Hydrogen: the new Australian manufacturing export industry and the implications for the

National Electricity Market (NEM)

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Introduction

"The unique opportunities for this scale of hydrogen production that also support the electricity system arise when the developments connect to shared electricity networks, rather than being developed in isolation of the existing shared networks. When this occurs, there is significant scope for generation following, ancillary and network support services to be provided in a way that is beneficial to the broader electricity market, while servicing hydrogen demand".

(Hydrogen to Support Electricity Systems, GHD Advisory for the Department of Environment, Land Water and Planning, February 2020)

Over the course of 2019 and 2020, the Australian Government and state governments made a number of announcements in relation to a national hydrogen strategy and state strategies for the development of a hydrogen production industry in Australia. These strategies involve a bold vision for Australia to become a major player in hydrogen export, as well as detailed goals and extensive action and funding to achieve that vision.

Governments and industry since then have, in a comparatively short space of time, made numerous announcements on the funding of specific projects, both near term pilot projects and medium and long-term projects on a global scale. These proposals stretch from Bell Bay in Tasmania to Port Bonython in South Australia, the Latrobe Valley in Victoria, western Sydney in NSW, southern and northern Queensland, the Northern Territory and across the northern and southern regions of Western Australia.

Governments while setting out hydrogen strategies have referred often to the importance of getting the policy settings right. These policy settings are already evolving, and further work and engagement will be needed across government, industry bodies, including the Australian Energy Market Commission, and the hydrogen development industry. The industry is moving fast and so there is no better time than now to consider these policy settings and engagement across the sector. Over the course of 2021, the AEMC intends to publish a series of in-depth pieces on the regulatory frameworks in relation to the NEM that currently have, or will have, a direct bearing on hydrogen developments.

The opportunity for the NEM and its consumers and for the hydrogen projects themselves to benefit from being connected to the NEM is a significant one. Hydrogen can provide significant services to the NEM, given its flexibility. It can help to absorb large amounts of renewable energy, it can relieve congestion issues on the network, provide system services such as frequency response and provide significant flexible demand response. In turn, hydrogen projects may derive additional revenue from providing these services and they may be able to source cheaper and more reliable energy supply in the near and longer term.

The right policy settings can help turn this opportunity into reality. Analysis and engagement today across governments, market bodies and industry can provide guidance as to what those policy settings should be and how they can best be achieved.

This article provides a brief introduction to the industry, government goals and targets in the near future, the extensive list of projects proposed and under development, the implications for the NEM and hydrogen projects of grid connection and the policy implications for governments, market bodies and the industry.

The Hydrogen Export Industry

This section outlines what the hydrogen export industry is, the different ways hydrogen can be manufactured around the world and in Australia, the economics and flexibility of production, the implications for energy markets across Australia and the drivers of the decision to be grid connected or isolated from the grid and the implications of this decision.

What is hydrogen?

Hydrogen is a colourless, odorless gas with the lowest density of all gases. It is the most abundant element in the universe, found in the greatest quantities in water, and much smaller amounts in the atmosphere. For the most part, it doesn't play a particularly active role, remaining bonded to carbon and oxygen atoms.

What are its uses?

In terms of uses, hydrogen is often seen as the clean fuel of the future, generated from water and returning to water when it is oxidised. It has a number of uses, including:

- As a replacement to, or supplement of, *natural gas* in heating and cooking.
- *Transportation*, including in vehicles through hydrogen powered fuels cells to power buses and cars, and in maritime vessels and aviation.
- *Industry*, as an alternative chemical feedstock, for example to produce methanol for the production of plastics and pharmaceuticals, to hydrogenate oils from fats to make products like margarine, in the glass industry hydrogen is used as a protective atmosphere for making flat glass sheets and in the electronics industry, it is used as a flushing gas in the process of manufacturing silicon chips
- *Industry* for space heating and processing
- *Refining*, to remove sulphur from fuels in the oil refining process
- *Agriculture*, to make ammonia for fertilisers
- *Energy Storage*, for example by converting intermittent renewable energy into hydrogen or ammonia.

Currently in Australia, most of the hydrogen demand is as ammonia, and hence a number of the projects entering the feasibility stages of development are planned as integrated hydrogen/ammonia projects, as outlined in the following sections.

How is it made?

There are three methods for producing hydrogen from water. Two of these methods are through thermochemical reactions, using coal, in a process known as gasification, or natural gas, in a process known as steam methane reforming. The third method is through a process known as electrolysis in which hydrogen is extracted from water using electricity. If renewable electricity is used, electrolysis has the potential to produce hydrogen with no carbon emissions. This can be referred to as clean or renewable hydrogen. Most hydrogen is currently produced using the two thermochemical methods. Using fossil fuels means these processes also produce carbon emissions which would require these emissions to be captured at a high level, and permanently stored through carbon capture and storage processes, in order for any hydrogen produced to be considered emissions free.

In summary, the different colours of hydrogen and what they mean can be referred to as follows:

- Brown – Coal gasification
- Grey – Natural gas steam methane reforming
- Blue – Natural gas steam methane reforming with carbon capture and storage (CCS)
- Green – Using renewable energy to create hydrogen through electrolysis

Most hydrogen is produced today by using natural gas in steam methane reforming, i.e. most hydrogen is currently grey. According to the International Energy Agency (IEA), 6% of global natural gas is used to produce hydrogen.

Of hydrogen that is manufactured around the world today, the International Renewable Energy Agency (IRENA) have stated that 1,000 GW of electrolysers would be enough to replace the current mixed fossil fuel based hydrogen production. Global demand for pure hydrogen currently sits at 75 million tonnes per annum as at 2018.

Implications for energy markets

1. As a source of new load

Hydrogen manufacturing using electrolysis requires a dedicated or grid-connected electricity supply. The addition of this load has implications for energy markets. So too does the flexibility of this load, its ability to vary output either seasonally, or within the week or within day also has implications. Additionally, electrolysis as a process is interruptible in short spaces of time, which could enable hydrogen projects to participate in demand response and frequency, ancillary and system strength services markets.

Brown, grey and blue hydrogen production will also consume electricity. But the load implications may be less pronounced given the feedstock is primarily gas or coal.

In this section, given the greater electricity load involved in the electrolysis process, we focus on electrolysis and the three main types of electrolysis technologies currently available. These are alkaline electrolysers (ALK), polymer electrolyte membrane (PEM) electrolysers and solid oxide electrolysis cells (SOECs). The stage of development of each of these technologies varies from the ALK electrolysers, which have been used by industry for nearly a century, to SOEC electrolysers which have only been demonstrated at laboratory and small demonstration level.

Electrolysers can be rapidly ramped up or down to provide demand response and frequency control services to the electricity grid. They can also take advantage of excess power when wind and solar generators are operating at capacity resulting in less variable generation being constrained off at peaks times.

An Irena report found that state-of-the-art PEM electrolysers are particularly flexible in their operation, operating more flexibly and "reactively than current ALK technology." Since PEM technology offers a wider operating range and a shorter response time the PEM technology offers "a significant advantage in allowing flexible operation to capture revenues from multiple electricity markets". (See IRENA’s estimate of electrolyser flexibility in operation below).

Table 1: Dynamic operation of ALK and PEM electrolysis

	Alkaline	**PEM**
Load range	15-100% nominal load	0-160% nominal load
Start-up (warm-cold)	1-10 minutes	1 second - 5 minutes
Ramp-up/ramp-down	0.2-20%/second	100%/second
Shutdown	1-10 minutes	Seconds

Notes: Values for 2017

Source: FCH JU (2017b)

PEM "systems can be maintained in stand-by mode with minimal power consumption and are able to operate for a short time period (10 to 30 minutes) at higher capacity than nominal load (beyond 100%, up to 200%)," IRENA has noted. "With both upward and downward regulation capability, a PEM electrolyser can provide capacity for high-value frequency containment reserve (FCR) without sacrificing available production capacity." IRENA explains that "operators of PEM electrolysers can supply hydrogen to their clients (for industry, mobility or injection into the gas grid), while still being able to provide ancillary services to the grid with low additional [capital or operating] costs, provided that sufficient hydrogen storage is available."

Additionally, at times when the supply demand balance on the electricity grid is tight, hydrogen production can be halted, and stored hydrogen converted back to electricity when needed to meet peak electricity system needs. Used effectively, this could allow for better integration of renewable energy technologies into Australian electricity grids and improved investment cases for renewable energy projects. Further, it would increase the options for electricity market operators to maintain power supplies in an emergency, improving energy supply security and reliability.

IRENA has noted that "the full flexibility benefits and systemic added value of PEM electrolysers" are likely best captured where they are grid-connected. IRENA notes this configuration enables the hydrogen facility operator to capture ancillary service revenues and other revenues from providing grid services, it also allows the hydrogen production facility to optimise the capacity factor of the plant and its electricity purchases from the grid where required.

2. As storage, including for onsite and grid-connected power generation.

Hydrogen can be used to provide energy storage, for example by converting intermittent renewable energy into hydrogen. This hydrogen can then be used as fuel for power generation, either through a fuel cell or direct combustion in a gas turbine.

Gas turbines already have the ability to burn gas streams with significant portions of hydrogen included in them, blended with natural gas or fuel gas. GE gives examples of turbines in operation that burn fuel blends containing more than 70%

hydrogen, going up to 90%. GE have a fleet of 25 gas turbines that have operated on fuels with at least 50% hydrogen by volume.

Fuel cells combine hydrogen and oxygen to produce electricity, heat and water. Fuel cells that run on pure hydrogen are used in mobile as well as stationary applications. Currently stationary fuel cells are used in a number of applications to generate electricity particularly for distributed generation or auxiliary power. Fuel cells, in generating electricity and heat at the same time, can also be used as co-generation systems in residential buildings, hospitals, swimming pools and other buildings.

The increasing availability of hydrogen at commercial rates, and stored on site in plentiful volumes, as well as falling costs of fuel cells will likely see increasing use of hydrogen power fuels, for distributed generation, auxiliary power, and depending on economics, for the export of dispatchable power to the grid.

3. As fuel – a substitute for and compliment to natural gas

One of the six work streams of the National Hydrogen Strategy, Hydrogen in gas networks, is a kickstart project established to look at the feasibility of allowing up to 10% hydrogen in the domestic gas network, both for use in place of natural gas and to provide at scale storage for hydrogen. This project, led by the South Australian Government in conjunction with the Future Fuels Cooperative Research Centre, on behalf of the COAG Energy Council found that the addition of 10% hydrogen to a typical natural gas blend "has no significant impacts or implications on gas quality, safety or risk aspects".

A number of the pilot projects currently being progressed (or commissioned/ operational) in Australia involve the injection of hydrogen into local gas distribution networks. The list of these projects is included in a state-by-state summary to follow.

The injection of up to 10% hydrogen into natural gas networks has implications in terms of the uncertainty around the operation of the national rules framework under scenarios where part of the gas stream is hydrogen.

The study cited above concluded that policy-makers needed to turn their attention to:

- The impact of blending 10% hydrogen on the operation of the framework
- "Whether the regulatory framework, or parts of it, should apply to gases other than natural gas such as hydrogen".

The review identified a number of areas within the regulatory framework requiring further investigation:

- Third party access and the implications of 10% hydrogen in the gas stream.
- Gas markets. The review found that consideration should be given to the impacts on short term trading markets and the declared wholesale market if hydrogen is added directly to the distribution network. In addition, the review said it could also be worthwhile to consider "whether it is necessary to establish similar gas markets at the distribution level to facilitate the trading of hydrogen and capture hydrogen flows, or whether this can be left to bilateral contracts between hydrogen producers and users".
- Transparency. The review advised onsideration should be given to whether, if hydrogen is blended into the distribution network, bulletin board information should be made available for hydrogen data as is made available for natural gas, understanding that this data is only required at the transmission level in the gas market currently. The Australian Energy Market Operator's (AEMO's) role gathering information on the gas market for the gas statement of opportunities, "should be maintained for hydrogen production as should any relevant information gathering provisions."
- Consumer protections. These currently apply to the retail of natural gas. Hydrogen should also be considered in this context.

The report concluded that it is anticipated that the COAG Energy Council would task officials to work with the AEMC and AEMO to provide advice on proposed amendments.

The economics of hydrogen production

The economics of hydrogen production today varies across the different technologies used for production. Indicative costs derived from IEA figures imply the following in AUD/kg terms:

- Brown/Grey - $2.5/kg
- Blue - $3.5/kg
- Green - $5.5-8/kg

The economics of these types of hydrogen versus each other is expected to change as the capital costs of electrolysers changes, and also as electricity costs, natural gas costs and carbon prices change.

In relation to green hydrogen production costs, IRENA maintain that "a combination of cost reductions in electricity and electrolysers, combined with increased efficiency and operating lifetime, can deliver an 80% reduction in hydrogen cost". As a consequence, IRENA state the production costs of green hydrogen could become "cheaper than any low carbon alternative" before 2040.

In 2018, electrolysis costs under PEM technology were estimated to be $6.08-7.43/kg in the CSIRO's National Hydrogen Roadmap: Pathways to an economically sustainable hydrogen industry in Australia.

IRENA show in their report Green Hydrogen Cost Reduction: scaling up electrolysers *to meet the 1.5 C climate goal*, the key drivers of potential cost reductions could come from reductions in the capital cost of the electrolyser, reduction in energy costs, increases in the efficiency of electrolysers from 50-83 kwh/kg to <45kwh/kg and an increase or near doubling in the useful life of the electrolyser from the present 50,000-80,000 hours to a 100,000 to120,000-hour range. Note that the thermodynamic efficiency limit for electrolysis is 40 kWh/kgH2, the higher heating value of hydrogen. The CSIRO concluded that "it is generally considered that efficiencies better than 45 kWh/kg are unlikely to be achieved".

Based on this, it is clear that energy costs will play a key role in ensuring that the hydrogen industry is competitive longer term. For every $10/MWh improvement in the electricity price, the cost of hydrogen is lowered by approximately $0.45/kg, assuming improvements in the efficiency of electrolysers take place. The cost of transmission services is no less important.

The *H2 under $2* target is put forward often as it relates to the ability of hydrogen to compete in particular sectors. On 15 April 2020, the Minister for Energy and Emissions Reduction, Angus Taylor, stated "The Government has set an economic goal for hydrogen of 'H2 under 2' - that is Hydrogen at or under $2 per kilogram. That's the point where hydrogen becomes competitive with alternatives in large-scale deployment across our energy systems".

Why is location important?

There are multiple factors required for successful large-scale production of hydrogen, not the least of which is its location and the access to services, markets and infrastructure that help inform the decision on where to locate the plant. A report to the COAG Energy Council Hydrogen Working Group found some of the key factors that make a location suitable for large scale hydrogen production include:

- Water availability
- Availability of gas pipeline infrastructure
- Electricity grid connectivity
- Road, rail and port infrastructure
- Access to low-cost electricity over long timeframes

Locations with these features present will be more suitable for hydrogen production over the long term. Given the importance of location to the investment decision, the provision of as much information as possible to facilitate the decision-making process is key.

In 2019, the COAG Energy Council identified areas best suited to hydrogen production. In addition to these reports, the COAG Energy Council developed a mapping tool based on a multi-criteria assessment which shows areas with high potential for future hydrogen production.

The multi-criteria assessment identified that coastal Australia is generally best suited for large-scale hydrogen production, assuming that locational decisions will be constrained by existing infrastructure, and that water would be available from desalination with minimal extra costs to production. Regional locations are identified as particularly well-suited for hydrogen production. The use of regional locations for hydrogen production has the potential to have a significant benefit for the NEM as more distributed renewable generation connects to the grid. The presence of large loads in regional locations combined with a flexible operating profile could offer important services to keep the grid secure and stable during large fluctuations in generation output throughout the day.

It is worth noting that the need for system services across the grid is not uniform. Jurisdictions with higher penetration rates of renewable energy generation, such as South Australia, have a greater need for system services than others. As a consequence, the locational decision for hydrogen can have implications for the areas of the grid where it can provide the greatest benefit to the whole system.

The price impacts, both over annual timeframes and within day timeframes, of high penetrations of renewable generation are also not currently uniform across regions of the NEM. "Duck curve" effects of high rooftop solar penetration, for example, are currently particularly pronounced in South Australia, with high penetration rates as a portion of the overall level of demand. It is expected that the growth of large-scale renewables as well as distributed energy resources (DER) will continue to worsen the "duck curve" effect in other regions of the NEM. Once again, the importance of location here in the investment decision relates both to the benefit to the hydrogen investment case, and to wider system benefits once the plant is up and running. Hydrogen projects, more than most types of load in the NEM, may have significant scope to alleviate duck curve effects in particular jurisdictions due to the size of demand and flexibility of operation.

The mutual benefit between the electricity system and hydrogen export developments

Due to the flexible characteristics of hydrogen production, these developments will be able to provide a number of services to the electricity system that become increasingly important with a high penetration of renewables.

The location of hydrogen plant is an important factor in realising the mutual benefits that can be achieved. An example of this is the decision on whether to place hydrogen load "upstream" or "downstream" of a thermal constraint on the network. "Upstream" of the constraint refers to any generation capacity that would be curtailed due to the constraint binding. The location of the hydrogen plant "upstream" of the constraint will allow the hydrogen plant to access abundant resources during times when the constraint is binding. It will also allow the hydrogen plant to act as a "sponge" to utilise excess generation, and therefore increase the capacity that can be generated "upstream" of the constraint before generation is curtailed.

The development of Renewable Energy Zones (REZs) now planned in multiple jurisdictions across Australia would likely see an even greater mutual benefit from hydrogen export projects locating in parts of the grid where they can help to absorb plentiful renewable generation output, both on annual and within day timeframes.

As well as relieving network congestion issues, hydrogen developments can provide a number of services to the electricity system, including essential system services and demand response. The provision of these services, as well as assisting the wider system, would also involve a financial return for hydrogen projects, in addition to revenues from the sale of hydrogen produced.

The benefit of hydrogen projects to the NEM has also been highlighted by AEMO in the 2020 ISP. AEMO noted that "*Embedded electrolysers (utility scale or distributed) could provide benefits to power system security, operability and reliability, depending on their location, infrastructure deployed in the plant, their commercial and technical operations, and supported by market reforms that incentivise and reward appropriately*".

AEMO mention benefits such as the relief of congestion (for appropriately placed projects), responsive demand, provision of frequency control services and voltage support services to transmission and distribution networks (depending on inverter design).

The on-grid versus off-grid decision

There are three different options for hydrogen projects in relation to grid connection:

- Off-grid and self-supporting
- Partly off-grid, and partly on-grid, to the extent a project optimises the transmission capacity in a particular region, utilising existing spare capacity
- Fully on-grid

The GHD Advisory report noted that the number of sites across the Australian grid that can support 1 GW of load is quite limited and may be restricted to areas where power stations have retired or aluminium smelter load has been retired. The availability and cost of transmission capacity are both central to facilitating on-grid hydrogen development.

Deloitte, in their study of hydrogen export scenarios for Australia for the National Hydrogen Strategy Taskforce, suggested that developments under the higher hydrogen growth scenarios are more likely to be driven by hydrogen developments that are off-grid and co-located with renewable power supplies. The report suggested that if the current electricity regulatory frameworks persist, new developments are likely to prefer the unregulated or lightly regulated economic environment that off-grid developments afford.

However, early-stage projects may prefer grid connection. These projects, likely to be smaller in scale than subsequent developments will require less energy supply thereby providing for a range of potential locations at which to connect to the grid utilising existing or shared infrastructure. With the need to achieve high-capacity factors in operation in order to reach viable production cost levels, particularly while capital costs are still declining as the industry grows, grid connection may provide compelling benefits to early phase business cases. In contrast, the costs of off-grid generation, at the required capacity factor, for early hydrogen projects may be prohibitive. During the early stages in the development of the industry, grid connection is likely to be the more feasible approach.

Out of the three significant green hydrogen projects proposed for South Australia, two (Port Bonython and Cape Hardy/ Port Spencer) are planned to be serviced by a new private transmission line between the generation portion of the project and the production and processing facilities at the port. Given their planned size, this may be driven by limitations in the existing network to meet such significant additional new load along the transmission path.

Reported potential transmission use of system (TUOS) and locational demand charges for the on-grid Port Adelaide project are in the order of $20/MWh with an expected energy cost of $40/MWh via a power purchase agreement (PPA).

Hydrogen projects that choose to be connected to the wider grid may be able to enjoy a much greater level of reliability and security of supply at much lower cost over the longer term. This applies both to the load side of the project (the electrolyser) and where projects are integrated with renewable developments, to the generation side as well. A lack of availability of either asset, strands the matching asset in the development, while an integrated but connected facility is in a much better position to manage this risk.

There are, in summary, trade-offs to the decision to be on grid or off grid. These trade-offs will be impacted by the policy framework as it applies to hydrogen projects and flexible large loads in the NEM.

Government and Industry commitment to the sector and the potential scope of the industry

The vision for the hydrogen sector, at a national and state level, is bold. This vision is already being translated into material progress in terms of pilot hydrogen projects under construction, significant export projects moving into the commercial feasibility stages and multi-GW projects being considered for the longer term.

Government and industry commitments to the sector have been accelerating in the last 12 months. A summary of federal, state and territory government policies, funding and commitments is provided in the appendix as are tables of projects and proposals announced to date by state and territory.

Scope for exports

Australia's national hydrogen strategy shows potential growth trajectories for global hydrogen demand of between 2 and 9 million tonnes by 2030 and between 20 and 230 million tonnes by 2050. This compares to global demand for hydrogen in 2018 of 70 million tonnes, according to the IEA, almost all of which is produced through fossil fuels. Off the back of this projected growth, Deloitte created four scenarios for the future growth of the industry in Australia and estimated a range of between 2 and 20 million tonnes for Australia's share of this market by 2050.

ARUP's report to the COAG Energy Council Hydrogen Working Group in November 2019 maintains that Australia has the potential to export up to 500,000 tonnes of hydrogen to meet 2,489,000 tonnes of predicted demand from Japan and South Korea alone. A number of early stage projects under development are being progressed in partnership with large hydrogen users in the region (project partnership details, where available, are also provided in the appendix).

NEM electricity load implications

The study by Deloitte described the potential electricity load associated with hydrogen industry development as ranging from 5.5-912 TWh depending on the scenario. Deloitte compared this to the 205 TWh of electricity produced in the NEM in 2018-2019 and the 18 TWh produced in the SWIS network in Western Australia each year. As a consequence, Deloitte concluded that installed electricity capacity in Australia would need to increase by between 3% and five-fold.

Connected NEM load associated with hydrogen projects in TWh terms may not be far away, even allowing for only early stage and pilot projects. Longer term, proposed projects in NEM locations, summarised in the appendix, would on their own contribute up to almost half the existing load of the NEM, assuming the full list of projects so far muted were to go ahead, and assuming a grid connection.

Conclusions

The hydrogen projects and proposals put forward in Australia and the vision for a hydrogen industry put forward across all Australian governments represents a huge opportunity for the Australian economy as a whole and for regional economies across Australia.

Hydrogen producing projects can be located off the main transmission grid or within it. Particularly in the early stages of hydrogen industry development, grid connection may be more viable than off-grid development. The scope for mutual benefit between the broader electricity system and the hydrogen production industry, where projects are located on grid, is significant. Benefits of on-grid connection to hydrogen projects include a more reliable and secure electricity supply, markets in addition to hydrogen for system services, demand response and other products related to the flexibility of hydrogen operation. The wider benefits of hydrogen to the grid include the ability to follow and absorb increasing amounts of renewable energy, the provision of system services, the relief of congestion on the transmission network helping to defer transmission investments and facilitate further renewable generation connections.

For this mutual benefit to be captured as early as possible and to the greatest extent possible the policy settings and frameworks need to be right. This is best achieved through engagement between governments, rule-making bodies like the AEMC, and the growing hydrogen development industry.

Through a series of upcoming articles, the AEMC will address:

- The benefits of hydrogen export to the NEM – particularly in relation to additional services hydrogen can supply to the NEM.
- Hydrogen production and location in the NEM across the wider grid.
- Hydrogen and policy considerations arising in facilitating hydrogen development in the NEM
- Hydrogen and natural gas markets

There is a significant opportunity for mutual benefit between the future hydrogen export economy and the NEM and its existing end users. The mutual benefit invites exploration in more detail at this juncture in the markets history, in order to create regulatory frameworks that can facilitate the development of an industry with such great potential for the wider Australian economy.

Appendix: Information from commonwealth, state and territory government hydrogen strategies and commitments

Commonwealth Government National Hydrogen Strategy

In November 2019, the Australian Government released Australia's National Hydrogen Strategy with a vision for a clean, innovative, safe and competitive hydrogen industry aiming to position the Australian hydrogen export industry as a major player by 2030.

The strategy outlines an adaptive approach that equips Australia to scale up quickly as the hydrogen market grows. It includes a set of nationally coordinated actions involving governments, industry and the community. A Hydrogen Working Group was established, with Dr Alan Finkel as chair to help establish the strategy.

The Strategy explains that Australia has the resources to take advantage of increasing global momentum for clean hydrogen and make it a key energy export. The industry has the potential for thousands of new jobs, many in regional areas, and billions of dollars in economic growth between now and 2050. The strategy, according to the hydrogen taskforce, can help to integrate more low-cost generation, reduce dependence on imported fuels, and help reduce carbon emissions, both in Australia and around the world.

A key element of Australia's approach will be the creation of hydrogen hubs, to provide the industry with its springboard to scale. Hubs are envisaged to make the development of supporting infrastructure more cost effective, promote efficiencies from economies of scale and promote synergies from sector coupling. These steps will also be complemented by early steps to use hydrogen in transport, industry and gas distribution networks, and integrate hydrogen into electricity systems in a way that enhances reliability.

The National Hydrogen Strategy also states that Australia will work with other countries to "develop a scheme to track and certify the origins of internationally traded clean hydrogen". In 2021, Australia's Smart Energy Council announced a partnership with the German Energy Agency to co-operate on the development and certification of the production of renewable hydrogen in each of the countries, including the creation of a certification scheme.

The strategy identifies 57 joint actions, themed around:

- National coordination
- Developing production capacity, supported by local demand
- Responsive regulation
- International engagement
- Innovation and research and development (R&D).
- Skills and workforce
- Community confidence

These actions consider hydrogen in relation to a number of markets including exports, transport, industrial use, gas networks and electricity systems.

In March 2020, the COAG Energy Council established the Hydrogen Project team to implement the strategy.

The Hydrogen Working Group established by National Cabinet is focused on six works streams:

- Hydrogen exports
- Hydrogen for transport
- Hydrogen in the gas network
- Hydrogen for industrial users
- Hydrogen to support electricity systems
- Cross Cutting issues.

The Commonwealth government has committed $500m to advancing Australia's hydrogen industry since 2015. $13.4m of this has already been provided to implement and coordinate the National Hydrogen Strategy. This funding includes the $70m Renewable Hydrogen Deployment Funding Round run by the Australian Renewable Energy Agency (ARENA) announced in 2019 and $300m is provided through the Clean Energy Finance Corporation's Advancing Hydrogen Fund, launched in May 2020.

One of the priorities for the strategy in 2020 was international collaboration. A number of announcements have been made with international governments for cooperation on hydrogen, including:

- The Republic of Korea

- Japan
- Singapore
- Germany

At the end of 2020, the Hydrogen Project Team reported progress on key initiatives and projects including the international partnerships noted above, reviewing the domestic legal frameworks to support the industries development, supporting a review of options to integrate hydrogen into Australia's gas networks, commissioning a National Hydrogen Infrastructure Assessment, working towards a guarantee of origin certification scheme and establishing data frameworks to support an annual 'State of Hydrogen" report.

Australian Renewable Energy Agency (ARENA) funding for Hydrogen

In 2019, ARENA announced the Renewable Hydrogen Development Funding Round of up to $70m to help fast track the development of renewable hydrogen in Australia. This initiative followed the release of the National Hydrogen Strategy and is in line with the Australian Government's focus on growing a competitive hydrogen industry in Australia.

In April 2020, ARENA opened the $70m funding round. The funding round is aimed to demonstrate the technical and commercial viability of hydrogen production at a large scale using electrolysis.

On 20 July 2020, ARENA announced a shortlist of seven applicants for this funding. All applicants reportedly have well developed projects that involve deploying 10 MW or larger electrolysers, made up of various end uses including transport, gas injection, renewable ammonia production, power and industrial use. These projects are as follows:

- WA: APA Group, Badgingarra Renewable Hydrogen Project. JV between APA and Woodside. Hydrogen for use in power generation, transport and industrial applications. Long term options for pipeline delivery of hydrogen to Perth.
- WA: ATCO Australia, Clean Energy Innovation Park, 10 MW Electrolyser, to produce 4.2-4.6 tonnes of green hydrogen per day.
- WA: BHP Billiton Nickel West, 10 MW electrolyser, use in refinery to reduce emissions.
- WA: Yuri Project in Pilbara, ENGIE and Yara fertilisers. Hydrogen for Ammonia. Existing Ammonia plant.

- Victoria: Australian Gas Networks, Hydrogen Park Murray Valley, 10 MW electrolyser, gas for injection into gas distribution networks of Albury (NSW) and Wodonga (VIC), with potential to supply industry and transport sectors.
- Queensland: Dawson Mine, Macquarie and Anglo American, hydrogen production to power mine vehicles.
- Tasmania: H2 TAS, Woodside and Countrywide energy in Bell Bay region. 10 MW pilot producing 4.5 tpd for domestic transport sector.

The full application stage now runs to January 2021, with preferred projects to be selected by mid-2021, financial close by the end of 2021 and construction to commence in 2022.

Clean Energy Finance Corporation (CEFC) Funding for Hydrogen

In May 2020, the Australian Government established the Advancing Hydrogen Fund and gave the Clean Energy Finance Corporation (CEFC) the task of administering the fund. The *Clean Energy Finance Corporation Investment Mandate Direction 2020* directs the CEFC to make available up to $300 million in CEFC finance to support the growth of the Australian hydrogen industry. An early priority for this funding is to invest in projects included in the ARENA Renewable Hydrogen Deployment Funding Round.

The CEFC expects to provide either debt or equity finance to eligible larger-scale commercial and industrial projects, typically requiring $10 million or more of CEFC capital. The Mandate directs the CEFC to prioritise projects that focus on one or more of the following:

- Production projects
- Developing export and domestic hydrogen supply chains, including export industry infrastructure
- Establishing hydrogen hubs
- Other projects to support domestic demand for hydrogen.

The fund draws on existing CEFC finance. In line with the CEFC act, projects seeking CEFC finance through the fund are required to be commercial, draw on renewable energy, energy efficiency and/or low emissions technologies and contribute to emissions reduction.

Other federal funding

Separate to this funding, in September 2020, additional funding was announced by the Commonwealth Government of $70.2m to be spent on establishing a regional hydrogen export hub, which could be cited in the Latrobe Valley (Vic) or Darwin (NT), North West WA, Gladstone (Qld), Hunter Valley (NSW), Bell Bay (Tasmania) and the Spencer Gulf (South Australia).

The South Australia Government Hydrogen Action Program

South Australia first published a hydrogen strategy in September 2017, the Hydrogen Roadmap for South Australia. In Late September 2019, South Australia released the Hydrogen Action Plan, including the commitment of $1.25m towards a landmark study to identify optimal locations for renewable hydrogen production and export infrastructure.

The Hydrogen Action Plan sets out 20 actions across five key areas to help scale up renewable hydrogen production for export and domestic consumption. These five key areas are:

- Facilitating investments in hydrogen infrastructure.
- Establishing a world class regulatory framework
- Deepening trade relationships and supply capabilities.
- Fostering innovation and workforce development
- Integrating hydrogen into the energy system.

South Australia also announced the Hydrogen Export Modelling tool in September 2019, which comprises a landmark study of existing and potential infrastructure required for an international scale renewable hydrogen export value chain.

In South Australia's *Hydrogen Export Prospectus*, published in October 2020, the government promotes South Australia as a world class hydrogen supplier and highlights the advantages of investing in South Australia to fulfil demand for clean hydrogen. The government lists four potential export supply chains, three exporting green hydrogen and one blue hydrogen. The three green hydrogen projects, their export capacity and electricity requirements are listed below, add up to a total of between 10-26 TWh assuming an electrolyser efficiency of 45 kWh per kg of Hydrogen. These projects are:

- Port Bonython green hydrogen. 125,000-250,000 tpa of hydrogen, electrolyser size of 1.2-2.5 GW. Estimated 6-11 TWh at 45 kwh per kg H_2.
- Cape Hardy/Port Spencer green hydrogen. 60,000-250,000 tpa of hydrogen with reported electrolyser size of 0.6-2.6 GW. Estimated 3-11 TWh at 45 kwh per kg H_2
- Port Adelaide green hydrogen. 30,000-80,000 tpa of hydrogen, electrolyser size of 200-800 MW. Estimated 1-4 TWh at 45 kwh per kg of H_2.

Nearer term hydrogen projects in South Australia are attracting significant funding in the case of the 75 MW Eyre Peninsula Gateway hydrogen project with $240m of funding announced by the South Australian government on 6 November 2020.

South Australia will see its first pilot plant come into operation this year, the ‘Hydrogen Park South Australia’ has a 1.25 MW Siemens proton exchange membrane (PEM) electrolyser that will be used to make hydrogen to be blended with natural gas to create a 5% blend for injection into the local gas distribution network.

The South Australian Government has committed over $1 million as part of its Hydrogen Action Plan towards identifying locations for renewable hydrogen production and export infrastructure and has allocated $4.9 million through its $150 million Renewable Technology Fund towards the Australian Gas Network’s demonstration project, ‘Hydrogen Park South Australia’. The government has allocated $10m in total to renewable hydrogen through its Renewable Hydrogen Fund to encourage private sector investment.

Queensland Government Hydrogen Industry Strategy

In September 2018, the Queensland Government released the Advancing Queensland’s Hydrogen Industry discussion paper. In May 2019, following feedback to this paper and discussions with stakeholders, the government released the Queensland Hydrogen Industry Strategy 2019-2024. The strategy focuses on five key areas:

- Supporting innovation

- Facilitating private sector investment
- Ensuring an effective policy framework
- Building community awareness and confidence
- Facilitating skills development for the new technology.

The objective of the strategy is to drive the development of a sustainable and competitive hydrogen industry in Queensland. The vision is to be supplying an established domestic market by 2030 in addition to export partners.

The government also established a $15m hydrogen industry development fund to support hydrogen projects in Queensland. Subsequently an additional $10m of funding was announced. There were four successful recipients under the first round of the Hydrogen Industry Development Fund including projects in Townsville, Brisbane, Gladstone and the Scenic Rim. The next round will open following consultation with industry set for January 2021.

NSW Government Hydrogen Initiative

The NSW Government's Hydrogen Initiative is part of its Net Zero Plan Stage 1: 2020-2030, that seeks to reach net zero emissions by 2050.

NSW's hydrogen initiative is aimed to help accelerate the emerging hydrogen market and build domestic demand. The State will support research, development and commercialisation of hydrogen technologies and has set an aspirational target of 10 per cent hydrogen blending in the gas network by 2030.

The memorandum of understanding between the Commonwealth government and the state of New South Wales, released on 31 January 2020, also addressed joint support for hydrogen, including a Hydrogen Technology Program to support the commercialisation of hydrogen technologies in NSW, including recommendations arising from the National Hydrogen Strategy.

Victoria Government Hydrogen Investment Program

The Victorian Hydrogen Investment Program (VHIP), established in December 2018, sets out a pathway to developing the Victorian hydrogen sector.

The program covers three activity streams to kick-start the development of the Victorian hydrogen sector:

1. Market testing – through the request for industry submissions (RFIS) process, the Victorian Government will determine the current extent of market interest and opportunity for hydrogen, including status of potential projects. This process will inform future investment programs.
2. Policy development – by undertaking stakeholder consultation through a Victorian Hydrogen Industry Development Discussion Paper in 2019, which will be used to develop a Victorian Hydrogen Industry Development Plan (IDP).
3. Victorian Government investment program – funding to leverage hydrogen research, trials, pilots and demonstrations, creating a strong base of industry knowledge, skills and seed funding. The investment program will be based on the RFIS process and aligned with the IDP.

The Victorian government has invested $50m in a pilot scheme to turn Latrobe Valley coal into Hydrogen.

In a combined effort, the Victorian and Australian governments have allocated $150 million to supporting the $500 million project in the Latrobe valley to produce hydrogen in Victoria and export it to Japan.

The Victorian Government is currently developing the Green Hydrogen Industry Development Plan.

Tasmanian Government Renewable Hydrogen Action Plan

The Tasmanian Renewable Hydrogen Action Plan, published in March 2020, sets out a vision for Tasmania to capitalise on its existing and expandable renewable energy resources to become a world-leader in large-scale renewable hydrogen production for domestic use and export, becoming a significant global supplier of renewable hydrogen for export and domestic use from 2030.

The goals under the plan include:

- By 2022-2024
    - Commenced production of renewable hydrogen

    - Locally produced renewable hydrogen is being used in Tasmania
    - Export based renewable hydrogen projects are well advanced
- By 2025-2027
    - Tasmania has commenced export of renewable hydrogen.
- From 2030
    - Tasmania is a significant global producer and exporter of renewable hydrogen
    - Locally produced renewable hydrogen is a significant form of energy used in Tasmania.

The plan is supported by four key pillars:

- exploring the opportunities for using locally produced renewable hydrogen in Tasmania and for export
- providing financial support for renewable hydrogen projects for export and domestic use, plus investment attraction activities with international trade partners
- ensuring a robust and supportive regulatory framework, and the assessment of supporting infrastructure
- building community and industry awareness, developing skills, and supporting research and education.

The Tasmanian Government has developed a $50 million package of support measures over 10 years, as part of the Tasmanian Renewable Hydrogen Industry Development Funding Program. This includes a $20 million Tasmanian Renewable Hydrogen Fund, $20 million in concessional loans, and $10 million in support services including competitive electricity supply arrangements and payroll tax relief.

The Tasmanian Government released a status report on the plan on 25 November 2020 outlining how the state is tracking in implementing the 25 actions under its plan to develop the hydrogen industry. Recently the government announced a $2.6m investment for the feasibility of three large scale renewable hydrogen projects in Tasmania as part of the $50m funding program.

The status report outlines:

- The delivery of the Tasmanian Renewable Hydrogen Industry Development Funding Program
- A series of investigations underway to examine the opportunities for domestic hydrogen use in Tasmania
- Work to develop the Bell Bay Advanced Manufacturing Zone, and other suitable sites, as potential hydrogen hubs
- Leading the development of a hydrogen community education and engagement strategy nationally
- Ongoing trade and investment work undertaken by the Office of the Coordinator-General

- Progressing work to prepare Tasmanian workers to have the necessary skills to support a future hydrogen industry.

ACT Hydrogen Strategy

Policies in relation to hydrogen, in particular for hydrogen vehicles and injection into the natural gas distribution network are being developed as part of the ACT Government's *Sustainable Energy Policy 2020-25*.

Northern Territory government renewable hydrogen strategy

The Territory's renewable hydrogen strategy was released in July 2020. The Territory has embraced a target of net zero emissions by 2050, and hydrogen can play a central role in its realisation, according to the strategy. The Territory's aspiration is to be an international scale renewable hydrogen technology research, production and downstream manufacturing centre.

The strategy outlines a five-point hydrogen plan for government and industry to work together:

- Local industry development – preparing industry capabilities, logistics and supply chains to facilitate the adoption of renewable hydrogen
- Resource management – investigate how to optimise the Territory's resources and infrastructure to facilitate hydrogen industry development
- Grow and harness demand – promote the Territory as an attractive export hub and investigate domestic hydrogen applications to build demand
- Support innovation – incorporate new ways of researching, trialling and adapting emerging technologies to optimise hydrogen opportunities
- Responsive regulation – establish effective regulatory frameworks for the development of a safe and efficient hydrogen industry.

Western Australian Government Renewable Hydrogen Strategy

The WA Renewable Hydrogen Strategy was launched in July 2019, aiming to harness WA's renewable energy resources, vast land mass and history of exporting energy to international markets. The WA Renewable Hydrogen Roadmap was subsequently launched in November 2020, identifying 26 initiatives the WA Government is driving to realise the WA strategies vision, mission and goals.

WA's vision is to be a significant producer, exporter and user of renewable hydrogen. Its key strategic focus areas are:

- Export
- Remote applications
- Hydrogen blending in natural gas networks
- Transport

The government has set goals for 2022 and 2030:

- By 2022
  - Project approved to export renewable hydrogen
  - Renewable hydrogen used in a remote location in WA
  - Renewable Hydrogen is distributed in a WA gas network.
  - A refuelling facility for hydrogen vehicles is available in WA
- By 2030
  - WA's share in global hydrogen exports is similar to its share in LNG today
  - WA's gas pipelines and networks contain up to 10% renewable hydrogen blend.
  - Renewable hydrogen is used in mining haulage vehicles
  - Renewable hydrogen is a large fuel source for transportation in regional WA.

In 2020, through its $10m Renewable Hydrogen Fund the Western Australian Government invested $1.68m across seven renewable hydrogen feasibility studies.

Appendix: State and Territory projects and proposals announced to date

South Australia

Name	Location	Hydrogen Type	Electrolyser/ Project Size	Planned Output	Stage of development	Investors	Target Market	Financials
Hydrogen Park South Australia	Adelaide	Green	1.25 MW	Up to 175t per year	Commissioning	Australian Gas Infrastructure Group, SA gov	Natural gas injection, Transport	AGIG: $6.4m SA gov: $4.9m
Crystal Brook Energy Park	Crystal Brook	Green	50 MW	Up to 9125t per year	Planning	NEOEN, SA gov	Storage/power generation	SA gov: $1m grant, $4m grant and $20m loans on FID
Eyre Peninsula Gateway Hydrogen Project	Port Bonython	Green	75 MW	40,000t of ammonia per year	Planning	H2U, Mitsubishi, SA gov	Ammonia export	SA gov: $4.7m grant, $7.5m loan
Port Bonython green hydrogen	Port Bonython	Green	1.2-2.5 GW	125,000 – 250,000t per year	Proposed		H2 export, Ammonia export, Storage/power generation	
Cape Hardy/Port Spencer green hydrogen project	Cape Hardy	Green	0.6-2.6 GW	60,000 – 250,000t per year	Proposed		H2 export, Ammonia export, Storage/power generation	
Port Adelaide green hydrogen	Port Adelaide	Green	200 – 800 MW	30,000 – 80,000t per year	Proposed		H2 export, Ammonia export, Storage/power generation	
Port Bonython blue hydrogen	Port Bonython	Blue	10-760 MW generation capacity required	24,000 – 49,000 TJ gas per year	Proposed		H2 export, Ammonia export, Storage/power generation	

Queensland

Name	Location	Hydrogen Type	Electrolyser/Pr	Planned Output	Stage of	Investors	Target Market	Financials

			oject Size		development			
APA Renewable Methane Demonstration Project	Wallumbilla	Green	5kW	340 kg per year	Operational	APA, ARENA, Southern Green Gas	Natural gas injection	APA: $1.1m
QUT Hydrogen Process Research and Development	Redlands	Green	40kW (PEM), 10 kW (AEM)		Construction	QUT, ARENA, CS Energy, Queensland gov, Sumitomo Electric Industries, Energy Developments ltd.	H2 Export	$7.5m total cost. ARENA: $3.35m grant CS Energy: $0.5m Queensland gov: $0.25m
Hydrogen Park Gladstone	Gladstone	Green	175kW	7.3t per year	Construction	AGIG, AGN, Queensland gov	Natural gas injection	AGIG/AGN: $2.42m Queensland gov: $1.7m grant
Renewable Hydrogen Production and Refuelling Project	Bulwer Island	Green	220kW	28t per year	Construction	BOC		$4.18m estimated cost. $0.95m ARENA, $3.2 BOC.
H2 Hub Gladstone	Gladstone	Green	3GW		Planning	H2U	Hydrogen export, Ammonia export	
Sun Metals renewable hydrogen facility	Townsville	Green	15 MW	1,800t per year	Planning (construction exp. 2021)	Sun Metals, Queensland Government	Transport, power, gas blending	Queensland Gov: $5m grant
Gladstone green hydrogen	Gladstone	Green	10 MW		Proposed	Stanwell Corporation, Iwatani Corporation	Hydrogen export	Feasibility study $5m. ARENA $1.25M. Stanwell $3.75m.
Pacific Solar Hydrogen project	Gladstone	Green		200,000 t H2 / year	Proposed	Austrom Hydrogen	Hydrogen export, Ammonia export	
Dyno Nobel green hydrogen and ammonia	Moranbah	Green	160MW		Proposed	ARENA, Dyno Nobel	Ammonia domestic	ARENA: $0.98m grant

Green hydrogen and ammonia at Queensland Nitrates facility	Moura	Green	30MW	20,000t per year ammonia, 3500t per year hydrogen	Proposed	Queensland Nitrates, NEOEN, Worley	Ammonia domestic	Feasibility study cost $3.8m ARENA: $1.9m. Full project est. $150-200m.
Dawson Mine green hydrogen	Moura	Green	10MW		Proposed	Anglo American, Macquarie	Transport.	
Green Hydrogen Australia Group	Bundaberg	Green	80MW	6000t per year	Proposed	H2X, Elvin Renewables, Denzo, Plug Power	Transport	

New South Wales

Name	Location	Hydrogen Type	Electrolyser/Project Size	Planned Output	Stage of development	Investors	Target Market	Financials
Horsley Park Green Gas Project	Sydney	Green	500kW		Construction	Jemena, ARENA	Natural gas injection	Total cost $18m ARENA: $7.5m grant
H2Store pilot	Tamworth	Green			Planning	UNSW, Providence Asset Group, H2Store	Hydrogen storage	Providence Asset Group: $3.5m
Project NEO		Green	1000 MW		Proposed	Infinite Blue Energy	Storage/power generation	
Port Kembla Hydrogen Hub					Proposed			

Victoria

Name	Location	Hydrogen Type	Electrolyser/Project Size	Planned Output	Stage of development	Investors	Target Market	Financials
Hydrogen Energy Supply Chain Pilot Project	Latrobe Valley	Blue		3t per year	Operating (Pilot)	Kawasaki Heavy Industries, J-Power, Iwatani Corporation,	Hydrogen export	Federal and Victorian gov: $150m

						Marubeni Corporation, Shell, ENEOS Corporation		
Toyota Ecopark Hydrogen	Altona	Green		21t per year	Construction	Toyota	Transport, power	$3m ARENA, $4.3 Toyota
Hydrogen Park Murray Valley	Aulbury-Wodonga	Green	10MW		Planning	Australian Gas Networks	Natural gas injection	
Portland Renewable Hydrogen	Portland	Green	50 MW	10,000 t per year	Proposed	Countrywide Energy (CRE), Glenelg Shire Council, Port of Portland	Ammonia and natural gas	

Tasmania

Name	Location	Hydrogen Type	Electrolyser/Project Size	Planned Output	Stage of development	Investors	Target Market	Financials
ABEL Energy Bell Bay Powerfuels Project	Bell Bay	Green	100 MW	16,000tt per year	Proposed	ABEL Energy	Domestic H2, Methanol export	
H2Tas	Bell Bay	Green	10MW	1642.6t per year	Proposed	Woodside Energy, Countrywide Renewable Energy	Transport	
Origin Energy Bell Bay Green Hydrogen and Ammonia	Bell Bay	Green	500MW	420,000t per year ammonia	Proposed	Origin Energy, Tasmanian gov	Hydrogen export, Ammonia export	Feasibility est. cost $3.2m. Tasmanian gov: $1.6m grant
Fortescue Metals Group green hydrogen and ammonia	Bell Bay	Green	250MW	250,000t per year ammonia	Proposed	Fortescue Metals	Ammonia export	
Grange Resources Renewable Hydrogen plant	Port Latta	Green	90-100 MW		Proposed	Grange Resources	Natural gas replacement in industrial process	

ACT

Name	Location	Hydrogen Type	Electrolyser/Project Size	Planned Output	Stage of development	Investors	Target Market	Financials
Hydrogen test facility	Canberra	Green	200kW		Operational	Evoenergy, Canberra Institute of Technology	Testing	
Hydrogen Refuelling Station	Canberra	Green			Commissioning	NEOEN, ActewAGL, ACT gov	Transport	

Western Australia

Name	Location	Hydrogen Type	Electrolyser/Project Size	Planned Output	Stage of development	Investors	Target Market	Financials
Clean Energy Innovation Hub	Jandakot	Green	260kW	23t per year	Operational	ATCO, ARENA	Natural gas injection	Total cost $3.6m ARENA: $1.79m grant
Fortescue Metals at its Christmas Creek site	Christmas Creek	Green	2 * 700kW	65.7t per year	Construction	Fortescue Metals, BOC, ATCO, Western Australian gov	Transport	Total cost $32m.
Denham Hydrogen Demonstration Plant	Denham	Green	348kW	13t pear year	Planning/Commissioning Dec 2021	Horizon Power, ARENA, Western Australian gov	Storage/power generation	Total cost $8.9m ARENA: $2.6m, Western Australian gov: $5.7m
Hazer Group Commercial Demonstration Plant	Perth	Blue		100t per year	Planning	Hazer Group, ARENA, Mitchell Asset Management	Transport, Storage/power generation	ARENA: $9.4m, MAM: $6m
Clean Energy Innovation Park	Jandakot	Green	10MW	1679t per year	Planning	ATCO, Western Australian gov	Transport	ATCO: $0.125m, Western Australian gov: $0.375m
Dampier to					Planning	AGIG, Western	Storage/power	Western

Bunbury Natural Gas Pipeline upgrade						Australian gov	generation	Australian Government: $216,000 grant, AGIG: $243,000
Yara Pilbara Renewable Ammonia project	Murujuga	Green	10MW	30,000t per year	Planning	Yara, ENGIE, ARENA	Ammonia export	ARENA: $0.995m $2.8m Yara and ENGIE
Asian Renewable Energy Hub	Port Hedland	Green	23 GW	9.9 mtpa	Planning	InterContinental Energy, CWP, Vestas, Pathway Investments	Hydrogen export, Ammonia export	$36 bn projected cost
Cockburn Renewable Hydrogen	Cockburn	Green			Proposed	City of Cockburn, Western Australian gov	Transport	Western Australian gov: $149,412 grant
Badgingarra Renewable Hydrogen Project	Badgingarra	Green			Proposed	Woodside	Storage/power generation, Transport	
Arrowsmith Hydrogen Project	Dongara	Green		9125t per year	Proposed	Infinite Blue Energy	Transport	
Geraldton Export-Scale Renewable Investment project	Geraldton	Green		20,000t per year ammonia	Proposed	BP, GHD, ARENA	Hydrogen Export, Ammonia Export	BP $2.7m ARENA, $1.71m
Murchison Renewable Hydrogen project	Kalbarri	Green			Proposed	Hydrogen Renewables Australia, Siemens, Copenhagen Infrastructure Partners	Hydrogen export, Natural gas blending	$10bn projected cost
BHP Nickel West Green Hydrogen project	Kwinana	Green	10MW		Proposed	BHP	Transport	

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