation and Training Hub adjacent to its Stanwell Power Station where hydrogen technologies will be tested. This includes Hysata demonstrating their next generation Australian-made hydrogen electrolyser technology at commercial scale with funding from ARENA and Stanwell.

Credit: Stanwell Corporation. CQ-H2 artist impression.

Western Australia

Western Australia's (WA) vision is to be a globally significant producer, user and exporter of renewable hydrogen.

WA Advantages

- High-intensity renewable energy resources – with one of the highest solar irradiance in the world and excellent wind resources.
- Land and existing infrastructure – with an area one-third of the Australian continent, low population density, world-class industrial and export infrastructure, WA is an ideal location to develop large-scale renewable energy generation.
- Skilled workforce – WA has a technically skilled workforce, expertise across the energy sector and relevant research capabilities.
- Established industry with strong international partnerships – many of the world's largest mining and oil and gas companies have a local presence in WA and are looking at transitioning to a hydrogen future.
- Proximity to global markets – WA is Australia's western gateway to Asia and has a long term partnership with major Asian economies, in particular in the energy sector.

Western Australian Renewable Hydrogen Strategy

In 2019, the WA Government announced its Renewable Hydrogen Strategy (WA Strategy). A refreshed Strategy is currently underway, which will detail the state's continued commitment to support and develop a renewable hydrogen industry in WA.

The refreshed WA Strategy outlines the establishment of renewable hydrogen hubs in WA with investment in supporting infrastructure and the use of renewable hydrogen to decarbonise processes to produce green products (including ammonia, iron and alumina) and use in other WA priority sectors. The refreshed WA Strategy describes how WA is well-placed to export renewable hydrogen products and technologies globally.

Key actions of the refreshed WA Strategy include:

- Streamlining approvals.
- Supporting the delivery of common-use and other enabling infrastructure, and Strategic Industrial Areas (SIAs).
- Promoting skills and research, development and demonstration.
- Empowering Aboriginal People.
- Strengthening strategic partnerships for investment and trade.

Developing domestic capabilities and applications of renewable hydrogen, thereby improving local hydrogen industry expertise, will contribute to decarbonising global and WA economies.

To date, the Australian and WA governments have committed over $3 billion in funding to expand and modernise electricity grids in Perth, the South West, as well as in the North West Pilbara region. The WA Government has committed $500 million under the Strategic Industries Fund (SIF) to unlock WA's SIAs and pave the way for WA to become a global clean energy powerhouse. The SIF is on top of the $160 million in lease incentives scheme to attract clean energy projects to the SIAs. $13 million was allocated to renewable hydrogen projects in the initial round of the Investment Attraction Fund (IAF), with a $60 million IAF New Energy Round including provision for hydrogen projects.

The 2019 WA Strategy established a $15 million Renewable Hydrogen Fund (RHF) that led to the delivery of several innovative projects in Western Australia, including:

- The Yuri Renewable Ammonia Project (under construction) which demonstrates the potential to produce green ammonia for export using renewable hydrogen.
- The ATCO Gas Blending Project that incorporated hydrogen into a portion of the natural gas network to provide lower carbon gas to areas of Perth.
- The ATCO Refueller for a refuelling facility for hydrogen fuel cell electric vehicles in Perth.
- Horizon Power's Denham Micro-grid project which provided hydrogen-based firm capacity to up to 100 residential houses in Denham.

Hydrogen Hubs

- Extensive work has been undertaken to develop hydrogen hubs in the Pilbara, Mid West and Kwinana. Hydrogen hubs are intended to improve competitiveness by co-locating demand and supply and attract investment through infrastructure provision.
- The Australian and WA Governments have a $140 million agreement to build the Pilbara Hydrogen Hub, a major centre for hydrogen production and export. The WA Government has also committed $60 million to develop the Mid West Hydrogen Hub and the Australian Government has announced $70 million for H2Kwinana.

Fast-track Approvals

- The WA Government has committed $44.3 million to speed up approvals on job-creating projects for WA, established a Green Approvals team and an Office of the Coordinator General to assist in streamlining approvals for green energy projects including renewable hydrogen.

Legislative Reforms

- The introduction of diversification leases under the Land Administration Act expands the legislative framework for land access for renewable energy projects. Reform is also underway to increase approval efficiency under the Environmental Protection Act.

Find out more:
www.wa.gov.au/government/publications/western-australian-renewable-hydrogen-strategy-and-roadmap

South Australia

Through the State Prosperity Project, The Government of South Australia is making a once-in-a-generation investment along with world leading legislation to unlock industrial scale renewable energy, water and hydrogen production to enable green manufacturing and exports and attract investment.

The South Australian Government's **Hydrogen Jobs Plan** will deliver a world-leading hydrogen power plant, electrolysers and storage facility in Whyalla. The project includes 250MWe of electrolysers, 200MW of power generation and a hydrogen storage facility.

Offtake for industrial applications is a key objective of the project to enable green manufacturing opportunities which have the potential to transform the Upper Spencer Gulf. The South Australian Government has signed an agreement with the GFG Alliance to explore opportunities for renewable hydrogen offtake from the facility to support the decarbonisation of the Whyalla Steelworks. The Australian Government awarded $63.2 million towards the purchase and commissioning of a low carbon electronic arc furnace to support green steel manufacturing.

The **Port Bonython Hydrogen Hub** is anticipated to be South Australia's first large-scale clean hydrogen production precinct for both export and domestic markets. The South Australian Government is collaborating with the Commonwealth and private sector to deliver the project, located 16 kilometres from Whyalla.

First movers are expected to export clean hydrogen by 2030, before scaling up to maximise the economic return to South Australia. An Expressions of Interest process commenced in June 2024 seeking involvement from businesses to jointly investigate the development of a hydrogen-based Direct Reduction Iron plant in South Australia. This will form part of the South Australian Government's **Green Iron and Steel Strategy**.

The **Northern Water project** aims to provide a new, climate independent water source for the Far North, Upper Spencer Gulf and Eastern Eyre Peninsula regions of South Australia, to enable the growth of industries crucial to achieving net zero, including expansion of copper and magnetite production and the emerging green hydrogen industry. The final decision to proceed with the construction of the desalination plant and 600km transfer pipeline is expected in late 2025.

Private sector hydrogen developments are progressing in South Australia with a range of state, Commonwealth and international government funding.

Operating:

- **AGIG HypSA Project** – 1.25 MW electrolyser and up to 10% hydrogen blend network injection, powering around 4000 homes and businesses.

Under Development:

- **AGIG Hyp Adelaide Project** – Hydrogen gas to be produced by a 60 MW electrolyser and be blended at up to 20% by volume into Adelaide's gas networks for over 350,000 residential and business customers.
- **Marubeni (Bolivar)** – 150 kW electrolyser and 5 MW battery to demonstrate renewable hydrogen production and storage to transport hydrogen via metal hydride technology to Indonesia.
- **Iron Road / Amp Energy (Cape Hardy)** – Up to 10 GW electrolyser (initially 1 GW) over the next decade to produce green hydrogen for green ammonia production and other hydrogen derivatives.
- **Vast Solar SM1 Solar Methanol Project (Port Augusta)** – 10 MW electrolyser producing hydrogen and combining with 15,000 tonnes per annum CO_2 (from co-located Calix lime plant) to produce up to 7500 tonnes per annum of methanol.
- **Hallett Group Green Cement Project (Port Augusta)** – $125 million green cement transformation project in collaboration with Korean company, Elecseed with 6 MW hydrogen electrolyser.

Legislation

The South Australian Government has legislated the ***Hydrogen and Renewable Energy Act 2023*** which streamlines processes for companies to invest in South Australian projects. The Act provides a 'one window to government' licensing and regulatory system for the whole lifecycle of large-scale hydrogen and renewable energy projects.

Hydrogen Jobs Plan

The Government of South Australia has committed more than half a billion dollars to the Hydrogen Jobs Plan, to build a world-leading hydrogen power plant, electrolyser and storage facility near Whyalla, in the state's Upper Spencer Gulf region, in 2026.

The Hydrogen Jobs Plan aims to:

- provide jobs for South Australians
- enhance South Australia's grid security, through new dispatchable generation
- prove large-scale hydrogen production and generation technology
- help unlock pipelines of renewable energy developments and business opportunities
- activate other hydrogen projects in development, including export-focused projects
- support South Australia's continued clean energy transition and decarbonisation.

The 250 MWe electrolysers will be one of the world's largest, providing additional grid stability for homes and businesses around the state by utilising excess renewable energy generated from large-scale wind and solar farms to produce green hydrogen. The 200 MW renewable hydrogen power plant will be a new source of flexible power providing firming services for industrial customers in South Australia. The associated storage facility will store hydrogen for the operation of the power plant and potential use by local industry looking to decarbonise their operations.

The South Australian Government has entered into Early Contractor Involvement agreements with an ATCO Australia and BOC Linde consortium, as well as EPIC Energy for the project.

Artist's impression of the proposed Hydrogen Jobs Plan facility.

Find out more:
www.hydrogen.sa.gov.au

Tasmania

Tasmania is uniquely placed to assist in the transitioning energy landscape in the export and local use of green hydrogen and its derivatives, such as green methanol and green ammonia.

Importantly, developing a green hydrogen economy is consistent with Tasmania's clean and green reputation where the Tasmanian Government has legislated a new emissions reduction target for Tasmania of net zero emissions, or lower, from 2030 across all industries.

Like the rest of Australia, export scale projects will need to be supported by the build out of new renewables. However, Tasmania is one of a few places in the world that can offer 100% renewable energy through its hydropower and wind resources to help power export scale projects, as well as access to existing deep water ports in industrial precincts, and has abundant fresh water.

More information is available in the Tasmanian Renewable Hydrogen Action Plan released in 2020.

Local Market Activation - Tasmanian Renewable Hydrogen Industry Development Fund

Feasibility Studies - The Tasmanian Government provided $2.6 million to support 3 feasibility studies investigating large-scale renewable hydrogen projects in Tasmania, including green ammonia and green methanol export scale projects, and the use of hydrogen to replace natural gas in a minerals processing plant. Knowledge sharing reports from these studies are available at www.recfit.tas.gov.au/hydrogen.

The Green Hydrogen Price Reduction Scheme (GHPRS) was launched in late 2023 and will allocate up to $8 million to incentivise the production, sale and use of green hydrogen within Tasmania. The scheme aims to bring the sale price of green hydrogen down to a level that is competitive with other energy or fuel sources. The GHPRS will support small-to-medium-scale green hydrogen production projects within the range of 5-10 MW. The successful applicant was announced on 13 May 2024.

Green Hydrogen Bus Trial - The Tasmanian Government has allocated $11 million to Metro Tasmania's Zero Emission Bus (ZEB) Trials. The hydrogen fuel cell bus trial will commence later in 2024 and includes 3 buses in Hobart and a new hydrogen refuelling station.

Tasmanian Green Hydrogen International Engagement and Export Strategy

The strategy was released in May 2022 and the Tasmanian Government has established the following international partnerships in green hydrogen:

- Memorandum of understanding (MoU) with the Port of Rotterdam to work together to investigate the feasibility of future exports of green hydrogen from Bell Bay, Tasmania, to the Port of Rotterdam in the Netherlands. A supply chain study has been finalised and is available at www.recfit.tas.gov.au/hydrogen.
- MoU with the region of Flanders, Belgium, on green hydrogen cooperation. The agreement focuses on the development of international supply chains, research and development and project collaboration.
- A Joint Declaration of Intent for collaboration in relation to green hydrogen with the state of Bremen in Germany. The scope of this agreement includes sharing of knowledge on green hydrogen, climate change and Antarctic cooperation.

Work has commenced on the development of an MOU with the Australian Antarctic Division to cooperate on understanding the role of green hydrogen in decarbonising Antarctica. A Tasmanian Renewable Hydrogen Industry Network was formed in a partnership between the Tasmanian Government and the Bell Bay Advanced Manufacturing Zone to:

- help local businesses engage with industry experts and other Tasmanian businesses with interest in the hydrogen space
- feature hydrogen industry experts speaking about the importance of hydrogen to the Tasmanian economy and the opportunities that will arise for Tasmanian business as it grows.

Tasmanian Green Hydrogen Hub

In January 2024, the Australian and Tasmanian governments announced a Grant Agreement for the Tasmanian Green Hydrogen Hub (TGHH), which unlocked $70 million of Australian Government funding towards the $300 million TGHH project at Bell Bay. The Tasmanian Government has partnered with TasPorts, TasNetworks, TasWater, Tasmanian Irrigation and the Bell Bay Advanced Manufacturing Zone Pty Ltd to deliver this project over the next 4 years.

It will provide open access infrastructure in the areas of electricity transmission, water and ports and will include local market activation projects. This announcement further supports the vision of the Tasmanian Renewable Hydrogen Action Plan. A hydrogen-powered marine vessel will be delivered as the first demonstration project under the market activation stream of the TGHH. The first stage of this project aims to support up to 300 MW in electrolyser capacity, then scale up over time.

Photo of Bell Bay Advanced Manufacturing Zone. The aim is to transition the Bell Bay Advanced Manufacturing Zone to a Zero Emission Industrial Precinct through integration with the TGHH.

Find out more:
www.recfit.tas.gov.au/future_industries/green_hydrogen

Northern Territory

Hydrogen will play a crucial role in the Northern Territory (NT) achieving its target of net zero emissions by 2050 and in realising its ambition to facilitate global decarbonisation.

The Territory is well-placed to support the establishment of a local and export-scale hydrogen industry, leveraging the Territory's competitive advantages including:

- Abundant renewable energy resources, including globally competitive solar and wind resources and large areas of land with potential for development.
- Demonstrated experience and capability in delivering world-scale energy production and export projects, and the ability to adapt these skills to hydrogen projects.
- Strategic location in close geographical proximity to key international export markets.
- A well-developed infrastructure network to support an export-scale hydrogen industry, including deep-water port electricity, and gas networks, road and rail.

Northern Territory Renewable Hydrogen Master Plan

In 2021, the NT Government released its Renewable Hydrogen Master Plan, outlining the key foundational activities it is undertaking to enable private sector investment and support the establishment of a local and export renewable hydrogen industry, including through:

- fit-for-purpose hydrogen regulations and legislation
- territory-wide renewable energy resource assessments
- strategic water and land use planning
- workforce skills and capability development
- fostering research and innovation
- assessment of early commercial applications to grow demand.

Enabling Infrastructure

In addition to industry development, the Territory is also undertaking a master-planning approach to key enabling infrastructure to support large-scale hydrogen projects:

Middle Arm Sustainable Development Precinct

The NT Government is working with industry and the Australian Government to transform 1,500 hectares at Middle Arm, adjacent to Darwin Harbour, into a globally competitive, sustainable industrial precinct. The precinct will include processing, production and export facilities with a focus on low emission, clean hydrogen, carbon capture and storage and critical minerals processing.

The NT Government has committed $28 million to support detailed design, strategic environmental assessments, business case development and preliminary infrastructure works. Additionally, the Australian Government has committed $1.5 billion in planned equity to support the construction of common user marine infrastructure, including modular offloading facility, a common user wharf, and widening of shipping channels, to fast track precinct development.

Find out more:
www.territoryrenewableenergy.nt.gov.au

Project Facilitation

To facilitate the significant interest in the Territory as a hub for hydrogen production, the NT Government is taking a proactive approach by streamlining environmental and regulatory approvals for coordinated proponent outcomes and maximum value for the Territory.

The NT Government's Investment Territory team supports and facilitates projects of economic significance from development through to operation. Major Project Status is granted to significant, complex projects with strategic and economic impact.

Darwin H2 Hub

In January 2024, the NT Government awarded Major Project Status to the Darwin H2 Hub, a new export-scale green hydrogen project, which is being developed by international renewable energy company TE H2 (formerly Total Eren). Proposed to be located at the Middle Arm Precinct, the Darwin H2 Hub is expected to produce more than 80,000 tonnes per year.

Credit: Northern Territory Government. Across the NT there is strategic land use and resource planning underway, including for key enabling infrastructure and renewable energy resource assessments (including solar and wind) for potential large-scale energy generation.

Australian Capital Territory

Net Zero Emissions Territory

The Australian Capital Territory (ACT) Government has a legislated target of achieving net zero greenhouse gas (GHG) emissions by 2045 at the latest under the *Climate Change and Greenhouse Gas Reduction Act 2010*. The ACT Climate Change Strategy 2019–2025 sets out the next steps in how the ACT Government will work with the community to respond to climate change and achieve net zero emissions by 2045.

Since achieving the 100% renewable electricity target in 2020, the ACT has focused efforts on reducing emissions from fossil fuel gas use (19.9%) and transport (64.6%) – the two largest remaining contributors to the ACT's current greenhouse gas emissions*. The ACT's Integrated Energy Plan provides a pathway for the ACT's energy system transformation and contributes to the Territory achieving net zero emissions by 2045. Electrification will be the best option to decarbonise most gas applications.

Renewable hydrogen could play an important, but targeted role in decarbonising the ACT's niche applications that are difficult or currently impossible to electrify. These applications include those that require high temperatures to support production, such as asphalt producers and glassworks facilities. Heavy equipment, plants and machinery may also face challenges to electrification. There is also opportunity to explore the role of renewable hydrogen to decarbonise heavy road transport in the ACT.

Hydrogen for Transport – Australia's first public hydrogen refuelling station

In March 2021, Hyundai, ENGV, ActewAGL, the ACT Government and renewable energy developer Neoen Australia collaborated to open and operate Australia's first public hydrogen refuelling station. The station was designed and built by Pacific Energy and the station was then acquired by Pacific Energy in April 2024 – it produces and stores hydrogen on site and can currently refuel up to 30 vehicles with plans for expansion in place.

The ACT Government operates 20 hydrogen fuel cell vehicles, the first and largest government fleet of hydrogen vehicles in Australia. The lessons learned through this trial will serve as a base to expand the number of zero emissions vehicles in the ACT.

Transport is the largest source of emissions in the ACT, contributing over 60% of all greenhouse gas emissions. Opportunities for hydrogen to support emissions reduction from transport, especially for commercial fleet operators, are present in the ACT owing to its small footprint and road links to NSW and Victoria.

Green Hydrogen Knowledge Economy in the ACT

The $17 million Energy Innovation Fund and the ACT Government's renewables auction industry contributions will continue to invest in energy innovation research and development activities, including support for the development of a green hydrogen knowledge economy in the ACT. Existing grants have supported projects such as large-scale underground hydrogen storage technology, on-demand renewable hydrogen production technology, and liquid organic hydrogen storage technology.

The Australian National University has a broad portfolio of hydrogen research, including:

- the development of highly efficient electrolysers, materials, and devices for hydrogen storage in liquid organics and layered materials
- innovative use of renewable hydrogen in industrial processes
- social licence issues, certification, governance, and economics to address prerequisites and underpinnings of an emerging Australian hydrogen economy.

Find out more about the ACT's Integrated Energy Plan: **www.climatechoices.act.gov.au**

* ACT Greenhouse gas Inventory for 2022-23 www.climatechoices.act.gov.au/__data/assets/pdf_file/0003/2329824/ACT-Greenhouse-Gas-Inventory-Report-2022-23.pdf

Australia's first liquid hydrogen storage facility

Industry contributions from the ACT Government's renewables auction industry commitments continue to support renewable energy research, development and investment in the ACT.

This $1.4 million project aims to develop an innovative Liquid Organic Hydrogen Storage (LOHS) technology and prove its energy industry potential. Liquid organic hydrogen storage is a solution to store hydrogen at room temperature and ambient pressure, a solution for the storage and transport of large-scale renewable energy.

The project expects to expand and validate the performance, safety and scale-up potential of this new technology in an industrial context to support the development of the hydrogen economy in Australia.

It not only includes the technology development but also the regulatory study on how to remove barriers for the future commercialisation and deployment of the LOHS technology at scale.

Led by ARC Laureate Fellow Professor Yun Liu from the Australian National University in collaboration with a team of academics and industrial engineers from the University of New South Wales (Canberra) and Hydrogenia, this project is supported by an Australian Research Council grant, and industry contributions from Global Power Generation Australia (GPG Australia) as part of the ACT Government's renewables auction industry commitments.

Credit: ACT Government

Credit: ENGIE. Wide angle shot of the ENGIE Yuri Green Hydrogen Project site, showing where solar panels will be installed, with the Yara Pilbara Fertilizers plant in the background.

1. Why develop an Australian hydrogen industry?

Key points

- Hydrogen will play an essential complementary role to electrification in decarbonising the global economy, particularly in hard-to-abate sectors.
- Global momentum for hydrogen has accelerated over the past 5 years, with many countries lifting their ambition, and increasing international competition for investment.
- Australia is well-placed to produce hydrogen due to our natural advantages and capabilities.
- Australia aspires to be a global hydrogen leader, playing an important role as a global hydrogen supplier, supporting energy security for our trade and strategic partners and enabling international emissions goals to be met.
- Australia's hydrogen project pipeline is significant – around 20% of the global total.

1.1 Global demand for hydrogen is Australia's opportunity

Global momentum for hydrogen has steadily built over the past 5 years as countries seek to reduce their emissions in line with Paris Agreement goals. This trend will continue. The International Energy Agency's (IEA) Announced Pledges Scenario forecasts low-emission hydrogen production will rise from 30 million tonnes in 2030 to over 250 million tonnes by 2050. Global demand under the IEA's Net Zero Emissions by 2050 Scenario is even bigger, at around 420 million tonnes, more than 4 times existing demand.[9]

Most of Australia's largest trading partners, covering the bulk of Australia's exports by value,[10] have committed to achieving net zero emissions by around the middle of this century. Many of our partners have signalled an intention to make hydrogen a central component of their future energy strategy. Significant hydrogen users and import target announcements include:

- Japan: targeting the use of 3 million tonnes per year of hydrogen by 2030, 12 million tonnes by 2040 and 20 million tonnes by 2050.[11]
- Republic of Korea: targeting the use of 3.9 million tonnes of hydrogen per year by 2030, up from 220,000 tonnes in 2021.
- European Union: targeting the import of 10 million tonnes of hydrogen in 2030 (plus 10 million tonnes of domestic production).

Although the level of competition is rising around the globe, Australia's renewable energy resources position Australia well for hydrogen production and related export and manufacturing opportunities.

9 IEA 2023, *Hydrogen Net Zero Emissions Guide*. www.iea.org/reports/hydrogen-2156

10 CCA 2021, *Trade and Investment trends in a decarbonising world*. www.climatechangeauthority.gov.au/sites/default/files/Trade%20and%20investment%20trends%20in%20a%20decarbonising%20world_0.pdf

11 METI Ministry of Economy, Trade and Industry 2020, *Green Growth Strategy Through Achieving Carbon Neutrality in 2050*. www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/index.html

Why Australia for hydrogen?

Australia's comparative advantages in the global hydrogen economy

World-class renewable energy

- Largest producer of solar energy per person, and 6th largest in absolute terms, in 2021
- 3rd lowest cost for generating solar power among major solar-power producers
- In the top 15 global onshore wind energy producers, with 6 priority areas for offshore wind industry development
- 6th most attractive country for renewable energy investment
- 262,000 km^2 of land highly suitable for hydrogen production using renewable electricity
- Over 100 hydrogen projects in the pipeline and the first country to ship liquified hydrogen

Skilled workforce and globally recognised innovation ecosystem

- One of the highest ratios of renewable energy patents in the world – on par with the United States and Germany – and almost 40,000 renewable energy patents in the last 2 decades
- One of the world's most highly skilled workforces and #1 ranking as most attractive place for talent in the world
- High-impact research across multiple fields, including materials science and engineering, and 7 institutions in the world's best 100 universities

Political and economic stability which represents low sovereign risk for investors

- Good governance, strong institutions and the rule of law
- Transparent regulation and open markets
- Sophisticated financial markets and a large managed funds sector

Ready to supply global hydrogen markets

- Committed to the Paris Agreement's goals and global climate leadership - backed by legislated emissions targets that will see hydrogen used locally
- Predicted by the International Energy Agency to be the 2nd largest net-exporter of low-emissions hydrogen by 2030 and the largest by 2050
- Becoming a renewable energy superpower, with 17 free trade agreements and bilateral agreements on clean energy and hydrogen with major trade partners in Asia, Europe, the United States and the United Kingdom
- Proximity to, and close economic ties with, key importing countries including Japan and the Republic of Korea
- Long-standing track-record as a reliable and trusted resources and energy supplier

For sources, refer to *Austrade's Benchmark Report 2023* and *Australian Hydrogen Equipment, Technology and Services capability directory*, available at: www.globalaustralia.gov.au

1.2 Australia's 2024 National Hydrogen Strategy

In February 2023, the Australian Government, with the support of all states and territories, committed to review the 2019 National Hydrogen Strategy.[12] This decision reflected:

- that further concerted effort will be needed if Australia is to realise our hydrogen export opportunity, which is central to our ambition to become a renewable energy superpower
- the need to explicitly consider the role of hydrogen in Australia's decarbonisation pathway and energy transformation.

Achieving Australia's 2030 emissions reduction target of 43% below 2005 levels is a critical step towards the long-term objective of net zero emissions by 2050.[13] While electrification will play a central role in Australia's net zero transition, hydrogen will need to play an important complementary role to help decarbonise existing hard-to-abate sectors (see Box 1).

The 2024 Strategy also considers the hydrogen industry's vital role as the basis of future investment and exports. Global hydrogen demand represents a significant economic opportunity for Australia and a way through which we can contribute to global decarbonisation. Hydrogen can be exported as an energy carrier to countries less well-placed to generate renewable electricity.

Box 1: Hydrogen's decarbonisation potential

Australia has a legislated commitment to achieve net zero emissions by 2050. To support this, the Australian Government is preparing decarbonisation plans for 6 key sectors. The 2024 National Hydrogen Strategy intersects closely with 3 of these sectoral plans:

- **Industry** - Hydrogen represents a prospective chemical feedstock or high-temperature fuel for several hard-to-abate industrial sectors. Ammonia produced with hydrogen also offers a pathway to reduce upstream emissions from fertilisers and explosives. Green metals (specifically iron and alumina) are likely hydrogen users and sectors that align with the principles included in the National Interest Framework.
- **Transport** - While less likely to be used widely in small vehicles, hydrogen presents a real opportunity to decarbonise heavy duty and long-haul transport – heavy road, rail, maritime and aviation fuels.
- **Electricity and Energy** - Hydrogen intersects with this sectoral plan as:
  - **A substitute for and complement to natural gas-based power generation**. Hydrogen will be used as a fuel for peaking power generation to firm the grid, including under the South Australian Government's Hydrogen Jobs Plan.
  - **A source of new load and load flexibility.** Large-scale hydrogen production using electrolysis will require substantial amounts of renewable energy. As such, even a small amount of load flexibility in grid connected facilities will potentially provide substantial benefits to maintaining grid balance.
  - **Long duration energy storage**. Hydrogen can be a medium for static energy storage; for example, when intermittent renewable energy is used to produce hydrogen. Underground storage of gases is common practice and large quantities of hydrogen could be stored in salt caverns or depleted gas reservoirs. Pipelines are another significant storage option.

12 ECMC 2023, *Energy and Climate Change Ministerial Council Communique*. www.energy.gov.au/sites/default/files/2023-02/ECMC%20Communique%20-%2024%20February%202023.docx

13 The Climate Change Act 2022 legislated Australia's emissions reduction targets of 43% below 2005 levels by 2030 and net zero by 2050

Australia can also export low-emissions products manufactured locally using hydrogen such as iron, alumina, ammonia and low carbon liquid fuels. This domestic production capacity will also support the resilience of our supply chains in the face of potential global disturbances.

Global momentum has steadily built in recent years and many countries are positioning to capture the opportunity from hydrogen and downstream sectors such as green metals. Australia has advantages in terms of our renewable energy and geological endowments, but these alone are not enough. Without further action, Australia risks ceding this opportunity to our competitors.

For these reasons, the 2024 National Hydrogen Strategy outlines our revitalised national effort to unlock our hydrogen potential. It is the strategic policy framework underpinning the Australian Government's substantial hydrogen investments through the 2024-25 Budget and under the Future Made in Australia agenda.

In the 5 years since Australia's inaugural strategy, Australia's governments have focused efforts on the early foundations for industry growth (Figure 1). But to date we have lacked the incentives needed to drive economies of scale and build experience. The 2024 National Hydrogen Strategy moves beyond early industry activation measures to focus on what is necessary for industry to develop, invest in and deliver large-scale hydrogen production-and-use projects. As a result, delivering both environmental and economic advantages for Australia.

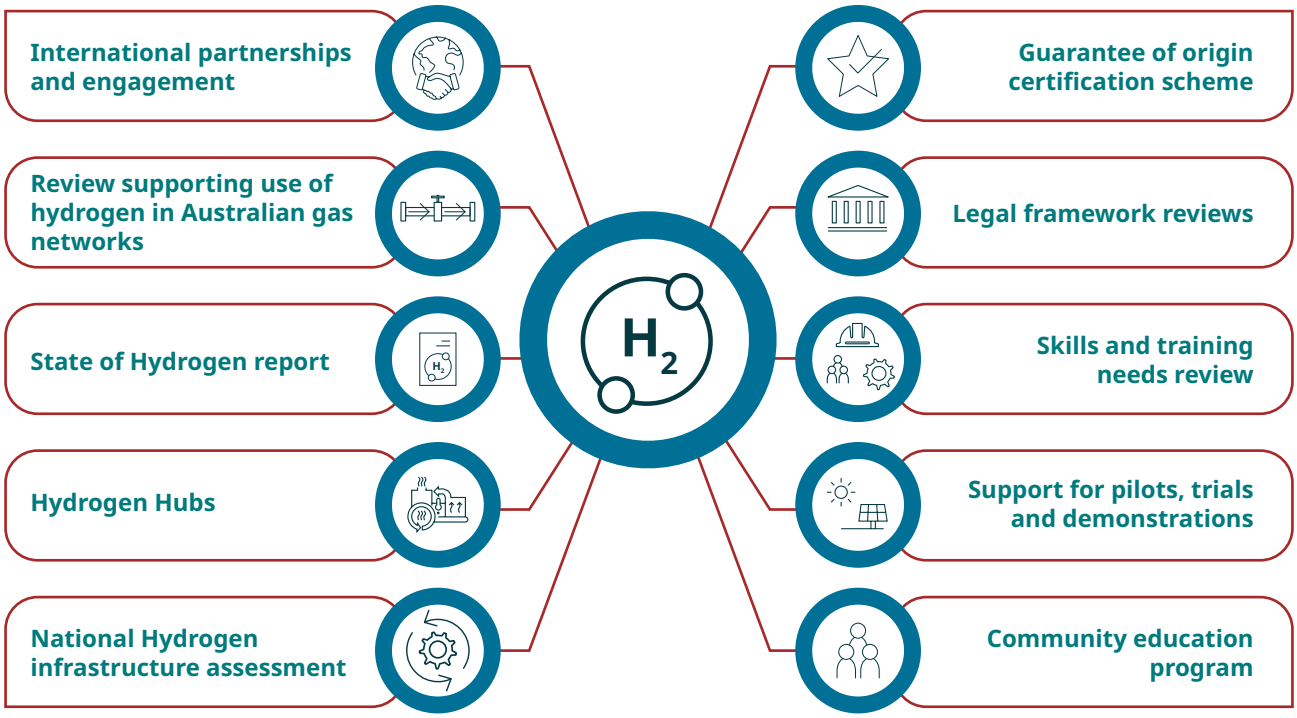


Figure 1 **Early actions and policies to activate Australia's nascent hydrogen industry**

2. Unlocking cost-competitive hydrogen production

Key points

- Australia will adopt a long-term national hydrogen production target to signal our hydrogen ambitions, help attract investment, and support infrastructure planning. Australia will target producing at least 15 million tonnes of hydrogen annually, with a stretch potential of 30 million tonnes annually, by 2050.
- Australia will set 5-yearly milestones to track progress against the national target. The first 5-yearly milestone in 2030 is 0.5 million tonnes of production annually, with a stretch potential milestone of producing 1.5 million tonnes annually.
- Hydrogen production incentives, particularly the Hydrogen Headstart program and the Hydrogen Production Tax Incentive announced under the Future Made in Australia agenda, will catalyse the investment needed to achieve these targets.
- Related initiatives supporting ultra low-cost renewable energy – the biggest component of hydrogen production costs – will also contribute to hydrogen industry development.
- Australia's governments will work together to plan and deliver key infrastructure, including for hydrogen storage, transport and water. Governments will also progress place-based measures that integrate hydrogen hubs with decarbonisation of broader industrial precincts.

2.1 Hydrogen production targets

Targets provide focus, greater certainty for investors, signal intention, drive coordinated action and set the basis for measuring success. Many countries have established hydrogen production or use targets as part of their hydrogen strategies with clear linkages to their decarbonisation policies.[14]

Targets can bolster investor confidence by sending a clear signal to trading partners about the future marketplace in Australia for hydrogen and hydrogen-based fuels. Through a national production target, the Australian Government can demonstrate to business and investors, both domestically and overseas, that Australia is committed to building its hydrogen industry and providing investment and regulatory certainty consistent with the goal. A hydrogen production target can outline the scale and timing for Australia's hydrogen ambitions, giving both producers and users of hydrogen the confidence and certainty they need to plan and invest.

A national hydrogen production target can also help inform wider planning and investments by governments. This includes helping infrastructure planners across all levels of government to consider when and where long lifetime assets, such as renewable energy and ports, may be needed. A target can support coordinated action across and within governments by providing confidence on the scale and timing for hydrogen's availability, which can in turn inform the design of emissions reduction policies and standards. This includes the sectoral decarbonisation plans that will inform Australia's net zero plan.

Modelling for the National Hydrogen Strategy considered hydrogen's expected role across the Australian economy in 5-yearly increments. Each scenario enables the Australian economy to reach the legislated target of net zero carbon emissions by 2050.

14 IEA Clean Energy Ministerial Hydrogen Initiative, *Global hydrogen targets*. www.cleanenergyministerial.org/content/uploads/2022/07/aspirational-targets-briefing-150722.pdf

Credit: Hysata. Hysata electrolyser manufacturing facility at Port Kembla.

To aid comparison with existing analyses each scenario adopted a range of assumptions that were generally aligned with those used to underpin:

- the Australian Industry Energy Transitions Initiative[15]
- the Australian Energy Market Operator's (AEMO's) Integrated System Plan.[16]

Each of these analyses were developed through extensive consultation and based on the best available information.[17]

The modelling output was used as a primary input to the formation of a base target and stretch potential. The base hydrogen production target reflects a substantial growth trajectory for the Australian hydrogen industry and is the more likely endpoint reflecting strong levels of policy support and the level of engagement from the various elements of the hydrogen industry.

Realising the stretch potential would be significantly more ambitious. It would reflect a much bigger investment in Australia by partner countries, as well as the opportunities provided by the energy transition and global decarbonisation, and striving to become a hydrogen powerhouse on a global scale. Realising this stretch potential would mean Australia capitalising on markets beyond our borders in relation to the export of hydrogen, including through the export of low carbon liquid fuels or green metals made with hydrogen.

'Australia could set production and demand targets to realise its ambitions to be a hydrogen leader by 2030. Setting 2030, 2040 and 2050 targets would give the market certainty and accelerate domestic demand.'

Copenhagen Infrastructure Partners

15 Climateworks Centre and Climate-KIC Australia 2023, *Pathways to industrial decarbonisation: Positioning Australian industry to prosper*. www.energy-transitions.org/publications/pathways-to-industrial-decarbonisation

16 Australian Energy Market Operator 2023, *2023 Inputs, Assumptions and Scenarios Report, July 2023*. https://aemo.com.au/-/media/files/major-publications/isp/2023/2023-inputs-assumptions-and-scenarios-report.pdf?la=en

17 CSIRO 2024 *Scenario modelling of the production and consumption of hydrogen in Australia*, CSIRO, Australia.

TARGET 1

Australia will produce at least 15 million tonnes of renewable hydrogen per year, with a stretch potential of 30 million tonnes by 2050.

Australia's long-term national hydrogen production targets (Figure 2) are aligned with our national emissions reduction targets. The production target demonstrates the Australian Government's commitment to building the hydrogen sector to enable decarbonisation domestically and for our trading partners. The production target, coupled with supporting policies and programs such as production incentives, will help signal and substantiate Australia's hydrogen ambitions, attracting investment in the sector. The target will also support long-term infrastructure planning such as for renewable energy production or ports.

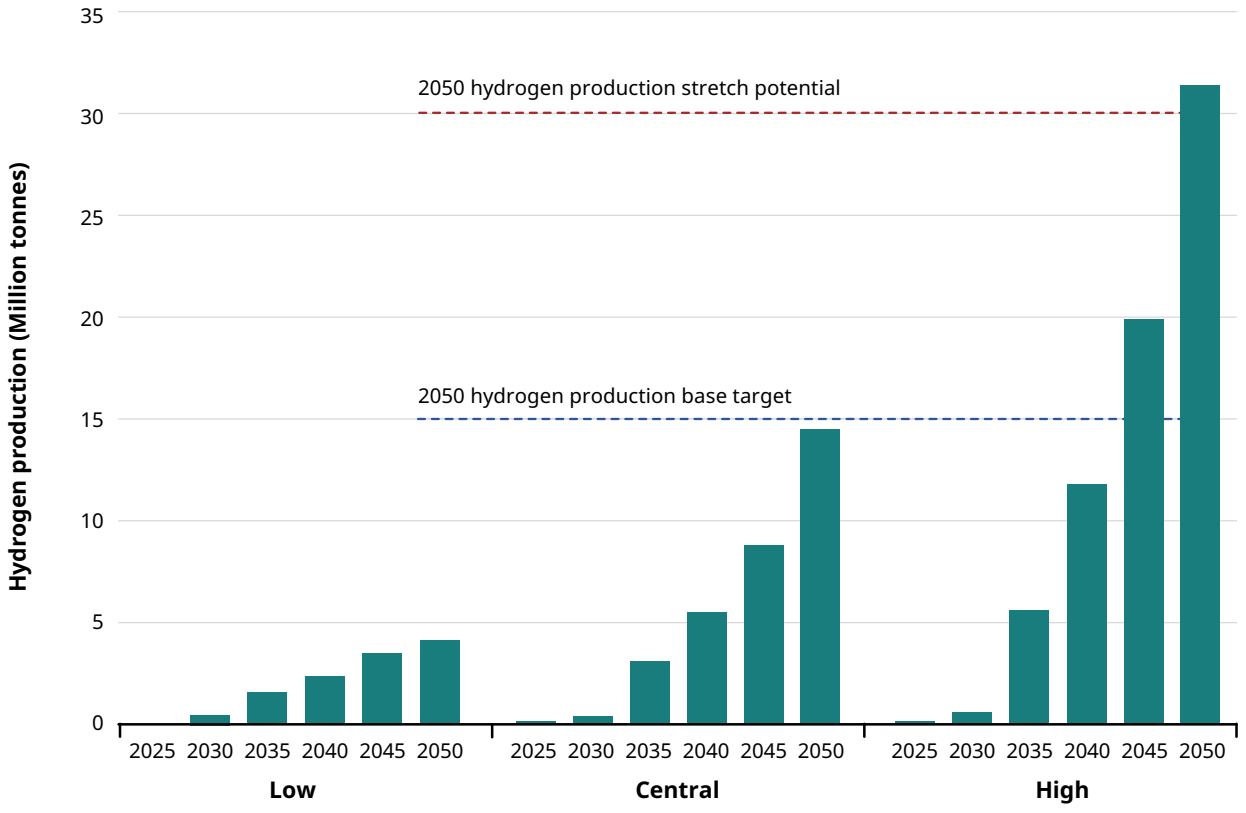


Figure 2 **Modelled hydrogen production for 2025-2050**

Showing Australia's base target and stretch potential for 2050, and associated production trajectory in 5-yearly increments under the 3 scenarios considered. The Low case is informed by the AEMO Step Change scenario; Central was also informed by the Step Change scenario but with additional export driven production; High was informed by the AEMO Green Energy Export scenario with additional export.

Source: CSIRO 2024 Scenario modelling of the production and consumption of hydrogen in Australia

ACTION 1

Focus government support on renewable hydrogen, complemented by suitable emissions intensity thresholds and other requirements for government-supported hydrogen projects, with GO certificates to form the basis of verification.

Box 2: Prioritising support to renewable hydrogen

The 2019 National Hydrogen Strategy envisaged the establishment of a 'clean' hydrogen industry, using a technology neutral approach. This included hydrogen produced through renewable electricity powered electrolysers and/or fossil fuel-based production coupled with substantial carbon capture and storage (capture rates of 90% or more).

The Australian policy landscape has subsequently shifted, with commitments to a net zero economy by 2050 and ambitious goals for emissions-reduction and renewable generation in 2030. The Australian Government has also outlined its ambition to become a renewable energy superpower.

In light of these commitments, the Australian Government has prioritised its policy efforts and financial support towards renewable hydrogen projects, which are clearly aligned with Australia's net zero goals.

A range of analyses indicate that renewables are likely to offer the lowest cost, lowest emissions intensity and be most scalable in the long-term. For example, scenario analysis based on the latest efficiency and cost data found electrolysis contributed over 98% of total hydrogen production out to 2050.[18] Other factors include the:

- Australian project pipeline, based on IEA data, is overwhelmingly focussed on renewable hydrogen production projects, which is consistent with the global trend (Figure 3)
- expectation of future offtake preferences for renewable hydrogen in some global markets
- modular and scalable nature of electrolyser-based production
- high cost of achieving high carbon capture rates (greater than 90%)
- expectation that electrolyser-based production will decrease in cost compared to a relatively static cost of carbon capture and the increasing cost of fossil fuels.

The Australian Government will also establish emissions intensity thresholds and other requirements for government-supported renewable hydrogen projects. The Guarantee of Origin (GO) scheme certificates will form the basis of verification.

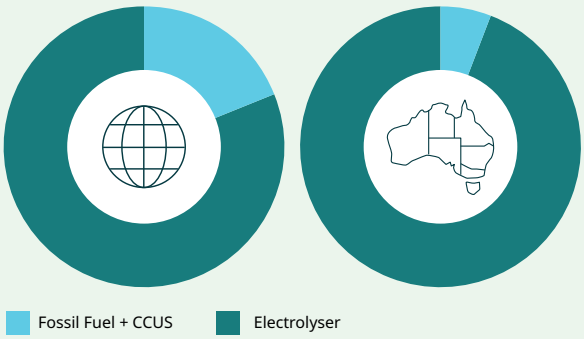


Figure 3 **Production pathway of announced projects**

18 CSIRO 2024 *Scenario modelling of the production and consumption of hydrogen in Australia*, CSIRO, Australia.

5-yearly production milestones

To complement the long-term production target, a series of 5-yearly milestones will provide for short-term progress monitoring, reporting and ongoing policy development (Figure 4). They will provide valuable indicators both of the development of Australia's hydrogen industry and of the pace at which the global hydrogen opportunity is emerging.

CSIRO's scenario analysis and consideration of the existing project pipeline suggests production may be around 0.5-1.5 million tonnes by 2030. Achieving these levels of production will depend on a range of factors, including Australia's efforts to incentivise production and build a supportive enabling environment and wider factors such as the development of supply chains, markets and international demand for hydrogen and its derivatives.

The Australian Government is delivering a combination of initiatives that provide a solid basis for industry, investors, communities and workers to achieve our first hydrogen production milestone for 2030. The government will also continue to work with our international partners to develop international markets and supply chains. Australia will take an adaptive approach to production milestones and will reconsider the level of milestones if there is evidence of international demand developing either faster or slower than anticipated.

TARGET 2

In addition to the 2050 hydrogen production target, Australia's progress will be measured against the following annual hydrogen base and stretch production milestones:

- **2030: 0.5 – 1.5 million tonnes**
- **2035: 3 – 5 million tonnes**
- **2040: 5 – 12 million tonnes**
- **2045: 9 – 20 million tonnes**

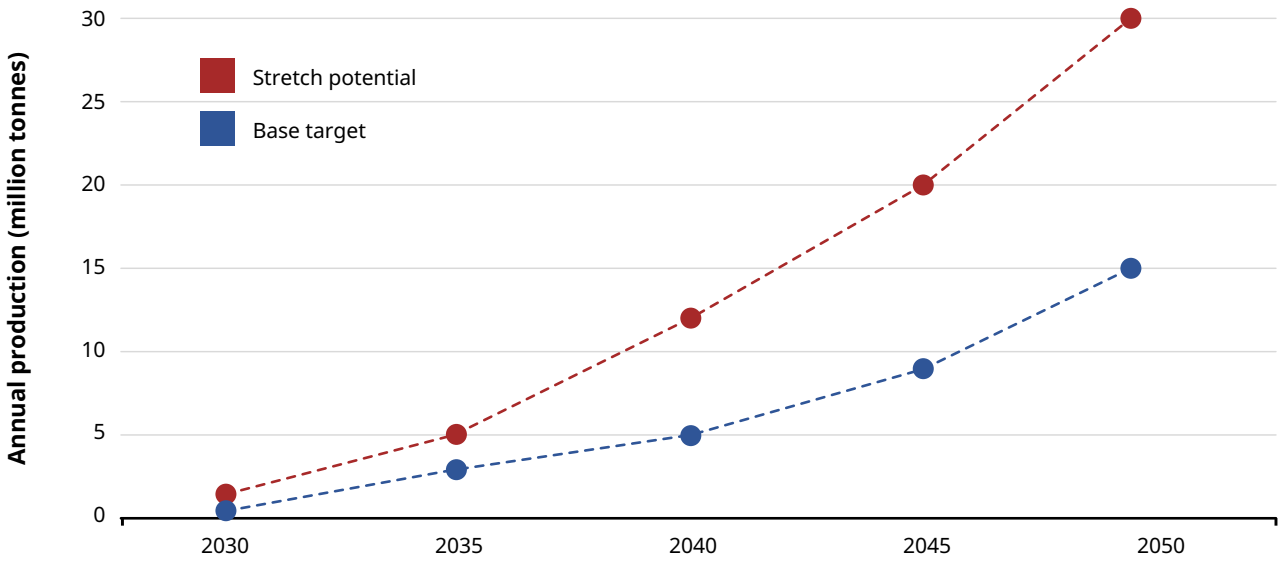


Figure 4: **5-yearly base and stretch production milestones**

Achieving the national production target

Achieving Australia's 2050 base production target will require significant investment in renewable energy and other infrastructure. With hydrogen production expected to scale-up over the 2030s and 2040s, modelling for the strategy suggests that the near-term impacts on Australia's energy systems will be modest.

To achieve the base production target, around 3 GW of electrolyser capacity could be needed by 2030, with this subsequently growing to 150 GW by 2050 to achieve 15 million tonnes of production. Hydrogen production, alongside other trends within the Australian economy (such as electrification of transport and manufacturing), will require a substantial build out of Australian electricity supply. Approximately 1,200 TWh of electricity could be required across the economy for hydrogen production by 2050.[19]

Analysis for the strategy suggests that, as the sector scales, hydrogen production is likely to shift to the highest quality renewable energy regions where electrolysers are not grid connected.[20] This will enable producers to achieve economies of scale and take advantage of low renewable-energy costs, and low transmission-infrastructure costs. At large production volumes, there are cost benefits to producing hydrogen close to the renewable energy source and subsequently transporting by pipeline to the point of use. This represents a significant opportunity for renewable energy project developers to consider off-grid projects. Where hydrogen is used in value added manufacturing (such as in ammonia, iron or alumina production), there may be advantages for industries to co-locate their facilities with hydrogen production to avoid costs associated with transporting hydrogen.

This is consistent with other analyses that have found that, as the sector scales, it will often be more efficient for hydrogen production and renewable energy to be co-located.[21] The hydrogen would be used locally or transported by dedicated hydrogen pipelines to end users. 'Moving molecules' (rather than 'moving electrons') reduces the need for any further investment and construction of electricity transmission infrastructure with the pipelines also offering a short-to-medium term storage solution ('line packing').

Where projects are grid connected, they provide a flexible source of electricity demand and could support energy storage. Both characteristics may be used to support grid stability.

The land required for hydrogen production is expected to be significant but manageable in the context of Australia's vast landmass (see Figure ES-1). Analysis by Geoscience Australia for the 2019 National Hydrogen Strategy concluded around 262,000 km^2 (or around 3% of Australia) of coastal areas is highly suitable for hydrogen production using renewable electricity, with further prospective locations inland. To put this in context, achieving the base production target in 2050 could involve a geographical footprint of less than 7,000 km^2, while achieving the stretch potential could involve around 14,000 km.[22] This level of land use indicates the hydrogen sector could use less than 0.2% of the Australian landmass by 2050.

19 DCCEEW 2023, *Australian Energy Statistics, Electricity generation by fuel type 2021-22 and 2022*. www.energy.gov.au/publications/australian-energy-statistics-table-o-electricity-generation-fuel-type-2021-22-and-2022

20 Arup 2024, *Infrastructure to enable hydrogen industry development – additional scenarios building on the National Hydrogen Infrastructure Assessment*, Arup, Australia.

21 Clean Energy Finance Corporation 2021, *The Australian Hydrogen Market Study*. www.cefc.com.au/insights/market-reports/the-australian-hydrogen-market-study/

22 Estimated geographical footprint is based on CSIRO analysis (unpublished) of land requirements for 35 renewable energy projects, which found an average direct impact area of 23.9 km^2/GW for solar renewable energy. The National Hydrogen Strategy estimates assume a 25% capacity factor for solar, and no technology improvements over time. The estimates presented here are of a similar order of magnitude to other published estimates, including ARENA 2023, *ULCS: How ultra low-cost solar can unlock Australia's renewable energy superpower - White paper 2023*. https://arena.gov.au/assets/2023/04/the-incredible-ulcs-ultra-low-cost-solar-white-paper.pdf

2.2 Cost-competitive hydrogen production

Hydrogen is an emerging industry, both globally and in Australia, and this contributes to higher production costs compared to well established fossil fuel technologies across a range of industries. However, the rapid increase in the deployment of large-scale wind and solar photovoltaic generation technologies in recent years, indicates it is possible to rapidly bring down production costs as projects are supported to realise scale deployment.

Analysis conducted for the preparation of the 2024 Strategy indicated Australian hydrogen production costs will fall substantially over the coming decades.

Analysis for the strategy suggests the current cost of renewable hydrogen production is in the range of $5-10/kg (equivalent to around US$3-7/kg), but this will fall substantially over the period to 2050 (Figure 5). As more projects come online, lower production costs will be driven by falling costs for the major elements of the hydrogen cost stack, namely renewable energy and electrolysers. By 2050, renewable energy costs are expected to fall by 40-60%, while electrolyser costs could fall by 88-94%.[23] These expectations accord with other analyses which indicate hydrogen production costs at the 'farmgate' are projected to fall below US$2/kg by 2050 in many locations,[24] positioning Australian projects among global leaders.[25]

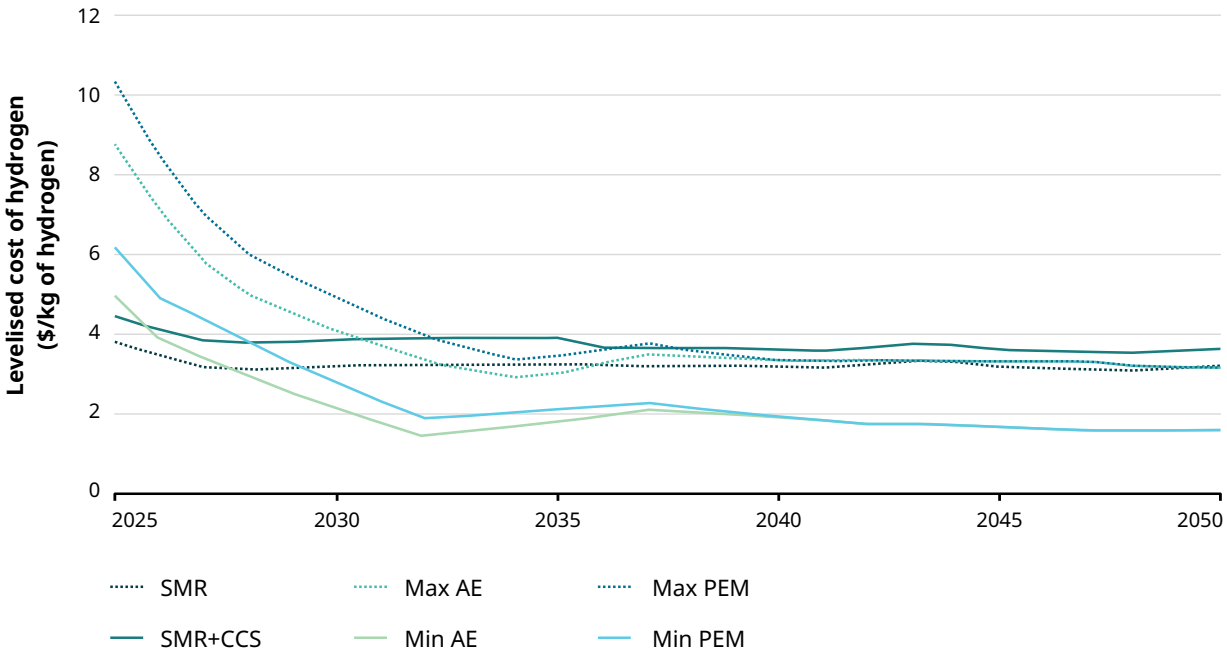


Figure 5 **Levelised Cost of Hydrogen production by method over time**

Source: CSIRO 2024 Scenario modelling of the production and consumption of hydrogen in Australia.
Note: PEM =Proton exchange membrane electrolyser. AE = Alkaline electrolyser. SMR = Steam methane reforming, SMR + CCS = Steam methane reforming + Carbon Capture and Storage.

23 P Graham, J Hayward, J Foster and L Havas, 2023, *GenCost 2022-23: Final report*, CSIRO, Australia, www.csiro.au/en/research/technology-space/energy/GenCost

24 Arup 2024, *Infrastructure to enable hydrogen industry development – additional scenarios building on the National Hydrogen Infrastructure Assessment*, Arup, Australia.

25 Other analyses suggest globally competitive production costs are likely to be in the range of US$1-2/kg in 2050. For example, McKinsey and Hydrogen Council 2023, *Global Hydrogen Flows – 2023* Update. https://hydrogencouncil.com/en/global-hydrogen-flows-2023-update/

Hydrogen costs delivered to international markets will also reflect mid-stream processes, such as transmission, compression and shipping. All suppliers will incur these costs, but some countries will have advantages such as proximity to markets. For example, the shipping component for Australian exports to Tokyo are estimated to be comparatively low, meaning hydrogen produced in the United States, Algeria and Chile would need to be around US$0.20/kg of hydrogen (or around 10%) cheaper than Australian produced hydrogen to be competitive.[26] Other studies, such as the HySupply analysis of an Australia-Germany hydrogen supply chain, have found that shipping distance is not a barrier for Australian exports to Europe.[27]

Reducing renewable energy costs

Energy is the largest component of the hydrogen production cost stack, representing around 70% of total production costs. The availability of low-cost renewable electricity will be vital to reducing hydrogen production costs and ensuring Australia's hydrogen and hydrogen products are globally competitive.

Australia is working to unlock ultra low-cost renewable energy by targeting technology innovations and breakthroughs and by driving renewable energy deployment to achieve economies of scale.

The Australian Government has announced substantial support to increase renewable energy deployment, such as the Capacity Investment Scheme and Rewiring the Nation. These investments will help to scale-up renewable energy supply and reduce costs. The government is also taking action to address bottlenecks and constraints that can increase project costs, such as in supply chains (section 2.4), workforce (section 2.5) and regulatory processes (Section 4.2).

Technology advances will enable further cost reductions. ARENA is directing significant investments towards reducing renewable energy costs. ARENA's ambitious 30-30-30 vision for ultra low-cost solar would deliver 30% solar module efficiency at an installed cost of 30 cents per watt by 2030.

Through the 2024-25 Federal Budget, the Australian Government has provided $5.1 billion to boost ARENA and support it to develop and commercialise technologies critical to net zero. This funding includes $1.9 billion over 10 years to support ARENA to continue its core investments in renewable energy and related technologies over the long term.

Other institutions, including CSIRO and Australia's universities, are also investing in innovative renewable energy technologies.

Bridging the cost gap – hydrogen production incentives and financing

To accelerate the development of Australia's hydrogen industry, the Australian Government is introducing the Hydrogen Production Tax Incentive which will offer a time-limited and demand-driven refundable tax offset of $2/kg to eligible hydrogen producers. In addition, $4 billion has been committed to the Hydrogen Headstart program, to provide revenue support for large-scale early movers. These programs are similar to the schemes used in other countries and enable large-scale hydrogen projects to proceed with greater certainty over future revenue streams (see Box 3).

These measures will help drive deployment, build experience in the Australian hydrogen and finance sectors with large scale projects, and help bridge the commercial gap. By targeting the 'green premiums' that are not yet reflected in market prices, they will help the current pipeline of projects achieve final investment decision and unlock the next wave of investment. These are key strategic investments that will enable the sector to scale up and ensure Australian hydrogen projects are globally cost-competitive.

ACTION 2

Provide early policy support to enable the scaling up of the hydrogen industry to achieve production costs that are competitive with incumbent fossil fuels and to secure early offtake agreements.

26 C Johnston, MHA Khan, R Amal, R Daiyan, I MacGill 2022, *Shipping the sunshine: An open-source model for costing renewable hydrogen transport from Australia*. International Journal of Hydrogen Energy, Volume 47, Issue 47.

27 R Daiyan, I MacGill, R Amal, H Losch and R Schlogl 2023, *Final Report of the Australian German HySupply Project*, www.globh2e.org.au/_files/ugd/8d2898_3aa5c4ede91f4f4e9f70c07df13f4243.pdf

Box 3: Hydrogen Production Tax Incentive and Hydrogen Headstart

Hydrogen Production Tax Incentive

The Australian Government has committed to a new Hydrogen Production Tax Incentive (HPTI) to accelerate the deployment of renewable hydrogen production in Australia. The HPTI will provide time-limited, demand-driven production support to eligible renewable hydrogen producers.

The HPTI will be delivered through Australia's tax system, claimable at a rate of $2/kg of eligible hydrogen produced. Support will be provided for hydrogen produced between 2027–28 and 2039–40 to projects that reach final investment decision by 2030. Each facility will have access to the HPTI for a maximum of 10 years from first production.

Hydrogen Headstart

Hydrogen Headstart is a competitive program which will provide revenue support to large-scale renewable hydrogen projects in Australia, over a maximum 10 year period. The program aims to bridge the commercial gap between the production costs and sale price of renewable hydrogen, or derivative products such as ammonia or methanol. The program complements the support provided through the tax system by the HPTI by providing targeted, time-limited support for a small number of early-mover, innovative projects that face higher barriers to deployment.

Australian-based hydrogen projects powered by 100% renewable energy are eligible to apply. Projects must be located at a single site with a minimum electrolysis deployment of 50 MW. The program's merit criteria emphasises deliverability, project maturity, cost competitiveness, emissions abatement, First Nations engagement and inclusion, and broader benefits to the Australian economy.

The Australian Government announced an initial $2 billion for the Hydrogen Headstart program in the 2023-24 Budget. Round 1 of the program commenced in 2023. The government committed additional funds to the program through the 2024-25 Budget, bringing total funding available to $4 billion. The program is administered by ARENA.

Taken together, the HPTI and Hydrogen Headstart could together bring online 10 to 20 large-scale renewable hydrogen projects, with over 5 GW of electrolyser capacity producing over 1 million tonnes of hydrogen per year once operational. These estimates are based on the available data from projects under active consideration and represent more than double Australia's current annual hydrogen production from fossil fuel sources.

Bringing online this many projects could unlock over $50 billion of private sector investment in Australia's emerging hydrogen sector. To put this in context, the Grattan Institute has separately identified that this volume of hydrogen could be sufficient to decarbonise the equivalent of Australia's total production of ammonia, alumina and iron.[28]

28 Grattan Institute 2023, *Hydrogen: Hype, hope, or hard work?*. https://grattan.edu.au/wp-content/uploads/2023/12/Hydrogen-hype-hope-or-hard-work-Grattan-Institute.pdf

The novel nature of renewable hydrogen technology adds risk to projects, which is directly proportional to a hydrogen project's financing cost. Businesses also noted that the risk of realising a return can mean projects struggle to secure sufficient capital to see them through early development. For example, front end engineering and design (FEED) studies can cost tens of millions of dollars.

The Australian Government has engaged a core of specialist investment groups that can support hydrogen projects, including the:

- Clean Energy Finance Corporation (CEFC)
- Northern Australia Infrastructure Facility (NAIF)
- Export Finance Australia (EFA)
- National Reconstruction Fund Corporation (NRFC).

These bodies can provide financing options to support Australia's hydrogen industry. For example, the CEFC established the $300 million Advancing Hydrogen Fund in 2020. To date there have been limited viable investment opportunities, due mainly to a mismatch between investment return, investment risk settings and the maturity of the projects.

ACTION 3

Consider reforms that may further enable specialist investment groups to play a bigger role in supporting the hydrogen industry to mature and secure further finance through traditional capital markets.

2.3 Hydrogen infrastructure, hubs and precincts

Developing a hydrogen industry of sufficient scale to support export industries will require substantial infrastructure investments. As well as port infrastructure, government investment will be needed in expanding electricity networks, hydrogen pipelines, transport, water and social infrastructure to support regional workforces.

An immediate priority for the Australian Government will be to leverage its hydrogen hub investments (Box 4).

Hydrogen hubs support low-cost hydrogen production by concentrating delivery of new infrastructure and enabling firms to:

- share the initial costs of supporting infrastructure
- benefit from a skilled local workforce
- encourage collaboration.

Box 4: Hydrogen hubs in Australia

The Australian Government is investing more than $500 million to support the development of hydrogen hubs in regional Australia.

Hydrogen hubs are locations where producers, users and exporters of hydrogen work side by side to share infrastructure and expertise. They will help the hydrogen industry springboard to scale by:

- lowering the cost of production
- encouraging innovation
- enhancing skills and training efforts.

The Australian Government has announced funding, with co-contributions from industry and state governments, for hub projects in:

- the Pilbara and Kwinana in Western Australia
- the Hunter in NSW
- Bell Bay in Tasmania
- Gladstone and Townsville in Queensland
- Port Bonython in South Australia.

There are opportunities to expand hydrogen hubs to a broader precinct model that supports regional decarbonisation. These can incorporate the operations of other sectors that align to the principles included in the National Interest Framework.

Shared infrastructure and economies of scale would lower the costs for decarbonising existing facilities within the region as many heavy industries tend to be geographically concentrated.[29] Efficient approvals, reliable energy, pre-existing infrastructure and port access would be equally advantageous for the hydrogen industry and other new industries seeking to establish in Australia, such as green metals, critical minerals processing and clean energy manufacturing.

Governments at all levels would need to work in meaningful partnership to develop expanded hydrogen hubs connected to other industrial decarbonisation opportunities. This work has commenced, but is at an early stage. States and territories will play a leading role in driving the development of individual precincts. The states and territories can leverage existing zoning arrangements, such as Strategic Industrial Areas, State Development Areas and Special Activation Precincts, while the Australian Government could play a coordinating and enabling role.

Leveraging hubs to support wider precincts aligns with the role of the Net Zero Economy Authority (NZEA), which will promote an orderly and positive net zero economic transformation for Australia, its regions, industries, workers and communities. The following principles may help guide governments and industry in progressing a precinct-based approach:

- Clear governance arrangements, including local industry and government partners, to provide coordination and leadership in developing precincts.
- Net zero roadmaps, master planning and precinct-level business cases that assess regional capability, hydrogen demand and infrastructure priorities can help integrate precincts with wider energy system planning and industrial transformation. This can guide the long-term infrastructure build on the supply side to enable private investment on the demand side.
- Active engagement by governments with industry and the financing sector can help align policies and funding mechanisms (both existing and new) and facilitate investment in line with the masterplans and roadmaps.

> 'Co-location of supply and demand when possible is one of the best ways to reduce costs. Access to lower-cost, firmed renewable electricity, a skilled workforce, bulk materials handling ports and water resources also have economic benefits.'
>
> **- Climateworks Centre**

ACTION 4

Support the integration of hydrogen hubs into the broader scoping, planning and development by Australian governments of industrial precincts.

Australian governments are driving changes to AEMO's Integrated System Plan (ISP) to ensure that it can best support the energy transformation. An expanded ISP will consider the ongoing electricity (including firming) needs arising from hydrogen production. It will also include a more thorough examination of how hydrogen can contribute to the National Electricity Market (NEM) and its various system requirements. Similarly, PoweringWA has been established to coordinate delivery of the electricity infrastructure needed to support decarbonisation within the South West Interconnected System.

The Western Australian Department of Energy, Mines, Industry Regulation and Safety – Energy Policy WA is leading the implementation of the Pilbara Energy Transition Plan which seeks to establish a high voltage common user transmission network to accelerate decarbonisation, limit impact on country and support new jobs. This will be facilitated by access to (up to) $3 billion of concessional finance allocated to Western Australia under the Rewiring the Nation program.

29 Climateworks Centre 2023, *Renewable energy industrial precincts: Scaling up industrial decarbonisation through a coordinated approach*. www.climateworkscentre.org/wp-content/uploads/2023/05/Renewable-energy-industrial-precincts-Scaling-up-industrial-decarbonisation-through-a-coordinated-approach-May-2023-.pdf

The Australian Government undertook the inaugural National Hydrogen Infrastructure Assessment (NHIA)[30] over 2021 and 2022, and has commissioned updated modelling scenarios as part of the strategy development.[31] For the sector to scale-up, there will be a need to further mainstream Australia's hydrogen goals within existing institutions and planning frameworks. In that context, the next NHIA will be completed in consultation with other key infrastructure planning agencies, including Infrastructure Australia, the AEMO and state infrastructure planning agencies.

With hydrogen hubs providing an anchoring focus for broader precinct-based decarbonisation opportunities, the next iteration would benefit from being brought forward and completed over 2025 and 2026.

Consideration will be given to the need for additional analysis to inform the NHIA, which could include:

- hydrogen storage needs for different purposes, timeframes and locations
- hydrogen pipeline corridors, easements and route alignment
- water infrastructure needs, underpinned by the best available science
- port capability and capacity, shipping routes and refuelling requirements
- heavy transport infrastructure needs.[32]

ACTION 5

Deliver the next iteration of the National Hydrogen Infrastructure Assessment over 2025 and 2026 in consultation with key infrastructure planning agencies, with subsequent analysis conducted at least every 5 years.

Box 5: National Hydrogen Infrastructure Assessment (NHIA)

Modelling for the NHIA, completed in 2023, includes a range of scenarios that illustrate the optimum infrastructure system for an Australian hydrogen production sector. Additional scenarios were commissioned as part of the strategy development, which included an additional focus on water infrastructure. Taken together, these modelling scenarios provide a range of insights regarding the potential evolution of hydrogen related infrastructure in Australia:

- Hydrogen production is expected to predominantly follow the electrolysis pathway using renewable electricity, although steam methane reforming, with CCS, may play a role during the initial phase of industry growth.
- Hydrogen is initially expected to be produced close to demand locations, but as the sector scales up, production is expected to be located closer to high-quality renewable energy sources (such as Renewable Energy Zones), with hydrogen molecules delivered to demand locations by a network of dedicated pipelines.
- A range of hydrogen storage solutions are likely to be required, including short-term storage such as tanks, and long-term underground storage in salt caverns and potentially depleted gas fields.
- Low water availability may be a barrier to hydrogen development in some parts of Australia, particularly dry inland regions. In other areas, new water infrastructure such as desalination plants, recycling, stormwater harvesting, and pipelines will be needed in the long term.

30 ARUP Australia 2023, *National Australia Infrastructure Assessment*. www.dcceew.gov.au/sites/default/files/documents/national-hydrogen-infrastructure-assessment-final-report.pdf

31 Arup 2024, *Infrastructure to enable hydrogen industry development – additional scenarios building on the National Hydrogen Infrastructure Assessment*, Arup, Australia.

32 See separate sections on water (Section 4.3) and long-haul transport (Section 3.3.1) for further discussion of related infrastructure issues.

Analysis and planning initiatives by state and territory governments are also informing industry scale-up needs. These include:

- The NSW Hydrogen Infrastructure Masterplan – Modelling Assessment Report
- Queensland's Hydrogen Production and Export Opportunities Report.

Transporting hydrogen

The means by which hydrogen is transported over land is likely to evolve over time and depend on the end use. The NHIA found that hydrogen is most likely to be transported by a combination of road and pipelines in the near and medium term. Dedicated hydrogen pipelines will be the most economical means of transporting large hydrogen volumes from around 2040.[33]

Inter-regional shipping of hydrogen within Australia was not considered under the first NHIA. Issues relating to transporting hydrogen by ship are discussed in Section 2.3.3 and Section 3.3.3.

Analysis by Frontier Economics found that converting existing gas transmission pipelines for use with hydrogen costs less than new pipelines.[34] As with the NHIA and other analyses,[35] the modelling generally found it most efficient to produce hydrogen adjacent to sources of renewable generation and to transport the hydrogen to the point of demand through pipelines. In all scenarios hydrogen was being used by some industrial customers for high-temperature heat, as chemical feedstock or for electricity generation.

Analysis for the updated strategy suggests demand for hydrogen transported by low-level blending into distribution networks may be lower than was anticipated through the 2019 Strategy. CSIRO's scenario modelling limited blending to a maximum of 10% hydrogen, but found it was not required for residential and commercial gas customers in the distribution networks by 2050 (Figure 6). While a subsequent shift to 100% hydrogen may offer some efficiency, other analyses have also concluded that electrification is a more prospective decarbonisation pathway for gas use in buildings. This is due to a range of technical, economic and logistical reasons, with electricity already cheaper for many consumers than gas.[36]

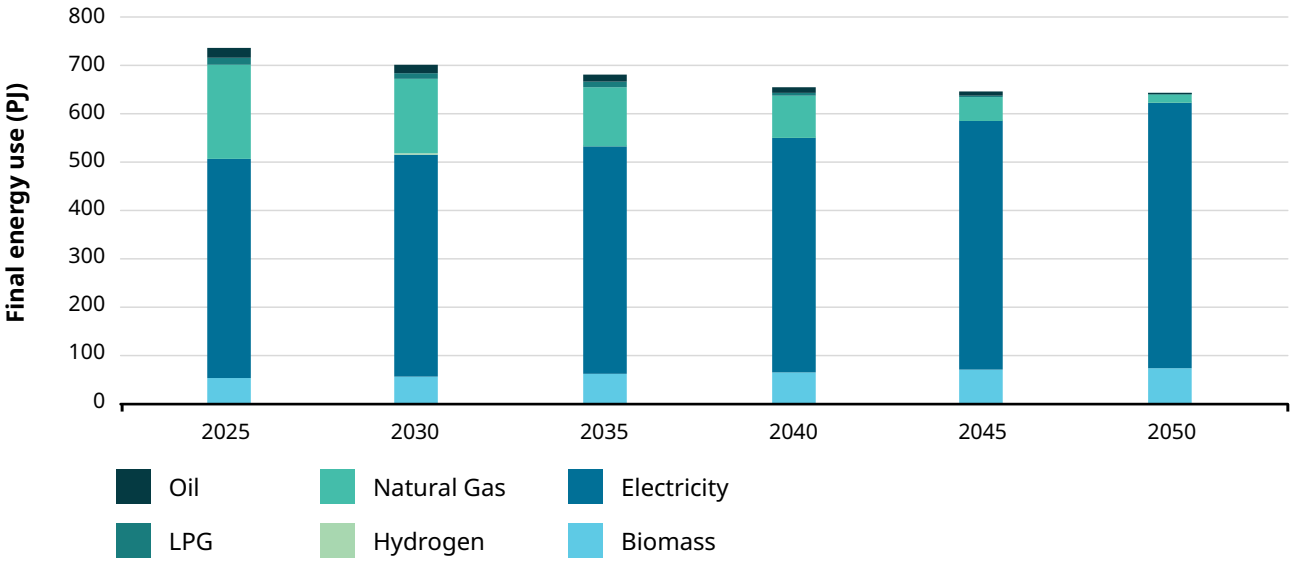


Figure 6 **Modelled energy use across combined commercial and residential buildings over time indicating there may be little hydrogen used in these sectors**

Source: CSIRO 2024 *Scenario modelling of the production and consumption of hydrogen in Australia*, central scenario.

33 ARUP Australia 2023, *National Australia Infrastructure Assessment.* www.dcceew.gov.au/sites/default/files/documents/national-hydrogen-infrastructure-assessment-final-report.pdf

34 Frontier Economics 2023, *Economic analysis of hydrogen blending and conversion*, Frontier Economics, Australia.

35 A Pascale, M Tabatabaei, S Smart 2023, *Downscaling – Hydrogen and synthetic fuel production, transmission and storage*, Net Zero Australia. www.netzeroaustralia.net.au/wp-content/uploads/2023/04/Downscaling-Hydrogen-synthetic-fuel-production-transmission-storage.pdf

36 T Wood, A Reeve, and E Suckling 2023, *Getting off Gas: why, how and who should pay?*, Grattan Institute.

Australian governments have taken steps to remove barriers to transporting hydrogen by pipeline, where this mode of transport makes sense. Governments have reformed the national gas regulatory framework which now provides certainty to hydrogen projects by supporting efficient investment in new hydrogen pipelines. These reforms aim to avoid the risk of pipeline duplication and give confidence that future shippers will have fair terms for third party access to hydrogen pipelines. Since the 2019 Strategy, governments have also supported hydrogen blending projects, including some still in development, and these are providing early demonstrations of hydrogen production and use in Australia.

The 2024 Strategy is focussing on the most prospective domestic demand sectors for hydrogen-based decarbonisation, as outlined in Chapter 3. It will be important to further consider the hydrogen transport needs of these demand sectors, including in a hub or precinct context.

ACTION 6

The Australian Government will work with the states and territories and other experts to improve understanding of future hydrogen transport needs to inform the next iteration of the National Hydrogen Infrastructure Assessment.

Hydrogen storage

Hydrogen storage will play an essential role in the hydrogen ecosystem, particularly if hydrogen is to provide long duration electricity system firming services. For example, the South Australia Government's Hydrogen Jobs Plan will see the delivery of the equivalent of 250 MW of electrolyser capacity, 200 MW of power generation and renewable hydrogen storage in Whyalla by late 2025. Various analyses have indicated the respective roles that different storage options can play in the future hydrogen economy, including hydrogen tanks, pipeline line-packing and long-term geological storage.[37,38,39]

Underground salt caverns are likely to be among the lowest-cost long-term storage options for hydrogen in Australia. Salt caverns provide benefits in being able to achieve relatively high cycling rates, and an environment free of methane impurities. Depleted oil and gas fields may provide further potential underground hydrogen storage options in regions where thick salt accumulations have not been identified or do not exist. While not yet a commercially mature hydrogen storage option, depleted gas fields may have the advantages of being close to existing infrastructure and potential hydrogen demand-and-supply locations.

The Australian Government, through Geoscience Australia, is investing in the pre-competitive geoscience needed to identify suitable salt accumulations and demonstrate viability for hydrogen storage. Through the 2024-25 Budget, the government has committed an initial $566.1 million over 10 years (and further funding to 2058-59) for the new Resourcing Australia's Prosperity initiative, which will enable Geoscience Australia to deliver national mapping of resource potential for critical minerals, strategic materials, naturally occurring hydrogen and other resources to support the net zero transition.

Detailed assessment of national hydrogen storage needs will be considered through the next NHIA. This will consider the benefit of hydrogen storage and the need for different types of storage within required scales and timeframes.

ACTION 7

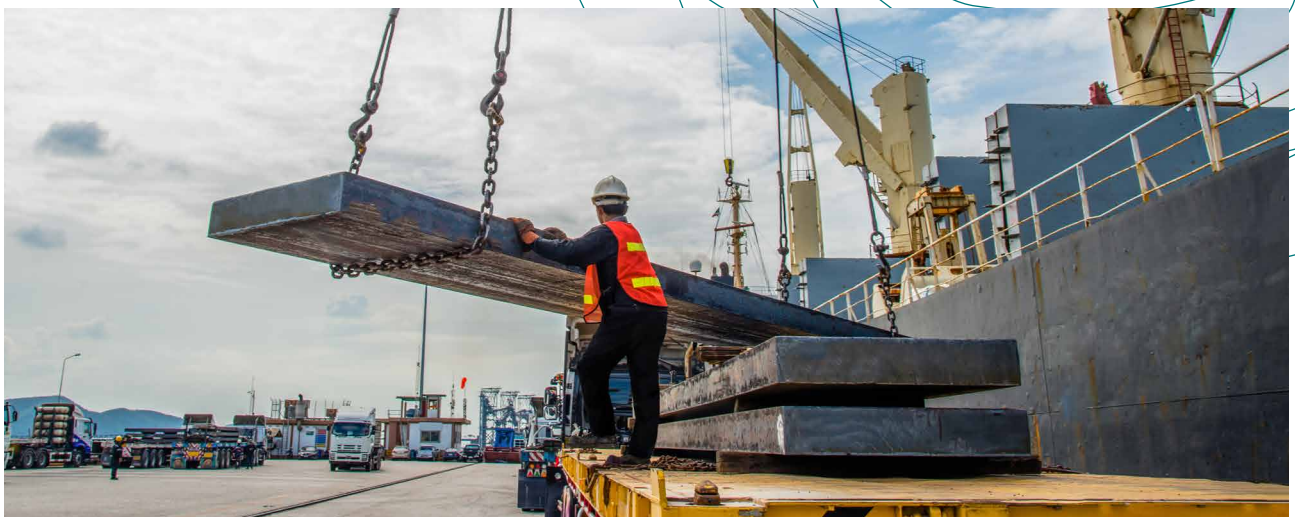
Support Geoscience Australia's precompetitive data program to identify suitable sites for hydrogen storage opportunities.

Australia does not currently have nationally consistent regulatory arrangements that adequately address underground hydrogen storage. This is a potential impediment to industry and infrastructure development and means that the community may not get a fair return from tenements awarded to private proponents.

37 Frontier Economics 2023, *Economic analysis of hydrogen blending and conversion*, Frontier Economics, Australia.

38 Arup 2024, *Infrastructure to enable hydrogen industry development – additional scenarios building on the National Hydrogen Infrastructure Assessment*, Arup, Australia.

39 A Pascale, M Tabatabaei, S Smart 2023, *Downscaling – Hydrogen and synthetic fuel production, transmission and storage*, Net Zero Australia. www.netzeroaustralia.net.au/wp-content/uploads/2023/04/Downscaling-Hydrogen-synthetic-fuel-production-transmission-storage.pdf



ACTION 8

Support the establishment of fit-for-purpose and nationally consistent regulatory arrangements for the geological storage of hydrogen.

> 'Innovation, deployment and cost reductions in hydrogen storage can benefit not only the cost of producing hydrogen but benefit the electricity market, including all consumers.'
>
> **Iberdrola Australia**

Port infrastructure (bunkering and export opportunities)

Global seaborne trade of hydrogen and its derivatives is projected to grow to make up to one third of all seaborne energy trade in 2050. Australian ports do not currently bunker significant volumes of marine fuels, as ships commonly fuel in Singapore before and after visiting Australia.[40] However, there is an opportunity for Australia to capture more of this international bunkering activity due to the inherent lower cost of refuelling closer to the point of fuel production.

It may be possible to refit existing port infrastructure used for liquefied natural gas (LNG) to suit the storage of ammonia, when the infrastructure is no longer required for LNG exports.[41] However, further assessment of port infrastructure and capacity to bunker is required. The change from one dominant fuel (diesel) to potentially several fuels (biofuels, methanol, ammonia) may also challenge some ports which will need to develop the capacity to store and handle various fuel types.

Given the lower energy density of alternative fuels, ships running on these fuels may also need to bunker fuel more frequently. New, and potentially more, ports with the capacity to bunker low-emission fuels, may be required along major trading routes. The impact of changing marine fuels on domestic marine operations will also be important to consider, and the distribution of hydrogen-based fuels by ship may also be viable for other large sources of demand located close to port facilities.

Through Mission Innovation, green shipping corridors have been identified and knowledge resources developed.[42] More detailed study of this opportunity will take place as part of the next NHIA and the Maritime Emissions Reduction National Action Plan under development by the Department of Infrastructure, Transport, Regional Development, Communications and the Arts.

40 The process of bunkering fuels includes the logistics of storing, loading, and distributing fuel among available shipboard tanks

41 Columbia | SIPA 2020, *Zero-Carbon Fuels for Marine Shipping 2020*. https://cdn.catf.us/wp-content/uploads/2020/06/21092831/2020_SIPA_Zero-Carbon-Shipping.pdf

42 Mission Innovation 2024, *Green Shipping Corridor Hub*, https://mission-innovation.net/missions/shipping/green-shipping-corridors

ACTION 9

Consider the readiness and prospects of ports to store and export hydrogen, import renewable energy components, and to provide safe marine refuelling using low-carbon liquid fuels such as hydrogen, ammonia and methanol.

2.4 Supply chains

Producing cost-competitive hydrogen will depend on affordable access to specialised equipment and componentry for electrolysers and renewable energy processing. Australian manufacturing of electrolysers is small but showing promising signs with the opening of new production facilities in Gladstone[43] and Port Kembla.[44] Stakeholders have reported tight supply chains for technologies like electrolysers. The IEA expects supply chains to improve, with ample supply of solar panels and electrolysers to have emerged by 2030, albeit concentrated in a small number of countries and therefore vulnerable to disruption.

A Future Made in Australia envisages Australia maximising the economic and industrial benefits of the move to net zero and securing Australia's place in a changing global economic and strategic landscape. This underpins the establishment of the Future Made in Australia Innovation Fund, to be delivered by ARENA. This program will provide pre-production support to the industries that align with the principles included in the National Interest Framework. Australian companies and researchers have been at the leading edge in developing high-efficiency renewable energy and electrolyser technologies, and there is an opportunity to build sovereign capability by leveraging this expertise.

This builds on other actions the Australian Government is taking to improve supply chains and develop sovereign manufacturing. The National Reconstruction Fund Corporation (NRFC) will target investments in Australian projects that diversify and transform industry. Of the $15 billion allocated to the NRFC, the government has earmarked $3 billion towards renewables and low emissions technologies, one of 7 priority areas identified for NRFC investment.

The Net Zero Manufacturing Initiative, recently launched by the NSW Government with funding of up to $275 million available in its first round, is an example of the strategic investments being made at the state level to enhance sovereign capabilities in electrolyser manufacturing.

> 'The Strategy can play a significant role in the establishment of long-term sovereign manufacturing capability, which will bring the necessary supply chain for the hydrogen industry to Australia.'
>
> **InterContinental Energy**

ACTION 10

Support the development of sovereign clean technology and emissions-reduction manufacturing industries.

The Australian Government is also working with international partners to build resilient global supply chains. Partnering with other countries, including support for research, development and commercialisation, as well as enabling direct foreign investment can ensure Australia retains access to the technologies it needs. Australia is actively engaged to build supply-chain security through the Quad partnership and has bilateral relationships with a focus on clean energy with the United States, Germany, India, Japan, Singapore and the Republic of Korea.

ACTION 11

Identify opportunities that leverage Australia's research, development and demonstration (RD&D) capabilities to advance hydrogen technology manufacturing in Australia.

43 Fortescue 2024, *Fortescue officially opens Gladstone Electrolyser Facility*. https://fortescue.com/news-and-media/news/2024/04/08/fortescue-officially-opens-gladstone-electrolyser-facility

44 Hysata 2023, *Hysata opens new electrolyser manufacturing facility in Port Kembla with $23m vote of confidence from Australian and Queensland Governments*. https://hysata.com/news/hysata-opens-new-electrolyser-manufacturing-facility-in-port-kembla-with-23m-vote-of-confidence-from-australian-and-queensland-governments/

2.5 Workforce

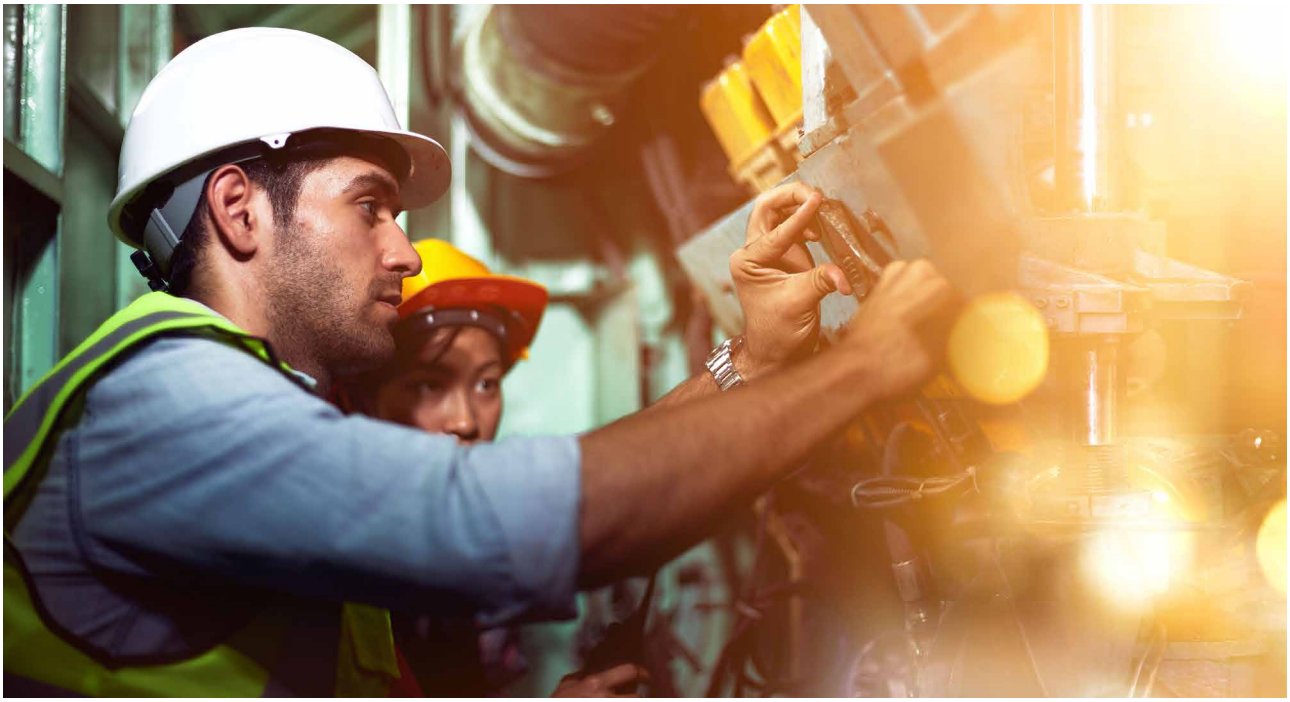
For Australia's hydrogen industry to be competitive, it must be supported by an appropriately skilled 'hydrogen-ready' workforce. Both governments and the hydrogen sector itself will play important roles in building the local workforce needed for hydrogen production to scale up.

Since 2019, significant work has been undertaken by governments to understand workforce issues and barriers facing hydrogen and the clean energy transition more generally (Box 6). Jobs and Skills Australia has identified 3 main pathways to meet the growing demand in the hydrogen and renewables workforce:[45]

- education and training through tertiary education and Vocational Education and Training (VET) systems
- migration of skilled workers and international specialists
- supporting workers transition from related fields and fossil fuel-based industries.

Significant investments and new dedicated institutions have been established to identify and address clean energy workforce needs and bring forward the development of a skilled workforce to deliver Australia's clean energy and hydrogen ambitions.

This includes establishing a national network of 10 Jobs and Skills Councils (JSCs) to provide industry with a stronger, more strategic voice in ensuring the VET sector delivers better outcomes for learners and employers. The work of JSCs will include identifying skills and workforce needs for renewable energy and acting as a source of intelligence on issues affecting the net zero transition. Powering Skills Organisation, Buildskills Australia, and the Mining and Automotive Skills Alliance, in collaboration with other JSCs whose remit touches on hydrogen, will undertake industry-led work on skills, career pathways and training packages for the clean energy workforce, including for hydrogen production and use.



45 Jobs and Skills Australia 2023, *The Clean Energy Generation*. www.jobsandskills.gov.au/publications/the-clean-energy-generation. In particular, see Figure 4.1 in Section 4a on page 102.

Other investments and institutions include:

- The Net Zero Economy Authority (once established), which will support workers to access new employment, or to acquire skills to improve their employment prospects.
- Jobs and Skills Australia (JSA), which provides independent advice and information on current, emerging and future skills needs across the economy.
- Support for capital-intensive and fit-for-purpose training facilities through VET facility upgrades and by co-investing with Victoria in a Hydrogen Technology and Skills Training Centre.
- Establishment of the Building Women's Careers program to advance structural and cultural change to improve women's access to flexible and inclusive vocational education and training opportunities.
- The Australian Government's New Energy Apprenticeship Program, which supports the clean energy workforce in the hydrogen and renewable manufacturing sectors.
- Working with AFAC, the Australian and New Zealand National Council for fire and emergency services, to develop pilot training material for critical incident first responders.
- Wider investments to strengthen the VET sector through the National Skills Agreement.[46]

States and territories have announced measures and strategies specific to their jurisdictions, such as:

- Queensland's Hydrogen Industry Workforce Development Roadmap 2022-2032
- Victoria's Hydrogen Hub's (VH2) Hydrogen Skills Roadmap and Hydrogen Energy Worker Training Centre
- South Australia's Hydrogen Workforce Taxonomy and Roadmap
- NSW's Hydrogen Centre of Excellence.

46 DEWR 2023, *National Skills Agreement*. www.dewr.gov.au/skills-reform/national-skills-agreement

'The production of green hydrogen for the purposes of powering manufacturing with clean, renewable sources of energy, and the manufacture of clean hydrogen technologies themselves, present enormous opportunities to aid Australia's advanced industrial transformation and build entire domestic industries and sectors around major export opportunities.'

Australian Manufacturing Workers' Union

Governments will continue to consider hydrogen workforce needs, including through the National Energy Workforce Strategy. Among other things, that strategy will consider Australian, state and territory government coordination on energy workforce issues. Key institutions, including Jobs and Skills Australia and the Jobs and Skills Councils can also provide workforce analysis, industry intelligence, guidance and support in relation to identifying and addressing skills and training needs.

Jurisdictions could also consider what additional actions may be required to support hydrogen workforce mobility, such as work on mutual recognition arrangements for hydrogen-related job areas. To maximise national consistency, there will need to be an ongoing focus on improving transparency of training development and work to strengthen linkages, both internally between governments and externally with business and relevant professional organisations.

Importantly, governments cannot build this workforce alone. Looking ahead, there will be an expectation that hydrogen businesses adopt a leadership role by investing in the development of workforce capacity, capability and expansion. The Community Benefit Principles that will be applied to Future Made in Australia support include the promotion of safe, secure and well-paid jobs and investment in training and skills development.

ACTION 12

Support workforce development initiatives at all levels of government in line with responsibilities, with reference to analysis and guidance from key institutions including the Department of Employment and Workplace Relations, Jobs and Skills Australia, and the Jobs and Skills Councils.

Box 6: Australia's hydrogen workforce needs

The 'Clean Energy Generation' report by Jobs and Skills Australia (released in 2023) examined Australia's current clean energy workforce and what it needs to look like to ensure it grows at the pace and scale required. The report identifies the risk of a shortfall of VET qualified workers, especially amongst electricians and other VET qualified workers. Australia will need approximately 26,000 to 42,000 more electricians by 2030, and the clean-energy supply workforce will likely need to grow from approximately 53,000 workers currently to 84,000 by 2050.

The 'Developing Australia's hydrogen workforce' report delivered by PwC for the then Australian Industry and Skills Committee (released in 2022) estimated that, if Australia was to produce 2.5 million tonnes of hydrogen in 2030, it would require between 13,150 and 16,050 full time employees across 46 existing roles. The report noted that existing roles will need to be augmented to undertake hydrogen activities. It was not expected that many roles will require significant upskilling or retraining to engage in the hydrogen economy. Nevertheless, some action will be required with the report identifying 26 hydrogen-specific capabilities that fall within these roles of which only 15% were assessed as having sufficient coverage within the education and training system. This report estimated the most in-demand roles will be for engineers, technicians and tradespersons.

2.6 Research and innovation

Innovation will play an important role for Australian hydrogen producers to be competitive. Australia is a demonstrated global innovation leader in developing 'game changing' ultra efficient electrolysers using a variety of technologies, direct solar catalysts and the electrolysis of sea water.

CSIRO's review of Australia's hydrogen RD&D ecosystem found that there is limited targeted support for projects aimed at advancing hydrogen technologies at technology readiness levels (TRLs) in the range 4–6 (Figure 7).[47] Such projects tend to be higher risk and high cost, and therefore are often underinvested in by the private sector. More targeted support for TRL 4-6 would act to accelerate the commercialisation of hydrogen technology innovations in Australia, rather than overseas. This could in turn stimulate the development of hydrogen technology and component manufacturing in Australia.

This aligns with the Australian Government's Future Made in Australia policy agenda to build our sovereign manufacturing base, broadening and diversifying Australia's economy and creating jobs for local, highly trained workers.

The Australian Government provides significant support for hydrogen-related RD&D to research institutions, including CSIRO, Australia's universities and cooperative research centres. A number of institutions, most notably ARENA, direct funding towards the Australian Government's renewable energy RD&D priorities. ARENA has recently been provided with $1.9 billion for ongoing delivery of its core function to fund the development, commercialisation, manufacture and deployment of new renewable energy technologies. This work will be further expanded through the newly established Future Made in Australia Innovation Fund through which ARENA will unlock private capital across new industries like green metals and low carbon liquid fuels.

The government also encourages private sector investment in research through tax offsets provided for under the Research and Development Tax Incentive. States and territories also operate a range of programs and partnerships focussed on hydrogen research partnerships.

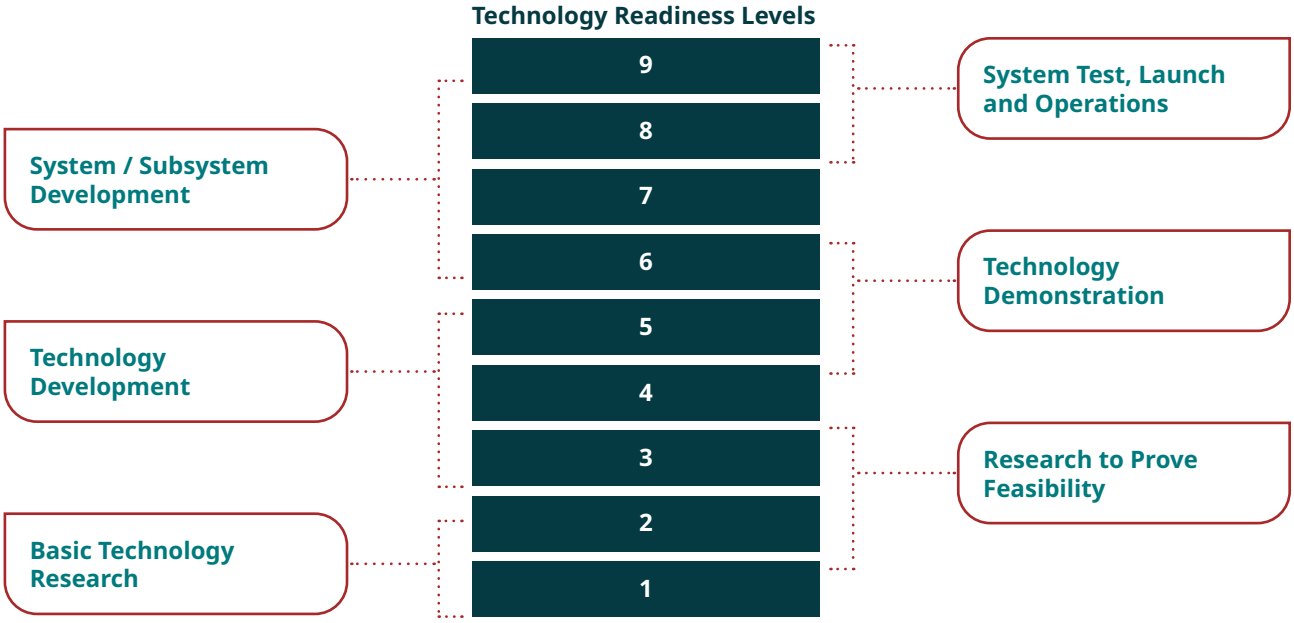


Figure 7 **Technology Readiness Levels (TRLs)**

47 CSIRO 2024 *Review of priority technologies and RD&D for Australia's hydrogen industry development,* CSIRO, Australia.

ACTION 13

Australia will seek opportunities to increase RD&D investment in the TRL 4-6 range through programs and grants, including through ARENA.

> 'Government can play a valuable role in partnering with the private sector on R&D activities. An excellent case study in this type of support is the UK offshore wind sector, which benefited from multiple government agencies supporting different aspects of research and supply chain development.'
>
> **ENGIE**

The Australian Government has explored opportunities to build high value international RD&D collaboration with partners overseas. This includes the $5 million International Hydrogen Research Collaboration Program, which sent delegations of Australian hydrogen experts to leading hydrogen research institutions in the United Kingdom, Germany, the United States, France, Japan, Singapore, and the Republic of Korea. The India-Australia Green Hydrogen Taskforce may also identify additional opportunities for hydrogen trade and collaboration in research.

ACTION 14

Identify opportunities to work with partners on RD&D and position Australia at the forefront of international hydrogen-related research collaboration.

Export

RD&D that optimises domestic and international common use infrastructure (e.g. distribution and conversion assets, domestic ports and international import terminals).

Heavy Industry

RD&D will be critical to de-risking the use of hydrogen as a feedstock for chemicals production (e.g. ammonia and hydrogen derivatives) and the use of hydrogen for combustion to produce high-temperature process heat for minerals processing.

Heavy Road Mobility

RD&D in hydrogen distribution (e.g. road and pipeline) and refuelling infrastructure (e.g. compression and dispensing technologies) can help reduce costs as refuelling infrastructure networks are rolled-out - particularly in support of Australian heavy freight needs.

Hydrogen Production and Storage

- RD&D in electrolysis, biomass and waste conversion (to fuels and chemicals), fossil fuel conversion (with CCUS) and natural hydrogen production will diversify hydrogen production pathways, help to alleviate pressure on supply chains and support a greater number of end-use cases.
- RD&D in compression and liquefaction, underground storage, advanced materials, and hydrogen carriers can help minimise storage costs and requirements to create region-specific, competitive storage options, in addition to existing commercial hydrogen storage options.

Hydrogen Technology Manufacturing

The manufacture of hydrogen technologies is an emerging global industry creating an opportunity for Australia, but near-term action is required to maximise Australia's prospects of becoming a leading manufacturer of hydrogen technologies (e.g. electrolysers) and specialised hydrogen components (e.g. end-use separation and purification materials). Actions could support local operations and maintenance capability development and address supply chain risks.

Figure 8 **Opportunities to advance hydrogen through research and development and subsequent manufacturing opportunities**

Source: CSIRO 2024 Review of priority technologies and RD&D for Australia's hydrogen industry development.

3. Using hydrogen to decarbonise Australian industries and exports

Key points

- Hydrogen, and other commodities such as green metals and low carbon liquid fuels that will likely rely on hydrogen, are prioritised in the Future Made in Australia package.
- Hydrogen will provide a foundation for new value-added 'green' export manufacturing industries, with the most prospective being:
  - ammonia
  - iron
  - alumina.
- Domestic users will also benefit from the growth of Australian large-scale export-focused hydrogen production, which will reduce costs and build supply chains. This will enable hydrogen to play an important role in Australia's decarbonisation, with the most prospective domestic use sectors being:
  - heavy road freight
  - long-haul transport (aviation, shipping)
  - power.
- Future Australian Government policies and programs to support hydrogen production and use will reflect these priorities. Hydrogen production incentives will reduce costs and increase supply and availability, which will help drive hydrogen adoption, including by many safeguard facilities.
- Governments can help overcome hydrogen deployment barriers and bring forward use by supporting infrastructure development or RD&D.

3.1 Targeting the most prospective opportunities

A Future Made in Australia identifies the importance of the hydrogen sector due to hydrogen's potential to contribute to domestic decarbonisation, economic resilience, and domestic security. The renewable hydrogen sector is a priority in the Future Made in Australia package.

Analysis and consultation conducted for the strategy considered the most prospective use cases for hydrogen in Australia. This analysis reinforces that Australia can capture significant economic opportunities and contribute to global decarbonisation by focusing support on large-scale hydrogen production to underpin the following new green export facing industries:

- ammonia
- iron
- alumina.

These sectors align with Australia's comparative advantages, and with the right support can be internationally competitive.

There is strong confidence that global demand for these green commodities will emerge in the coming years and decades, noting many customers in key markets have adopted long-term decarbonisation goals. Similarly, there is a growing consensus that hydrogen will play a role in decarbonising these industries. Both in Australia and overseas, businesses and researchers are working actively to advance technologies that use hydrogen to decarbonise these industries.

A Future Made in Australia points to the benefits associated in developing these domestic manufacturing industries to ensure resilient supply chains and minimise the impact of future global supply chain shocks such as those experienced during the COVID-19 pandemic. Key measures announced through the Future Made in Australia Budget package will support these industries, such as by:

- reducing the cost of hydrogen as a major input to production (for example, through the Hydrogen Production Tax Incentive or expanded Hydrogen Headstart program),

- research and innovation (for example, through the Future Made in Australia Innovation Fund), or
- investments in the enabling environment specific to those sectors (for example, through the expansion of the Guarantee of Origin scheme to include green metals).

ACTION 15

Prioritise support for the development of Australian hydrogen for use in prospective export-facing industries, particularly green ammonia, iron and alumina.

> 'The processes that appear to hold the greatest benefits for more immediate "no regrets" planning and investment include iron, ammonia, methanol and alumina. This is because each of these sectors is more dependent on hydrogen for decarbonisation and can also drive large sources of demand. These are scalable markets and support both direct and indirect growth in jobs.'
>
> **Australian Hydrogen Council**

Hydrogen also represents an important decarbonisation technology for:

- heavy road freight
- long-haul transport (aviation, shipping)
- power.

While important to our decarbonisation pathway, the scale of demand is likely to be smaller than for the large-scale export-facing sectors.

Domestic sectors will benefit from growing Australian export-focussed hydrogen production through large-scale projects that drive sector-wide cost reductions and supply chain development. Governments can further enable hydrogen use in these domestic sectors with targeted support or actions to overcome barriers or bottlenecks, and through investments in research and innovation that bring forward technology development.

ACTION 16

Work with industry to understand barriers and challenges to hydrogen adoption in prospective domestic sectors, including in the context of developing sectoral decarbonisation plans for energy, industry and transport.

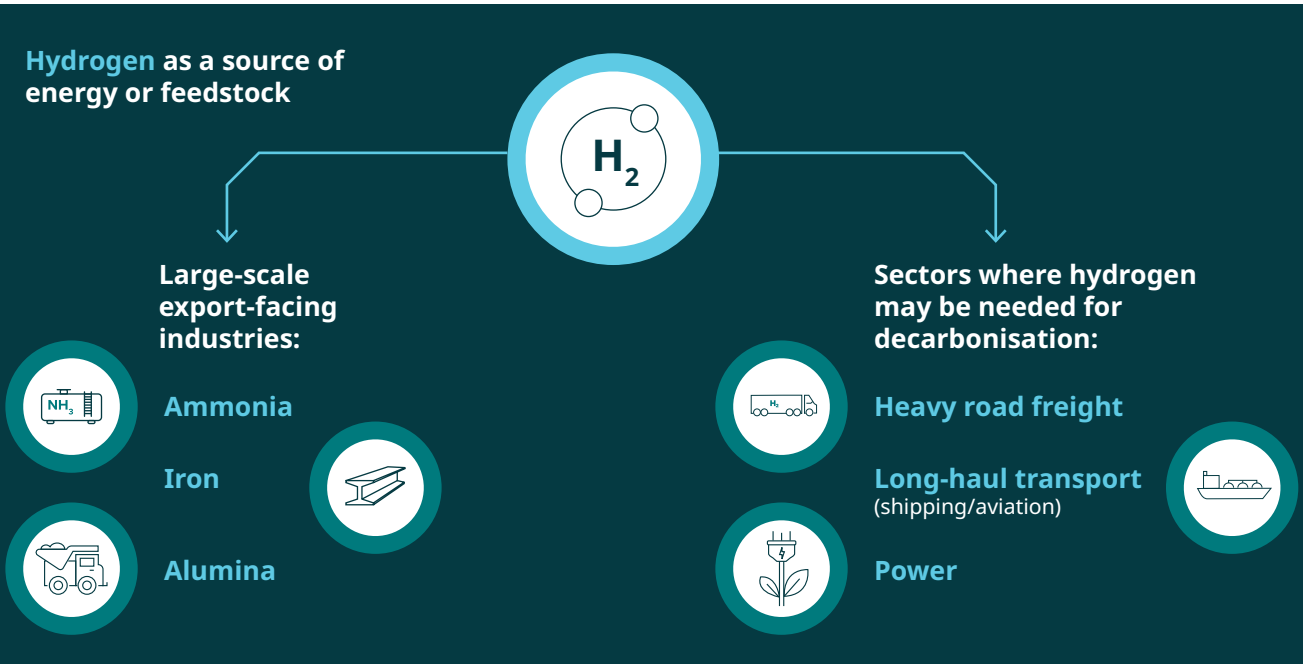


Figure 9 **Prospective use cases for hydrogen in Australia**

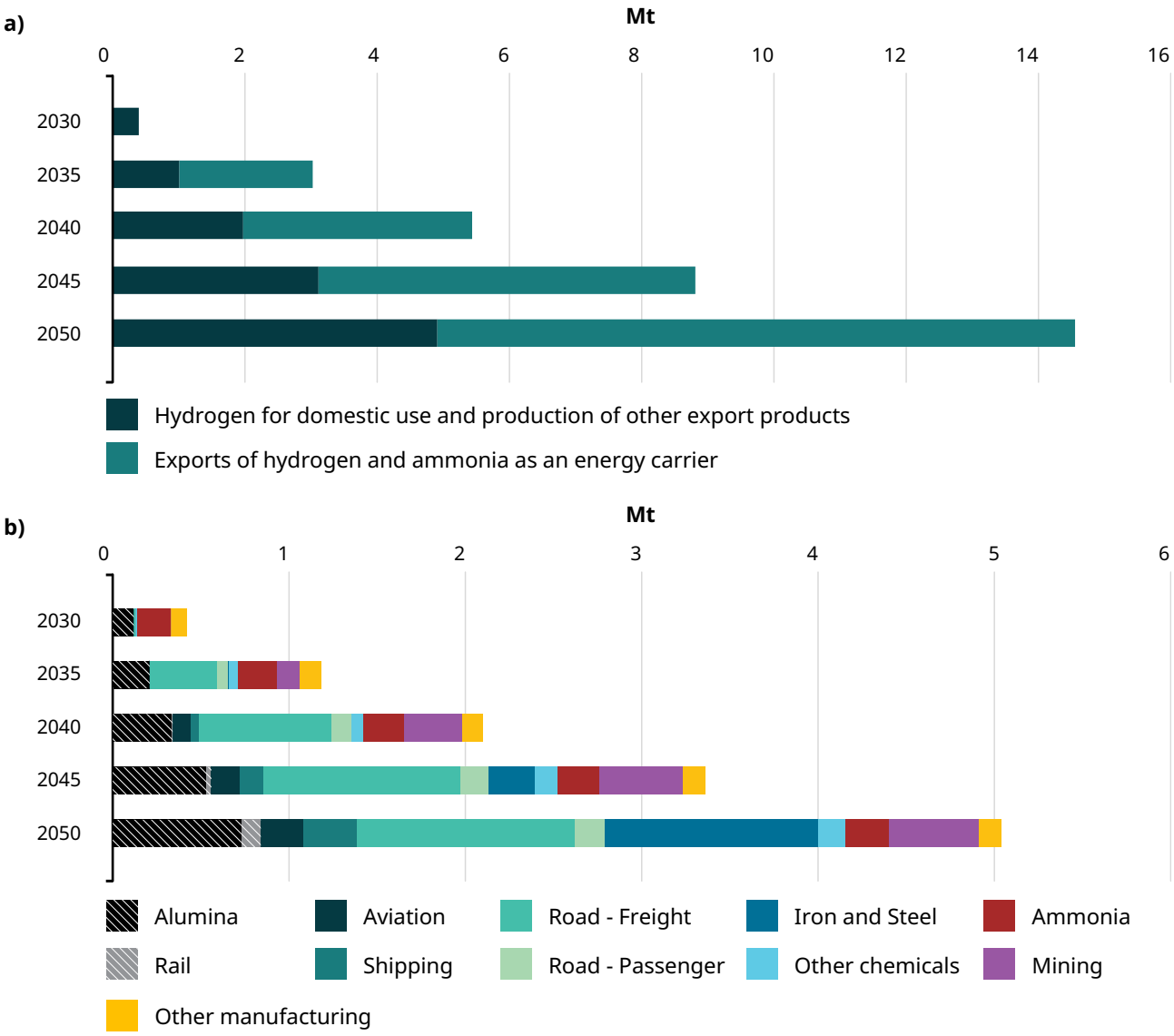


Figure 10 **CSIRO-modelled hydrogen demand over time, showing (a) hydrogen production for exports vs domestic use (including for manufacturing), and (b) domestic hydrogen use by subsector**

Source: CSIRO central scenario.

Note: CSIRO's modelling assumes around 10 million tonnes per year of hydrogen energy exports in 2050 in the central scenario. The balance between this and exports of hydrogen embedded in green metals and chemicals produced by new facilities could change, and will likely be determined by global market developments.

Over time, demand for hydrogen by these industries is expected to increase as firms internalise the cost of emissions in fossil fuel incumbents. This will be steered both by regulatory requirements and customer, investor and shareholder demands. Many companies have already adopted ambitious emissions goals or will be seeking to export to countries demanding low-emissions fuels or feedstocks. The Safeguard Mechanism will play an important role in supporting this shift over time, including through the adoption of hydrogen (Box 8).

Box 7: Australia's Carbon Leakage Review and hydrogen

Australia and many other countries are stepping up efforts to tackle climate change, but the level of ambition differs between jurisdictions. This creates the potential for production to shift from countries with more ambitious emissions reduction policies to those with less robust emissions reduction policies, potentially resulting in increased global emissions. This risk can create a disincentive for Australian projects to bring forward the adoption of technologies, including those using hydrogen.

The Australian Government is undertaking a review, led by Professor Frank Jotzo, of additional policy options to address carbon leakage, including considering the feasibility of an Australian Carbon Border Adjustment Mechanism (CBAM), particularly in relation to steel and cement.

Box 8: Safeguard Mechanism and hydrogen

The Safeguard Mechanism is the key policy to reduce emissions from Australia's industrial sector and will be a driver for domestic hydrogen demand. It sets legislated limits known as baselines on the greenhouse gas emissions of Australia's largest industrial facilities. These emissions limits will decline, predictably and gradually, on a trajectory consistent with achieving Australia's emission reduction targets of 43% below 2005 levels by 2030 and net zero by 2050.

The Safeguard Mechanism covers many existing users of fossil fuel-based hydrogen producers, including major ammonia producers and oil refineries, and may incentivise those sectors to switch to hydrogen. Other Safeguard facilities may see hydrogen as a prospective option for industrial heat or feedstock. Analysis for the department's emissions projections suggest that Safeguard facilities could drive demand of 0.03-0.3 million tonnes of hydrogen by 2030 and 0.2-0.6 million tonnes of hydrogen by 2035.

The Safeguard Mechanism provides a regulatory obligation to manage and reduce emissions, which will help drive hydrogen adoption by some facilities. In addition, the Australian Government is focused on supporting prospective sectors to adopt hydrogen and potentially bring forward hydrogen use to create spill-over benefits for broader hydrogen industry development. Hydrogen production incentives will help enable this by reducing hydrogen costs and increasing supply and availability.

Facilities not covered by the Safeguard Mechanism may also be able to access incentives to reduce their emissions by switching to hydrogen, through the Australian Carbon Credit Unit (ACCU) Scheme. Those ACCUs can then be sold to private sector buyers and governments to generate income.

3.2 Hydrogen to underpin large-scale export-facing sectors

Green ammonia

Ammonia is a globally traded commodity and is the largest consumer of fossil-fuel-based hydrogen in Australia. It is a key input to fertiliser, chemical production and explosives, and is being trialled globally as a fuel for both electricity generation and marine transport.

The IEA anticipates significant growth in global demand for clean ammonia.[48] Ammonia is versatile, having applications both as a feedstock or fuel. Ammonia is also an efficient transport vector for hydrogen (noting it has lower energy needs to achieve liquefaction compared to liquid hydrogen). For these reasons, most announced hydrogen export projects – around 80% of potential global production for export – are prioritising ammonia for transporting hydrogen. Many of the large-scale hydrogen developments in Australia's project pipeline are targeting ammonia for export, particularly to Japan and the Republic of Korea.

Prioritising clean ammonia will help scale-up Australian hydrogen production and activate the broader industry by developing supply chains and building experience and familiarity with new technologies. Large-scale clean ammonia production could also enable an Australian green fertiliser industry.

The existing Australian ammonia industry, which supplies both domestic and export consumers, uses around 420 thousand tonnes of grey hydrogen per year across 7 facilities. This production accounts for around 4 million tonnes of Australia's annual carbon dioxide emissions. Replacing grey hydrogen is the only pathway for decarbonising this industry.

The Australian Government will continue to work with the sector to enable the transition to clean ammonia. Significant funds have already been awarded to key projects to support capital costs and infrastructure.

This includes:

- up to $47.5 million in ARENA funding for the Yuri green ammonia demonstration project in the Pilbara
- $70 million Australian Government contribution to the Hunter Valley Hydrogen Hub Project through the Regional Hydrogen Hubs program, complemented by $45 million in NSW Government funding.

Five out of six shortlisted projects under the first round of the Hydrogen Headstart program involve the production of hydrogen for ammonia. The Hydrogen Production Tax Incentive and the additional funding for Hydrogen Headstart will further incentivise investments in Australian clean ammonia projects. The Safeguard Transformation Stream of the Powering the Regions Fund is also available to support ammonia plants to decarbonise.

> 'Prioritising the decarbonisation of ammonia production is indeed a promising strategy for achieving both hydrogen industry growth and industrial decarbonisation in the short-term. However, it is important to note it should be part of a broader approach that includes promoting the use of hydrogen in other sectors as well, such as transport, energy, and steel production.'
>
> **Business Council for Sustainable Development Australia**

Green iron

Australia, the world's largest iron ore producer and exporter,[49] should play a leading role in decarbonising the iron and steel industry. As highlighted in A Future Made in Australia, we have significant comparative advantages, including world-leading iron ore reserves, renewable energy resources and a highly skilled resources sector. These position us to be a leading global supplier of low-emissions iron to domestic and global markets. Increasing Australia's onshore value-adding of our commodity exports to produce green metals is a prospective and relatively low-cost pathway to indirectly export Australia's renewable energy resources.

48 IEA 2023, *Global Hydrogen Review 2023*. www.iea.org/reports/global-hydrogen-review-2023

49 DISR 2023, *Resources and energy quarterly December 2023*. www.industry.gov.au/publications/resources-and-energy-quarterly-december-2023

> ‘Of Australia’s clean energy export opportunities, the largest and most economically viable appears to be using renewable hydrogen to produce ‘green’ (near zero-emissions) iron and steel.’
>
> **Grattan Institute**

Using locally produced hydrogen in the production of green iron (and other green metals) can deliver cost and emissions benefits compared to a scenario where the iron ore and energy are shipped separately to international destinations. This is a significant advantage for Australia, given our renewable energy and resource endowments. The Net Zero Australia modelling project found that onshoring Australia’s energy exports using hydrogen offers significant efficiency gains from avoiding the conversion of hydrogen to an exportable form, but instead using it directly in clean mineral processing – iron ore reduction, alumina refining and aluminium smelting.[50]

Established industrial processes, such as direct reduced iron (DRI) production can use green hydrogen to replace fossil fuels. Such a step up in manufacturing will require access to the right type of iron ore. Magnetite represents 38% of Australia’s economic demonstrated resources of iron ore (primarily located in Western Australia and South Australia) and is presently well suited to existing direct reduction processes.[51] With existing magnetite mines, steel-making facilities, and magnetite deposits that are amongst the largest in the world, the South Australian Government is actively investigating the development of a hydrogen-based DRI plant to be established before the end of the decade.

Hematite is mined predominantly in the Pilbara and comprises the bulk of Australia’s iron exports. Production processes utilising hematite for DRI require further research and development to be commercially viable.[52] This will be a strong focus of a recently announced collaboration between major Australian mining operators BHP and Rio Tinto and the steelmaker Bluescope.[53] Alternative technologies under development can make use of either crushed hematite or magnetite ores in a fluidised bed reactor in combination with hydrogen, or with a mix of natural gas and hydrogen.

As renewable energy and hydrogen production costs fall, hydrogen may also substitute for existing natural gas use in wider processes within iron production plants.

In the long-term, there may be opportunities for Australia to integrate its green iron capacity into an expanded steel manufacturing industry.

In line with these opportunities, the Australian Government has committed $18.1 million over 6 years from 2024–25 for foundational initiatives to expedite the emergence of Australia’s green metals industry. This will be achieved through enhanced industry and research collaboration, exploration of opportunities to improve the use of Australian scrap metal and undertaking further consultation on incentives to support the production of green iron, steel, alumina and aluminium. The government has also committed to expanding the Guarantee of Origin scheme to incorporate green metals, including iron, steel and aluminium (Section 5.3).

50 D Davis, A Pascale, A Vecchi, B Bharadwaj, R Jones, T Strawhorn, M Tabatabaei, M Lopez Peralta, Y Zhang, J Beiraghi, U Kiri, O Vosshage, B Finch, R Batterham, R Bolt, M Brear, B Cullen, K Domansky, R Eckard, C Greig, R Keenan, S Smart, 2023, *Net Zero Australia – Modelling Summary Report*. www.netzeroaustralia.net.au/wp-content/uploads/2023/04/Net-Zero-Australia-Modelling-Summary-Report.pdf

51 Geoscience Australia 2020, *Australia’s Identified Mineral Resources 2020 – Commodity Summaries – Iron Ore*. www.ga.gov.au/digital-publication/aimr2020/commodity-summaries#iron-ore-section

52 Climateworks Centre and Climate-KIC Australia 2023, *Pathways to industrial decarbonisation: Positioning Australian industry to prosper*. www.energy-transitions.org/publications/pathways-to-industrial-decarbonisation/

53 BHP 2024, *Australia’s leading iron ore producers partner with BlueScope on steel decarbonisation*. www.bhp.com/news/media-centre/releases/2024/02/australias-leading-iron-ore-producers-partner-with-bluescope-on-steel-decarbonisation

Credit: Rio Tinto. Rio Tinto Yarwun Alumina Refinery.

Green alumina

Australia is the world's largest exporter of alumina, currently producing around 20 million tonnes of alumina per year. Australia's alumina refining industry uses natural gas for calcination and is estimated to be responsible for about 15 million tonnes of carbon dioxide emissions a year, or 3% of Australia's total emissions.[54] Hydrogen use in high-temperature calcination could reduce refining emissions by around 30%.[55] Global demand for aluminium (and therefore alumina) is expected to grow through the energy transition due to its use in various low-emissions technologies.[56]

Both hydrogen and electrification may play roles in decarbonising alumina production. Depending on location, hydrogen calcination technology could involve lower upfront capital expenditure as it can be cheaper to retrofit to existing plants than electric calcination. However, reducing the cost of hydrogen as a fuel will be important, noting that operating costs could otherwise be higher than electric calcination.

The Australian Government has identified green metals as a priority industry in the Future Made in Australia package and has supported projects to trial hydrogen use in high-temperature applications. This includes ARENA's $32.1 million contribution to the first-of-a-kind pilot project to trial hydrogen calcination technology at Rio Tinto's Yarwun refinery, near Gladstone.[57] ARENA's 2022 roadmap for decarbonising Australian alumina highlights near-term opportunities for hydrogen use in the calcination process and is informing its ongoing investments.[58]

> 'There is a need for government support for early adopters of decarbonised industrial heat so they can start to develop business cases for change and manage financial and/or technology risks.'
>
> **Australian Hydrogen Council**

Hydrogen is also prospective for other high-temperature heat and chemical applications including green metal processing in established industries, such as copper and zinc, and for new critical minerals industries. An initial focus on alumina will also have cross benefits for these industries.

54 Emma Herd, Dr Steve Hatfield-Dodds 2023, *The energy super power opportunity: Can Australia seize the advantage in a net zero world?*, Ernst & Young Australia. www.ey.com/en_au/sustainability/the-energy-superpower-opportunity

55 Emma Herd, Dr Steve Hatfield-Dodds 2023, *The energy super power opportunity: Can Australia seize the advantage in a net zero world?*, Ernst & Young Australia. www.ey.com/en_au/sustainability/the-energy-superpower-opportunity

56 IEA 2030, *The Role of Critical Minerals in Clean Energy Transitions*. https://iea.blob.core.windows.net/assets/ffd2a83b-8c30-4e9d-980a-52b6d9a86fdc/TheRoleofCriticalMineralsinCleanEnergyTransitions.pdf

57 ARENA 2023, *Yarwun Hydrogen Calcination Pilot Demonstration Program*. https://arena.gov.au/projects/yarwun-hydrogen-calcination-pilot-demonstration-program

58 Deloitte 2022, *A Roadmap for Decarbonising Australian Alumina Refining*. Final report prepared for ARENA by Deloitte, https://arena.gov.au/assets/2022/11/roadmap-for-decarbonising-australian-alumina-refining-report.pdf

3.3 Hydrogen to support Australia's net zero pathway

Transport was responsible for 21% of Australia's emissions in 2023. The decarbonisation pathways are expected to vary across different segments of the industry. For example, battery electric vehicles (BEVs) are currently the leading means of decarbonising light and medium-sized road vehicles. However, the use of hydrogen fuel cells, or of hydrogen as a feedstock for ammonia, methanol or synthetic transport fuels, offers advantages to heavy vehicles in the road, air and marine transport sectors. The low-carbon liquid fuels sector aligns with the principles included in the Australian Government's National Interest Framework. Hydrogen may also play a role in Australia's future power sector.

Heavy road freight

Hydrogen as a fuel is prospective for Australia's heavy duty and linehaul road freight transport sector. Scenario modelling for the strategy suggests hydrogen use in heavy freight could scale-up by around 2035 and represent almost half of final energy use by 2050 (Figure 13). The potential advantages of hydrogen in heavy freight include:

- much shorter refuelling times, being especially important where time-cost is of key importance
- payload advantages compared to carrying large, heavy batteries
- greater range between refuelling stops
- reduced need for significant upgrades to electricity infrastructure at depots to facilitate charging or fast charging loads.

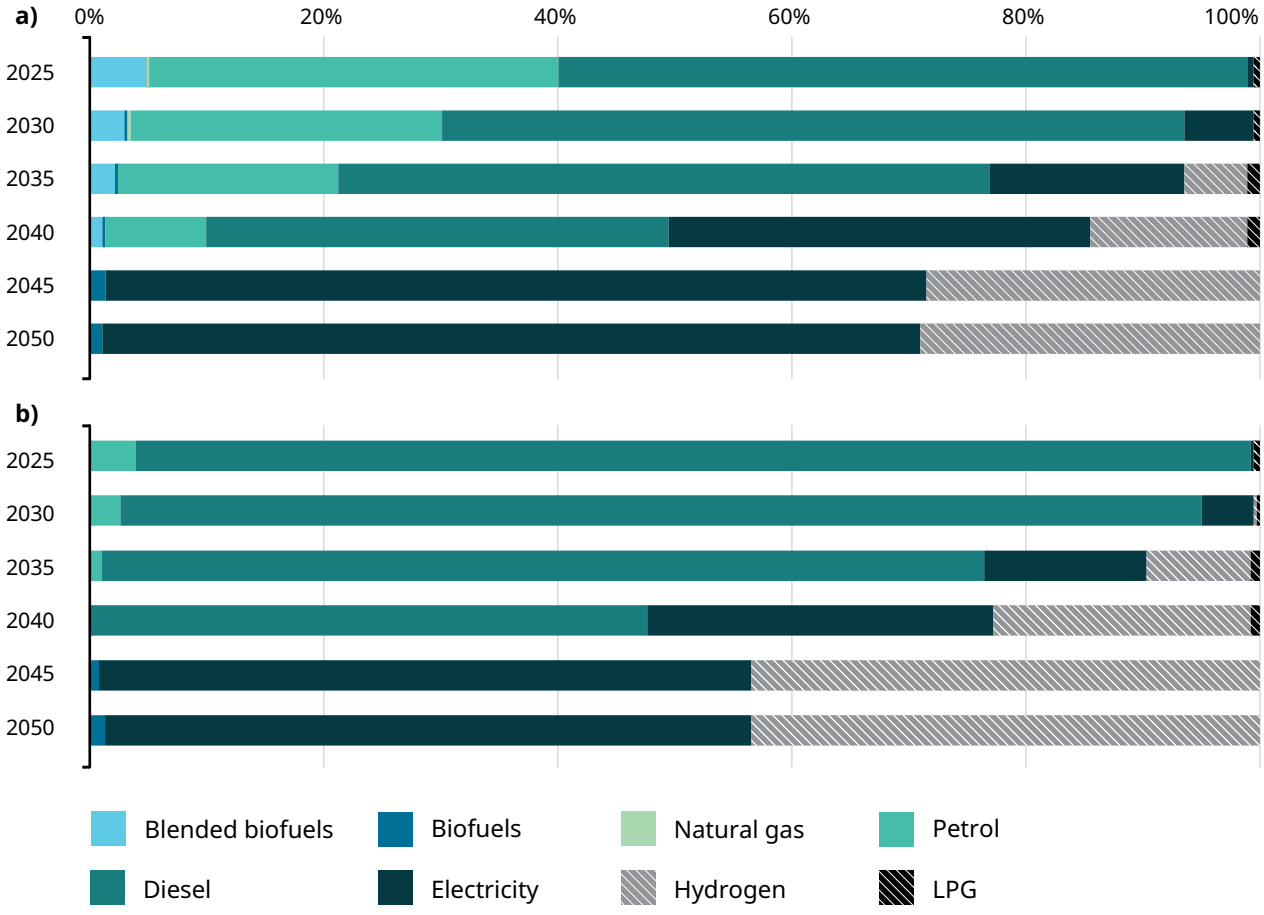


Figure 11 **Proportion of final energy use in the (a) road transport and (b) road freight sectors**

Source: CSIRO 2024 Scenario modelling of the production and consumption of hydrogen in Australia, central scenario.

The sector is important to the Australian economy and, like all sectors, will need to reduce emissions to meet our net zero target. Through targeted investments in technology, enabling infrastructure and regulation, governments can help industry identify and prepare for the most prospective pathways in different applications.

Box 9: Hydrogen and electrification in an Australian transport context

To inform the preparation of the strategy, CSIRO undertook analysis with its Transport Network Strategic Investment Tool (TraNSIT) to understand the proportion and emissions footprint of Australia's articulated heavy road freight that might be difficult to decarbonise via electrification.

Articulated heavy road freight contributes 13% of Australia's transport emissions, or 2.5% of our total emissions. The analysis found that 15% of all articulated heavy road freight trips modelled in TraNSIT are more than 350 km but represent over 60% of the annual CO_2 emissions from modelled articulated heavy road freight.

While TraNSIT only models a sample of all articulated trips and 350 km is a simplified measure of current battery electric vehicle range, this analysis reinforces that decarbonising the transport sector will likely rely on a range of technologies operating in parallel. The exact mix remains uncertain. As well as trip length, other factors like tonnage, road quality and gradient, and logistical challenges (such as the availability of recharging infrastructure at loading/unloading locations) may make hydrogen prospective for freight routes. Conversely, future advances in battery and recharging technologies may make BEVs prospective for longer routes.

Analysis from the CEFC[59] and more recently from the iMove CRC[60] found hydrogen fuel cell electric vehicle (FCEV) trucks may be competitive with diesel vehicles and BEVs in the near future, but noted the need to resolve:

- supply from manufacturers of a variety of large trucks to suit Australia's freight needs and in quantities that can create fleet sizes that justify the hydrogen distribution and refuelling infrastructure
- supply of FCEV trucks that meet industry standards for reliability and have acceptable range
- proof of fuel consumption and operational cost benefits
- low-cost hydrogen distribution
- appropriate vehicle applications that provide operational benefits versus BEV alternatives.

Existing efforts and investment by Australia's governments are helping to overcome such challenges. For example, the Australian Government has made up to $80 million available through the Driving the Nation Fund for Hydrogen Highways, to be matched by co-investments from state and territory governments. This program aims to roll out hydrogen refuelling networks on key freight routes. The Australian Government, through ARENA and several state governments, has also funded trials of back to base applications.[61]

Transport related regulatory reform has been a strong focus, including the development of a National Code of Best Practice for hydrogen refuelling, and progressive reforms to vehicle mass and width regulations to enable Australia to import a greater range of new vehicle technologies.

Hydrogen is versatile and provides potential decarbonisation pathways for other land transport applications. For example, rail transport is another heavy transport sector that has shown some promise in relation to the use of hydrogen fuel cells.[62]

59 Clean Energy Finance Corporation 2021, *The Australian Hydrogen Market Study*. www.cefc.com.au/insights/market-reports/the-australian-hydrogen-market-study

60 iMove CRC 2023, *Prospects for decarbonising freight transport in Australia*. https://imoveaustralia.com/wp-content/uploads/2024/05/Prospects-for-decarbonising-freight-transport-in-Australia.pdf

61 For example, Viva Energy Australia 2022, *Hydrogen transport future for Geelong.* www.vivaenergy.com.au/media/news/2022/hydrogen-transport-future-for-geelong, and; Renewables, Climate and Future Industries Tasmania 2023, *Hydrogen Bus Trial*. www.recfit.tas.gov.au/what_is_recfit/green_hydrogen/bus_trial

62 R Knibbe, D Harding, E Cooper, J Burton, S Liu, Z Amirzadeh, R Buckley and PA Meehan 2002, *Application and limitations of batteries and hydrogen in heavy haul rail using Australian case studies, Journal of Energy Storage*. https://doi.org/10.1016/j.est.2022.105813

'Decarbonisation of the transport sector will mostly occur through widespread adoption of battery electric vehicles. However, hydrogen is likely to have a role in decarbonising transport in use cases with high vehicle utilisation, long distances, and high loads, and especially use cases that have a combination of all three'

Grattan Institute

ACTION 17

Support the targeted use of hydrogen for transport, either through direct use in hydrogen fuel cell vehicles or as a low-carbon feedstock for the production of low carbon liquid fuels, alongside support for other pathways like electrification and alternative fuels.

Aviation

Low-carbon liquid fuels based on hydrogen will play a significant role in decarbonising the aviation sector, which generates around 2.5% of the world's carbon emissions. Under the IEA's net zero by 2050 pathway, hydrogen could comprise 37% of the international aviation sector's final energy consumption by 2050, underscoring its potential decarbonisation importance.

Hydrogen provides a promising sustainable aviation fuel (SAF) feedstock – jet fuel made from renewable sources rather than fossil fuels. As a feedstock, hydrogen treatment or hydrogenation converts synthetic fuel feedstock into a product with a molecular structure that is equivalent to fossil fuels but with improved performance and emissions.

Hydrogen electric fuel cells (suited to shorter-haul flights) and direct combustion of hydrogen in turbine engines (larger, medium-distance flying) are also being considered and trialled globally to enable hydrogen powered applications.

Analysis informing the strategy suggests using hydrogen to make synthetic air fuels may be a prospective option for aviation in the medium and long-term. In the near-term, there is a role for government to support early-stage RD&D to:

- work through technical challenges and prove commerciality
- consider future aviation demand in planning for infrastructure at airports and connections with hydrogen hubs.

The Australian Government has committed $20.9 million over 4 years from 2024–25 (and $1.2 million per year ongoing) to undertake further consultation on incentives to support the production of, and demand for, low-carbon liquid fuels. The funding will also assist in the development of a low-carbon liquid fuels certification scheme through the Guarantee of Origin scheme.

The government will also look for opportunities for industry partnership and collaboration, noting hydrogen use in aviation will also be considered through the Australian Government's Transport and Infrastructure Net Zero Roadmap and Action Plan, the Australian Jet Zero Council, and the Aviation White Paper currently under development.[63]

63 L.E.K. Consulting Australia Pty Ltd ("L.E.K.") 2023, *Scenario Analysis of the Future of Australian Aviation*. Final report prepared for the Department of Infrastructure, Transport, Regional Development, Communication and the Arts, www.infrastructure.gov.au/sites/default/files/documents/aviation-white-paper-scenario-analysis-september-2023.pdf

Shipping and bunkering

Shipping emissions make up almost 3% of global carbon emissions. Hydrogen and its derivatives (particularly ammonia and methanol) are prospective fuels for long-distance shipping (see Figure 12). Electrification is expected to remain impractical for long-haul voyages and there are few alternative low emissions options.

The International Maritime Organization (IMO) regulates emissions for global shipping. The revised IMO Greenhouse Gas (GHG) Strategy, adopted in July 2023, has set interim emissions targets for international shipping for 2030 and 2040, with a goal to reach net zero by or around 2050.[64] The IMO GHG Strategy has also set interim targets for adopting zero or near-zero GHG emission technologies, fuels and energy sources by 2030.

The IEA considers green ammonia will be the most widely used fuel in 2050, although shipping companies currently appear to be favouring vessels that can be powered by methanol and bio-methane as drop-in fuels. Australia is currently developing a Maritime Emissions Reduction National Action Plan, which can support or complement the use of ammonia (and hydrogen) as a shipping fuel. The plan will:

- set strategic direction for both domestic and international emissions-reduction in the maritime sector
- facilitate the establishment of green shipping corridors from Australia.

> 'Green fuels can decarbonise hard-to-abate sectors such as shipping and aviation and drive economic benefits for Australia. Industry and government should work together to position Australia as a leader in this space and create new economic opportunities.'
>
> **Copenhagen Infrastructure Partners**

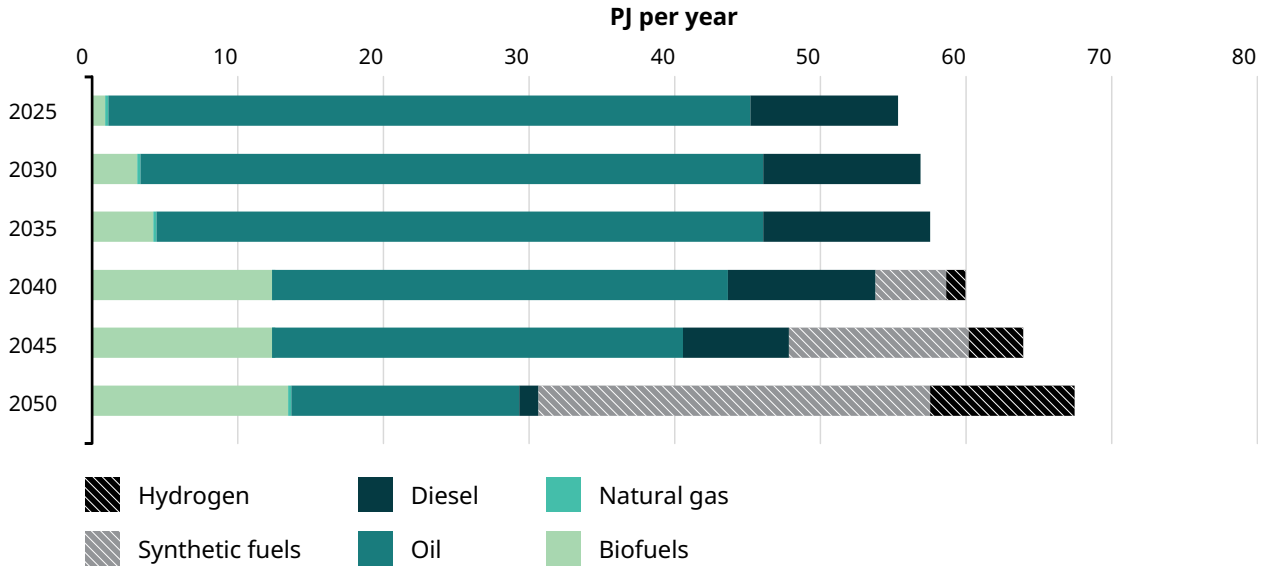


Figure 12 **Projected shipping fuel (domestic and international) use over time, including hydrogen used both directly and as an input to synthetic fuels (including ammonia, methanol and synthetic diesel)**

Source: CSIRO 2024 Scenario modelling of the production and consumption of hydrogen in Australia, central scenario.

Note: The Australian Energy Statistics splits fuel consumption out for coastal and international bunkers. Although the fuel is refined and/or supplied in Australia, it is consumed by outbound ships and not included in the National Greenhouse Gas Inventory and domestic carbon budget. These categories have been combined for this analysis.

64 IMO 2023, *Revised GHG reduction strategy for global shipping adopted*. www.imo.org/en/MediaCentre/PressBriefings/pages/Revised-GHG-reduction-strategy-for-global-shipping-adopted-.aspx#:~:text=The%20revised%20IMO%20GHG%20Strategy,points%20for%202030%20and%202040.

Power

Hydrogen represents an option as a clean energy source for electricity generation. This is particularly the case in countries that are net energy importers with limited scope for domestic energy production. For example, the Republic of Korea has a plan to introduce hydrogen and ammonia as a progressive replacement for fossil fuels in thermal electricity generation. Australian hydrogen exports can therefore play an ongoing role supporting other nations to achieve their future energy security and emissions reduction goals.

While Australia's future power system is expected to be dominated by solar and wind generation, there are also opportunities for hydrogen to play a role in supporting the reliability of our grids. Hydrogen electrolysers provide a flexible source of electricity demand and hydrogen can also be stored and provide a replacement for natural gas for firming generation. As we progress to our 82% renewables goal and beyond, long-duration energy storage will be increasingly important. In the longer term, bulk underground hydrogen storage, complementing pumped hydro projects such as Snowy 2.0, could cater for this demand.

AEMO's 2024 Integrated System Plan forecasts that almost quadruple the firming capacity from sources alternative to coal will be required to firm the NEM by 2050.[65] Hydrogen could be co-fired with (or replace) natural gas, in suitably constructed facilities, to reduce the emissions from gas-powered peaking plants. Analysis by Frontier Economics suggests hydrogen could be used for electricity production even in scenarios where gas distribution networks are not converted to hydrogen, since hydrogen turbines offer an opportunity to seasonally shift excess renewable generation from summer to winter.[66]

The Tallawarra B project near Lake Illawarra is a peaking power station capable of being powered by a blend of gas and hydrogen. Similarly, the South Australian Government has committed $593 million in capital funding for the development of a hydrogen production, generation and storage facility at Whyalla, South Australia. The Australian Government is also working closely with Snowy Hydro to enable hydrogen use at the Hunter Power Project gas-fired power plant at Kurri Kurri.

Credit: ATCO. ATCO Jandakot electrolyser

65 AEMO 2024, *2024 Integrated System Plan (ISP)*. https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2024-integrated-system-plan-isp

66 Frontier Economics 2023, *Economic analysis of hydrogen blending and conversion*, Frontier Economics, Australia.

ACTION 18

Support analysis on how hydrogen can optimally support Australia's transition to renewables, including for energy storage, grid firming and via the flexible use of electrolysers.

Hydrogen-powered generators also present a decarbonisation opportunity for remote community and mine sites. The role for hydrogen in most off-grid applications is likely to be as part of a suite of technologies, including renewables and battery energy storage systems to help deliver the achievement of a 100% renewable energy microgrid. Australian governments will continue to assess such early pilot and demonstration projects to gauge the economics and impact of investing in hydrogen for remote power applications.

Other applications

While light transport and domestic and commercial heating were identified as opportunities in the 2019 Strategy, technology and policy developments have meant that electrification is now likely to be the more dominant technology for these applications.

While the Australian Government will not focus its efforts towards driving hydrogen adoption in these sectors, technology advancements may change the viability of hydrogen in some applications or specific circumstances may mean hydrogen is more prospective.

The government will continue efforts to remove regulatory barriers to enable hydrogen adoption in such cases. For example, existing and well-advanced regulatory reform processes will enable companies and state and territory governments to progress projects that blend hydrogen in distribution gas pipelines where this enables efficient delivery of hydrogen to users. Similarly, the development of hydrogen refuelling infrastructure and regulation will enable hydrogen use in cars, noting FCEV models are still being developed by international manufacturers, and may be preferred in certain applications, for example, due to refuelling time advantages.

4. Securing community benefits

Key points

- Many hydrogen projects will be based in regional and remote areas, including on land and sea Country that have legally recognised rights for First Nations people. Best practice engagement with First Nations communities will help ensure hydrogen industry development takes community needs into account and local opportunities are realised.
- The Australian Government will work with key industry organisations on a voluntary hydrogen industry code of conduct. This can help demonstrate the industry's commitment to safe, ethical and responsible conduct and ensure it is benefitting communities.
- Implementing appropriate regulation will provide trust and reassurance to the community regarding safety and environmental risks. Australian governments will continue with existing regulatory work, explore the next tranche of reform needs, and examine options for providing ongoing advice on safety risks.
- Water is an essential resource for communities. Australian governments will consider principles and actions that will help plan for and manage demands for water, including from hydrogen production, in a new National Water Initiative.

Building Australia's hydrogen industry will provide benefits for local communities through jobs and regional economic growth. As technology costs fall and markets mature over the longer term, the economic benefits of the hydrogen industry will also be shared more widely across the broader Australian community. Published modelling has estimated Australia's renewable hydrogen industry development and related exports could produce $28.9 billion per year by 2040 and create around 33,000 direct and indirect jobs, with further economic benefits from other industries like green metals.[67] In the years ahead, the hydrogen sector can also help diversify regional economies where there is a high concentration of jobs that will be affected by the global energy transition.[68]

The *Future Made in Australia Act* will outline Community Benefit Principles. These principles relate to the:

- development of skilled, safe and secure workforces
- collaboration with local communities and First Nations communities directly affected by the transition to net zero
- strengthening of domestic industrial capability and supply chains
- compliance in relation to the management of tax affairs.

Government decision makers will have regard to the principles when delivering Future Made in Australia supports such as the Hydrogen Production Tax Incentive scheme. These principles align with the positions and actions contained within this strategy.

67 Accenture 2021, *Sunshot: Australia's opportunity to create 395,000 clean jobs*. https://assets.nationbuilder.com/climateaction/pages/3147/attachments/original/1660717384/Clean_exports_detailed_report_vf.pdf?1660717384

68 Deloitte Australia 2023, *Australia's Hydrogen Tipping Point*. www.deloitte.com/au/en/Industries/power-utilities-renewables/perspectives/australia-hydrogen-tipping-point.html

4.1 Opportunities for First Nations communities

Many large-scale hydrogen projects are expected to be developed in regional and remote areas on land and sea Country that have legally recognised rights for First Nations people, making them important partners in growing the hydrogen industry. The clean-energy transition also provides an opportunity to reset the historic approach large projects have taken to engagement with First Nations people. By embedding meaningful First Nations benefit-sharing into project development, design and implementation processes, communities will realise cultural, social and economic benefits through the growth of a new industry. The hydrogen industry will also benefit from improved social licence outcomes and greater certainty.

> 'Enabling and empowering First Nations to play a key and central role in Australia's renewable energy transition goes beyond just social licence issues - it presents a unique opportunity for Australia to design a system that is fair and just and which can also positively impact and result in other social and economic benefits for First Nations'
>
> **First Nations Clean Energy Network – Hydrogen Headstart consultation**

There are several initiatives currently underway that aim to ensure First Nations people can share in the benefits from the clean energy transition. The Australian Government is developing the First Nations Clean Energy Strategy to give First Nations communities a say in energy policies and programs as we transition to net zero. This strategy is supported by an extensive consultation process with First Nations people, communities and organisations, key amongst these being the First Nations Clean Energy and Emissions Reduction Advisory Committee.

The Australian Government is also developing a National Environmental Standard for First Nations Engagement and Participation in Decision-Making. The standard is part of several reforms to Australia's national environmental law, the *Environment Protection and Biodiversity Conservation Act 1999*, and aims to improve the ways in which First Nations communities are included in environmental planning.

The government has also expanded its pilot approach to First Nations engagement in the emerging hydrogen sector through the First Nations Renewable Hydrogen Engagement Fund to be delivered alongside the expanded Hydrogen Headstart program. The program is intended to support First Nations groups located near potential Hydrogen Headstart projects, to access services and advice to assist them in social and economic benefits from hydrogen projects.

It is essential Australian governments and the industry is committed to early engagement with First Nations communities, and respect for their cultural and heritage rights and self-determination.

ACTION 19

Support the coordinated production and dissemination of culturally appropriate and accessible education materials that provide factual information about hydrogen production, and the obligations of project proponents.

The program guidelines for the first round of the Hydrogen Headstart program include merit criteria and information requirements for project proponents to demonstrate their engagement with First Nations communities. This includes the extent to which First Nations communities have been, and will continue to be, engaged or involved with the negotiations, decision-making and benefit sharing of the project. A similar approach could be considered in other funding agreements to underpin adoption of best practice for First Nations engagement across the industry.

ACTION 20

Support the inclusion of specific criteria in funding program guidance and obligations in funding agreements with Australian governments that require proponents to adopt best practice when engaging with First Nations communities including benefit sharing.

4.2 Voluntary hydrogen industry code of conduct

Communities are generally positive about the benefits of hydrogen but are yet to form strong opinions on or gain an awareness about the utility of hydrogen.[69] The sector must take the lead to ensure it is safe, ethical and responsible and is seen to be contributing to communities.

Many industries establish member undertakings or codes of conduct to:

- ensure that both members and the public understand what can be expected when interacting with the industry
- provide guidance to new industry members
- provide at least an informal avenue to pursue improvements in behaviour.

For example, the Clean Energy Council (CEC) requires members to agree to a code of conduct in regard to how they relate to business, government, employees, suppliers, consumers and the community. The CEC has also established a Best Practice Charter for Renewable Energy Projects, which sets out voluntary commitments for good community engagement and responsible development.[70] These existing codes are directly relevant to hydrogen projects. The land required to develop new renewable generation facilities for hydrogen projects mean this may be the most noticeable component of a hydrogen project for many communities. Codes of conduct in relation to business interactions with their customers can also be established in regulation under the *Competition and Consumer Act 2010*.

ACTION 21

The Australian Government will encourage the hydrogen industry to adopt best practice stakeholder engagement, including through the development of a voluntary code of conduct, to maintain positive interactions with communities and industry.

A voluntary industry code of conduct would sit alongside other actions the Australian Government has taken to encourage best practice engagement by the renewable energy industry with local communities as well as the Future Made in Australia Community Benefit Principles. It would also provide a framework for communities to consider the economic challenges of developing these projects. The Australian Energy Infrastructure Commissioner (AEIC) has been established to receive and refer complaints from concerned community members about wind farms, large-scale solar farms, energy storage facilities and new major transmission projects. The AEIC also promotes best practices for business and government to adopt the planning and operation of these projects.

The government is also progressing actions in response to the Community Engagement Review[71] which identified opportunities to ensure community support and participation in Australia's renewable energy transition. This includes the implementation of a developer rating scheme, and a regulatory reform package to realise community benefits in regions affected by the energy transition.

69 Based on Mitchell Scovell and Andrea Wolton 2024, *Blue or Green? Exploring Australian acceptance and beliefs about hydrogen production methods*, Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2024.141151, and; P Ashworth, K Witt, M Ferguson, & S Sehic 2019, *Developing Community Trust in Hydrogen*, University of Queensland: Brisbane. https://espace.library.uq.edu.au/view/UQ:4ea6a57

70 Clean Energy Council 2021, *Best Practice Charter*. www.cleanenergycouncil.org.au/advocacy-initiatives/community-engagement/best-practice-charter

71 Andrew Dyer and Australian Energy Infrastructure Commissioner 2023, *Community Engagement Review Report, on behalf of the Department of Climate Change, Energy, the Environment and Water,* Canberra, 2 February 2024.

4.3 Regulation to build community trust

The development of appropriate and nationally consistent regulation, codes and standards applicable to Australia's hydrogen production will provide confidence, trust and reassurance to the community on safety and environmental standards, and certainty to businesses wanting to know how hydrogen projects can meet regulatory obligations. Regulation is a core responsibility for governments and there are a range of existing Commonwealth and jurisdictional regulations relevant to hydrogen production.

Proposed hydrogen projects may require approval under national environment law before they can go ahead. Environmental impacts associated with hydrogen production could include (but are not limited to): habitat disturbance from land clearing, disturbance to aquatic ecosystems from changes to water quality or hydrological regimes, and risks of environmental contamination from leaks/spills of saline waste or toxic substances (such as during transport). Ancillary infrastructure associated with hydrogen production may also require approval, including pipelines and new or expanded port facilities.

The Australian Government has acknowledged the need for more efficient and effective environmental approvals processes to enable the economy's transition to net zero by 2050. In the hydrogen industry, a slow rate of consideration by regulators will put Australia at a disadvantage compared with other countries. The Australian Government is progressing a significant reform program for the *Environment Protection and Biodiversity Conservation 1999 Act* (EPBC Act).[72] The government recently announced funding to strengthen and streamline environmental approval decisions for priority renewable projects. Funded elements include increased regulatory capacity, better guidance for proponents, and research into localised threatened species. Projects that avoid sensitive environmental areas through appropriate site selection have the fastest regulatory pathway under the EPBC Act.

Some jurisdictions have announced significant reforms to accelerate approval processes at the state or territory level. These reforms will enable hydrogen and related renewable energy projects to navigate approvals processes more efficiently while giving communities confidence about effective environmental outcomes.

In addition to streamlining environmental controls, the development of appropriate and nationally consistent regulation, codes and standards applicable to Australia's hydrogen will provide confidence, trust and reassurance to the community on safety and environmental standards, and certainty to businesses wanting to know how hydrogen projects can meet regulatory obligations. Regulation is a core responsibility for governments and a range of existing regulations are relevant to hydrogen production.

ACTION 22

Continue efforts across all levels of government to improve the efficiency and effectiveness of regulatory approval processes for safety and environmental protection.

Australian governments have consulted on and are developing National Hydrogen Codes of Best Practice, with an initial focus on hydrogen production and refuelling. An objective is to provide greater transparency and national consistency regarding the intersection of hydrogen with existing regulatory frameworks, such as work, health and safety (WHS) obligations. This work has been progressed in consultation with relevant regulators and agencies across the country, including with Safe Work Australia. These national codes will provide certainty and guidance both to companies and regulators on how hydrogen projects can meet regulatory obligations for safety and environmental protection, as well as assurance to communities and workers. Once completed, state and territory governments can facilitate hydrogen industry growth by ensuring the national codes are adopted within their existing regulatory agencies.

72 The Australian Government's Nature Positive Plan sets out the government's commitment to reform Australia's environmental laws to better protect, restore and manage our unique environment. DCCEEW 2022, *Nature Positive Plan: better for the environment, better for business*. www.dcceew.gov.au/environment/epbc/publications/nature-positive-plan

ACTION 23

Support the development and adoption of the National Hydrogen Codes of Best Practice in relation to hydrogen and ammonia.

As markets for hydrogen and associated products develop alongside rapid technological change, expert advice on safety and environmental protection will need to be developed. Governments, safety forums and workers would have an interest in this growing body of advice, particularly given this is an emerging industry.

Similar forums for the establishment and dissemination of safety advice already exist. For example, Australian governments convene working groups in relation to major hazard facilities, and in the United States, technical and safety matters are considered by the Hydrogen Safety Panel within the Centre for Hydrogen Safety.

ACTION 24

Consider the need for expert forums or bodies to advise governments on safety and environmental protection issues to ensure that best practice approaches are being employed.

4.4 Sustainable water use

Water is an essential resource for all communities, particularly in regional Australia, and underpins agriculture and other industries. Water supports communities' physical and mental health through safe drinking water, economic opportunities and upkeep of community facilities. Water, and the environments that depend on it, also hold important cultural and spiritual values, particularly for First Nations people.

Water consumption for the future hydrogen economy is likely to be considerable but not prohibitive, particularly in regions that have sufficient water sources to support sustainable hydrogen development.[73] Further scenario analysis for the strategy reinforced that low water availability may be a barrier to hydrogen development in some parts of Australia, particularly dry inland regions. In other areas, new water infrastructure such as desalination plants, water recycling, stormwater harvesting and pipelines will be needed, as will efforts to maximise the use of wastewater. [74]

In considering future hydrogen industry development, planners and proponents will need to consider what water is available in different areas, factoring in where water is fully allocated to existing uses, and options to complement with new sustainable water infrastructure. Early planning by governments and business will help ensure water infrastructure is available as the hydrogen sector scales-up over the coming decades.

The Australian Government, in partnership with CSIRO, is developing a nationally consistent approach to understanding water resource and wastewater management requirements needed for future hydrogen development.[75] Further research and science, as well as experience gathered as projects are brought online, will help inform water availability and demand for hydrogen across Australia and support effective infrastructure planning.

ACTION 25

Report annual project water consumption by the hydrogen industry through the annual State of Hydrogen report.

ACTION 26

To support infrastructure planning by companies and water planning agencies, future National Hydrogen Infrastructure Assessments will include a focus on water demand and availability for hydrogen production.

Developing new water infrastructure comes with high costs that must be seen to be fairly shared by all users. Securing suitable water supplies amongst competing demands will be critical to growing a sustainable hydrogen sector and building social licence and community acceptance. This will be aided where new water infrastructure needed for hydrogen production can be shared by townships, industries and agriculture to benefit entire communities.

The 2004 National Water Initiative is the national blueprint for how best to balance demands for water from various uses and guides integrated water management (including stormwater, recycled water, and desalinated water). Australian governments are working to renew the 2004 National Water Initiative to ensure water-resource planning better accounts for the impacts of a changing climate and the needs of emerging industries.

Ensuring a complementary relationship between national initiatives such as a renewed National Water Initiative and water management policy and frameworks in operation at a state/territory level will be crucial to sustainable water supply and usage outcomes for Australia's hydrogen industry.

ACTION 27

Support the consideration of water demand associated with hydrogen production in the development of a new National Water Initiative as a complement to water management policy and frameworks in operation at a state/territory level.

73 The National Hydrogen Infrastructure Assessment concluded that, at a national level, water demand for future Australian hydrogen production could be of a similar order of magnitude in 2050 to current water use in our mining sector. DCCEEW 2023, *National Hydrogen Infrastructure Assessment: Final Report*. www.dcceew.gov.au/sites/default/files/documents/national-hydrogen-infrastructure-assessment-final-report.pdf

74 Arup 2024, *Infrastructure to enable hydrogen industry development – additional scenarios building on the National Hydrogen Infrastructure Assessment*, Arup, Australia.

75 National Water Grid Authority 2023, *Securing water for an emerging Australian hydrogen industry*. www.nationalwatergrid.gov.au/projects/securing-water-emerging-australian-hydrogen-industry

4.5 Ensuring domestic hydrogen supply

As Australia transitions towards net zero emissions by 2050, the domestic economy will become increasingly reliant on a stable supply of hydrogen. The goal of establishing a hydrogen export industry also brings with it the risk that international market forces could impact Australia's domestic hydrogen and energy markets.

Establishing a hydrogen export industry will be crucial to driving down costs for renewable hydrogen, securing the foreign investment required to develop the sector and creating economies of scale that will enable a thriving domestic industry. Australian governments will ensure domestic hydrogen security is maintained in parallel to the establishment of an export industry. Transparent monitoring of underlying market conditions, including through broadening the National Gas Law to hydrogen, will enable Australian governments to monitor risk and ensure sufficient domestic supply while remaining a reliable supplier to international partners.

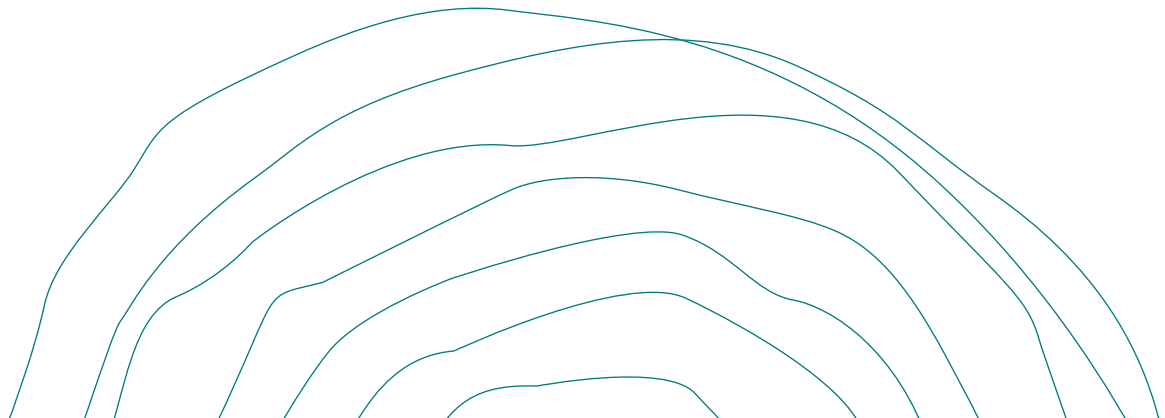
There are other policy mechanisms that could also be considered and the Future Made in Australia Community Benefit Principles note that supported projects should provide community benefits which includes strengthening domestic industrial capabilities, including through stronger local supply chains. This could include supply chains for well-priced domestic hydrogen.

Governments expect clear benefits to flow to Australian industry from developing hydrogen in Australia, and this includes moving towards abundant hydrogen supply - especially where hydrogen projects benefit from Australian public investment. Many industry developments observed so far, including those with an export-orientation, are already working with domestic industry to support domestic decarbonisation and provide enhanced social and economic benefits. As an initial action to give effect to intended domestic industry benefits, governments may encourage these domestic industry linkages through funding and program design. Governments intend for hydrogen to be available to Australian industry at competitive prices and volumes, while honouring contractual agreements with trading partners.

Governments do not see a need to apply market constraints at this time, but will develop lead indicators that will be used to monitor the security of domestic hydrogen supply. These lead indicators will help governments anticipate whether new steps are needed to ensure future supply chains continue developing in a way that supports Australian industry and matches government and community expectations.

ACTION 28

Monitor emerging risks to domestic hydrogen supply as part of the independent assessment undertaken for the annual State of Hydrogen report, and the 5-yearly review of the National Hydrogen Strategy.




Hydrogen H_2

5. Shaping international trade and global markets

Key points

- Australia will prioritise its international engagement, including by:
  - building on existing bilateral partnerships
  - engaging with major importers
  - working pragmatically with other emerging key exporters

  to:
  - shape global hydrogen market rules
  - ensure access to and advancement of key technologies
  - secure early-mover advantage in meeting emerging international demand.
- Australia will set a base hydrogen export target of 0.2 million tonnes and a stretch potential of 1.2 million tonnes of hydrogen (or equivalent in hydrogen embodied products) per year by 2030.
- Australia will work with our international trade partners to leverage international funding or co-finance mechanisms so Australia can help meet their import needs.
- Expanding Australia's internationally aligned Guarantee of Origin scheme will continue to be a priority so Australian projects making, using and exporting hydrogen, as well as green metals and low carbon liquid fuels, can attract international investment and access global markets.

5.1 Capturing the international trade opportunity

2030 Export targets and stretch potential

Australia's energy exports play a pivotal role in enhancing global energy security, providing a stable and reliable supply of resources to meet the growing energy demands of our neighbours. A transition to clean energy sources must extend to transitioning our energy exports as not all countries have the same ability to produce hydrogen from renewable resources for their future energy needs.

A significant pipeline of Australian hydrogen projects are now under development (representing over $225 billion or more in capital investment).[76] If this project pipeline is realised, the IEA has noted Australia would achieve a leading role in international hydrogen trade flows by 2030.[77]

Internationally, key trading partners have announced hydrogen use or import targets for 2030, and Australia is well-placed to meet a significant share of this demand. Australia's comparative advantages mean we can also meet growing demand for products made with hydrogen like green iron and alumina.

To signal our intention for Australia's hydrogen export industry to materially contribute to the import and use targets of potential trade partners, the Australian Government is adopting short-term hydrogen export targets.

76 DISR 2023, *Resources and energy major projects 2023*, www.industry.gov.au/publications/resources-and-energy-major-projects-2023. Note a revised valuation methodology was used compared with previous years that excluded projects that were at an "Advanced Feasibility" stage. The preceding report from 2022 valued the pipeline at $230-$303 billion.

77 IEA 2023, *Global Hydrogen Review*. www.iea.org/reports/global-hydrogen-review-2023.

TARGET 3

Australia will export a base amount of 0.2 million tonnes and establish a stretch potential of 1.2 million tonnes of renewable hydrogen (or equivalent in hydrogen embodied products) per year by 2030.

As with the 2050 hydrogen production targets, the base hydrogen export target reflects a small number of advanced projects known to be targeting the international market. The stretch potential reflects Australia's interest in commencing hydrogen trade with partners such as Germany, Japan and the Republic of Korea.

'Australia is poised to produce clean hydrogen at scale, and export targets would help position the country as a stable export market and enhance the standing of Australian-based clean hydrogen producers as a partner of choice in the region.'

Japan Suiso Energy

'Adopt corresponding and specific hydrogen export targets (both firm in the shorter term, and indicative for longer timeframes) to send a clear signal internationally of Australia's anticipated role in the international marketplace.'

CWP Global

5.2 International investment

While Australia stands ready to be an international supplier of hydrogen and hydrogen products, significant investment will be needed for energy and other economic infrastructure such as ports. As with previous waves of resources and energy industry developments, Australia will seek to partner with our strategic and trade partners to enable this investment.

Foreign investment is welcome, recognising that in addition to the funding necessary to support our economic transformation this investment also:

- brings skills, technology, capability and talent to Australian firms and industries
- strengthens Australia's capability in research, development, and commercialisation
- improves the economic infrastructure that underpins growth and productivity in key industries and regions
- orients and prioritises global supply chains towards Australian opportunities.

Consistent support from all levels of government will be vital to securing the levels of international investment required to ensure Australia is competitive, and Australia has a number of faciliatory mechanisms in place:

- Through the 2024-25 Budget, the Australian Government has committed to establish a new front door for investors with major, transformational investment proposals related to the government's Future Made in Australia agenda to make it simpler to invest in Australia and attract more global and domestic capital.

  The front door will:

  - provide a single point of contact for investors and companies with major investment proposals
  - deliver a joined-up approach to investment attraction and facilitation
  - identify priority projects related to the government's Future Made in Australia agenda
  - support accelerated and coordinated approvals decisions
  - connect investors with the government's specialist investment vehicles.
- Austrade is Australia's investment attraction and trade promotion agency.
- The Net Zero Economy Authority will liaise with other Commonwealth agencies, state and local governments and associated agencies, the private sector and other organisations to identify, broker and catalyse investment in transformational projects. Australia has several agencies, including Export Finance Australia, the Northern Australia Infrastructure Facility, Clean Energy Finance Corporation and National Reconstruction Fund Corporation, that provide financing support for infrastructure and other investments.
- Australia's Sustainable Finance Strategy will support Australia's pathway to net zero, by providing a framework for reducing barriers to investment into sustainable activities.

Some of our major trading partners are implementing financing mechanisms to kick start progress towards their domestic emission reduction targets. These include contract-for-difference schemes and auctions to be administered by the European Union and Japan. Australia will collaborate with partner nations on Australian hydrogen projects that establish end-to-end supply chains with those countries.

ACTION 29

Pursue opportunities to leverage investment from other countries who are willing to provide co-funding and make other efforts to build end-to-end global supply chains.

Box 10: German-Australia Hydrogen Innovation and Technology Incubator (HyGATE).

The HyGATE initiative was committed to under the Australia-Germany Hydrogen Accord signed in June 2021 and was intended to strengthen collaboration with German partners to reduce the cost of renewable hydrogen production and support technology innovation in the industry.

Funding of up to $50 million from Australia and up to €50 million from Germany will be invested in new projects under HyGATE. Australia is providing the following funding for 4 projects:

- $20.74 million to Edify Energy Ptd Ltd. to develop, construct and operate the Edify Green Hydrogen Project in partnership with Siemens to contribute to the Australia–Germany supply chain in Townsville, Queensland.
- $19.48 million to Vast Solar to develop a methanol production plant using heat from concentrated solar thermal energy, including a 10 MW electrolyser producing green hydrogen in Port Augusta, South Australia.
- $8.98 million to Hysata Pty Ltd. to develop a new 'capillary-fed' electrolyser to test the delivery of low-cost hydrogen in Port Kembla, NSW.
- $800,000 to ATCO Australia Pty Ltd. for a feasibility study into deploying an electrolyser and ammonia facility to make advancements in hydrogen technologies and storage in the Illawarra region, NSW.

ARENA is administering the HyGATE Initiative on behalf of the Australian Government (through the Department of Climate Change, Energy, the Environment and Water). Projektträger Jülich (PtJ) is administering the HyGATE Initiative on behalf of the German Government (through the German Federal Ministry of Education and Research).

5.3 Guarantee of Origin scheme

The Guarantee of Origin (GO) scheme is a critical measure that will provide a transparent, verified, objective, and trusted emissions accounting framework covering hydrogen and related products. Administered by the Clean Energy Regulator, the GO scheme provides objective and consistent information on production and life-cycle emissions, giving consumers of Australian hydrogen and renewable electricity confidence in the emissions intensity and other environmental attributes of these products.

The Australian Government has committed to expand the GO scheme to incorporate green metal production and low carbon liquid fuels.

Australia is working to ensure the GO scheme is accepted by partners as being capable of demonstrating that clean energy exports meet import market requirements, including through:

- enhancing government-government bilateral and multilateral engagement, such as by establishing mutual recognition agreements and joint studies
- taking a lead role in existing and future certification multilateral forums.

ACTION 30

Implement the Guarantee of Origin scheme in 2025, and progressively increase the scope of the scheme to support the expansion of the hydrogen industry.

'Agreements to ensure consistency between Australia and other nations as to what constitutes low carbon hydrogen are required.'

Glencore

5.4 Strengthening international partnerships

Hydrogen is a key component in existing clean energy partnerships with major trade and strategic partners, as summarised in Appendix B. Deepening collaboration on RD&D, and supply chain development including with countries like the Republic of Korea, Germany, Japan, India and the United States, can position Australia at the leading edge for innovative hydrogen technologies and help build global supply chain resilience.

Australia will also continue to work through multilateral forums to:

- progress international governance and certification frameworks
- foster innovation and technology transfer
- shape and influence trade rules and norms
- mobilise and enable a skilled workforce
- promote regulatory harmonisation
- foster diverse, robust and efficient clean energy supply chains.

ACTION 31

Existing partnerships will be prioritised as vehicles for furthering our international hydrogen objectives. Australia will look for opportunities to grow global markets and build end-to-end supply chains.

> 'Much of the capital required for Australia's energy transition will need to come from overseas investors in partnership with Australian businesses and governments…The need for national leadership across multiple fronts cannot be understated.'
>
> **Australian Hydrogen Council**

6. Looking ahead

Key Points:

- Australia will continue to take an adaptive approach to develop our hydrogen industry.
- The National Hydrogen Strategy will be reviewed every 5 years, with the review to include a focus on progress against the targets and milestones detailed in the strategy, and consideration of the need for additional policy measures.
- The annual State of Hydrogen report will highlight emerging trends that may necessitate minor or urgent policy measures ahead of the next 5-yearly review.

6.1 An adaptive approach

The current expected development trajectory for the hydrogen industry to 2050 can be characterised according to the following stages:

- 2020 – 2030: Industry activation and initial scale production
- 2030 – 2040: Increase scale production and export of hydrogen and derivatives
- 2040 – 2050: Scaling up of export and consolidation of domestic use, including the realisation of more challenging uses such as aviation.

However, to meet these expectations will require immediate and ongoing action as well as predictable adjustment to meet changes in technology, market dynamics and global politics. Companies are also better able to take strategic decisions regarding long-term investment into technology and projects where there is relative policy stability.

A comprehensive policy review every 5 years balances policy stability with responsiveness and will enable the strategy to function as an input to future updates to Australia's Nationally Determined Contribution. Minor or more urgent policy reforms will be considered annually through the State of Hydrogen assessment and report.

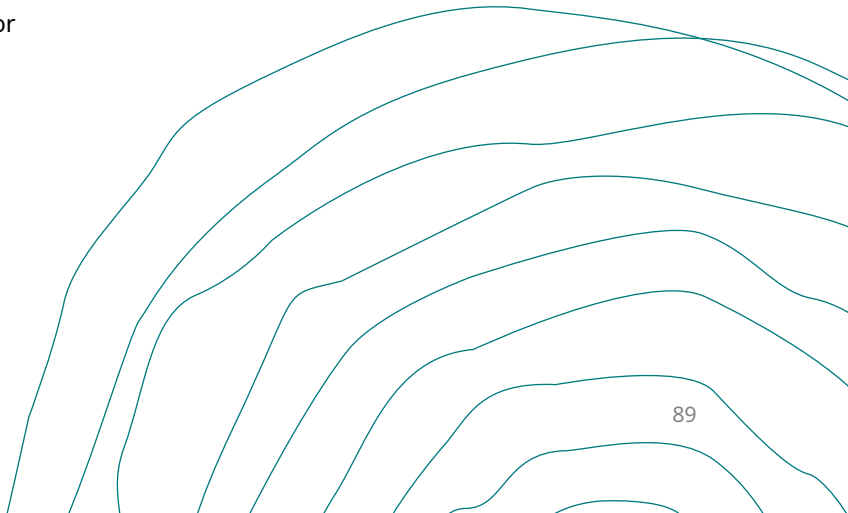
ACTION 32

Complete a full review of the National Hydrogen Strategy every 5 years, with the review to include a focus on progress against the targets and milestones detailed in the strategy, and consideration of the need for additional policy measures.

Chapter 2 of the strategy outlines the path to the progressive reduction in the cost of producing hydrogen, including efficiencies realised from delivering large-scale, export facing hydrogen projects. The Hydrogen Headstart program and Hydrogen Production Tax Incentive reflect that to achieve scale early and position Australia as a global hydrogen leader, governments will need to provide financial support. However, over time hydrogen businesses will be expected to contribute to the tax base when able and specific government support mechanisms can be retired.

ACTION 33

Monitor the value of direct revenue support in the hydrogen sector and anticipate shifts that allow returns to taxpayers in the future. This will include considering trends in technology costs, international market developments (including policy support in competitor countries) and the pace at which the costs of carbon emissions are internalised within the most prospective hydrogen using sectors.



6.2 Tracking progress and measuring success

The Department of Climate Change, Energy, the Environment and Water has commissioned annual independent assessments against the 13 industry development signals identified in the 2019 Strategy, which has been included in consecutive State of Hydrogen reports. This publication allows for the strategy's implementation to be tracked by external stakeholders and complements the Australian Government's internal implementation planning and governance arrangements to oversee the delivery of the strategy.

The State of Hydrogen's assessment framework will be updated and extended to detail industry development in each priority hydrogen demand area, water consumption from hydrogen production, regulatory approval times, consideration of the security of domestic hydrogen supply, and progress towards the targets and milestones outlined in this strategy.

ACTION 34

Publish an annual State of Hydrogen report centred around an independent assessment of progress. This will highlight emerging trends that may necessitate minor or urgent policy measures ahead of the next 5-yearly review.

6.3 Governance and institutions

Implementation, monitoring and review of the National Hydrogen Strategy will be led by the Australian Government with accountability to the Parliament of Australia, most directly through the Minister for Climate Change and Energy. However, as a priority industry under the Future Made in Australia agenda, implementation of the 2024 National Hydrogen Strategy and subsequent monitoring and reporting activities will also be of central interest to this broader government policy framework.

Australian state and territory governments have also developed hydrogen strategies to guide industry development in their respective jurisdictions. This strategy provides an overarching framework for communicating Australia's approach to hydrogen sector development from a national perspective. Adopting a broadly consistent national approach alongside policy set by state and territory governments ensures Australia's hydrogen policies can be made clear to the international community and other audiences while taking regional differences into account.

The Australian Government will continue to monitor industry progress and review the National Hydrogen Strategy in collaboration with the states and territories and seek to maximise endorsement of the national policy including through the Energy and Climate Change Ministerial Council.

Appendix A:

List of Targets and Strategic Actions

Targets	
1	Australia will produce at least 15 million tonnes of renewable hydrogen per year, with a stretch potential of 30 million tonnes by 2050.
2	In addition to the 2050 hydrogen production target, Australia's progress will be measured against the following annual hydrogen base and stretch production milestones: • 2030: 0.5 - 1.5 million tonnes • 2035: 3 – 5 million tonnes • 2040: 5 – 12 million tonnes • 2045: 9 – 20 million tonnes
3	Australia will export a base amount of 0.2 million tonnes, with a stretch potential of 1.2 million tonnes of renewable hydrogen (or equivalent in hydrogen embodied products) per year by 2030.
Actions	
Unlocking cost-competitive hydrogen production	
1	Focus government support on renewable hydrogen, complemented by suitable emissions intensity thresholds and other requirements for government-supported hydrogen projects, with GO certificates to form the basis of verification.
2	Provide early policy support to enable the scaling up of the hydrogen industry to achieve production costs that are competitive with incumbent fossil fuels and to secure early offtake agreements.
3	Consider reforms that may further enable specialist investment groups to play a bigger role in supporting the hydrogen industry to mature and secure further finance through traditional capital markets.
4	Support the integration of hydrogen hubs into the broader scoping, planning and development by Australian governments of industrial precincts.
5	Deliver the next iteration of the National Hydrogen Infrastructure Assessment over 2025 and 2026 in consultation with key infrastructure planning agencies, with subsequent analysis conducted at least every 5 years.
6	The Australian Government will work with the states and territories and other experts to improve understanding of future hydrogen transport needs to inform the next iteration of the National Hydrogen Infrastructure Assessment.
7	Support Geoscience Australia's precompetitive data program to identify suitable sites for hydrogen storage opportunities.
8	Support the establishment of fit-for-purpose and nationally consistent regulatory arrangements for the geological storage of hydrogen.
9	Consider the readiness and prospects of ports to store and export hydrogen, import renewable energy components, and to provide safe marine refuelling using low-carbon liquid fuels such as hydrogen, ammonia and methanol.
10	Support the development of sovereign clean technology and emissions-reduction manufacturing industries.
11	Identify opportunities that leverage Australia's research, development and demonstration (RD&D) capabilities to advance hydrogen technology manufacturing in Australia.
12	Support workforce development initiatives at all levels of government in line with responsibilities, with reference to analysis and guidance from key institutions including the Department of Employment and Workplace Relations, Jobs and Skills Australia, and the Jobs and Skills Councils.
13	Australia will seek opportunities to increase RD&D investment in the TRL 4-6 range through programs and grants, including through ARENA.
14	Identify opportunities to work with partners on RD&D and position Australia at the forefront of international hydrogen-related research collaboration.

Using hydrogen to decarbonise Australian industries and exports	
15	Prioritise support for the development of Australian hydrogen for use in prospective export-facing industries, particularly green ammonia, iron and alumina.
16	Work with industry to understand barriers and challenges to hydrogen adoption in prospective domestic sectors, including in the context of developing sectoral decarbonisation plans for energy, industry and transport.
17	Support the targeted use of hydrogen for transport, either through direct use in hydrogen fuel cell vehicles or as a low-carbon feedstock for the production of low carbon liquid fuels, alongside support for other pathways like electrification and alternative fuels.
18	Support analysis on how hydrogen can optimally support Australia's transition to renewables, including for energy storage, grid firming and via the flexible use of electrolysers.
Securing community benefits	
19	Support the coordinated production and dissemination of culturally appropriate and accessible education materials that provide factual information about hydrogen production, and the obligations of project proponents.
20	Support the inclusion of specific criteria in funding program guidance and obligations in funding agreements with Australian governments that require proponents to adopt best practice when engaging with First Nations communities including benefit sharing.
21	The Australian Government will encourage the hydrogen industry to adopt best practice stakeholder engagement, including through the development of a voluntary code of conduct, to maintain positive interactions with communities and industry.
22	Continue efforts across all levels of government to improve the efficiency and effectiveness of regulatory approval processes for safety and environmental protection.
23	Support the development and adoption of the National Hydrogen Codes of Best Practice in relation to hydrogen and ammonia.
24	Consider the need for expert forums or bodies to advise governments on safety and environmental protection issues to ensure that best practice approaches are being employed.
25	Report annual project water consumption by the hydrogen industry through the annual State of Hydrogen report.
26	To support infrastructure planning by companies and water-planning agencies, future National Hydrogen Infrastructure Assessments will include a focus on water demand and availability for hydrogen production.
27	Support the consideration of water demand associated with hydrogen production in the development of a new National Water Initiative as a complement to water management policy and frameworks in operation at a state/territory level.
28	Monitor emerging risks to domestic hydrogen supply as part of the independent assessment undertaken for the annual State of Hydrogen report, and the 5-yearly review of the National Hydrogen Strategy.
Shaping international trade and global markets	
29	Pursue opportunities to leverage investment from other countries who are willing to provide co-funding and make other efforts to build end-to-end global supply chains.
30	Implement the Guarantee of Origin scheme in 2025, and progressively increase the scope of the scheme to support the expansion of the hydrogen industry.
31	Existing partnerships will be prioritised as vehicles for furthering our international hydrogen objectives. Australia will look for opportunities to grow global markets and build end-to-end supply chains.
Looking ahead	
32	Complete a full review of the National Hydrogen Strategy every 5 years, with the review to include a focus on progress against the targets and milestones detailed in the strategy, and consideration of the need for additional policy measures.
33	Monitor the value of direct revenue support in the hydrogen sector and anticipate shifts that allow returns to taxpayers in the future. This will include considering trends in technology costs, international market developments (including policy support in competitor countries) and the pace at which the costs of carbon emissions are internalised within the most prospective hydrogen using sectors.
34	Publish an annual State of Hydrogen report centred around an independent assessment of progress. This will highlight emerging trends that may necessitate minor or urgent policy measures ahead of the next 5-yearly review.

Appendix B:

Australia's international engagement on hydrogen

Austrade

- Austrade is Australia's national investment attraction and trade promotion agency.
- Austrade works closely across government and with Australia's state and territory governments, to support Australia's transition to a net zero and renewable energy superpower. This work includes attracting productive foreign direct investment in net zero-aligned sectors, supporting export opportunities and helping companies commercialise innovation across net zero sectors.
- Austrade brokers introductions, facilitates business to business engagement and promotes Australia's hydrogen opportunities and Australian Government policies and programmes internationally, to support Australian hydrogen industry growth.

Bilateral

Australia–United States Net Zero Technology Acceleration Partnership

- Established in July 2022. This is a formal partnership to accelerate the development and deployment of zero emissions technology and to cooperate on critical minerals supply chains to reduce greenhouse gas emissions while supercharging economic growth.
- The partnership establishes a framework for practical cooperation including support of applied research, development, pilot projects, and demonstration projects of mutual benefit with a focus on the development and deployment of technologies, including hydrogen towards zero or negative emissions.

Australia–Japan Partnership on Decarbonisation through Technology

- Established in June 2021. Australia and Japan are focussing on lower emissions liquefied natural gas (LNG) production, transport and use, clean fuel ammonia, clean hydrogen, carbon capture, use and storage, carbon recycling, and low emissions steel and iron ore.

Australia–Singapore Partnership on Low Emissions Technologies in Maritime and Port Operations

- Established in June 2021. Australia and Singapore are accelerating the deployment of low emissions fuels and technologies like clean hydrogen, battery storage and electrification.
- Established in October 2020, the Australia-Singapore MoU on low emissions solutions includes collaboration on Hydrogen; CCUS; renewable energy trade; measurement; and reporting verification of emissions.

Australia–Republic of Korea Low and Zero Emissions Technology Partnership

- Established in November 2021. Australia and the Republic of Korea are advancing technologies and trade systems for hydrogen supply, low emissions steel and iron ore, and CCUS.

Australia-India Letter of Intent on New and Renewable Energy Technology

- Established February 2022. Australia and India have committed to work together on reducing the cost and scaling up the deployment of ultra-low-cost solar and clean hydrogen, including electrolysers.
- In May 2024, Australia and India established the India-Australia Green Hydrogen Taskforce which aims to identify opportunities to accelerate the manufacture and deployment of green hydrogen.

Australia-Germany Hydrogen Accord

- Established June 2021. Australia and Germany are working together to accelerate the development of a hydrogen industry under a new hydrogen accord by establishing the Australia-Germany Hydrogen Innovation and Technology Incubator (HyGATE) to support real-world pilot, trial, demonstration, and research projects along the hydrogen supply chain; facilitating industry-to-industry cooperation on demonstration projects in Australian hydrogen Hubs; and exploring options to facilitate trade of Australian hydrogen and its derivatives produced from renewable energy sources.

Australia-United Kingdom Clean Technology Partnership

- Established in July 2021. Australia and the United Kingdom have committed to work together to collaborate on making low emissions technologies globally scalable and commercially viable. The partnership will focus on R&D across key technologies including clean hydrogen; carbon capture and use; carbon capture and storage; small modular reactors including advanced nuclear designs and enabling technologies; low emissions materials including green steel; and soil carbon management.

Australia-Netherlands Memorandum of Understanding on Cooperation in the Field of Hydrogen

- Established in January 2023. Australia and the Netherlands will support the development of a renewable hydrogen supply chain from Australia to Europe. The Memorandum of Understanding includes knowledge exchange on policy, certification and innovative technologies; port infrastructure and supply chain development; innovative hydrogen technologies, including shipping, equipment and services; and government policies about safety, social licence and regulations for hydrogen.

Australia-Denmark Strategic Partnership Arrangement

- Australia is working with Denmark to explore opportunities for cooperation across 3 pillars:
  - Advancing action on climate change and green transition
  - Promoting peace and security as we engage in a changing geopolitical environment
  - Enhancing collaboration in areas of strategic importance.

Multilateral

Mission Innovation Clean Hydrogen Mission

- Australia is a member of Mission Innovation's Clean Hydrogen Mission. The Mission has the goal to increase the cost-competitiveness of clean hydrogen by reducing end-to-end costs to a tipping point of 2 USD/kg by 2030. Costs reduction needs to happen across the value chain including, production, handling, transportation, and storage.

Clean Energy Ministerial (CEM) Hydrogen Initiative

- Australia works with the CEM Hydrogen Initiative to ensure the successful deployment of hydrogen within current industrial applications; enabling deployment of hydrogen technologies in transport (e.g. freight, mass transit, light-rail, marine); and exploring the role of hydrogen in meeting the energy needs of communities.

QUAD Clean Hydrogen Partnership

- Australia has partnered with Japan, India and the United States to strengthen and reduce costs across all elements of the clean hydrogen value chain, leveraging existing bilateral and multilateral hydrogen initiatives in other fora. This includes technology development and efficiently scaling up the production of clean hydrogen, identification and development of delivery infrastructure to safely and efficiently transport, store, and distribute clean hydrogen for end-use applications, and stimulating market demand to accelerate trade in clean hydrogen in the Indo-Pacific region.

Indo-Pacific Economic Framework (IPEF) Clean Economy Agreement

- Australia is working with IPEF on a regional hydrogen initiative to promote deployment of renewable and low-carbon hydrogen and its derivatives. IPEF partners plan to establish work programs in other areas such as emissions accounting to facilitate growth in green trade and sustainable finance frameworks to unlock greater private sector support for decarbonisation.

International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE)

- Australia works with its IPHE partners to share information and help facilitate multinational research, development, and deployment initiatives that advance the introduction of hydrogen and fuel cell technologies on a global scale. This is achieved by IPHE's working groups: the Education & Outreach Working Group and the Regulations, Codes, Standards & Safety Working Group.

Appendix C:

Analysis for the strategy

Lead	Outputs	Description
CSIRO	Modelling, analysis and report – Scenario modelling of the production and consumption of hydrogen in Australia.	CSIRO modelled the role of hydrogen to help achieve Australia's 2030, and net zero 2050 target under three scenarios (high, central and low adoption of clean hydrogen) based on an understanding of domestic decarbonisation needs and export opportunities by sector.
ARUP	Analysis and Report – Activating domestic demand for hydrogen	The National Hydrogen Strategy of 2019 primarily focused on the supply side of hydrogen, its production and distribution. However, the review of the NHS has a greater emphasis on the demand side of the hydrogen market. To inform that focus, this report identified short, medium and long-term opportunities to stimulate domestic demand for clean hydrogen to better inform the market, reduce investment risk perceptions, support industry activation and better inform government policy choices.
ARUP	Analysis and Report – Updated analysis of Australian Hydrogen Hubs	The report explores how hydrogen hubs can play a role in the decarbonisation of Australia's hard-to-abate sectors, particularly helping to decarbonise industrial precincts and support development of new net zero export opportunities. The potential sectors for early hydrogen development are identified, and locations for prospective hydrogen hubs are explored. Finally, the ways in which hubs develop and can be supported by governments are examined, considering both international and Australian case studies.
CSIRO	Analysis and Report – Clean Hydrogen Research, Development and Demonstration (R&D&D) Priorities	CSIRO provided analysis on potential priority clean hydrogen related technologies and specifically the critical focus areas for research, development and demonstration projects for the next decade that could position Australia as a global hydrogen leader.
CSIRO	Analysis and Report – Review of Australia's Clean Hydrogen Research and Innovation Ecosystem	CSIRO conducted a review of the roles of existing organisations in supporting Australia's hydrogen RD&D and a review of Australian and overseas operating models for national research and innovation.
ARUP	Modelling, analysis and report – Infrastructure to enable hydrogen industry development – additional scenarios building on the National Hydrogen Infrastructure Assessment	This analysis and report build on from the 2023 National Hydrogen Infrastructure Assessment, and further improves understanding and assessment of critical enabling infrastructure needs to support industry activation and position Australia to be a clean hydrogen leader by 2030. As well as various updated assumptions, this analysis includes an additional focus on water infrastructure for the future hydrogen economy, which was informed by a technical note exploring water availability and demand scenarios based on current water infrastructure planning.

Appendix D:

Stakeholder engagement that informed the strategy

The Australian Government undertook formal open public stakeholder consultation as part of the development of the 2024 National Hydrogen Strategy from July 6 to August 18 in 2023. The government released a National Hydrogen Strategy **Consultation Report** to assist this review and inform discussion, inviting feedback and formal submissions. The government undertook in 2023 and 2024 over 65 face to face meetings with stakeholders to consult and gain expert feedback on this formal review of the National Hydrogen Strategy.

There were 115 stakeholder submissions to the National Hydrogen Strategy Review Consultation available from The Department of Climate Change, Energy, the Environment and Water's Consultation Hub.[78] The organisations that contributed public submissions to the review of the National Hydrogen Strategy are listed below.

ABEL Energy
ACI
AEC
ANU Hydrogen Fuels Project, part of the Zero Carbon Energy for the Asia Pacific research initiative.
APA
ATCO
Australian Academy of Technological Sciences and Engineering
Australian Aluminium Council
Australian Financial Markets Association
Australian Gas Infrastructure Group
Australian Hydrogen Council
Australian Land Conservation Alliance
Australian Logistics Council
Australian Manufacturing Workers' Union
Australian Parents for Climate Action
Australian Petroleum Production and Exploration Association
Australian Pipelines and Gas Association
Australian Steel Institute
Australian Hydrogen Research Network
BlueFloat Energy
Boundless Earth
BP
Business Council for Sustainable Development Australia
CFMMEU (Maritime Union of Australia and Construction Divisions)
Chamber of Minerals and Energy of Western Australia
Charles Stewart Lee
Chevron
Climateworks Centre
CO2CRC
Copenhagen Infrastructure Partners
CS Energy
CWP Global
Daniel Schepis, Stephan Modest, Sudha Mani and Sharon Purchase
David Archibald
Elizabeth Thurbon, Alexander Hynd and Hao Tan
Energy Australia
Energy Networks Australia
ENGIE Australia & New Zealand
Engineers Australia
Environmental Defenders Office
EWAN MCLEAN
Ex Testing and Certification Pty Ltd
Fortescue
Frontier Energy Limited
Gas Appliance Manufacturers Association of Australia
Gascoyne Green Energy
German-Australian Chamber of Industry and Commerce
Glencore
Grattan Institute
Green LOHC Pty Ltd
Hiringa Energy
Hycamite
Hycel Deakin University
Iberdrola Australia
IECEx, ANZEx and JASANZ
Institute for Energy Economics and Financial Analysis (IEEFA)
InterContinental Energy
Jemena
J-Power and Sumitomo Corporation
Low Emission Technology Australia (LETA)
Mining and Energy Union
Monash Energy Institute
Nigel Howard
NSW Powerfuel Including Hydrogen Innovation Network
Origin Energy
Paul M
PDC Machines
Provaris Energy
Public Interest Advocacy Centre (PIAC)
Queensland Farmers' Federation
Regional Development Australia - Illawarra
Rheinmetall Defence Australia
Rio Tinto
Robert Horsnell
Stralis Aircraft
Sunshine Hydro
Tejaswy
Townsville Enterprise
Toyota
Transgrid
Tree Energy Solutions (TES)
Victorian Chamber of Commerce and Industry
Water Services Association of Australia
Wilderness Society
Worley

78 DCCEEW 2024, *Provide your submission - Review of the National Hydrogen Strategy*. https://consult.dcceew.gov.au/review-of-the-national-hydrogen-strategy/survey/list

Appendix E:

Governance

The Australian Government led the development of the 2024 National Hydrogen Strategy collaborating in concert with states and territory governments via regular consultation through a Commonwealth, state and territory government Hydrogen Reference Group and regular Energy and Climate Change Ministerial Council (ECMC) meetings.

Within the Australian Government, The Department of Climate Change, Energy, the Environment and Water had carriage of this work working closely via a formal Australian Government National Hydrogen Strategy Steering Committee with high level representatives from the following departments:

- Department of Climate Change, Energy, the Environment and Water
- Department of Industry, Science and Resources
- Department of Infrastructure, Transport, Regional Development, Communications and the Arts.

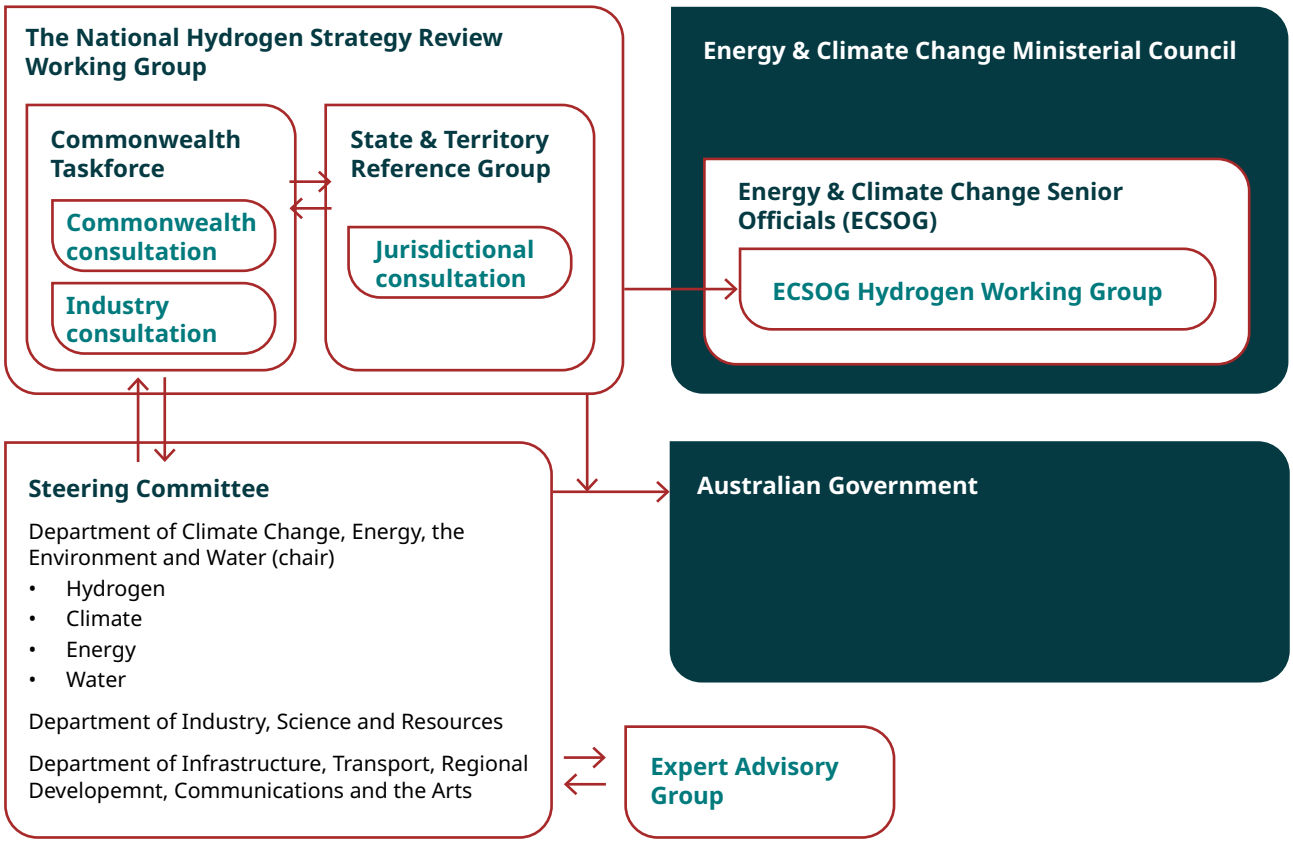


Figure 13 **National Hydrogen Strategy review governance structure.**

Appendix F:

Advisory Group members

Chair:

Jo Evans PSM, Deputy Secretary, Department of Climate Change, Energy, the Environment and Water (DCCEEW)

Members

Brad Archer, Chief Executive Officer, Climate Change Authority

Kobad Bhavnagri, Global Head of Strategy, Bloomberg NEF

Prof Michael Brear, Director, Melbourne Energy Institute

Tim Buckley, Director, Climate Energy Finance

Wendy Black, Head of Policy, Business Council of Australia

Dr Amanda Cahill, Chief Executive Officer, The Next Economy

Peter Chesworth, Head of Division Minerals and Resources, Department of Industry, Science and Resources (DISR)

Nevenka Codevelle, Executive General Manager, Australian Energy Market Operator

Dr Andrew Feitz, Director Low Carbon Geoscience and Advice, Geoscience Australia

Dr Alan Finkel AC

Dr Cathy Foley AO, Australia's Chief Scientist

Anna Freeman, Policy Director – Decarbonisation, Clean Energy Council

Trevor Gauld, National Policy Officer, Electrical Trades Union of Australia

Darcy Gunning, Community and Campaigns Organiser, Australian Manufacturing Workers' Union

Dr Patrick Hartley, Leader of CSIRO's Hydrogen Industry Mission

Penny Howard, National Research Officer, Maritime Union of Australia

Erwin Jackson, Policy Director, Investor Group on Climate Change

Joanna Kay, General Manager, Zero Carbon Hydrogen Australia

Darren Miller, Chief Executive Officer, Australian Renewable Energy Agency

Matthew Maloney, Assistant Secretary, Climate and Energy, Treasury

Rupert Maloney, Executive Director – Alternative Fuels, Clean Energy Finance Corporation (CEFC)

Thomas Mortimer, National Policy Director, Australian Workers' Union

Karrina Nolan, Executive Director, Original Power, First Nations Clean Energy Network

Tennant Reed, Director – Climate Change and Energy, Australian Industry Group

Alison Reeve, Energy and Climate Deputy Program Director, Grattan Institute

Dr Fiona Simon, Chief Executive Officer, Australian Hydrogen Council (AHC)

Anna Skarbek, Chief Executive Officer, Climateworks Centre

Prof Anne Tiernan, Griffith Business School

Zoe Whitton, Managing Director, Head of Impact, Pollination

Appendix G:

Abbreviations, acronyms and glossary

AEMO – Australian Energy Market Operator, responsible for operating Australia's largest gas and electricity markets

ARENA – Australian Renewable Energy Agency

BEV – battery electric vehicle, fully electric vehicle with rechargeable batteries and no internal combustion engine

Blue hydrogen – hydrogen produced using fossil fuels with substantial carbon capture and storage. The 2019 National Hydrogen Strategy noted that, to produce hydrogen from natural gas or coal at acceptably low levels of carbon emissions, capture rates of 90% or more will likely be required

CBAM – Carbon Border Adjustment Mechanism

CCS or **Carbon Capture and Storage** – the process of capturing and permanently storing carbon emissions

CEFC – Clean Energy Finance Corporation

CEM or **Clean Energy Ministerial** – a global forum held to promote policies and to share best practices with the aim of accelerating a transition to clean energy. The forum includes partnerships and collaboration between the private sector, public sector, non-governmental organisations, and others

Center for Hydrogen Safety – a not-for-profit, membership organisation established by the American Institute of Chemical Engineers to promote the safe operation, handling and use of hydrogen

Clean hydrogen – hydrogen produced using renewable energy or fossil fuels with substantial carbon capture and storage

CO_2 – carbon dioxide

CO_2-e – carbon dioxide equivalent, a metric used to compare the emissions from various greenhouse gases to determine their individual and total contributions to global warming

CSIRO or **Commonwealth Scientific and Industrial Research Organisation** – Australia's national science research agency

Demand response – a planned change in the power consumption of an electricity user to assist in matching electricity demand and supply

DRI or **Direct Reduced Ironmaking –** the chemical removal of oxygen from iron ore in its solid form

ECMC – Energy and Climate Change Ministerial Council

Electrolysis and **electrolysers** – electrolysis is the process of using electricity to split water into hydrogen and oxygen. This reaction takes place in a unit called an electrolyser

Emissions or **Carbon emissions** – carbon dioxide released to the atmosphere from burning fossil fuels, manufacturing, mining, land use and other activities

Energy market bodies – bodies which have a role regulating and operating Australian energy systems and markets

Energy markets – commodity markets that deal specifically with the trade and supply of energy, generally electricity, gas, and liquid fuels

Energy systems – includes energy markets and energy supply networks

EPBC Act – the *Environment Protection and Biodiversity Conservation Act 1999,* Australia's main national environmental legislation

EFA – Export Finance Australia

FCEV – fuel cell electric vehicle – an electric vehicle that uses electricity from a fuel cell powered by hydrogen, rather than electricity from batteries

FMiA or **Future Made in Australia** – the Australian Government's Future Made in Australia package

Gasification – a process that converts fossil fuel-based materials into gases

GDP – gross domestic product

GJ – gigajoule, a unit of electrical energy equal to 1,000,000 kilojoules

Green hydrogen or **Renewable hydrogen** – hydrogen produced through electrolysis using renewable electricity

Grey hydrogen – hydrogen produced using natural gas without substantial carbon capture and storage

GO scheme or **Guarantee of Origin scheme** – an internationally aligned assurance scheme being designed to track and verify emissions associated with hydrogen, renewable electricity and other products (such as green metals and low carbon liquid fuels) made in Australia

GWh – gigawatt hour, a measure of electrical energy in terms of the use of one gigawatt of power for one hour, equal to 1,000 MWh

HPTI or **Hydrogen Production Tax Incentive** – A program aimed at accelerating the deployment of renewable hydrogen production in Australia by providing time-limited, demand-driven production support through Australia's tax system to eligible renewable hydrogen producers

The HPTI will be delivered through Australia's tax system, claimable at a rate of $2 per kilogram of eligible hydrogen produced. Support will be provided between 2027–28 and 2039–40 for projects that reach final investment decision by 2030. Each facility will have access to the HPTI for a maximum of 10 years from first production

Hydrogen – a colourless, odourless, tasteless, flammable substance that is the simplest chemical element in the periodic table. It is virtually non-existent in its free form on Earth and requires energy to liberate it from the material forms in which it is found. In this strategy, references to 'hydrogen' should be taken to mean 'clean hydrogen', unless otherwise specified. See also 'clean hydrogen'

Hydrogen Headstart – a competitive program which will provide revenue support to large-scale renewable hydrogen projects in Australia to bridge the commercial gap between the production costs and sale price of renewable hydrogen, or derivative products such as ammonia or methanol

Hydrogen hubs – aggregations of various users of hydrogen in one area. They may be in ports, cities, or remote areas

HyGATE – the Australia-Germany Hydrogen Innovation and Technology Incubator to support real-world pilot, trial, demonstration, and research projects along the hydrogen supply chain

IEA – International Energy Agency

IPEF – Indo-Pacific Economic Framework

IMO – International Maritime Organisation

Integrated System Plan – a whole-of-system plan that provides an integrated roadmap for the efficient development of the National Electricity Market (NEM) over the next 20 years and beyond

IPHE – International Partnership for Hydrogen and Fuel Cells in the Economy

IRENA – International Renewable Energy Agency

JSA – Jobs and Skills Australia

JSC – Jobs and Skills Councils

kWh – the amount of electrical energy provided by one kilowatt of power for one hour

LNG – liquefied natural gas, the form in which natural gas is transported over long distances

Mission Innovation – a global initiative of 23 countries and the European Commission to accelerate clean energy innovation

MWh – the amount of electrical energy provided by one megawatt of power for one hour. Equal to 1,000 kWh

NAIF – Northern Australia Infrastructure Facility

NZEA – Net Zero Economy Authority

NHIA or **National Hydrogen Infrastructure Assessment** The inaugural assessment of infrastructure needed to establish and scale up Australia's hydrogen industry which was published in 2023

NEM – National Electricity Market – a wholesale electricity market that interconnects Queensland, New South Wales, Victoria, South Australia, Australian Capital Territory, and Tasmania

NRFC – National Reconstruction Fund Corporation

PJ – petajoule, a unit of electrical energy equal to 1,000,000 gigajoules

R&D – Research and development

RD&D – Research, development and demonstration

Renewable energy – energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat

SAF or **Sustainable Aviation Fuel** – renewable or waste-derived aviation fuels that meet sustainability criteria

Safeguard Mechanism – An emissions reduction policy under which legislated limits—known as baselines— are set on the greenhouse gas emissions of Australia's largest industrial facilities. These emissions limits will decline, predictably and gradually, on a trajectory consistent with achieving Australia's emission reduction targets of 43% below 2005 levels by 2030 and net zero by 2050

Sectoral decarbonisation plans – in line with Australia's commitment to achieve net zero emissions by 2050, the Australian Government is preparing decarbonisation plans for 6 key sectors – electricity and energy, transport, industry, agriculture and the land, resources, and the built environment

State of Hydrogen report – an annual report to track Australia's hydrogen industry development and progress against global developments

Steam methane reforming – a method to extract hydrogen using natural gas. It involves catalytically reacting natural gas with steam to produce hydrogen and carbon monoxide (a mixture known as syngas). A subsequent reaction involving more steam produces further hydrogen while also converting carbon monoxide (CO) to carbon dioxide (CO_2)

Supply chain – activities involved to make, move, store and use a product

TWh – Terawatt hour, the amount of electrical energy provided by one terawatt of power for one hour, equal to 1,000 GWh

VET – Vocational Education and Training