

Australia's Emerging Hydrogen Economy

In Search of Export Opportunities

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Summary

The Australian government foresees an opportunity to scale the hydrogen economy, centred on exporting hydrogen and associated vectors to the Asia Pacific region. Australia was the third country to release a National Hydrogen Strategy (NHS) in 2019, and policies have been introduced to support the development of a national hydrogen industry (Government of Australia 2023). Within Australia's broader efforts to decarbonize its economy, considerations revolve around which role hydrogen may play in the domestic energy transition, the potential size of its future hydrogen export market, and what opportunities exist for value creation along the entire hydrogen supply chain.

In this chapter we provide an overview of hydrogen development in Australia. We begin with a brief overview of Australia's climate and energy policy and its position in regional and global energy markets. We then discuss the state of hydrogen supply and demand in the domestic economy, before outlining the main policy initiatives and stakeholders. We then consider the external dimensions of Australia's national hydrogen policy, which is closely linked to the opportunity for exports of hydrogen and associated vectors with low carbon intensity.

A key policy issue lies in overcoming the economic and technical barriers to enabling the rapid deployment of Australia's resources to support decarbonization at home, while building international supply chains for large-scale export of low-cost renewable energy. It is in this context that hydrogen has emerged as a central vector for Australia's transition towards a net-zero economy, enjoying broad support from both national and state governments and industry. Hydrogen is being trialled as an option for supporting decarbonizing of the domestic economy, with developments in its use as a chemical feedstock, electricity grid support, mining and off-grid applications, and in blending in gas networks. However, a large part of the interest in developing a hydrogen industry is linked to its export potential, including the potential for increasing the share of value-added metals using hydrogen, such as green iron and alumina.

Australia's external hydrogen strategy reflects this export focus. Australia's first NHS was released following major trading partner Japan's 2017 launch of its hydrogen strategy, and national and state government support for industry development has a substantial – although not exclusive – export focus. The most advanced partnership is with Japan, with a March 2023 announcement of additional investment from Japan to enable commercialisation of a pilot project using hydrogen produced from a mix of coal and biomass. Moreover, Australia has the largest number of announced hydrogen projects globally. However, by 2023 only one project reached FID, and there has been concern that Australia's inherent advantages in terms of proximity to markets in the Asia Pacific, land availability, and abundant low-cost renewable energy may not lead to a substantial hydrogen export industry without additional measures put in place. The Hydrogen Production Tax Incentive and Hydrogen Headstart programs sought to respond to increased international competition, and the Australian government and industry bodies have been actively involved in negotiating frameworks for governing the calculation of emissions embedded in different hydrogen production methods.

An additional issue facing government and industry is the technology choice for hydrogen production. The first NHS committed the government to supporting “clean hydrogen”, which it defined as hydrogen produced using electrolysis as well as steam-methane reforming (SMR) coupled with carbon capture and storage (CCS). The state of Victoria has even supported unabated coal gasification technology within the large-scale HESC project. These developments are consistent with the fact that Australia has abundant fossil fuel resources in addition to low-cost renewable energy, both of which can be used in the production of hydrogen. Public consultations leading up to the adoption of the 2019 NHS also showed substantial support among industry for the use of fossil fuels in the production of hydrogen. More recent policy developments, including the revised 2024 National Hydrogen Strategy, and substantial incentives included in the 2024-2025 federal budget, show a shift by the federal government towards an emphasis on renewable hydrogen.

Finally, a key question that remains unanswered will be the competitiveness of these different forms of hydrogen production in export markets and the role of hydrogen in the broader long-term decarbonization efforts across the region. This also has important implications for Australia's domestic economy, given the enormous growth in electricity demand implied by a large increase in Australian exports of low-carbon hydrogen.

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1 Introduction

The Australian government foresees an opportunity to scale the hydrogen economy, centred on exporting hydrogen and associated vectors to the Asia Pacific region. Australia was the third country to release a National Hydrogen Strategy (NHS) in 2019, and policies have been introduced to support the development of a national hydrogen industry (Government of Australia 2023). Within Australia's broader efforts to decarbonize its economy, considerations revolve around which role hydrogen may play in the domestic energy transition, the potential size of its future hydrogen export market, and what opportunities exist for value creation along the entire hydrogen supply chain.

In this chapter we provide an overview of hydrogen development in Australia. We begin with a brief overview of Australia's climate and energy policy and its position in regional and global energy markets. We then discuss the state of hydrogen supply and demand in the domestic economy, before outlining the main policy initiatives and stakeholders. We then consider the external dimensions of Australia's national hydrogen policy, which is closely linked to the opportunity for exports of hydrogen and associated vectors with low carbon intensity. Australia's hydrogen strategy also reflects the interdependence of green industry policies (Meckling & Hughes 2018), with the focus on export potential in response to traditional commodity trading partners' planning to use hydrogen in decarbonization.

2 Hydrogen within Australia's decarbonization strategy

The federal government elected in May 2022 increased Australia's Nationally Determined Contribution lodged with the United Nations Framework Convention on Climate Change (UNFCCC). The government committed Australia to reducing greenhouse gas (GHG) emissions by 43 percent by 2030 relative to 2005 levels and achieving net-zero emissions by mid-century. It also set a national renewable energy target of 82 percent by 2030. The government incorporated the national GHG emissions reduction target into the Climate Change Act that became law in 2022, increasing the credibility of this commitment.

The Climate Change Act requires the government to submit an Annual Climate Change Statement ('Annual Statement') to parliament on progress towards achieving the country's GHG emissions target. Under current policy settings, the 2023 Annual Statement found emissions at 24.5 percent below 2005 levels, projected to be 42 percent below 2005 emissions by 2030, thereby broadly in line with its commitments (Commonwealth of Australia 2023a). The reduction in emissions is driven by the decarbonisation of the electricity sector, for which emissions fell 22.9 percent between 2005 and 2023 due to a rise in renewable energy deployment and the retirement of emissions-intensive coal-fired power plants.

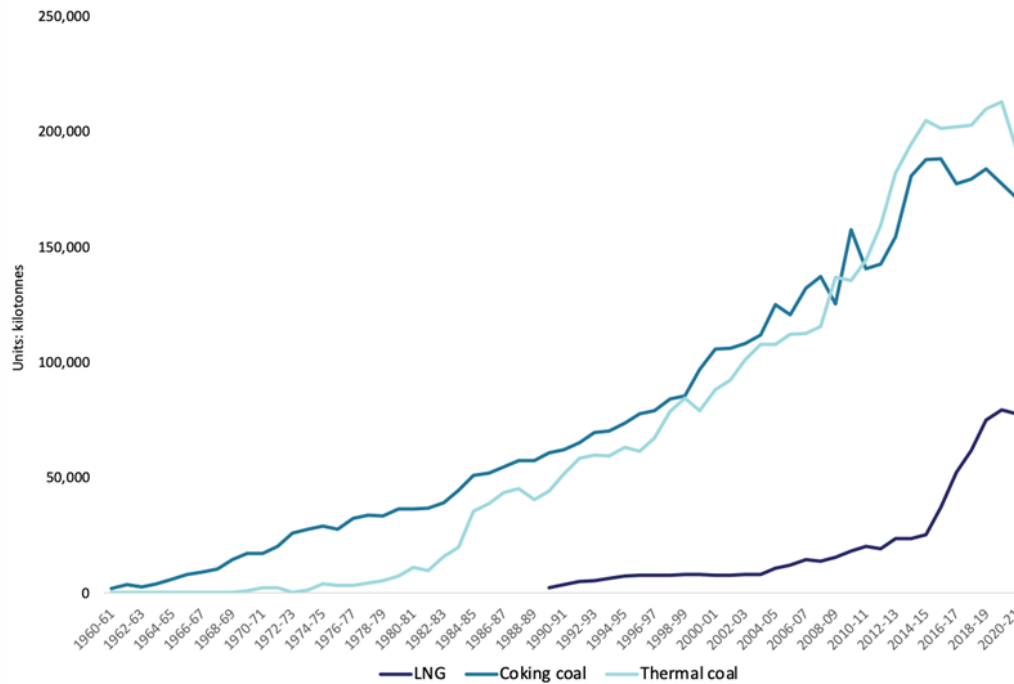
The Annual Statement also summarises current initiatives undertaken to support Australia's new climate strategy (Commonwealth of Australia 2023a). Central to achieving the net-zero mid-century target are six sectoral decarbonisation plans focused on electricity and energy, industry, resources, the built environment, agriculture and land, and transport. The role of hydrogen is expected to be made clear through the decarbonisation pathways outlined in these sectoral plans. An important additional element in the government's climate mitigation strategy is a reform of the Safeguard Mechanism, which places an obligation on large GHG emitters – defined as those with Scope 1 emissions of more than 100,000t of CO₂e per year – to keep their net emissions below a baseline that decreases year-on-year and offers a number of options for managing excess emissions.

Australia's legacy energy system is heavily reliant on fossil fuels, however, its abundant low-cost solar and wind resources have enabled the rapid decarbonization of its electricity system. In 2022 around 32 percent of electricity was generated by renewable energy sources (Commonwealth of Australia 2023a). A 2010 assessment of Australia's resources notes that "if only 0.1 percent of the incoming radiation could be converted into usable energy at an efficiency of 10 percent, all of Australia's energy needs could be supplied" (Australian Government 2010). Australia also has abundant resources of offshore wind energy, which are complementary to other renewable energy resources in terms of their daily and seasonal profiles (Australian Energy Market Operator 2022).

Despite the dynamic development of domestic renewable energy, Australia remains a major supplier of gas and thermal coal to the Asia Pacific region, as well as coking coal used in steel manufacturing (Figure 1). Consequential emissions from the use and processing of Australian exports are larger than domestic emissions and have been assessed at around four percent of total global annual emissions (Burke et al. 2022). Governments and industry are now shifting to explore the potential of exporting climate-friendly commodities, with consideration given to hydrogen and ammonia, and increasingly value-added low-carbon products such as green iron and alumina. Yet despite this interest in an export-oriented hydrogen industry a 2023 NHS review expressed concern that Australia was falling behind competitors for export markets (Government of Australia 2023). The review also noted the potential opportunity to establish a green iron ore processing industry using renewable energy and hydrogen, suggesting increased appetite for considering downstream value-added applications of hydrogen. The use of hydrogen to increase value creation in iron and steelmaking in Australia is identified as a large-scale economic opportunity (Jotzo 2022) and was given emphasis in the revised National Hydrogen Strategy released in 2024 (Government of Australia 2024). The national government identified the opportunity to shift down the value chain by increasing onshore manufacturing of low emissions products, including by potentially newly establishing an iron ore processing industry based on renewable hydrogen. Australia is currently a bulk commodity supplier, exporting 900 Mt of

iron ore annually as the world's largest global producer, but with limited domestic steel production capabilities (Commonwealth of Australia 2022b).

FIGURE 1 AUSTRALIAN EXPORTS OF GAS, THERMAL COAL AND COKING COAL, IN PHYSICAL UNITS



Another important question is which technologies will be supported through policy frameworks to produce hydrogen for domestic use and exports. Hydrogen can be produced using gas or coal, with or without carbon capture and storage (CCS), as well as through electrolysis using electricity with different levels of carbon intensity. All technology pathways are available to Australia, given the abundant reserves of both fossil fuel and renewable energy resources. The choice of production technology has major implications for GHG emissions from energy inputs as well as fugitive emissions (i.e. leakage) in hydrogen production processes (Longden et al. 2022).

3 Australia's hydrogen economy: policy and market developments

Hydrogen already plays a role in industrial processes within the domestic Australian economy, acting as a feedstock for ammonia production (~65 percent of total consumption) and refining processes for crude oil (~35 percent of total consumption), along with a number of smaller industrial processes. There is little hydrogen produced for sale on a merchant basis, with the majority used directly in ammonia production and in refining processes (Gratham 2021). The largest facility is located in Western Australia and produces up to 850,000 metric tons of ammonia annually using steam-methane reforming (SMR) for domestic fertilisers and mining, as well as for ammonia exports to Asia-Pacific fertilizer markets.

Australia's 2019 NHS identified an expansion of potential end-uses for hydrogen domestically as a pathway to scaling local industry and preparing for the potential of large-scale exports (Commonwealth of Australia 2021). As of September 2024, there were 98 hydrogen projects, of which 81 were either under development or construction. Of these, 20 projects were designated as having an export focus, with domestic end-uses focused on transport, blending in the existing gas network, and industrial uses (HyResource, 2024).

A 2022 NHS review of the state of hydrogen industry development found some limited progress on the domestic demand-side, hampered due to hydrogen's lack of competitiveness. In the power sector, for example, battery and pumped-hydro options were identified as receiving more attention than hydrogen for load balancing and grid-firming applications. Similarly, the 2022 review reported some progress in the use of hydrogen in mining and off-grid applications, though limited by the continued use of diesel. Likewise, progress was slow in heavy transport given the focus on battery electric vehicles, although governments were collaborating on the development of a hydrogen refuelling network on freight highways. Hydrogen also had not yet been applied in industrial heating processes beyond feasibility studies (Commonwealth of Australia 2022a).

Reflecting this, a revised NHS released in 2024 focused on a more limited number of end-use cases within the domestic economy centred on heavy road freight in the near-term, with longer-term consideration given to research and analysis into possible uses in aviation, shipping and bunkering, and the power sector. The focus on export potential remains, but with an increased focus on the potential opportunities to use hydrogen domestically in value-adding processes such as the production of green iron for export (Government of Australia 2024).

The revised 2024 NHS also established a series of quantitative targets to provide greater certainty to the industry, beginning with the goal of producing 15MT of hydrogen annually by 2050, with a stretch target of 30 MT. In addition, the new NHS set an export target of 0.2MT of renewable hydrogen exported by 2040, with a stretch goal of 1.2MT, and put in place an annual reporting process, along with a strategic review every five years.

3.1 Early-stage project support

Policies supporting the scaling of the hydrogen industry span the Commonwealth and state governments within Australia's federal system. The initial strategy adopted by the federal government proposed an "adaptive approach" to scaling hydrogen, centred on removing barriers to industry development and increasing domestic demand and supply, while recognising uncertainty about hydrogen's long-term role in decarbonization pathways domestically and globally. Consistent with this, the initial policy phase was designed to scale up production by advancing pilot, trial, and demonstration projects, building hydrogen hubs, assessing supply chain infrastructure, and supporting the development of supply chains for hydrogen hubs (COAG Energy Council 2019).

Funding has been disbursed through Australia's innovation system support for research, development, and demonstration (RD&D) projects in hydrogen and ammonia. As of September 2024, federal government support specific to hydrogen totalled AUD12.4 billion,

with a further AUD29.4 billion available for hydrogen projects that had a more general intent. State governments provided an additional AUD5.0 billion and AUD13.4 billion in hydrogen-specific and hydrogen-eligible support, resulting in a combined total of almost AUD60.2 billion in public funding (HyResource 2024b).

Two key public investment bodies disbursing hydrogen-specific funding are the Australian Renewable Energy Agency (ARENA), and the Clean Energy Finance Corporation (CEFC) (see information box). ARENA committed more than AUD190 million towards the development of renewable hydrogen projects, including three 10MW electrolyser projects, AUD22.1 for universities and research organizations, and investments in transport-related projects (Commonwealth of Australia 2022b). In 2023, ARENA also announced AUD50 million in funding for support of renewable hydrogen and low-emissions iron and steel (Australian Renewable Energy Agency 2023), following a 2021 funding round focused on solving technical and logistical challenges related to ammonia, the use of methane as a fuel carrier, hydrogen fuel reciprocating engines, biological hydrogen production, and the use of photovoltaic electrolysis for hydrogen generation (Australian Renewable Energy Agency 2021).

The CEFC provides debt and equity finance through the Advancing Hydrogen Fund, valued at up to AUD300 million, for projects that develop supply chains, establish hydrogen hubs, and enable domestic demand for hydrogen. The first funding provided by the CEFC under the fund was up to AUD 12.5 million in support of five fuel-cell driven trucks and the development of the SunHQ H2 hydrogen hub. The hub is located in Queensland, and in the first phase will produce approximately 140 tonnes of hydrogen via a PEM electrolyser, with the hydrogen used to displace heavy vehicle diesel fuel used in the operation of a zinc refinery. In addition to the CEFC, the project is supported by ARENA (AUD 3.02 million) and the state government of Queensland (AUD5 million) and reached Final Investment Decision (FID) in August 2021. Consistent with the inside-out industry development model, the project is initially domestic in scope, but later phases envision an opportunity to export renewable hydrogen to South Korea. A feasibility study was also carried out to examine the possibility of developing hydrogen export facilities at the port of Port of Townsville, supported by a Memorandum of Understanding signed between the port and Ark Energy as the project proponent.

BOX: MAJOR PUBLIC INVESTMENT BODIES ENGAGED IN THE HYDROGEN SECTOR

Australian Renewable Energy Agency

The Australian Renewable Energy Agency (ARENA) is a Commonwealth corporate entity created in 2012 with the mission to “to support the global transition to net zero emissions by accelerating the pace of pre-commercial innovation, to the benefit of Australian consumers, businesses and workers.” ARENA is required by law to develop a funding strategy aligned with its objectives and priorities, with current strategic priorities identified as: 1) optimising the transition to renewable electricity through supporting ultra-low cost generation, supporting energy storage, large scale renewables integration, and flexible demand; 2) commercialising clean hydrogen across the value chain; 3) supporting the transition to low carbon metals; 4) decarbonising land transport.

Clean Energy Finance Corporation

The Clean Energy Finance Corporation (CEFC) is a commonwealth government-owned entity established by the Clean Energy Finance Corporation Act 2012. Through the Act it is enabled to invest in the development or commercialisation of clean energy technologies, defined as energy efficiency, low emissions and renewable energy technologies, with a primary focus within Australia. The CEFC Corporate Plan 2022-23 states investments are consistent with decarbonisation pathways, specifically investments in transmission and renewable energy, energy efficiency, electrification and fuel switching. It also identifies the reduction of non-energy emissions through recycling, and bio-sequestration and soil carbon in agriculture. The majority of its lending occurs through investment in debt instruments, with the goal of leveraging additional funds from the private sector.

Traditional research funding schemes also play a role. The Commonwealth Scientific and Industrial Research Organisation (CSIRO), for example, manages an incubator program valued at more than AUD16 million designed to support hydrogen-related pilot projects at an early stage of development. The Australian Research Council (ARC) also supports a number of hydrogen-related projects, including the Heavy Industry Low-carbon Transition Cooperative Research Centre (HILT CRC). The HILT CRC was provided with AUD 39 million dollars in 2021 over ten years, unlocking AUD 175 million in partner investments to support collaboration across companies operating in heavy industry, the research community, and government entities. The centre incorporates a range of different technologies for decarbonising heavy industry, including the use of hydrogen direct-reduced iron (DRI) processes and their applicability to Australian ores. This is crucial for Australia given its important role as a major global exporter of iron ore and coking coal for iron and steel production.

3.2 Support for large-scale project development and enabling infrastructure

In its review of the NHS the government found that Australia's export-led strategy was under risk from international competition, underlined by increased public investment in the United States and other jurisdictions to support hydrogen production and exports. It also noted that only one project had reached FID by the end of 2022 (Government of Australia, 2023). In response, the federal government created the AUD2 billion Hydrogen Headstart programme to invest in large-scale 100% renewable hydrogen projects. Funding is available for up to 10 years from the date of commissioning as is designed to eliminate the gap between hydrogen production costs and alternative technologies. Six projects were shortlisted for potential support in the first funding round, representing more than 3.5 GW of electrolyser capacity (see figure 2 below). In addition, the government identified 11 industrial hubs to enable economies of scale for both domestic and export use-cases through co-locating hydrogen-related infrastructure, and a Regional Hydrogen Hubs Program committed AUD 526 million of co-investment along with state governments, with total investment of around AUD 1 billion.

Finally, supporting the near and long-term targets of its revised NHS, the federal government made additional commitments to large-scale deployment of hydrogen through the 2024-5 budget, including a Hydrogen Production Tax Incentive (HPTI). The HPTI provides AUD2/kg for up to ten years for renewable hydrogen produced between 2027-8 and 2039-40, with FID required to be reached by 2030 in order to be eligible. An additional AUD1.3 billion investment over ten years was also made available for the Hydrogen Headstart program, and additional funding was allocated in support of the NHS, and for ARENA initiatives including renewable hydrogen (Commonwealth of Australia 2024).

FIGURE 2 PROJECTS SHORTLISTED FOR SUPPORT UNDER AUSTRALIA'S HEAD-START PROGRAMME



3.3 Technology selection for hydrogen production

Governments face the choice of which hydrogen production technologies should be made eligible for public funding. Reflecting the availability of abundant coal and gas reserves, the 2019 NHS adopted a broad approach by supporting hydrogen produced via electrolysis as well as SMR combined with CCS. The Victorian state government body Invest Victoria, for example, proposed the use of lignite coupled with CCS as a viable and commercially attractive option for enabling hydrogen export, reflecting the states large reserves of lignite and legacy industry from coal mining and power generation. The Hydrogen Energy Supply Chain (HESC) project (see section 7) utilises coal (and biomass) from the Latrobe Valley in Victoria to produce hydrogen for export to Japan, in collaboration with a consortium of Japanese corporate partners. HESC is the only project that foresees producing hydrogen through coal gasification.

The consultation process leading up to the release of the 2019 NHS showed support for enabling multiple technology streams. The major gas producer Woodside supported hydrogen produced through gas coupled with CCS. On the demand side, the Australian Gas Infrastructure Group argued for enabling the blending of hydrogen in existing gas pipeline infrastructure as a strategy for scaling up the hydrogen industry and reducing greenhouse gas emissions from the gas network infrastructure. Against this, a number of organisations opposed the use of fossil fuels in hydrogen production. The Climate Council of Australia, a non-governmental organisation, argued against the inclusion of fossil fuel coupled with CCS, and Beyond Zero Emissions argued that a focus on hydrogen could delay rapid decarbonisation, while recognising that renewable hydrogen has a role to play in decarbonising the steel sector and fertiliser production.

Despite support for a broad range of technology options for hydrogen production, the largest share of new projects focus on the production of hydrogen using electrolysis, and the revised 2024 NHS shifted to prioritise renewable hydrogen, justified by an assessment it is likely to be the least cost and lowest emissions option in the long run (Government of Australia 2024). The 2024-5 budget also prioritised renewable hydrogen production. Of the

98 projects under development or construction, 72 are focused on electrolysis as the production method (HyResource, 2024). Furthermore, applicants to the Headstart scheme were required to ensure the hydrogen production process used electrolysis and was powered fully by renewable energy. ARENA funding programs also support the production of hydrogen using renewable energy.

Beyond choices about which technology options to support when financing hydrogen production and infrastructure, Guarantee-of-Origin (GO) schemes provide information about embedded emissions, including for hydrogen, enabling consumers to select their preferred products. The Department of Climate Change, Energy, the Environment and Water has worked to develop an internationally-aligned GO scheme encompassing hydrogen that provides an emissions accounting framework, certifying emissions embedded in hydrogen and associated vectors. The proposed GO takes a well-to-delivery gate approach, covering the emissions produced from the supply of materials, production, transport and storage to the point of consumption or export, with enabling legislation planned for 2024 (Commonwealth of Australia 2023).

To summarise, the commonwealth government has increased Australia's international climate commitment since entering into government in May 2022 and retained the previous government's focus on hydrogen as a domestic decarbonization option as a first stage towards scale-up for export. A central focus of policy support is the development of hydrogen hubs, combined with a near term focus on examining the feasibility of domestic end-uses, including into the existing ammonia industry. This is aligned with key policy documents that envision hydrogen as a substantial export industry with significant implications for Australia's energy system, given the potential of at least some renewable hydrogen projects to be connected to domestic electricity markets. However, as the scale of future demand for international exports remains highly uncertain, the government's focus until mid-decade lies on scaling-up domestic production and demand through an adaptive policy framework.

4 Australian state governments: policy settings

The national, and state and territory governments have divided responsibilities in the energy sector under Australia's federal system. State governments have developed a series of hydrogen strategies, underpinning additional RD&D initiatives, as well as human capital development and demand creation.

TABLE 1 STATE GOVERNMENT HYDROGEN STRATEGIES

State/ Territory	Document	Year
Queensland	Queensland Hydrogen Industry Strategy	2019 ¹
New South Wales	NSW Hydrogen Strategy	2021 ²
Victoria	Victorian Renewable Hydrogen Industry Development Plan	2021 ³
Tasmania	Tasmanian Renewable Hydrogen Action Plan	2020 ⁴
South Australia	Hydrogen Action Plan	2019 ⁵
Western Australia	Western Australian Renewable Hydrogen Strategy and Roadmap	2019 ⁶
Northern Territory	Renewable Hydrogen Master Plan	2021 ⁷

The 2021 hydrogen strategy released by the state government of New South Wales (NSW) focuses on hydrogen produced using electrolysis. It notes that CCS, which is required to reduce the carbon emissions from traditional SMR-based hydrogen production, would not be commercially deployable before 2030, and that such SMR-based hydrogen would be unlikely to have a price advantage over renewable hydrogen by that time. The NSW plan also establishes targets for 2030. On the supply side, they include the operation of 700 MW of electrolyser capacity, 110,000 tonnes per year of green hydrogen production and a price target of AUD2.80/kg. On the demand side, the strategy targets the deployment of 100 refuelling stations, 10,000 hydrogen vehicles and 10 percent blending of hydrogen in the existing gas network by volume. These commitments are supported by a number of public funding streams, including AUD 3 billion across a mix of subsidies and tax relief for renewable hydrogen production, and funding to support the conversion of a gas-fired power plant for renewable hydrogen, in collaboration with the Commonwealth government (HyResource 2024b).

While the state of Queensland is a large producer and exporter of gas, its industry strategy also focuses on renewable hydrogen. Key initiatives include AUD 96 million for workforce development and AUD 35 million for a hydrogen industry development fund that supports the development of a renewable hydrogen production facility for use with fuel cell trucks, a demonstration project using wastewater to produce hydrogen via electrolysis, additional trials with heavy trucks and buses, and a project to enable the blending of hydrogen in the gas network. Other hydrogen plans produced in Western Australia, South Australia and Tasmania similarly emphasize the central role of renewable hydrogen production pathways.

In contrast, Victoria is the state where the HESC project is located. At the demonstration phase, this uses coal gasification to produce hydrogen before liquification for transport to

¹ Government of Queensland (2019)

² Government of New South Wales (2021)

³ Government of Victoria (2021)

⁴ Government of Tasmania (2020)

⁵ Government of South Australia (2017)

⁶ Government of Western Australia (2021)

⁷ Northern Territory Government (2020)

Japan. Victoria has a large resource base of coal in the Latrobe Valley, which has been used historically in the power sector. While the Victorian state government places an emphasis on renewable hydrogen in its 2020 industry development plan, it notes that it also supports other forms of hydrogen production and has provided AUD 50 million for the pilot phase of the HESC project (HyResource 2024b).

4.1 Hydrogen exports and implications for domestic energy markets

The role of hydrogen in the Australian economy is partially linked to future demand for hydrogen within other countries' decarbonization pathways, reflecting the interdependent nature of policies being pursued by the respective governments. In this vein, a key question is the scale of future demand. A 2018 study commissioned by ARENA on the potential market for Australian hydrogen exports found that core demand was likely to be located in China, Japan, South Korea, and Singapore. It also found that under different demand scenarios, Australian exports could reach between 620,000 and 3.2 million tonnes (MT) by 2040, including 390,000 to 2 MT to Japan. The total value of these exports was estimated to amount to around AUD 2.6 - 13.4 billion (ACIL Allen Consulting 2018). The large range shows both the potential for growth in hydrogen, and the high degree of uncertainty around future export demand.

If hydrogen is scaled through electrolysis and the use of renewable electricity, this requires a large increase in electricity generation, creating a link between the export market for hydrogen and Australia's domestic energy markets. Model results suggest additional electricity demand from hydrogen exports of 39 TWh to 200 TWh by 2040 (ACIL Allen Consulting 2018). The 2024 NHS notes that the bulk of Australia's renewable hydrogen projects are likely to be unconnected to the transmission grid. If this is not the case, coupling the National Electricity Market (NEM) and West Australian Electricity Market (WEM) with power generators used to drive electrolyzers producing hydrogen for export could have important implications for domestic electricity markets, depending on the scale of deployment and locational choices made by project developers.

The Australia Energy Market Operator (AEMO) produces an Integrated System Plan (ISP) for the NEM bi-annually as a "whole-of-system plan for the efficient development of the NEM power system for a planning horizon of at least 20 years" (Australian Energy Market Operator 2022). The NEM is responsible for about 80 percent of total consumed electricity. The 2022 ISP consists of scenarios for the development of the domestic electricity market, including a "Hydrogen Superpower" scenario that would almost quadruple the amount of energy within the NEM in order to support large-scale exports of hydrogen. Under this scenario, hydrogen use in the domestic economy drives an additional electricity demand of 2 TWh in 2030, rising to 132 TWh in 2050. Renewable electricity used for hydrogen production to meet export demand would increase electricity demand by 49 TWh in 2030 and 816 TWh in 2050, making up 64 percent of total modelled underlying domestic electricity consumption in 2050. Installed capacity of utility-scale solar and wind power would need to increase under the "Hydrogen Superpower" scenario to more than 250 GW for each by 2050. This compares to around 60-70 GW in the "Step Change" scenario, which models rapid decarbonisation without large hydrogen export growth. The potential implications of large-scale hydrogen exports for the domestic electricity sector, both in terms of investment and operations, are thus substantial.

5 Promoting international hydrogen supply chains

The revised 2024 National Hydrogen Strategy notes that Australian trade partners have committed to making hydrogen a core component of their decarbonisation strategies and that the country is well positioned to be an important supplier in the global hydrogen economy due to abundant low-cost renewable energy, a skilled workforce, and low investment risk. It also points to the need to develop projects at scale and to secure foreign direct investment in order to scale up Australia's hydrogen industry (Commonwealth of Australia 2024). International partnerships are a core part of the strategy given the focus of Australia's hydrogen policy on export potential. In the near-term, policy has focused on the development of bilateral partnerships with the goal of testing the feasibility of supply chains and creating opportunities for technical collaboration in R&D (Government of Australia 2021a). In the federal budget for 2021 – 2022, AUD 565.8 million were set aside for “building strategic international partnerships to make low emissions technologies cheaper than high emitting alternatives.”

Currently, bilateral partnerships are being pursued between Australia and Japan, Germany, South Korea, and Singapore. A key remaining question is the extent to which Australia successfully enables the development of new supply chains in value-added products such as green iron and alumina, in addition to hydrogen and ammonia.

5.1 Japan

Bilateral collaboration between Japan and Australia has been underpinned by two agreements. In January 2020, the two countries signed a 'Joint Statement of Cooperation on Hydrogen and Fuel Cells', committing their governments to collaborate on supply chain development and in multilateral fora, including the Hydrogen Energy Ministerial Meeting, the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE), the Clean Energy Ministerial, and Mission Innovation. In June 2021, the two governments also signed the 'Japan–Australia Partnership on Decarbonisation through Technology'. The agreement is a statement of intent to collaborate on shared decarbonization objectives with a technology focus and identified, amongst other things, “clean fuel ammonia” and “clean hydrogen” as potential areas for joint action. The document notes the willingness of both countries to commit financial support to their joint objectives, albeit not referring to any specific projects or funding instruments.

In terms of supply chain development, a key initiative is the HESC project, already mentioned above. It was announced in 2018 and involves a pilot phase, as of 2019, when a plant for hydrogen production was constructed in the Latrobe Valley, Victoria to produce hydrogen via coal gasification. The generated hydrogen is transported by road in pressurised trailers to a loading terminal at the Port of Hastings, where it is liquefied and shipped to Japan. The project is expected to process up to 160 tonnes of lignite and use it to produce up to three tonnes of hydrogen over one year of pilot operations. The consortium delivering the project consists of the Australian federal government, the state government of Victoria, and AGL Energy on the Australian side, while the Japanese project partners are the Japanese Ministry of Economy, Trade and Industry, the New Energy and Industrial Technology Development Organisation (NEDO), Kawasaki Heavy Industries, J-Power, Iwatani Corporation, Marubeni Corporation, and Sumitomo Corporation.

The first shipment of 2.6 tonnes of liquefied hydrogen was delivered to the Port of Kobe in Japan on 25 February, 2022. The Australian federal government and the state government of Victoria provided AUD100 million of the total AUD500 million cost of the project. According to plans announced by the project partners the decision whether to scale-up and commercialise the endeavour is scheduled for the 2020s. Should the project reach FID, commercial operations would begin in the 2030s. If operating at commercial scale, HESC is modelled to produce 225,000 tonnes of liquid hydrogen per year. In March 2023 it was announced that the project will be supported by the Japan Clean Innovation Fund to scale up to producing between 30-40,000 tonnes per annum of hydrogen, beginning in the late 2020s.

One key concern is the emissions resulting from hydrogen generation through coal gasification. During the pilot phase, there is no scheme in place to remediate GHG emissions resulting from the production process, although the consortium delivering the project has undertaken to purchase carbon offsets with the stated aim of compensating emissions from coal gasification. Referring to the scaled-up project phase, the consortium notes that “HESC Project Partners, the Victorian Government, the Australian Government and the Japanese Government would not support or proceed with a HESC project without CCS” (Hydrogen Energy Supply Chain 2022).

There are additional projects between Australian and Japanese partners examining the feasibility of hydrogen and ammonia exports to Japan. Stanwell Corporation, in conjunction with Japanese firms Iwatani Corporation, Kawasaki Heavy Industries, Marubeni Corporation, Kansai Electric Power Company, and the APA Group, are carrying out a feasibility study of the potential for liquid hydrogen exports using electrolysis, near Rockhampton, Queensland. With the support of ARENA, the October 2020 study examined installing a 10MW electrolyser as a demonstration project. It found that the project was technically feasible but would require subsidising the capital costs of the electrolyser, and that there were limited opportunities for securing an offtake agreement domestically. The project then shifted to examining the feasibility of the construction of a 300MW electrolyser and liquefaction facility to enable the export of liquid hydrogen to Japan and to supply industrial customers domestically, with the potential to scale to 3GW in the early 2030s. FID is expected in 2023 and funding for the study is provided by ARENA and Japan’s Ministry of Economy, Trade, and Industry.

In addition, in March 2021, Sumitomo Australia, the Australian subsidiary of Japanese conglomerate Sumitomo Corporation, signed a Memorandum of Understanding with the Australian Gas Infrastructure Group, Central Queensland University, Gladstone Ports Corporation, and the Gladstone Regional Council to explore the development of a hydrogen ecosystem in Gladstone, Queensland. This would entail examining the feasibility of domestically-focused demand, including through blending of up to 10 percent hydrogen in the existing gas network while considering the option of enabling exports at scale by 2030.

Independently, Australian resources companies Rio Tinto and Japan’s Sumitomo Australia have signed a letter of intent to examine the feasibility of constructing a hydrogen pilot plant in Gladstone, Queensland for use at Rio Tinto’s Yarwun aluminium refinery. Mitsui and Company and the Japan Oil, Gas and Metals National Corporation (JOGMEC) are also conducting a feasibility study for hydrogen production with CCS in Western Australia. Finally, Mitsui has reached an agreement with the Australian company Wesfarmers Chemicals, Energy & Fertilisers to examine the technical and commercial feasibility of the production and export of SMR-based ammonia coupled with CCS in depleted gas fields owned by Mitsui E&P Australia. There are thus numerous projects at the early-stage of development involving investment by Japanese firms in hydrogen production in Australia, with many receiving funds from Japanese public investment bodies.

5.2 Germany

A second bilateral partnership pursued by Australia is with Germany. In September 2020, the Australian and German governments signed an agreement to examine the feasibility of a renewable hydrogen supply chain between the two countries, called HySupply. The project is funded by the Australian Department of Foreign Affairs and Trade and (then) Department of Industry, Science, Energy and Resources, and by the German Federal Ministry for Education and Research. The HySupply project is a two-year study administered on the Australian side by a mix of research and private sector partners. The feasibility study analyses hydrogen production costs using renewable electricity across a number of different sites in Australia, options for storage and transport, hydrogen recovery and distribution, and potential end-use sectors. It has produced an indicative cost breakdown across the value chain for hydrogen imported to Germany and shipped from Australia (Daiyan, Herawan, and Amal 2021).

In addition, in June 2021, the Australian and German governments signed a Declaration of Intent referred to as the ‘Australia-Germany Hydrogen Accord’. There are three initiatives under the agreement. The HyGate initiative supports pilot, trial, and demonstration projects between Australia and Germany, with Australia committing AUD50 million and the German government committing EUR50 million. The stated objectives of HyGATE are to “[f]acilitate collaboration between Australian and German partners, expedite scale up and commercialisation, enable the demonstration of new technologies through trials or demonstration projects in Australia, and support the development of a renewable hydrogen supply chain between Australia and Germany.” (Australian Renewable Energy Agency 2022). In

addition, ARENA is administering the competitive distribution of funding in Australia to identify priority projects, consistent with the near-term goal of developing an understanding of supply chain opportunities for Australia in hydrogen by 2025. Amongst other things, priorities include reducing the cost of hydrogen production, transport, and end-uses across the value chain, planning and operating large scale electrolyzers combined with renewable electricity generation, work on conversion and conversion technologies supporting the shipping of hydrogen and associated vectors, and the sustainable production of industrial intermediate products, such as green ammonia or green steel (Australian Renewable Energy Agency 2022, 5). Notably, the initial funding round for the HyGATE project only allows for hydrogen produced using renewable electricity.

A second component of the Accord is the facilitation of trade in hydrogen and associated vectors between the two countries. This includes plans for an auction focused on renewable ammonia, to be channelled through H2Global, the German initiative to facilitate long-term agreements for the purchase of hydrogen and its derivatives. In September 2024 the German and Australian governments signed a Declaration of Intent to negotiate a 400 million Euro funding window for European buyers of Australian hydrogen. The countries agreed to carry out a hydrogen auction for 2025, with subsequent annual auctions scheduled to begin in 2027-2028. The third component is a commitment to facilitate German participation in demonstration projects at Australia's hydrogen hubs.

5.3 South Korea

The third bilateral partnership Australia has initiated is with South Korea. The two governments signed a letter of intent in September 2019, agreeing to cooperate on hydrogen development. This was followed by the 'Australia-Republic of Korea Low and Zero Emissions Technology Partnership' signed in October 2021 and reaffirmed by the leaders of both countries in December of the same year through the 'Australia-Republic of Korea Comprehensive Strategic Partnership'. In the latter, then-Prime Minister Scott Morrison and then-President of the Republic of Korea Moon Jae-in agreed to collaborate in the low-carbon energy transition, noting that "early priorities include supply of clean hydrogen (including hydrogen-based compounds), low emissions iron ore and steel, and carbon capture, use and storage" (Government of Australia, 2021b).

Bilateral collaborative work on supply chain development under the partnership has commenced. In September 2022, the Han-Ho-H2 consortium was formed through the signing of a Memorandum of Understanding between Ark Energy, which is Australia-based and owned by South Korean Korea Zinc, petrochemical firm Hanwha Impact, and SK Gas (Ark Energy 2022). The project targets the development of 3 GW of solar PV and wind power in Collinsville, Queensland to produce one million tonnes of renewable ammonia annually by 2032. The project is supported by a feasibility study of up to AUD4.2 million, with FID expected around 2027.

5.4 Singapore

The fourth significant bilateral partnership in Australia's emerging hydrogen strategy has been developed with Singapore. As with the other partnerships it is undergirded by a number of headline agreements. The Singapore and Australian governments signed a Memorandum of Understanding on Low Emissions Technologies in 2020, which included a commitment to cooperate on examining hydrogen and hydrogen-based energy supply chains, shaping international hydrogen standards, and hydrogen R&D. This was followed by the announcement of an AUD30 million partnership in June 2021 to facilitate collaboration on the decarbonisation of maritime and port operations through the use of low carbon fuels. Under the partnership, governments from both countries are committing up to AUD10 million to fund industry-led pilot and demonstration projects over five years. Moreover, in October 2022, the new Australian federal government and the Singaporean government signed the 'Australia-Singapore Green Economy Agreement'. The broad-ranging agreement presages cooperation across a wide range of areas of relevance to decarbonisation, including trade and investment, standards setting, green and transition finance, technology, skills development, and innovation, business, and other partnership development.

6 Multilateral engagement

A key problem to be managed as hydrogen is traded across national borders is defining and accounting for emissions across the entire supply chain, including those released during the production of hydrogen. One strategy for managing this problem is the implementation of a GO scheme, which provides transparency on the emissions embedded in a given hydrogen product as well as other environmental impacts (COAG Energy Council 2021). An issues paper developed by the Australian government noted that a GO scheme enables consumers to understand the emissions embedded in hydrogen, although it left open whether government or industry should develop and administer the scheme.

Given the export focus of Australia's hydrogen strategy, its government has an interest in shaping multilateral frameworks governing the assessment of the carbon intensity of different hydrogen production methods. A key multilateral body through which governments are determining methodologies for calculating the emissions intensities of different production technologies has been the Hydrogen Production Analysis Taskforce (H2PATF), which is part of the International Partnership for the Hydrogen Economy (IPHE). There, Australia has been the lead country for developing the carbon accounting methodology for coal gasification with CCS, with Japan, South Africa and the United States as members of the working group. Australia has also participated in the working group examining SMR with CCS, along with the United Kingdom, the European Commission, and The Netherlands, led by France. The final report of H2PATF was released in November 2022. The methodology proposes calculating the GHG emissions per kilogram of hydrogen (kgCO₂e/kgH₂) and includes fugitive emissions from the extraction of feedstock and emission from the transmission grid (IPHE Hydrogen Production Analysis Task Force 2022).

In addition to the H2PATF, Australia has actively participated as a member of several multilateral organisations involved in information-sharing and capacity-building. Australia has acted as the co-lead with Germany and the European Commission, for example, in the 'Innovation Challenge 8: Renewable and Clean Hydrogen' at Mission Innovation (MI), centred on information-sharing around the benefits of hydrogen hubs (termed "Hydrogen Valleys"). A second MI initiative focuses on innovation in hydrogen with the goal of reducing well-to-grave costs to USD2/kg by 2030 through promoting RD&D and demonstrating and disseminating knowledge about technology-push and demand-pull innovation. The initiative incorporates innovation targeting CCS, consistent with Australia and some other countries' position towards hydrogen production technologies. Australia has also acted as the co-chair along with Chile, the United Kingdom, the United States, and the European Commission (Mission Innovation 2022). The Australian government has also been involved in the Centre for Hydrogen Safety, which promotes information sharing about hydrogen and fuel cell safety and has participated in energy ministers' meetings and working groups on climate sustainability and energy transition through the G20 and the APEC Working Group on creating a Low-Carbon Hydrogen International Standard. On the industry side, the Australian Hydrogen Council is a founding member of the Global Hydrogen Industrial Association Alliance (GHIAA), which focuses on information sharing between peak hydrogen industry bodies across 13 different countries.

7 Conclusion

For decades, Australia supported economic growth in the Asia-Pacific region through the export of carbon-intensive fuels such as coal and gas, along with commodities used in emissions-intensive processes such as steelmaking. At the same time, the country has abundant, low-cost renewable energy resources, which could play a role not only in decarbonizing its domestic economy but also in facilitating the reduction of GHG emissions in the region. For Australia, decarbonization is thus a challenge both for the domestic economy and for trade and export-linked investments.

A key policy issue lies in overcoming the economic and technical barriers to enabling the rapid deployment of these resources to support decarbonization at home, while building international supply chains for large-scale export of low-cost renewable energy. It is in this context that hydrogen has emerged as a central vector for Australia's transition towards a net-zero economy, enjoying broad support from both national and state governments and industry. Hydrogen is being trialled as an option for supporting decarbonizing of the domestic economy, with developments in its use as a chemical feedstock, electricity grid support, mining and off-grid applications, and in blending in gas networks. However, a large part of the interest in developing a hydrogen industry is linked to its export potential, including the potential for increasing the share of value-added metals using hydrogen, such as green iron and alumina.

Australia's external hydrogen strategy reflects this export focus. Australia's first NHS was released following major trading partner Japan's 2017 launch of its hydrogen strategy, and national and state government support for industry development has a substantial – although not exclusive – export focus. The most advanced partnership is with Japan, with a March 2023 announcement of additional investment from Japan to enable commercialisation of a pilot project using hydrogen produced from a mix of coal and biomass. Moreover, Australia has the largest number of announced hydrogen projects globally. However, by 2023 only one project reached FID, and there has been concern that Australia's inherent advantages in terms of proximity to markets in the Asia Pacific, land availability, and abundant low-cost renewable energy may not lead to a substantial hydrogen export industry without additional measures put in place. The Hydrogen Production Tax Incentive and Hydrogen Headstart programs sought to respond to increased international competition, and the Australian government and industry bodies have been actively involved in negotiating frameworks for governing the calculation of emissions embedded in different hydrogen production methods.

An additional issue facing government and industry is the technology choice for hydrogen production. The first NHS committed the government to supporting “clean hydrogen”, which it defined as hydrogen produced using electrolysis and SMR coupled with CCS. The state of Victoria has even supported unabated coal gasification technology within the large-scale HESC project. These developments are consistent with the fact that Australia has abundant fossil fuel resources in addition to low-cost renewable energy, both of which can be used in the production of hydrogen. Public consultations leading up to the adoption of the 2019 NHS also showed substantial support among industry for the use of fossil fuels in the production of hydrogen. More recent policy developments, including the revised 2024 National Hydrogen Strategy, and substantial incentives included in the 2024-2025 federal budget, show a shift by the federal government towards an emphasis on renewable hydrogen.

Another question that remains unanswered is how competitive these different forms of hydrogen production will be in export markets and the role of hydrogen in the broader long-term decarbonization efforts across the region. The size of the emerging regional hydrogen market and the competitiveness of Australian hydrogen production within it also have important implications for its domestic economy, given the enormous growth in electricity demand implied by a large increase in Australian exports of low-carbon hydrogen.

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