CME
The Chamber of Minerals & Energy of Western Australia

CMEWA

# TOWARDS COMPETITIVE CLEAN HYDROGEN

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# Towards competitive clean hydrogen

**The Chamber of Minerals and Energy of Western Australia (CME) is the peak resources sector representative body in Western Australia. CME is funded by member companies responsible for more than 88 per cent of the State's mineral and energy workforce employment, ranging from mining (mineral and petroleum commodities), manufacturing (alumina, basic inorganic chemicals and explosives) and support services (aviation, gas transmission pipelines and electricity supply).**

In 2020-21, the industry reported a record value of $210 billion (bn), with iron ore the most valuable commodity at $155bn. Petroleum products (including crude oil, condensate, liquefied natural gas, liquefied petroleum gas and natural gas) followed at $23bn, with gold third at $16.6bn.

The value of royalties received from the sector totalled $12.7bn in 2020-21, accounting for 31.7 per cent of general government revenue. Accounting for 47 per cent of the State's total Gross Value Added by industry, the sector is a significant contributor to the local, State and Australian economies.

CME's Competitiveness portfolio is focused on ensuring a globally competitive and stable environment that recognises the resources sector as a strategic driver of economic development and diversification. A key tenant of this is advocacy to support competitive settings to facilitate diversification into the production of value-added mineral concentrates, chemicals and other downstream products. Capitalising on opportunities in new strategic industries such as critical and battery minerals and hydrogen stands to play a key role in rising to the challenges of global warming and supporting economic recovery from the impacts of COVID-19.

# Foreword from Paul Everingham

Hydrogen has captured the imagination of policy makers, politicians, and industry over the past several years, demonstrated by the near obscurity of public discourse on hydrogen to a proliferation of government strategies, funding initiatives, and strategic positioning of industry and investors in a short period.

Hydrogen's appeal is many-fold. First is its versatility. As an energy vector, hydrogen carries energy stored or converted back into another form of energy. Hydrogen can be used in several ways, including various industrial chemical feedstock applications, transport and mobility, home heating, and stationary power and grid services. Critically, it offers a pathway to decarbonisation in hard-to-abate sectors and sectors where electrification is difficult or prohibitively expensive.

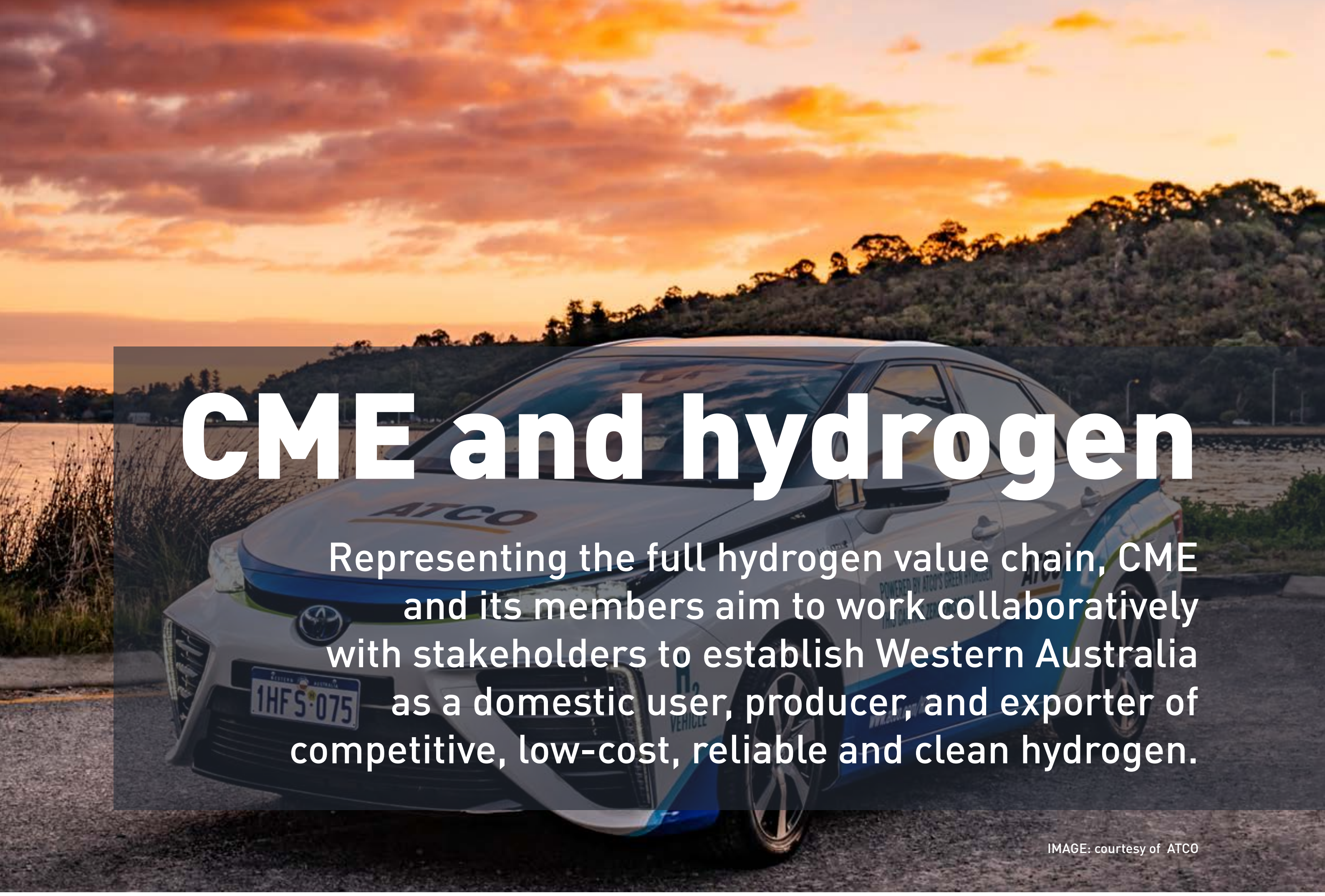
Hydrogen produces no greenhouse gases (GHG) when used, such as in a fuel cell to power a vehicle or when burnt for a source of heat. The process of producing hydrogen can, however, emit GHGs. Of the 75 million tonnes per annum (mtpa) of hydrogen currently produced, over 99 per cent of it is produced from processes that emit GHGs, such as steam methane reforming and coal gasification.[1]

For hydrogen to play a role in reducing emissions, hydrogen needs to be produced through electrolysis powered by renewable energy (green hydrogen) or existing methods that incorporate carbon capture (utilisation) and storage (blue hydrogen). Other 'colours' associated with clean hydrogen are under consideration in some jurisdictions, including 'pink' hydrogen produced from nuclear energy. While carbon intensity will differ from jurisdiction-to-jurisdiction, hydrogen produced from electricity supplied through the grid is also an option to consider in a phased approach to scale.

Given the entrenchment of renewable energy and battery technologies in power and transport markets, clean hydrogen is more likely to find a market in applications where decarbonisation options are not established, where electrification is prohibitively expensive or technically unfeasible, or where hydrogen technology provides utilisation superiority over competitors. The supply of clean hydrogen is likely to come from areas with established infrastructure and where there's an abundance of cheap renewable energy or natural gas with the ability to capture and inject $CO^2$.

While there is most certainly a hydrogen economy opportunity for Australia and Western Australia, there remains several challenges and success is far from given. State and Federal initiatives are under-resourced relative to international competitors, and industrial development support is yet to emerge to fully take account of the significant economic and technical challenges. Furthermore, legislative and regulatory reform is often uncertain and opaque, and hydrogen policies are not fully integrated into an *energy systems and economy wide abatement* framework.

CME has developed this work in close collaboration with its members and with an evidence base supported by a study from Australian Venture Consultants (AVC) – *Western Australia's Competitiveness in the Hydrogen Economy*. This position paper incorporates key findings from the AVC analysis, which unpacks the competitiveness of hydrogen in Western Australia. Importantly, the AVC study explores hydrogen economy developments in Western Australia's traditional energy export markets and assesses issues that will determine the future competitiveness of Western Australian hydrogen exports in those markets as well as, from a more topical perspective, other potential markets for Western Australian hydrogen.




# CME and hydrogen

**Representing the full hydrogen value chain, CME and its members aim to work collaboratively with stakeholders to establish Western Australia as a domestic user, producer, and exporter of competitive, low-cost, reliable and clean hydrogen.**

IMAGE: courtesy of ATCO

**Participation in a future global hydrogen economy as a supplier, customer or integrated producer and user is an increasingly relevant and important consideration for members of CME.**

CME represents members across the hydrogen value chain, including production, transport, storage, and use. Amongst our members, hydrogen presents several different opportunities and areas of interest. For some, it is a new export opportunity, while others are considering it as a low carbon alternative to products currently supplied to its customer base. Others are undertaking a systematic consideration of how hydrogen can deliver domestic emissions reduction relative to electrification options, while different members are already ready to blend hydrogen into the gas network or include clean hydrogen in their industrial feedstock.

Common to all is the need to see the implementation of sound and fit for purpose reform to establish Western Australia as a domestic user, producer, and exporter of competitive, low-cost, reliable, and clean hydrogen.

## Defining clean hydrogen

Different types of hydrogen production technologies have different emissions profiles. Green hydrogen production is zero emissions,[2] best-in-class blue hydrogen production is estimated to deliver between 20-50 per cent emissions reduction levels. In contrast, hydrogen production from the grid is dependent on the profile of renewables, gas, nuclear and coal in the local area. For this paper, reference to *clean* hydrogen is used and is intended to maintain technology neutrality provided the emissions profile is consistent with National and State emission reduction goals. This reference is consistent with Australia's National Hydrogen Strategy and aligned with the Western Australian Government, which supports different forms of hydrogen production technologies.

In arriving at the policy position and recommendations on hydrogen outlined in this document, CME and its members are guided by a series of energy and climate policy principles outlined on page four.

# CME climate policy

Climate change is a global challenge requiring coordinated action at international, national and sub-national levels. CME supports the Paris Agreement and its goal of limiting global warming to well below 2, preferably to 1.5 degrees Celsius, by reducing emissions to net zero as soon as possible and no later than 2050. Australia, as a signatory to the Paris Agreement, must actively contribute to this goal and fulfilment of its Nationally Determined Contributions.

CME will advocate for a sustainable development approach to climate change policy, including the transition to net zero emissions, a framework that balances the social, economic and environmental aspects associated with emissions reduction and ensures a just transition for those affected by the change. Australia must fulfil its aspirations in all three areas rather than viewing them as at odds with each other.

In the Australian context, CME will advocate for this best to be achieved through government-coordinated approaches that ensure:

- a national framework to achieve national objectives in a coordinated and efficient manner, providing policy stability and investment certainty for industry;
- a single, national emissions account that is up to date, transparent and publicly available;
- a transparent price signal across the whole economy and promotion of lowest cost abatement, leveraging existing mechanisms where possible, and appropriately considering the international competitiveness of trade exposed industries;
- investment in a broad range of affordable technologies including for energy efficiency, emissions reduction, carbon sequestration, and adaptation measures;
- Australia's competitive advantages in a future low emissions economy are leveraged through the development and supply of in-demand new energy and mineral commodities;
- a mature, liquid and affordable market for domestic offsets and allowing for international trade of credible offsets;
- related climate adaptation, land use and planning matters are progressed.

# CME energy principles

Linked to CME's Climate Policy, the following principles underpin CME's position on energy.

- **lower emissions future** – with a long history of technological adoption and value-add, the WA resources sector will play a key role in supporting the economy's ongoing transformation to a cleaner energy future.
- **one systems approach** – promote whole-of-government coordination on all aspects of renewable and non-renewable energy use and delivery, rather than a traditional siloed approach on individual parts. A genuine whole-of-system approach will minimise inadvertent and unintended outcomes for the economic growth of the WA resources sector.
- **keep the lights on** – maintain secure, stable and reliable energy supply, supporting diversification of a broad range of high-reliability generation sources and provide certainty on essential system services for large industrial loads; ensuring the rapid introduction of intermittent renewable generation does not present a risk to the system.
- **low and stable costs** – low and stable costs – efficient energy infrastructure informed by least cost, transparent and equitable market trading mechanisms and pricing to encourage competition and innovation by new and existing participants. As a critical input, the cost of energy is a barrier to new or increased value-adding economic activity in WA.
- **sustainable** – future proof and provide fit-for-purpose policy and regulation to keep pace with a changing environment. Public investment in developing technology or infrastructure should be coordinated and complement private investment.

# Colours of the rainbow

**Discussion of hydrogen quickly turns to how it is produced. This is typically discussed in colours, making hydrogen production easier to associate visually but not necessarily being a helpful shorthand to appreciating the complexities and rationale of each option. Brown, grey, green, blue, pink, yellow and even platinum have been referenced in the context of producing hydrogen. CME members are pursuing a range of projects that cut across various technologies – from production to use - but are united by the need for these production technologies to be aligned with climate goals, offer a clear pathway to scale to reduce costs, and which are informed by customer requirements.**

The AVC report recognises the need to support a range of technological options in this context, particularly as 'there is yet no clear consensus on the role or scope of hydrogen within the future of the global energy mix.' Further work also needs to be done to measure the embedded $CO^2$ content of various forms of hydrogen production, while the propensity for customers to pay a premium for clean hydrogen is only emerging.

The AVC report notes that blue hydrogen offers Western Australia the basis of comparative advantage, given the strong existing industry presence, substantial natural gas resources, and geological formations suitable for carbon capture and storage (CCS). Likewise, it recognises that blue hydrogen can never neutralise emissions, and blue hydrogen production requires a demonstrably competent CCS system to deliver emissions reduction outcomes. Noting that blue hydrogen will not be zero emissions, proponents of blue and green hydrogen pathways alike recognise this is a transitional pathway to zero emissions hydrogen.

This position paper will continue to reference hydrogen 'colours' for ease of reference and note its acceptance in the wider vernacular, but discussion would be better served by consideration of the full lifecycle carbon intensity of hydrogen production (including equipment) through to the method of transport, storage, and use. The broader environmental and social impacts of different production options are also important considerations.

Image: Courtesy of AGIG

# Why hydrogen and why now

## Strong global action on addressing GHG emissions

The focus on hydrogen has arisen from the need for global action to reduce GHG emissions. Ultimately, endeavours to produce clean hydrogen at scale and attempt to address its many technical challenges wouldn't occur but for industry and government objectives to align with the goals of the 2015 Paris Climate Agreement and net-zero emissions targets.

The Paris Agreement facilitated a newfound focus on reducing GHG emissions following the false-start of the Copenhagen Accord, which was not legally binding or universally adopted. At the Paris meeting of the United Nations Conference of Parties (COP), 196 parties[3] agreed to limit global warming to well below 2, preferably 1.5 degrees Celsius compared to pre-industrial levels. To achieve these objectives, parties agreed to achieve climate neutrality by mid-century and reach global peaking of GHG emissions as soon as possible. The Paris Agreement was vital for establishing National Determined Contributions (NDCs), whereby signatories outlined how they would specifically meet this goal every five years.[4]

This Agreement provided a global structure with regular timeframes to assess action transparently while allowing individual signatories to act relative to specific challenges of their jurisdiction.

Since the Agreement, a series of studies indicated that action under current NDCs in the aggregate are not enough to limit warming to 1.5 degrees Celsius. For example, the Intergovernmental Panel on Climate Change Sixth Assessment Report concluded that Paris Agreement goals would not be met unless there was an 'immediate, rapid and large scale' reduction in GHG emissions.[5]

Countries have recently been willing to set more ambitious goals to reduce national emissions in the shorter term. For example:

- The European Union (EU) is targeting at least 55 per cent net reduction in emissions from 1990 levels by 2030
- The United Kingdom enshrined its target to cut emissions by 78 per cent by 2035 compared to 1990 levels.
- The G7 has agreed to halve collective emissions over two decades to 2030

While the COP26 Glasgow Summit did not deliver agreement on new NDCs, the communique did commit parties to return in 2022 with new plans. In the private sector, energy and mining companies also set targets for their emissions, often in advance of governments and with greater ambition.[4] There are increasingly examples of executive remuneration linked to emissions key performance indicators and accounting for climate change risk in investment (or divestment) decisions.

Hydrogen is seen as a way to meet climate goals by governments and industries alike. A focus on hydrogen is also spurred by changing investor sentiment toward companies that are geared to GHG intensive activities. This trend has been underway for several years but came into sharp focus by the decision of Blackrock in January 2020 to exclude companies that generate over 25 per cent of their revenue from thermal coal from its actively managed funds. This followed years of activism by groups such as Climate Action 100+, a grouping of investors with $60 trillion[7] under management who actively engage companies to improve climate governance, cut emissions and strengthen financial disclosures. While clean hydrogen production remains more expensive than the alternative, investors and financiers are actively aligning themselves with projects to be well prepared to deploy capital when the time arrives.

# Hydrogen in mining

The majority of GHG emission reductions efforts in the mining sector relates to energy use. The volume of GHG emissions can be addressed through efforts that eliminate energy use in specific applications, reduce it (e.g. energy efficiency measures), substitute (e.g. replacement of diesel generation), offset (e.g. purchasing of carbon credits, carbon farming) or capture (e.g. CCUS).

In the context of mining applications, hydrogen is most often referenced for its potential in displacing diesel for haul trucks and heavy rail, and other mobile mining equipment.

Globally there are around 50,000 mining haul trucks that carry a payload of over 100 tonnes (t). Given its large share of Scope 1 emissions, it is a priority area for decarbonisation plans across the sector.

A range of zero emissions haul trucks are currently being investigated, of which hydrogen fuel cell trucks are one of several options being considered.

A fuel cell works like a battery by producing electricity to drive an electric motor. Unlike a battery, it does not require recharging, being fed by a constant flow of hydrogen that produces electricity to drive an electric motor.

There are comparatively fewer examples of hydrogen fuel cell trucks being developed compared to electrification options. Of note is Anglo American's investigation of renewable hydrogen production technology at its South African Mogalakwena PGM mine.[8] The pilot truck will include eight 100 kilowatt fuel cells and be fuelled by green hydrogen from a 3.5 megawatt (MW) electrolyser co-located on site. Announced in 2019, the pilot remains to be executed, although if the pilot proceeds to plan, then Anglo will expand the number of trucks in operation to 40 by 2024.[9]

There is another notable trial taking place in Chile. Known as Hydra, the Chilean Government and private sector participants are supporting the development of fuel cell electric vehicle power trains. After completing the trial in mid-2021, Original Equipment Manufacturers (OEMs) such as Komatsu and Caterpillar will be approached to integrate the system into existing truck models to launch pilot trials.[10]

While there aren't examples of hydrogen fuel cell haul trucks being used in Western Australia, FMG will roll out ten hydrogen coaches to replace the existing diesel fleet at Christmas Creek and will be supported by a refuelling station and green hydrogen produced on-site. The company providing these buses, Hyzon Motors, will also deliver two hydrogen fuel cell trucks to Wesfarmers (Coregas) within the next 12 months.[11]

Several alternative electrification options are being considered by the mining sector globally, including battery electric haul trucks, trolley electric battery haul trucks, and diesel-electric trolley haul trucks.

Several fleets of diesel-trolley haul trucks have existed for decades, particularly where access to cheap electricity or diesel is prohibitively expensive or unreliable. While these haul trucks need to use diesel when it is required to move away from the trolley (e.g. collecting ore from an underground pit) and at times when connected to the trolley, this technology is delivering GHG emissions reductions in some parts of the world now.

Globally, there are also trials using converted haul trucks to run completely as a battery electric vehicle (BEV). Work is underway that would combine a fully BEV with a trolley, meaning that the haul truck can carry a larger load and there'd be longer durations between charges. It is anticipated that OEMs will proceed with further research and development (R&D) and that a stronger market will emerge for BEV haul trucks and other mining equipment.

The flexibility that hydrogen haul trucks offer and the ability to refuel quickly could lead to the technology being competitive with BEV alternatives. However, even factoring in these advantages, it is likely that in the short term, BEV will be more competitive. It is plausible that hydrogen may not offer a compelling cost saving compared to electrification options in the longer term.[12] According to Advisian, there are a number of requirements that would need to be met to make hydrogen haul trucks competitive:

- Design and manufacturing numbers to meet Australian conditions and need
- Comparable utilisation and reliability compared to incumbents
- Demonstration of fuel consumption and operational benefits
- Low delivered cost of clean hydrogen

In addition to technology development for haulage and equipment, the mining sector is also progressively undertaking work on understanding optimal models for hydrogen production, transport and storage, and to understand how these challenges can be resolved.

Rail is another mining application where hydrogen could have a role. French company Alstom built the world's first commercial hydrogen train operating in Austria since 2018.

BEV locomotives require very large batteries - up to 25MW per hour to complete a 1000 kilometre route – while overhead electrification requires extensive infrastructure.[13] In September 2021 Roy Hill announced the purchase of a FLXdrive battery-electric locomotive that has the capacity of 7MWh.[14] Provided capital costs of fuel cells, storage, and hydrogen fuel continue to fall, hydrogen locomotives may become more competitive against incumbents in the long term.[15]

There aren't any existing known trials for using hydrogen fuel cell locomotives in mining, although prototypes have been considered.[16]


# Global targets, strategies, and support for hydrogen

IMAGE: Courtesy of ATCO

Linked to GHG reduction are emerging targets for hydrogen use. The emergence of several national targets and disparate views on the speed at which clean hydrogen will be adopted has made it more difficult to assess which markets will be most prospective to Australia. In assessing several regional energy export markets, the AVC study identifies Japan and Korea as the most prospective for potential Western Australian hydrogen exports.

While Japan's interest in incorporating hydrogen into its fuel mix far precedes this date, its 2017 Basic Hydrogen Strategy that outlined a target to import 300,000t of hydrogen annually by 2030 piqued Australia's interest and coincided with an Australian state and Federal foray into strategic thinking for hydrogen. This Strategy focuses on reducing the cost of locally produced and imported hydrogen, increasing uptake of hydrogen fuel cell electric vehicles (HFCEVs), and increasing the uptake through power generation and industrial processes. Further support followed through the NEDO Fuel Cell and Hydrogen R&D program (US$220m over five years) and the US$42 billion Green Towards Neutrality Strategy.

South Korea has likewise invested in hydrogen with significant domestic support to transition to hydrogen and support its domestic technology capabilities. It released its Hydrogen Economy Roadmap in 2019, which includes targets to increase the number of HFCEVs and refuelling stations, which would support the local industrial manufacturing base.

While further from Australia's shores, Europe has also garnered national interest on account of:

- the prominence of its energy transition policies and diplomacy
- as a market of interest for global Australian companies with an interest in hydrogen
- strong industrial and technology base

The European Commission's Hydrogen Strategy[17] released in 2020 recognises hydrogen as important, particularly in scenarios where electrification is difficult, inefficient, or more expensive.

This Strategy focuses on supporting renewable hydrogen, but it recognises that in the 'short and medium term', other forms of low-carbon hydrogen will be required to reduce emissions and support the development of a viable and liquid market.

Of EU nations, Australia has developed a particularly strong relationship with Germany. Germany has a specific budget in its own Strategy dedicated to developing international cooperation, leading to a supply-chain study investigating the feasibility of a green hydrogen supply chain between the two nations and a subsequent 'Germany-Australia Hydrogen Accord'. The Accord has three key pillars that may benefit Australia and Germany alike – Research, Promoting Hydrogen Trade, and Industry-to-Industry Collaboration.

While national targets appear promising, the continued uncertainty regarding the final shape of the emerging 'hydrogen economy' on present market conditions and policy settings means that the scale of this opportunity is likely to be constrained in scope over the medium term. The AVC analysis supports this, notably:

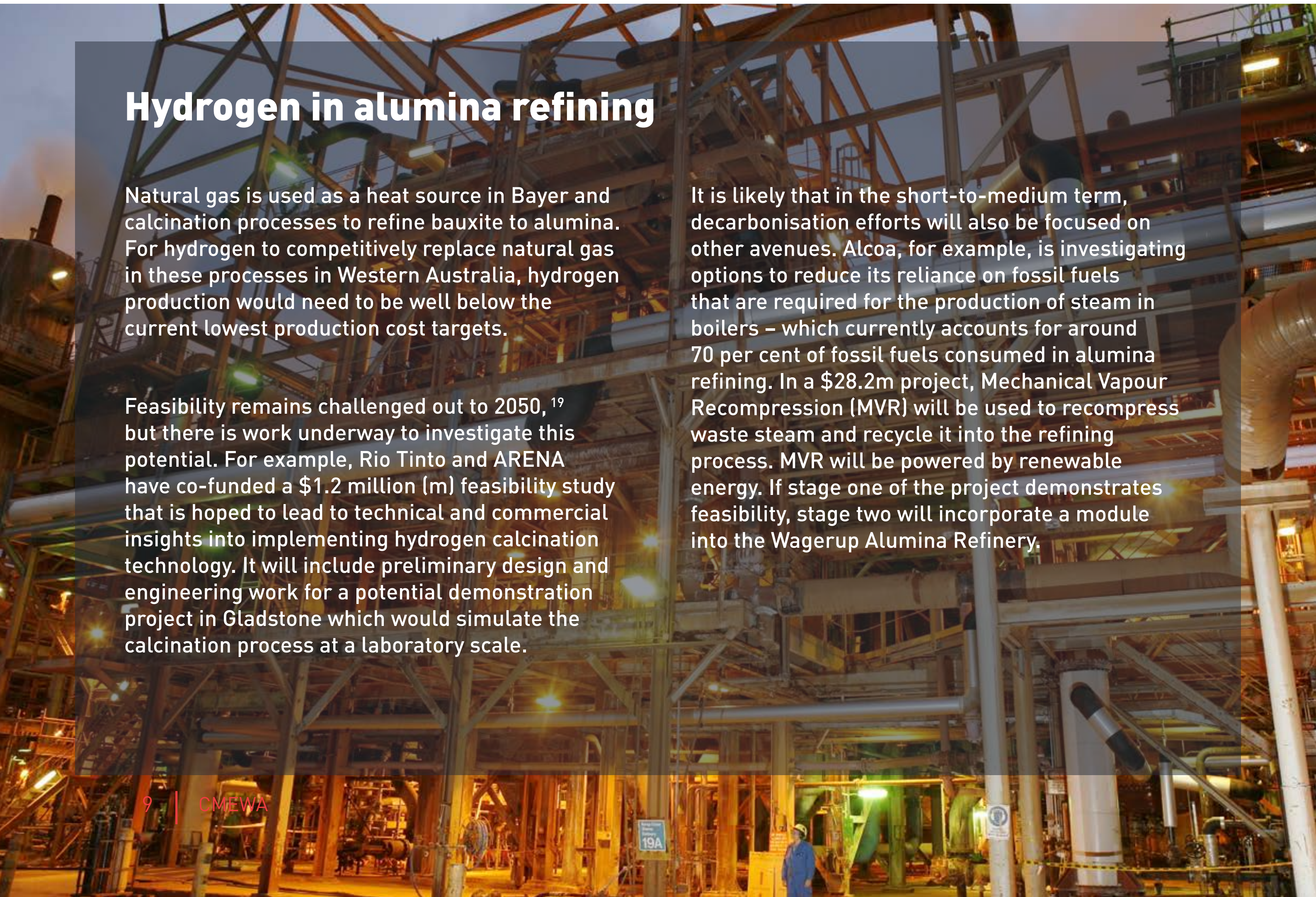
- The policy settings of a majority of Western Australia's existing trade partners in the region heavily prioritise expanded within-jurisdiction production of clean hydrogen. Accordingly, any nascent Western Australian export sector directed at these markets over the short term would face domestic supply competition subject to and benefitting from domestic policy settings that would likely provide a cost advantage over imports in a highly price-sensitive market.

- While there remains a high degree of uncertainty regarding the final scope and shape of the emerging global hydrogen economy, the scale of the potential market in most of these jurisdictions does not appear to be well aligned with Western Australia's goal to establish itself as a hydrogen supplier in a similar scale to its current LNG exports position.

- Western Australia's nascent hydrogen industry will face a very high level of competition from other global suppliers for a product that can be manufactured anywhere water and power are available.

- While the EU collectively represents one of the global frontrunners in hydrogen adoption, a combination of current installed capabilities, domestic policy aims, existing and closer trade links and specific market dynamics render it unlikely that the EU represents a significant opportunity for Western Australia as a hydrogen supplier in the medium term.

Japan is a potential standout destination that runs counter to this narrative and has a higher likelihood of supporting a large-scale Western Australian hydrogen export market. To a lesser extent but for similar reasons, Korea is also a potential market of scale within the medium-term. In simple terms, each of these jurisdictions is enacting policies that explicitly recognise a large role for imported hydrogen to meet projected needs and have already invested in pursuing partnerships with potential supplier nations, including Australia.



## Hydrogen in alumina refining

Natural gas is used as a heat source in Bayer and calcination processes to refine bauxite to alumina. For hydrogen to competitively replace natural gas in these processes in Western Australia, hydrogen production would need to be well below the current lowest production cost targets.

Feasibility remains challenged out to 2050,[19] but there is work underway to investigate this potential. For example, Rio Tinto and ARENA have co-funded a $1.2 million (m) feasibility study that is hoped to lead to technical and commercial insights into implementing hydrogen calcination technology. It will include preliminary design and engineering work for a potential demonstration project in Gladstone which would simulate the calcination process at a laboratory scale.

It is likely that in the short-to-medium term, decarbonisation efforts will also be focused on other avenues. Alcoa, for example, is investigating options to reduce its reliance on fossil fuels that are required for the production of steam in boilers – which currently accounts for around 70 per cent of fossil fuels consumed in alumina refining. In a $28.2m project, Mechanical Vapour Recompression (MVR) will be used to recompress waste steam and recycle it into the refining process. MVR will be powered by renewable energy. If stage one of the project demonstrates feasibility, stage two will incorporate a module into the Wagerup Alumina Refinery.

# Falling costs

**The final driver for a focus on green hydrogen is falling renewable costs. With electricity accounting for around half of green hydrogen production costs, cheap power is a clear prerequisite for this form of hydrogen production to become competitive.**

Based on the experience curve of solar and wind technologies over the past decade, there is cause to be optimistic that energy costs will continue to decline, making green hydrogen production more competitive as years progress.

Additionally, as further renewables enter wholesale electricity markets, price cannibalisation and reduced capacity factors will pressure returns. Developers and investors are considering alternative revenue options for their electricity supply and market to supply their electricity to.

There is also optimism that renewable hydrogen will become affordable through declining electrolyser costs as manufacturing scales up. For example, the cost of alkaline electrolysers declined by 40 per cent in Europe and North America from 2014-19.[18]

However, the speed at which technology costs reduce is not uniformly felt across industry and uncertainty of technology development poses several challenges to policy settings and investment decisions.

That said, all first of a kind technologies experience high costs at the beginning, with some succeeding and some not. Common to success stories – such as wind, solar and battery storage – is policy intervention of some description, including feed-in tariffs, manufacturing subsidies, concessional financing, carbon pricing and phasing out of incumbent technologies.

The blue hydrogen narrative is different, with blue hydrogen being more competitive today and arguably serving as a transition to the time when green hydrogen technology is more widely used.

## Australia’s framework

A federated system means that laws and regulations applying to a particular sector are likely to span national, state and local jurisdictions. Hydrogen is no different.

Each state and territory government and the Federal Government have a hydrogen strategy (in the case of the ACT, it’s in development). Parties such as the CSIRO have also produced strategies or roadmaps. Each published Strategy emphasises different competitive strengths, preferences, and objectives but generally avoids outright contradiction.

This reflects the level of interest and opportunity for hydrogen. While this interest is welcome, it is important to ensure that state and federal approaches are aligned to ensure coordinated development of the sector and avoid unnecessary duplication.

Similarly, competition for expertise and capital is healthy. Still, one needs to be cognisant in presenting a unified vision of the sector's development, particularly when communicating in competitive international markets.

## National framework

The Federal Government released Australia’s National Hydrogen Strategy in November 2019.[20] It outlined three priority areas to support the growth of Australia’s hydrogen sector– smart, consistent, light-touch regulations; shaping international markets; and accelerating technology commercialisation.

The Strategy outlines 57 actions to support its priorities and its measures of success[21], delivered through a series of working groups under the Council of Australian Governments framework, since superseded by the National Cabinet Reform Committee (ENCRC).

## Regulation

The ENCRC is currently undertaking several tasks to assess legislative and regulatory barriers to the further use of hydrogen. This work began in earnest with a scoping study from Clayton Utz in November 2019 of State and Federal laws essential to the hydrogen value chain and a series of high-level priorities for review and potential reform.

The ENCRC is used as the mechanism to ensure alignment between the states and federal governments.

Recent work has included reviewing the National Gas Law (NGL) to allow for hydrogen blending in gas networks and scoping studies that could see 100 per cent hydrogen used. At a June 2021 ENCRC meeting, Ministers agreed to a package of priority reforms, including expediting work to make amendments to the NGL to incorporate hydrogen and renewable gas blends, such as biogas. An initial consultation paper has been released, with consultation on draft reports and draft legislative amendments anticipated from March 2022.

The NGL has been adopted by Australian jurisdictions, so changes to the NGL would allow for coordinated adoption. Western Australia is a participating jurisdiction on a modified basis - in the case of hydrogen blending, it will adopt NGL changes.  That said, some jurisdictions have made amendments to their enacting legislation to provide for hydrogen blending, so the option is there to go it alone.

Regulatory reform work is spread across various working groups, initially established around focus areas and led by a particular jurisdiction that has developed particular expertise in the area. The working groups are developing a hydrogen export industry; hydrogen in the gas networks; hydrogen for transport; hydrogen to support electricity systems; hydrogen for industrial users; cross-cutting issues. It can therefore be difficult to keep track of the full suite of regulatory reform being considered by the Federal Government.

The Federal Government has also recently released a Discussion Paper on a Hydrogen Guarantee of Origin Scheme for Australia,  building on domestic and international engagement over the past few years.


## Shaping international markets

The Federal Government has been actively exploring international collaborations to support the foundations of clean hydrogen production and to position Australia as a future exporter and shaper of markets. Initiatives have included:

- Participation in the International Partnership on Hydrogen and Fuel Cells in the Economy, particularly on developing an agreed certification scheme.
- Bilateral agreement with Germany to study the growth of a green hydrogen supply chain between the two countries.
- Shaping internationally agreed safety standards, including through the US Centre for Hydrogen Safety.
- Collaboration with South Korea to develop a Hydrogen Action Plan.
- A Joint Statement on Cooperation on Hydrogen and Fuel Cells with Japan, particularly to support a liquified hydrogen export pilot project from Victoria.
- An agreement with Singapore to support the adoption of hydrogen in port and maritime applications.

While international engagement is in the remit of the Federal Government, States have similarly been engaging with other jurisdictions to establish strategic relationships.

# Accelerating technology commercialisation

Since being outlined as a priority by the National Hydrogen Strategy, accelerating technology commercialisation is underpinned by the Federal Government's Technology Investment Roadmap.  Its Strategy is to support the commercialisation of low emissions technologies to capture the benefits of commercialisation in Australia.

The Roadmap outlines four technology categories - priority low emissions technologies, emerging and enabling technologies, watching brief technologies, and mature technologies. Hydrogen falls within the first two categories, while the Roadmap provides a 'technology stretch target' for clean hydrogen production at $2 per kilogram.

In practice, Government support derived from strategic decisions of the Roadmap is likely to be administered by the Australian Renewable Energy Agency (ARENA).

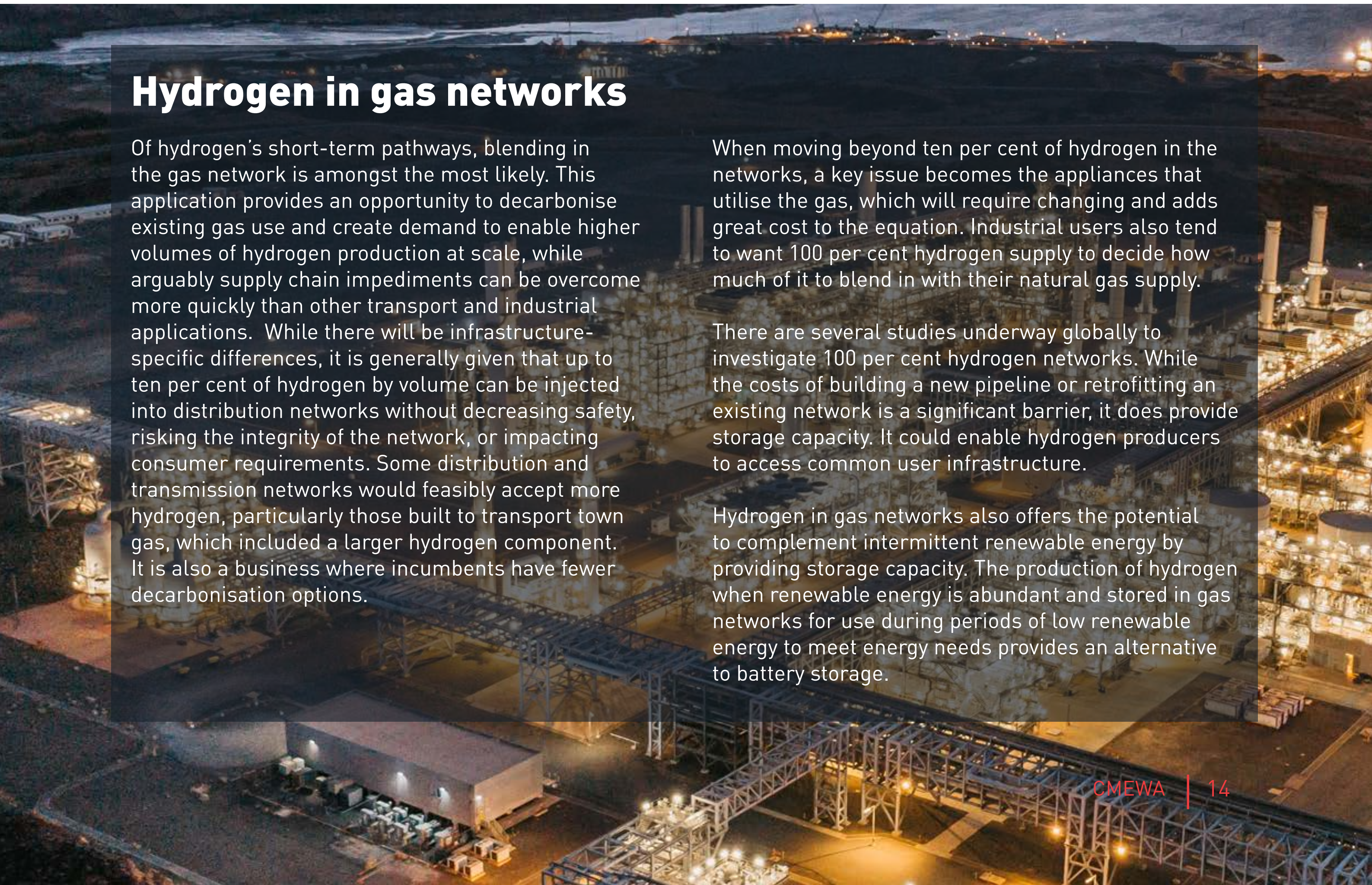
The Commonwealth Government established ARENA to invest in the renewable energy market within Australia, and to date, has been the central body to support funding of hydrogen projects.

This has included the $70m Renewable Hydrogen Deployment Funds grant program. Under this program, seven projects were shortlisted and three of these projects were subsequently selected for funding, of which two are Western Australian and the other in Victoria. Total funding was then expanded to $103m to address the funding requirements of all three projects.

The National Hydrogen Strategy also supported the creation of hydrogen hubs and clusters to drive innovation and reduce costs. The first tranche of funding was modest - $1.85m administered by National Energy Resources Australia (NERA) to support 13 clusters across Australia, of which three are located in Western Australia. Since then, the Federal Government has committed to $464m for seven industrial hubs, a substantial amount that can realistically achieve the objectives of a hub framework.

While support from the Federal Government is broadly welcomed by the industry, this is a globally competitive area where would-be major producers and consumers are likewise investing, and in several cases, investing more heavily.

In 2021, the Department of Industry, Science, Energy and Resources (DISER) commissioned Arup to deliver a National Hydrogen Infrastructure Assessment first agreed to under the National Hydrogen Strategy. The purpose of the study is to assess current industry initiatives and identify gaps through the supply chain, intending to understand what infrastructure investments are required to meet forecast demand.



## Hydrogen in gas networks

Of hydrogen's short-term pathways, blending in the gas network is amongst the most likely. This application provides an opportunity to decarbonise existing gas use and create demand to enable higher volumes of hydrogen production at scale, while arguably supply chain impediments can be overcome more quickly than other transport and industrial applications.  While there will be infrastructure-specific differences, it is generally given that up to ten per cent of hydrogen by volume can be injected into distribution networks without decreasing safety, risking the integrity of the network, or impacting consumer requirements. Some distribution and transmission networks would feasibly accept more hydrogen, particularly those built to transport town gas, which included a larger hydrogen component. It is also a business where incumbents have fewer decarbonisation options.

When moving beyond ten per cent of hydrogen in the networks, a key issue becomes the appliances that utilise the gas, which will require changing and adds great cost to the equation. Industrial users also tend to want 100 per cent hydrogen supply to decide how much of it to blend in with their natural gas supply.

There are several studies underway globally to investigate 100 per cent hydrogen networks. While the costs of building a new pipeline or retrofitting an existing network is a significant barrier, it does provide storage capacity. It could enable hydrogen producers to access common user infrastructure.

Hydrogen in gas networks also offers the potential to complement intermittent renewable energy by providing storage capacity. The production of hydrogen when renewable energy is abundant and stored in gas networks for use during periods of low renewable energy to meet energy needs provides an alternative to battery storage.

## Hydrogen for ammonia

Hydrogen is required for ammonia production – given this is an existing market pathway with sunk infrastructure, a great deal of government and industry attention has been focused on this application.

In Western Australia, Yara produces 150,000t per annum (tpa) of hydrogen. Its Pilbara ammonia facility has received State and Federal Government funding to incorporate a pilot green hydrogen production facility. As learnings are taken from the pilot project, Yara envisages entering Phase 1 with an electrolyser capacity of 150-500MW around 2026.

CSBP produces 56,000tpa of hydrogen for its ammonia production at Kwinana, which would increase if the company proceeds with its expansion plans.

Ammonia is also of interest as a carrier of hydrogen, where ammonia would be directly combusted at end-use or decomposed to high purity hydrogen. Transporting hydrogen in ammonia is seen as a viable option given existing global shipping and port infrastructure and the ability to ship hydrogen more efficiently compared to what is known thus far on shipping liquid hydrogen.

# Western Australia's landscape

The Western Australian State Government launched the Western Australian Renewable Hydrogen Strategy in 2019 to provide a framework for acting on the State's advantages. It sets out a vision 'for WA to be a significant producer, exporter and user of renewable hydrogen'[24] with an explicit focus on green hydrogen production capacity, focusing efforts on hydrogen produced from renewable energy rather than steam methane reforming.

*Advantages Outlined in the State Government's Renewable Hydrogen Strategy*

| Competitive Advantage | Advantage |
|---|---|
| **Land** | With a space of 2.5 million $km^2$ Western Australia is about one-third of Australia. With low population intensity and low land-use intensity, there is space and the ability to build large-scale renewable energy generation plants. |
| **Renewable energy resources** | Western Australia is home to high-intensity renewable energy resources. Western Australia's solar is amongst the highest irradiance in the world, and due to being on the western edge of the continent, it has excellent wind resources. |
| **Existing infrastructure** | Western Australia has a world-class industrial and export infrastructure that can accommodate the development of the hydrogen industry. |
| **Strong existing industry presence** | Because of Western Australia's established LNG industry and its ability to develop collaborative and globally competitive supply chains, many of the world's largest oil and gas companies have a local presence. Several major companies have expressed intentions to develop hydrogen projects in regional Western Australia. |
| **Skilled workforce** | Western Australia retains a technically skilled workforce with expertise across the energy sector and relevant research capabilities amongst various institutions. A skilled workforce will be essential to a local hydrogen industry. |
| **Access to markets** | Another comparative advantage for Western Australia is its geographical proximity to Asia and its long-term presence in these markets. There is potential to strengthen further Western Australia's strong partnerships with Japan and South Korea, which are key partnerships in the growing market for renewable hydrogen. This industry also presents opportunities for technology partnerships in Asia and Europe. |

These attributes provide some foundational advantages, although as the work from AVC supports, they generally do not provide clear competitive or comparative advantages.

None of these are absolute advantages, a reflection that hydrogen is a manufactured product that can be produced around the world. In the case of green hydrogen, it is processed from infinite resources not confined to a geographic endowment - it is unlikely that any nation will have claim to absolute advantage.

The AVC report notes that other Australian jurisdictions, such as Tasmania, may in fact, prove more competitive in the production of green hydrogen than Western Australia and other States. The Middle East – existing LNG competitors – has access to excellent renewable energy resources comparable to WA and governance structures where investment can respond quickly to government decisions. Middle Eastern countries are well positioned to be a supplier to Europe and are in similar proximity to Asian customers as WA exports would be.

Given that renewable resources and manufacturing expertise exists throughout the world, establishing a clear comparative and competitive advantage is a difficult proposition for nations across the globe. This is why CME has established a Hydrogen Working Group and put forward constructive recommendations to support capturing the hydrogen opportunity.

This includes making the most of what advantages Western Australia has, such as in the production of blue hydrogen that leverages a strong industry presence and customer network through Asia.

With the State's Hydrogen Strategy focused on green hydrogen, it logically follows that the State's Minister for Hydrogen Industry is likewise focused on green hydrogen in the execution of the Strategy. Blue hydrogen activity is led through the Hydrogen Industry portfolio, but given the specific title of the Strategy and naming convention of several groups, this is not always immediately clear. There are examples of State funding support for proponents that plan to implement a phased blue-to-green project, but key elements of blue hydrogen that sit outside of the Renewable Hydrogen Unit, who has primary responsibility for supporting the Minister for Hydrogen Industry and implementing hydrogen related reform. There is an opportunity to reform the State's hydrogen strategy to more clearly align and leverage the competitive enablers of CCS technology and existing gas infrastructure, with a view to reducing emissions in line with National and State targets and support a competitive transition to green hydrogen production.

Several of WA's advantages are not unique and we cannot presume that the hydrogen opportunity will be realised without a concerted and targeted reform effort. In assessing Western Australia's advantages stated by the Renewable Hydrogen Strategy, several conclusions can be drawn from analysis of the AVC report, including:

- The costs of establishing large scale renewable projects in WA are unlikely to be more affordable than many areas in Australia or globally

- There are similarly expansive areas of land in Australia and through the Middle East, the latter of which can authoritatively be activated for development with speed and subsidy

- It is unclear how existing LNG and other infrastructure can be leveraged for hydrogen production and export, while several countries have similar infrastructure, and extensive infrastructure specific to hydrogen production

- Other economies have far greater experience with hydrogen production and sunk cost infrastructure, and therefore have a distinct advantage for leveraging and developing skills

- With price, quality and reliability clear drivers, it cannot be presumed that established trading relationships in other commodities will transfer to hydrogen. Export trade is seaborne, meaning access to markets is fully flexible. It is anticipated that a significant portion of future hydrogen export trade will be seaborne, while there is also extensive pipeline delivery being used and explored in Europe and North America.

A strong industry presence in upstream and downstream petroleum and industrial segments could be a source of comparative and competitive advantage for the State. While this doesn't guarantee a final investment decision, it does place Western Australia in good stead. The fact that many are global companies and will be driven by optimised returns to shareholders, it is more the reason for the State Government to establish a timely framework to encourage investment decisions.

The AVC analysis also supports keeping technological options open – with a competitive or comparative advantage not established, it would be prudent to keep all avenues open to enable a pathway to clean hydrogen production at scale.

Indeed, the ambition of State Government goals is such that it requires substantial industry and government action to meet the timeframe. The 2022 goals are broadly on track, for which the Government and industry should be commended. Published at the end of this paper, CME's recommendations outline ways to leverage the best of Western Australia's position and establish this future industry.

# State Government goals

**By 2022**

- A project is approved to export renewable hydrogen from WA
- That renewable hydrogen is being used in one remote location in WA
- Renewable hydrogen is distributed in a WA gas network
- Refuelling factory for hydrogen vehicles is available in WA

**By 2030**

- WA's market share in global hydrogen exports is similar to its share in LNG today
- WA's gas pipelines and networks up to ten per cent renewable hydrogen blend
- Renewable hydrogen is used in mining haulage vehicles
- Renewable hydrogen is a significant fuel source for transportation in regional WA

**These State Government goals have been supported by around $90 million in State Government funding, including but not limited to:**

- $15m Rounds 1 and 2 of the Renewable Hydrogen Fund, supporting a range of hydrogen initiatives across the State.
- 2021-22 State Budget allocation of a further $50m fund.
- $4m in the 2021-22 Budget to expand the Renewable Hydrogen Unit in JTSI and to progress Mid-West hydrogen activation.
- $7.5m in the 2021-22 Budget for road infrastructure at Oakajee.
- $3m for a regulatory reform package
- $1m to identify geological locations for hydrogen storage
- $1m to develop a detailed hydrogen value chain model
- $600,000 for a study investigating the economic and regulatory reform to blend hydrogen into the gas network.
- $4.7m towards constructing demonstrator renewable hydrogen microgrid to power Denham


IMAGE: Courtesy of AGIG

# Hydrogen for steel

Green steel can refer to several ways of reducing GHG emissions through the steel making process. For example, action could be taken to

- Use renewable energy upstream in the mining and processing of iron ore
- Power electric arc furnaces that use natural gas as a reductant with renewable energy
- Use clean hydrogen as a reductant in both electric arc furnaces and blast furnaces.

Steel making accounts for around 5-9 per cent of global GHG emissions and presents a challenging decarbonisation pathway to use an alternative to coal/coke as the reductant required for steel making.

Most steel is produced in a blast furnace. Coal is used as a reductant to produce iron metal, and in doing so, carbon reacts with oxygen in the iron ore to produce $CO_2$.

Steel can also be produced by a direct reduction process, where natural gas is used as a reductant to produce iron metal. This method emits around half the $CO_2$ per tonne of steel compared to the blast furnace method and is commercially available technology. This method is commonly used to recycle scrap steel.

Several trials are now investigating using hydrogen as a direct reductant, further reducing GHG emissions.

Green Steel is an increasingly spoken topic in Western Australia and has been identified as a downstream opportunity by the Western Australian Government.

As put by the Mineral Institute Research of Western Australia (MRIWA), which has received $1 million in State funding for a green steel study - there are multiple possibilities for Western Australia to consider across an increasing spectrum of value-added activities

- Continuing to export iron ore; creating green hydrogen and exporting overseas for steel making;
- Producing direct-reduced iron locally, initially using gas-based direct reduction then subsequently through hydrogen direct reduction, and exporting overseas to be refined to steel;
- Producing steel locally, exporting semi-finished products for overseas fabrication.

Iron ore miners have started positioning themselves in the market, including an MoU between Rio Tinto and POSCO to 'jointly explore, develop and demonstrate technologies to transition to a low-carbon emission steel value chain', and a BHP & JFE Steel study to investigate material reductions to emissions through the steelmaking process. FMG/FFI have indicated a greater propensity to be involved more directly in the downstream activities and supplying green hydrogen directly.

JTSI has a dedicated team to shape policy direction, assess and administer grants, and engage with the industry. It is also responsible for coordinating action across different government departments, as it relates to hydrogen, to support the execution of the Hydrogen Strategy and stated goals.  Some of the work being undertaken is summarised below:

| | |
|---|---|
| **Certification** | The Government signed up to the Zero Carbon hydrogen certification scheme in June 2021. |
| **Land Tenure and Native Title** | The State Government has released for consultation a land tenure reform policy to enable renewable infrastructure build as a 'diversification lease'. |
| **Hydrogen Hubs** | With NERA support, the Department of Jobs, Tourism, Science and Innovation (JTSI) facilitated a workshop in August 2021 to consider issues associated with hydrogen hub developments.<br><br>The State Government is leading two implementation hub applications ($30-70m Federal Government funding each) for the Pilbara and Midwest. |
| **Legal Frameworks Review** | The State Government has engaged Jackson McDonald to deliver a legal framework review and identify priorities areas that would need to be addressed for the use of hydrogen, including specific barriers and pieces of legislation that are silent but may require qualification.<br><br>CME understands the timeline for release is Q4 2021. The scope is unknown and what legislation and regulation is being addressed is uncertain. |
| **Economic Reform gas networks** | The State Government has received proposals from industry on the economic reform required to facilitate blending into gas networks. The State Government is conducting its own reviews and awaiting Federally led reforms to the NGL. |
| **Oakajee** | The State Government released an Expression of Interest (EOI) in Q4 2021 to welcome ideas on how to transform the Oakajee Strategic Industrial Area into a globally competitive, sustainable industrial area, with a focus on the production of renewable hydrogen. The EOI had a strong response from national and global proponents, with the opportunity being progressed with additional State Government funding. |
| **Hydrogen and common user infrastructure planning** | Development WA has completed a gap analysis of Strategic Industrial Areas, which will help inform hydrogen proponent plans. The document has not been released publicly. |
| **Investment Attraction** | The JTSI Hydrogen Unit works closely with Invest and Trade WA to ensure that hydrogen opportunities in the State are marketed to international investors. Further support is expected as part of the $100m WA Investment Attraction and New Industries Fund (IAINF). |
| **Downstream opportunities** | The State Government has indicated it would like to establish manufacturing capabilities associated with hydrogen production and renewable infrastructure. |
| **Skills** | Department of Training and Workforce Development (with input from JTSI) will conduct a hydrogen skills mapping exercise to specifically characterise the needs of Western Australia. |
| **Transport EOI** | A $10m program for procurement and operation of hydrogen or green ammonia fuelled transport, and the installation of one or more refuelling stations. |

There are several formal governance structures which the State Government has tasked to support the further adoption of hydrogen. CME would welcome further clarity on each forum's objectives and work plan to establish ongoing industry consultation to support government objectives.

| Forum | Description / Purpose |
|---|---|
| **Renewable Hydrogen Council** | The Minister for Hydrogen Industry convenes a Renewable Hydrogen Council, which includes senior industry representatives. This high-level grouping has been used as a mechanism to help inform policy development and to engage government and industry internationally.<br><br>The Council doesn't have regularly set meetings, with the first meeting in 2021 taking place in October. |
| **Renewable Hydrogen Ministerial Taskforce** | In recognition of hydrogen touching on many different departments, there has also been a recent move to convene a taskforce comprising the Minister for Hydrogen Industry, Minister for Energy, and Minister for Lands. It is unclear whether this will be expanded to include the Minister for Environment and/or the Minister for State Development, Jobs and Trade. |
| **Climate Action** | A taskforce has been established to support the Government's Climate Policy. Released in November 2020, this policy identifies initiatives across Government that could contribute to the stated goal of net zero by 2050. As of August 2021, this taskforce is chaired by the Minister for Climate Action and includes Ministers for State Development, Jobs and Trade; Regional Development, Agriculture and Food, Hydrogen Industry; Mines and Petroleum, Energy; Transport; Planning, Lands, Finance; and Water. |
| **LNG Jobs Taskforce** | Included in the focus of the Taskforce is blue hydrogen and carbon capture storage and use. The skills and training focus of the Taskforce may also have direct or indirect relevance to skills and training development for hydrogen. |

The implementation of structure and initiatives under the WA Renewable Hydrogen Strategy is broadly welcomed by CME members, although at times there is a lack of awareness of the activities taking place across Government, how the activity directly supports the delivery of a work plan, and mechanisms for industry to engage with the policy making process constructively. CME encourages the State Government to consider expanding the scope and membership of the Renewable Hydrogen Council to reflect models established through the LNG Jobs Taskforce and Future Battery Industries as good practice examples that establish clear and consistent stakeholder input.

# Working with the Government to address challenges

The AVC analysis identifies several challenges to be addressed in order for Western Australia to take advantage of the hydrogen opportunity. Addressing the challenges will require a variety of mechanisms, of which there is a varying degree to what is within Government control.

The following is not an exhaustive discussion of challenges, but it highlights why support for market activation, production at scale, and addressing transport and storage challenges are critical. The depth and breadth of challenges also put the potential of hydrogen as a decarbonisation pathway in perspective relative to other options.

# Physical properties

Hydrogen has many physical properties that underpin its attractiveness as a potential store of energy, as well as characteristics that render it a very challenging store of energy from both a technical and commercial perspective.

The characteristics of hydrogen that render it attractive as a store of energy are as follows:

- **High specific energy** – the energy per unit of mass of hydrogen is approximately 2.5 times greater than that of natural gas and methane and 3.5 times that of gasoline, meaning that compared to other common fuels, it holds in orders of magnitude more energy by weight.

- **Low ignition energy** – the energy required to ignite hydrogen is 15 times less than that required to ignite natural gas, ten times less than methane and five times less than gasoline presenting, prima facie, more efficient combustion and release of the stored energy.

- **GHG emissions free combustion** – when used as a fuel, the only by-product from the combustion of pure hydrogen is water.

However, other physical characteristics of hydrogen pose some difficulties to its widespread adoption as a global energy source:

- **Small molecules** – hydrogen molecules are very small. In fact, diatomic hydrogen (H2) is the smallest molecule known to humankind. This means that hydrogen very easily leaks through joints, flanges and other valve components, and in some cases, materials used in storage vessels and pipelines. Moreover, pressurised hydrogen is prone to seeping into materials (such as steel) used in conventional gas pipelines and storage vessels, resulting in accelerated asset deterioration and safety issues.

- **Very light** – as a result of its small molecule size, hydrogen is also the lightest chemical, with a density that is approximately 7.5 times less than natural gas and methane. This means that under standard temperature and pressure conditions, large vessels are required for its storage. For example, the volume required to store 1 kilogram of hydrogen gas (approximately the amount needed to drive a standard vehicle 100 kilometres) would require an 11,000 litre storage vessel.

  Therefore, compressing hydrogen gas to a density that renders it practical as a fuel in most applications requires both significant energy and very robust storage vessels that can withhold the pressure, resist leakage, and are designed to withstand the structural integrity issues associated with a very small molecule size.

- **Safety** - the safety risks associated with manufacturing, storing and transporting hydrogen is an additional key challenge that the industry will need to overcome. Very little energy is required to ignite hydrogen, which burns very quickly and burns well at concentrations between 4 per cent and 75 per cent in the air, an extremely wide range compared to other common fuels.

  Further, hydrogen fires are odourless, characterised by a pale blue flame almost invisible in the daylight, and without significant radiated heat, making them difficult to detect. While the small, lightweight nature of hydrogen molecules leads them to disperse quickly in the open air, mitigating safety risks in some settings, where ignition occurs in a confined space, a very significant explosion shockwave will result.

The storage and transportation challenges that are presented by the molecule size, mass and liquefaction characteristics of hydrogen are met by three means: generation on-site for immediate consumption, thus avoiding any need for long-term storage and transport; using a chemical compound containing hydrogen (such as ammonia) as its storage and transport vector; and hydrogen fuel cell technology.

Given these difficulties, the use of hydrogen as a mainstream, flexible fuel that can replace the likes of natural gas and LNG will require significant, step-change innovation in cryogenics. It will likely require significant switching of existing gas storage and transmission infrastructure.

Doing this will require close collaboration between would-be producers and customers on both the export and domestic front. For hydrogen to be successful, these challenges need to be resolved so that it becomes cost competitive with alternative decarbonisation options.

## Hydrogen production cost projections

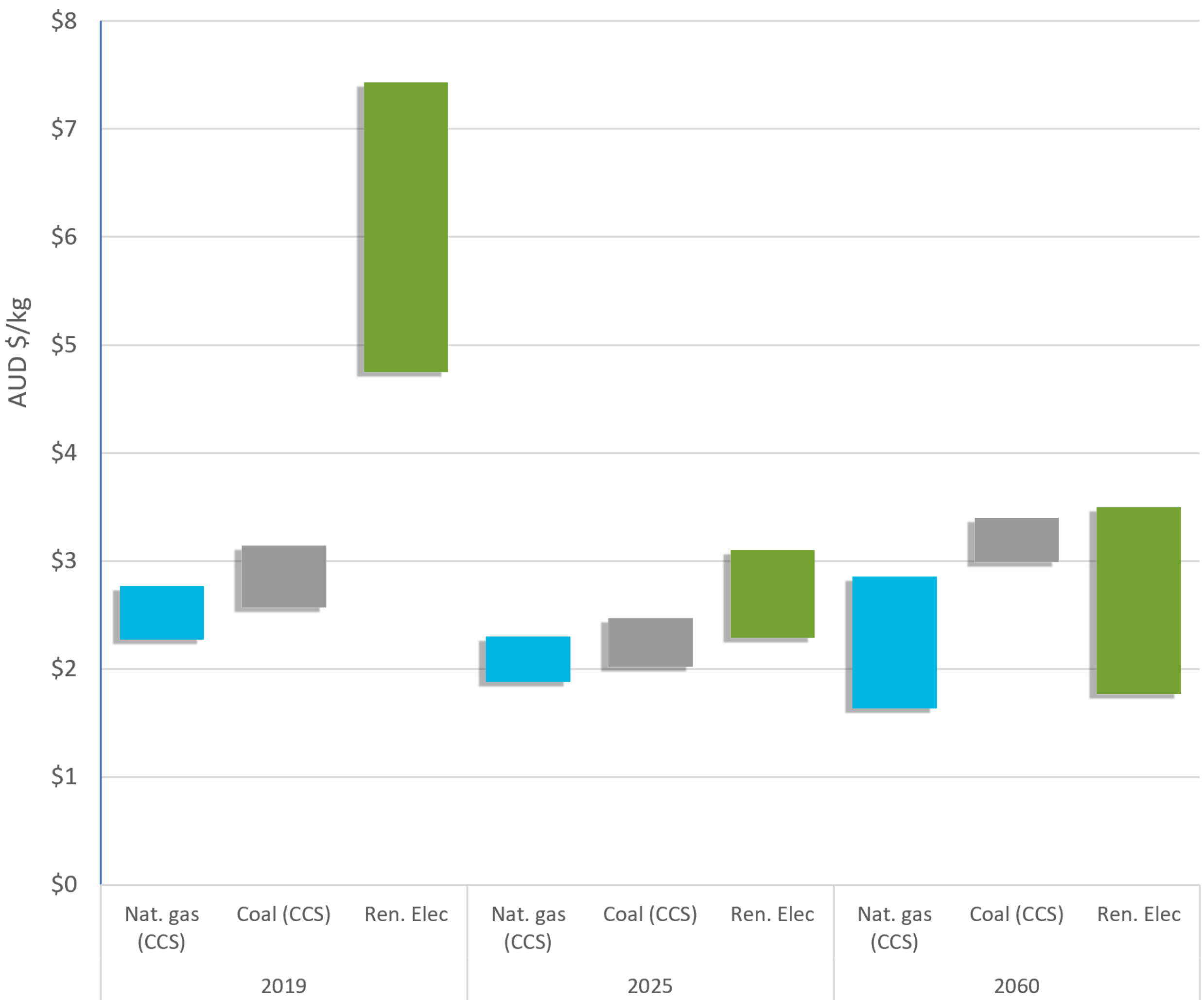
While environmental considerations are becoming increasingly important for government, industry and society more broadly, a fundamental barrier to wider adoption of hydrogen remains its cost to end-users. While final cost will also incorporate variables such as transport and storage, which are currently unviable, the primary cost component of hydrogen remains production cost.

As an emerging energy carrier with attendant uncertainty, and given the range of different production environments globally, production cost estimates for hydrogen differ, in some cases dramatically so.

While it is apparent that hydrogen production from fossil fuel sources is currently around three times cheaper than electrolysis, longer-term predictions vary. This is principally a result of electrolyser costs and electricity pricing, combined with continuing uncertainty as to any carbon pricing mechanism that would increase the production cost of hydrogen from fossil fuel sources.

Illustrated in the figure below, within the Australian context, green hydrogen production is expected to reduce in unit pricing substantially over the medium term, but it is unlikely to reach price parity within the decade. While this graph represents a range of Australian hydrogen production costs, individual proponents may hold different perspectives and indeed see green hydrogen as being cost competitive well before the end of the decade.

Figure: Range of projections for Australian hydrogen production costs, by technology[33]



To reduce costs, several initiatives can be taken to stimulate demand and offer a pathway to production at scale, including looking at the role of blue hydrogen production, which offers a more cost competitive and scalable pathway on today's technologies.

## Uncertain demand

Hydrogen has many industrial, chemical, and manufacturing applications. However, the vast majority of the approximately 75 mtpa[34] of hydrogen is currently utilised in three principal industries[35] :

- **Petrochemical industry** – accounting for approximately half of total global usage, hydrogen is used for refining, desulphurising and processing of fuels;
- **Ammonia industry** – accounting for around 40 per cent of total usage, hydrogen is a critical input to the manufacture of ammonia (NH3) that is, in turn, used primarily to manufacture agricultural fertilisers; and
- **Pharmaceutical and food industries** – most of the remaining global demand for hydrogen is as a chemical feedstock and catalyst (including as a hydrogenating agent) in pharmaceutical and food products.

The focus of recent interest in hydrogen is on its potential as an agent for storing energy, a use that has been proposed since the early 1800s.[36] By weight, hydrogen holds the highest energy concentration of any common fuel source and is relatively easily produced, with several production pathways requiring at a minimum only water and a source of electricity. However, mainly because of existing technical challenges, demand is not expected to grow significantly by 2030. Furthermore, uncertainty concerning technology development, government policy settings and customer uptake result in a significant divergence in demand forecasts out to 2050 and even in the shorter term to 2030. This is true for both blue and green hydrogen, although the challenges are starker for the latter.

Ultimately green hydrogen costs will not reach a competitive level by 2030 without significant subsidies – Bloomberg New Energy Finance (BNEF) estimates that $US150 billion (bn) is required globally to drive the price down to $US2 per kilogram.[37] While there has been an increase in investor interest in hydrogen – reflected in anecdotal feedback from members and public announcements of financial positioning - at $1.5bn, funds directed to hydrogen are a fraction of the $500bn across energy transition investments in 2020 and well short of BNEF estimates of what is required to reach cost competitiveness.[38]

Delivery of Government subsidies and support for clean hydrogen production should be done within an energy systems and whole-of-economy emissions reduction framework to avoid unnecessary costs. Decisions regarding hydrogen development are complex, and ultimately only a limited number of decisions can be made without agreement from other Departments and Ministers. Land tenure reforms stand out as a critical example of this, and CME welcomes the December 2021 release of tenure reform for consultation. It's also important in the context of emissions reduction, where you may have a dual driver of delivering the lowest cost abatement with market stimulation. A good example of this is fleet procurement, where invariably, the lowest cost option to meet emissions reduction goals is to procure lithium-ion buses. This, of course, fails to stimulate hydrogen production to meet predictable and scalable demand, thereby missing an opportunity to develop the clean hydrogen market. The Climate Action Taskforce on face value appears to be a sound structure for emissions reduction through a hydrogen pathway to be considered relative to other options.

The absence of an existing large hydrogen consuming industry in Western Australia – relative to elsewhere in the world - means there is comparatively limited domestic demand that can be the basis for Commercialising the supply of green or blue hydrogen. This situation has been recently worsened in the short term by the cessation of petroleum refining operation at Kwinana, and thus removal of local demand for desulphurising purposes.

The possibility of blending hydrogen in the existing natural gas network is one potential source of domestic demand. Others that could be considered are diesel replacement and, potentially, green steel manufacture.

Much of the Western Australian economy, particularly its large mining and agricultural sectors, is heavily reliant on diesel fuel and will remain so for the medium term.  As Western Australia's supply of diesel is entirely import dependent, this presents an energy security risk for these key industries and therefore the State.

Although the Western Australian passenger vehicle fleet will likely not represent a significant market given competition from battery electric vehicles, Western Australia can explore options to complement and ultimately replace its existing diesel vehicle fleet with hydrogen-powered vehicles.

This will reduce GHG emissions, address diesel fuel energy security issues and provide an easy and progressive pathway to switching to green hydrogen sources once they are cost competitive in Western Australia.

Western Australia's significant iron ore and metal alloying resources raise the possibility of a domestic green steel industry. While other costs, small domestic market and competition in export markets may ultimately render this prospective new sector unviable, it is worthy of further investigation.

If a viable green steel sector is established, it will create local demand for significant volumes of hydrogen. Overarching these options is the importance of establishing a pathway to scale to reduce costs.

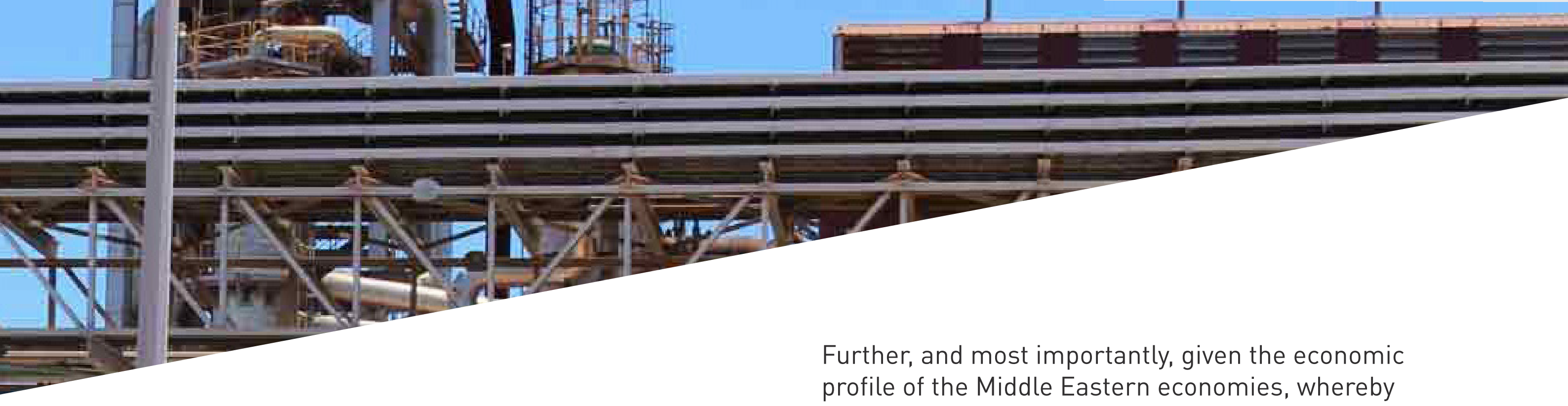
## Pathway to scale through hubs

Industrial hubs offer a model where organisations can gather around a shared endeavour or activity and with an approach that shares information and leverages each other's expertise. It can lead to technology breakthroughs, cost reductions, and the utilisation of products that would otherwise be wasted.

While hubs can be established around various focal points, establishing hubs with a covalence of complementary organisations and existing or high-potential demand centres is a logical starting point. Globally, ports are an attractive area to establish hubs and provide helpful case studies on what attributes can establish a successful model.[39]

Tellingly, leading examples such as the Port of Rotterdam and Teesside Hubs – incorporate multiple hydrogen production technologies and end-use cases. With State and Federal governments both interested in hub activation, there's an opportunity to establish hubs in WA to support commercialisation and market activation.

According to a draft Arup report for DISER, Western Australia has the highest forecast demand for hydrogen across Australia to 2050, with the Pilbara ranging from an estimated low of 3.7 to a high of 17.9mtpa, and Perth from a low of 1.1 to a high of 4.5mtpa.[40]



## Making timely changes

The full extent of challenges associated with clean hydrogen production, transport, storage, and use need to be recognised to make sound policy and investment decisions. While considered and realistic, it needs to be done with a sense of urgency to seize the opportunity that the hydrogen opportunity provides. For both green and blue hydrogen, there is a risk that if Western Australia is too slow to establish the governance frameworks and industry support required to enable the growth of clean hydrogen, other jurisdictions will get a foothold and be first to market.

As outlined by AVC, Western Australia faces significant competition from Qatar, Oman, and the UAE as they respond to the same perceived market opportunity and policy shifts towards an emerging hydrogen economy as Australia. They are doing so from a similar (if not in some instances superior) installed blue asset base and green generation potential. In the case of blue hydrogen production, these competitors have significant natural gas production and potential CCS assets. From the perspective of green hydrogen, they demonstrate high insolation, reliable wind resources, and access to large areas of sparsely populated and relatively underutilised land that could support the production of green hydrogen from solar or wind generation.

Further, and most importantly, given the economic profile of the Middle Eastern economies, whereby they are critically exposed to fossil fuels as the primary driver of State income, any emerging global shift away from fossil fuels to a hydrogen economy represents an existential threat – should a trade-oriented hydrogen economy of scale develop, current Middle Eastern petroleum producers are highly motivated to transition to a major supplier of blue and green hydrogen.

Closer to home, all other states and territories have a hydrogen strategy and are likewise progressing policy reform and supporting industry development. Tasmania, as an example, is underlined by cheap hydropower and connectivity to the National Electricity Market. A key focus of the Tasmanian State Government is to emphasise the availability of wholly renewable power provided at low cost via grid connection due to the high availability of mains-connected renewables, principally hydro and wind. It estimates this will allow renewable energy production at around 20-30 per cent cheaper than in other Australian jurisdictions reliant on off-grid or own-source renewable installations.

While timeliness and transparency to decision making are critical, not being first to market is not a death knell – for example, Australia was not the first to market for LNG. That said, the pace of change is only accelerating, so there is a clear risk of not establishing oneself in the market early. Analysis from AVC and CME member input demonstrates that there remains time to get policy settings firmly established for the decades to come in advance of clean hydrogen production becoming competitive for domestic use and export.

# Recommendations

CME and its members aim to work collaboratively with stakeholders to establish Western Australia as a domestic user, producer, and exporter of competitive, low-cost, reliable and clean hydrogen.

To address challenges and support WA taking advantage of the hydrogen opportunities, a series of priority recommendations have been identified. These are outlined below, with the most pressing issues indicated in orange.

| | |
|---|---|
| **Legislative and regulatory reform** | CME and its members believe that having visibility and input to State and Federal reform process is important to understand how government reforms will meet stated goals and ambitions and how reform will impact business and the ability to produce, transport, store and use hydrogen across a variety of applications. Interstate and global competition will be significant, and timeliness is of the essence. |
| **Recommendations** | For the State Government to work with industry to establish a framework for ongoing dialogue on supporting the development of a hydrogen value chain. |
| | As much as practicable, to align decision making in State Government, so that clean hydrogen is viewed within an energy systems and whole-of-economy emissions reduction context. |
| | Clarity and guidance from State and Federal Governments on where hydrogen projects fit within its respective Lead Agency and Major Project Status frameworks, including opportunities to streamline bilateral approval pathways. |
| **Hydrogen hubs** | CME and its members support an integrated ecosystem of the hydrogen value chain as an important component of market activation. World-class hubs will facilitate technological development, generate important learnings through the nascent sector, and reduce costs. |
| **Recommendations** | In establishing a series of hydrogen hubs in the State, industry and all levels of the Government coordinate to ensure alignment of purpose and learnings. |
| | CME supports a Government approach to developing hubs that is iterative, aligned with industry views on building to scale and customer emergence, and is focused on pre-competitive investment opportunities. |
| | Hubs would be well placed to work closely with centres of domestic demand to understand how the location of hydrogen production and transport and storage options can be optimised for local use. |

| | |
|---|---|
| **Land tenure** | Certainty of land tenure and infrastructure that enables renewable generation and hydrogen production at scale is a critical component in establishing a competitive hydrogen sector in Western Australia. |
| **Recommendations** | CME supports a practical multi-land use framework to support hydrogen development. The framework should consider the value of land use whilst facilitating other land uses for the benefit of the various interest holders and the people of Western Australia more broadly. |
| | In areas that are considered strategic import by the State, to identify opportunities for flexibility in rate charges at industrial sites. |
| **Government funding and support** | Additional funding is required from State and Federal Government that is directed to projects beyond the initial pilot or feasibility phase. Government support can be directed in a way that better facilitates the development of the sector, such as toward hubs and clusters and infrastructure. |
| **Recommendations** | When investing in infrastructure or projects, establish a visible and competitive process to allow proponents to frame a project that would provide the best outcomes and value to the State and Nation. |
| | In the context of delivering policies to reduce emissions across the economy to meet Paris Agreement goals, CME is supportive of options where the State Government can act as an off-taker for hydrogen and facilitate demand through changes to economic regulatory reform. |
| | State Government support and funding should be technology agnostic, with guidance updated to include all clean forms of clean hydrogen production consistent with Australia's and Western Australia's emissions reduction goals. |
| | Industry and the State Government to work openly and transparently regarding the Strategic Industrial Areas Gap Analysis so to identify shared infrastructure that can facilitate hydrogen production and use. |

| | |
|---|---|
| **Hydrogen certification** | Certification that establishes a globally recognised framework to market low emissions hydrogen adds value to the industry. Certification provides support in marketing a premium product and assists in financing projects. |
| **Recommendation** | CME supports State and Federal Government alignment of certification, so to avoid duplication and potential confusion with customers. |
| **Social licence** | Industry and government need to do more work to prepare consumers and the broader community for hydrogen. Education through effective channels need to be pursued and social licence to operate established. |
| **Recommendation** | CME members and all levels of government collaborate to set the foundation for a social licence to operate, focusing on Traditional Owner framing of hydrogen opportunities and unpacking the value of hydrogen development to local communities. |
| **Training and skills** | While there are some adjacent skills in the energy and resources sector, a collaborative forward looking plan for ensuring a well trained workforce will be pivotal for the hydrogen value chain in Western Australia. |
| **Recommendations** | Include hydrogen stakeholders for participation in the State's STEM Skills Strategy industry forums. |
| | Identify and implement timelines for the DTWD hydrogen skills mapping exercise. |
| **Downstream processing** | With such a focus on reducing costs for clean hydrogen, there remains further work to understand the value that will be delivered for the State. Such value can be derived through understanding the downstream processing opportunities associated with hydrogen production and use. |
| **Recommendations** | CME supports industry and all levels of the Government in further framing the barriers to downstream processes and identifying an iterative pathway to realising value adding opportunities. |
| | Continue to support initiatives like MRIWA Green Steel Challenge that approaches the green steel opportunity on a lifecycle basis. |

# Reference

[1] IHS Markit (2021), Hydrogen Market Outlook, April 2021; Geoscience Australia, Hydrogen, www.ga.gov.au/scientific-topics/energy/resources/hydrogen, website accessed July 2021; International Energy Agency (2020), World Energy Outlook: 2020, October 2020

[2] This doesn't take account of the CO2 embedded in the construction of renewable energy infrastructure, electrolysers, and other infrastructure required in green hydrogen production.

3 There are currently 193 signatories.

[4] Australia's current NDC is to achieve an economy wide emissions reduction of 26-28 per cent of 2005 levels by 2030.

[5] IPCC (2021), Sixth Assessment Report, https://www.ipcc.ch/report/ar6/wg1/

[6] As at 1 November 2021 BHP has set a target for GHG emissions reduction by at least 30% by 2030 compared to 2020 for Scope 1 and Scope 2 emissions and a long term net zero target for Scope 1 and Scope 2 emissions by 2050; FMG carbon neutral by 2030 for Scope 1 and Scope 2 emissions, 2040 for Scope 3 emissions; Rio Tinto is targeting a 50% reduction in Scope 1 and Scope 2 emissions by 2030 and a 15% reduction by 2025 from its 2018 baseline, net zero emissions from operations by 2050; Shell has set a target to reduce Scope 1 and Scope 2 emissions by 50% by 2030 compared to 2016 levels, net zero emissions from operations by 2050.

[7] As at November 2021.

[8] Anglo American (2021), Anglo American Collaboration on Feasibility Study for South Africa's Hydrogen Valley, https://www.angloamerican.com/media/press-releases/2021/31-03-2021; Moore, P (2020), International Mining, Anglo says seven mines set for hydrogen mining truck fleets by 2030, https://im-mining.com/2020/10/30/anglo-says-seven-mines-get-hydrogen-mining-truck-fleets-2030-rollout-40-mogalakwena-starts-2024/

[9] Moore, P (2021), International Mining, Anglo American says fuel cell-battery hybrid mining truck entering final phase, https://im-mining.com/2021/07/29/anglo-american-says-fuel-cell-battery-hybrid-mining-truck-project-mogalakewna-entering-final-phase-testing-start-q4-2021/

[10] Moore, P (2021), International Mining, Chile's HYDRA hydrogen mining trick powertrain project to report first results, https://im-mining.com/2021/03/16/chiles-hydra-hydrogen-mining-truck-powertrain-project-report-first-results/

[11] Ker, P (2021), Australian Financial Review, Meet the Aussie igniting the Tesla of hydrogen, https://www.afr.com/companies/energy/meet-the-aussie-igniting-the-tesla-of-hydrogen-20210714-p589kn

[12] Advisian (2021), Australian Hydrogen Market Study, https://www.cefc.com.au/media/nhnhwlxu/australian-hydrogen-market-study.pdf, p.57

[13] Advisian (2021), Australian Hydrogen Market Study, https://www.cefc.com.au/media/nhnhwlxu/australian-hydrogen-market-study.pdf, pp.58-59

[14] Roy Hill (2021), Media Release, Gina Rinehart's Roy Hill to make history with first battery-powered electric locomotive to operate in Pilbara, https://www.royhill.com.au/gina-rineharts-roy-hill-to-make-history-with-first-battery-powered-electric-locomotive-to-operate-in-pilbara/

[15] Advisian (2021), Australian Hydrogen Market Study, https://www.cefc.com.au/media/nhnhwlxu/australian-hydrogen-market-study.pdf, p.60

[16] For example, Anglo American considered a prototype in 2012.

[17] European Commission (2020), A hydrogen strategy for a climate-neutral Europe, https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf

[18] Bloomberg New Energy Finance (2020), Hydrogen Economy Outlook, https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf

[19] Advisian (2021), Australian Hydrogen Market Study, https://www.cefc.com.au/media/nhnhwlxu/australian-hydrogen-market-study.pdf

[20] Commonwealth of Australia (2019). Australia's National Hydrogen Strategy. https://www.industry.gov.au/sites/default/files/2019-11/australias-national-hydrogen-strategy.pdf

[21] Measures of success are that Australia becomes a top 3 exporter of hydrogen to Asian markets; Ensuring Australia has an excellent hydrogen related safety record; Hydrogen is providing economic benefits and jobs in Australia; Australia has a robust, internationally accepted, provenance certification scheme in place.

[22] Commonwealth of Australia (2021), Hydrogen Guarantee of Origin Scheme: discussion paper, https://consult.industry.gov.au/hydrogen-guarantee-of-origin-scheme

[23] Commonwealth of Australia (2020), Department of Industry, Science, Energy and Resources, Technology Investment Roadmap: First Low Emissions Technology Statement, https://www.industry.gov.au/data-and-publications/technology-investment-roadmap-first-low-emissions-technology-statement-2020

[24] Government of Western Australia (2019), Department of Primary Industries and Regional Development, Western Australian Renewable Hydrogen Strategy,. https://www.wa.gov.au/sites/default/files/2020-10/wa_renewable_hydrogen_strategy.pdf

[25] Advisian (2021), Australian Hydrogen Market Study, https://www.cefc.com.au/media/nhnhwlxu/australian-hydrogen-market-study.pdf

[26] See Wood, T. and Dunfas, G. (2020), Grattan Institute, Start with steel, a practical plan to support carbon workers and cut emissions, https://grattan.edu.au/wp-content/uploads/2020/05/2020-06-Start-with-steel.pdf

[27] See e.g. Hybrit, Thyssenkrupp also aims to produce 400,000 tonnes of green steel by 2025 (annual production is around 13 million tonnes).

[28] See further for MRIWA Green Steel Challenge: https://www.mriwa.wa.gov.au/challenges/green-steel/

[29] Rio Tinto (2021),Rio Tinto and POSCO sign climate MOU, https://www.riotinto.com/en/news/releases/2021/Rio-Tinto-and-POSCO-sign-climate-MOU
30 BHP (2021), BHP partners with JFE to address decarbonisation in the steel industry, https://www.bhp.com/news/media-centre/releases/2021/02/bhp-partners-with-jfe-to-address-decarbonisation-in-the-steel-industry

[31] Derived synthesis Bruce, S. et al (2018), National Hydrogen Roadmap, Commonwealth Scientific and Industrial Research Organisation, Commonwealth Government, Canberra, ACT; International Energy Agency (2020), CCUS in Clean Energy Transitions, 23 September 2020, IEA, Paris; International Energy Agency (2020), World Energy Outlook 2020, IEA, Paris

[32] Estimates vary, reputable sources range between 65-103 MMT.

[33] IHS Markit (2021), Hydrogen Market Outlook, April 2021; Geoscience Australia, Hydrogen, www.ga.gov.au/scientific-topics/energy/resources/hydrogen, website accessed July 2021; International Energy Agency (2020), World Energy Outlook: 2020, October 2020

[34] Office of Fossil Energy (2020), Hydrogen Strategy – Enabling a Low-Carbon Economy, Department of Energy, United States Government, July 2020

[35] Delivered cost. Bloomberg New Energy Finance (2020), Hydrogen Economy Outlook,
https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf

[36] Bloomberg New Energy Finance (2020), Hydrogen Economy Outlook, https://data.bloomberglp.com/professional/sites/24/BNEF-Hydrogen-Economy-Outlook-Key-Messages-30-Mar-2020.pdf

[37] See for example Port of Rotterdam, Port of Hamburg, Port of California.

[38] Arup (2021), NHIA Consultation Workshop: Industrial & Resources, DISER National Hydrogen Infrastructure Assessment

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