

H₂

VICTORIAN
RENEWABLE
HYDROGEN
INDUSTRY
DEVELOPMENT
PLAN

VICTORIA
State
Government



**Victoria is creating the foundations,
connecting the sector and leading
the way to be at the forefront of
emerging hydrogen technologies**

**Connected
transport network**



Victoria's connected transport network enables the potential for hydrogen integrated, multi-mode transport

**Highly-skilled
workforce**

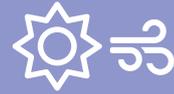


Victoria's highly-skilled workforce has region-leading capabilities and experience in gas systems





Renewable energy sources



Victoria is well resourced with abundant renewable energy



Extensive gas network



Victoria has the most extensive gas mains network in Australia



World-class education institutions



State-of-the-art education institutions, internationally engaged academic staff, world-leading research infrastructure and outstanding graduate outcomes

**Victoria is primed to take
advantage of the rapidly emerging
renewable hydrogen sector**



MINISTER'S FOREWORD

The Hon. Lily D'Ambrosio MP

Minister for Energy, Environment and Climate Change
Minister for Solar Homes



Working together across Victoria, we can accelerate decarbonisation, promote economic recovery and establish a thriving renewable hydrogen industry.

A renewable hydrogen economy can activate options for decarbonising our gas, freight, transport and industrial sectors, supporting more renewable energy in our electricity system, and taking our renewable energy to the rest of the world.

Up to 7,600 jobs are forecast to be generated nationally through emerging hydrogen opportunities, and hydrogen could add around \$11 billion each year to the national economy by 2050.¹ Victoria needs clear policies to ensure we can capitalise on this economic opportunity.

The Victorian Renewable Hydrogen Industry Development Plan sets out a blueprint for how the Victorian Government supports the growth of this emerging high potential sector.

We have a vision for renewable hydrogen to be a part of our economy and the transition to a net zero emission future

The emergence of a renewable hydrogen industry is ideally timed. Renewable hydrogen could play a critical role in reshaping Victoria's economy as it rebuilds following the COVID-19 pandemic.

The Victorian Government is fast-tracking the next generation of renewable energy, with \$108 million to unlock the next wave of cleaner, more reliable power, which could create thousands of jobs. As part of this fund the Victorian Government has committed \$10 million to accelerate Victoria's hydrogen industry. Victoria is also leading significant research through the Australian Hydrogen Centre (AHC); working with National Energy Resources Australia (NERA) to support the development of Regional Hydrogen Technology Clusters and partnering with hydrogen leaders across the sector.

Renewable hydrogen technology could also position Victoria to capitalise on our vast energy resources, provide low cost energy options in the long term and create opportunities for new jobs and economic growth.

Much of this work is already underway. The Renewable Hydrogen Industry Development Plan focuses and aligns current work, while highlighting new areas of opportunity to ensure Victoria can nurture this emerging sector. This plan complements significant investments and the Victorian Government's commitment to the Latrobe Valley Hydrogen Energy Supply Chain (HESC) and CarbonNet projects. However, this Plan is focused on opportunities in renewable hydrogen.

This Plan articulates our understanding of the benefits and opportunities for Victoria and how we can leverage our advantages to activate

market opportunities. We have based our approach for establishing a hydrogen economy around clear focus areas coupled with well-designed outcomes that outline our way forward.

This Plan complements the National Hydrogen Strategy while taking into account Victoria's ambitious renewable energy and emissions reductions targets. We are establishing the foundation for growing a renewable hydrogen economy in Victoria, connecting demand with use, and demonstrating leadership through our actions.

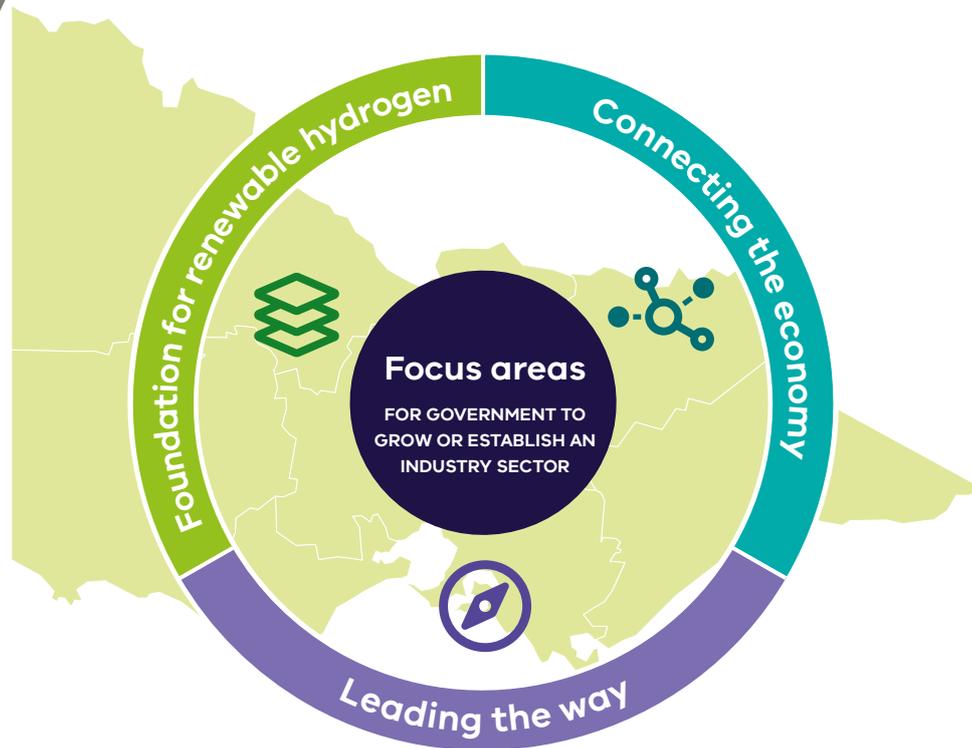
This is a call to action – we have a vision for renewable hydrogen to be a part of our economy and the transition to a net zero emission future.

A handwritten signature in blue ink, appearing to read 'Lily D'Ambrosio', written in a cursive style.



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Introduction

The Victorian Government is embracing the opportunities that come with transforming our energy system, and renewable hydrogen could play a pivotal role in this transition.

The Renewable Hydrogen Industry Development Plan (this Plan) sets out a blueprint for how the Victorian Government will lead and support a suite of outcomes to drive the development of a renewable hydrogen sector.

Although hydrogen from renewable energy is the only type of hydrogen production within the scope of this Plan, its development has been informed by and aligns with the policies, projects and initiatives which support other forms of hydrogen production in Victoria.

The focus areas for government are set out in this Plan and set the pathway to establishing a thriving renewable hydrogen industry that will:

- Create long-term jobs through new career pathways and skills clusters.
- Enable the export of renewable energy.
- Drive innovation.
- Build our skills and capacity in renewable hydrogen.
- Reduce greenhouse gas emissions across our industrial, energy and transport sectors.



What this Industry Development Plan will do

This Renewable Hydrogen Industry Development Plan sets out how the Victorian Government is laying the foundations for an emerging Victorian renewable hydrogen industry, connecting our economy to renewable hydrogen opportunities that bring new jobs and investment, spur economic growth and innovation in new energy technologies, and drive forward our clean energy transition.

Opportunities are emerging to recast our economy, introducing and accelerating greener ways to travel, use energy to heat our homes and manufacture goods using hydrogen and renewable energy.

Hydrogen can be produced a number of ways, and there are exciting projects underway investigating a range of technologies. This plan recognises the significant potential of hydrogen for our state, and has a focus on production of hydrogen using renewable energy.

Our economy can recover from the impacts of COVID-19 through investment in renewable energy projects and emerging technologies, including hydrogen.

This Plan takes a principles-based approach to establishing a new renewable hydrogen sector. The three focus areas of this document set out 18 outcomes, with a planned review period in 2025 to align with the setting of the next five yearly emissions reduction pledges. Each outcome is complemented by potential mechanisms that could be used to achieve them, spanning both public and private sector activities.

This Plan has been developed with consideration of the broader strategic context, including alignment with the National Hydrogen Strategy and a vision for net zero emissions by 2050.

Stakeholder consultation

The Victorian Government held extensive stakeholder consultations to inform development of the Plan, ensuring a broad range of expertise and perspective is represented in the document.

COMPLETED

Request for industry submissions ✓

Discussion paper ✓

Stakeholder workshops ✓

NOW

Industry development plan

NEXT STEPS

Future investment programs

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CONSULTATION

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KEY OPPORTUNITIES IDENTIFIED

Request for industry submissions
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Understand the market's gaps and strengths through project proposals

- Transport
- Power systems
- Gas pipelines
- Education
- Cross-sectoral

Greatest technology maturity projects in power systems and transport

High potential projects in gas pipelines, transport and power systems

Discussion paper
RESPONSES **101**

Understand the policy opportunities and challenges for Victoria and its regions

Workforce training and education

Community awareness and acceptance

Extensive gas distribution network

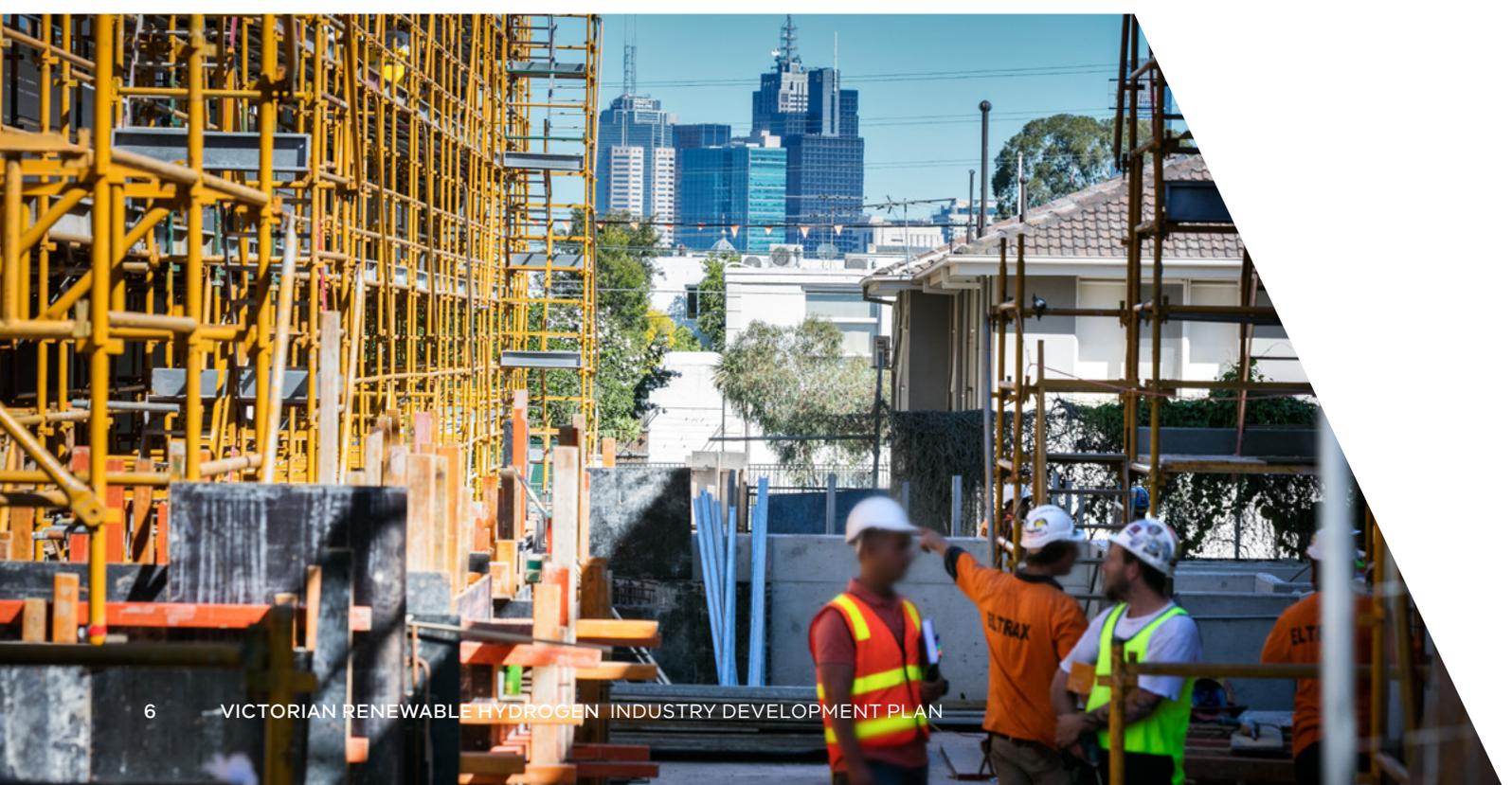
Coordinated approach between industry and government

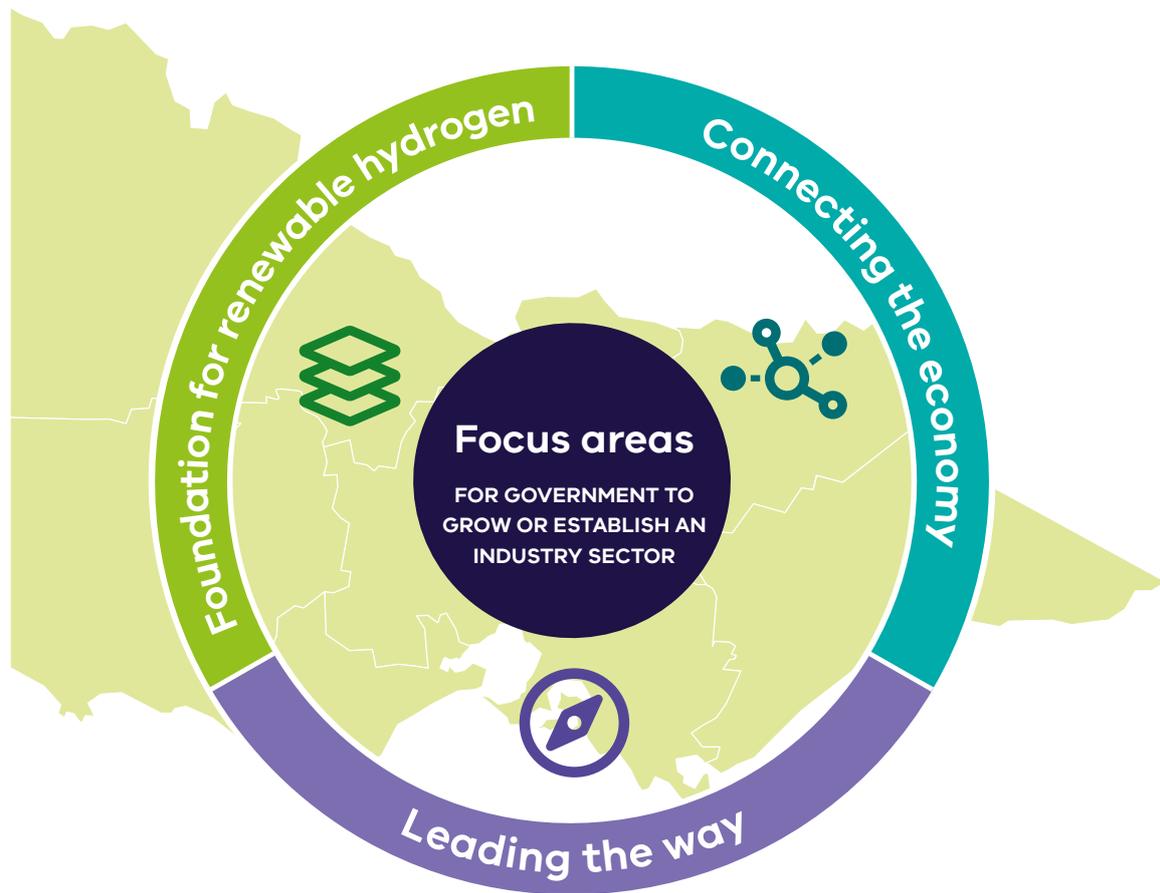
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Electricity infrastructure

Wind and solar resources

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How this Industry Development Plan has been shaped

This Plan has not been developed in isolation. Engaging with key players, recognising market opportunities and leveraging national policy have inputted to the shaping of this Plan.

Hydrogen is a versatile energy carrier that can be produced from a variety of sources, including renewable energy, coal and gas. While hydrogen produced from renewable energy is the focus of this Plan, the Plan has been informed by and aligns with policies and initiatives that also support other forms of hydrogen production in Victoria.

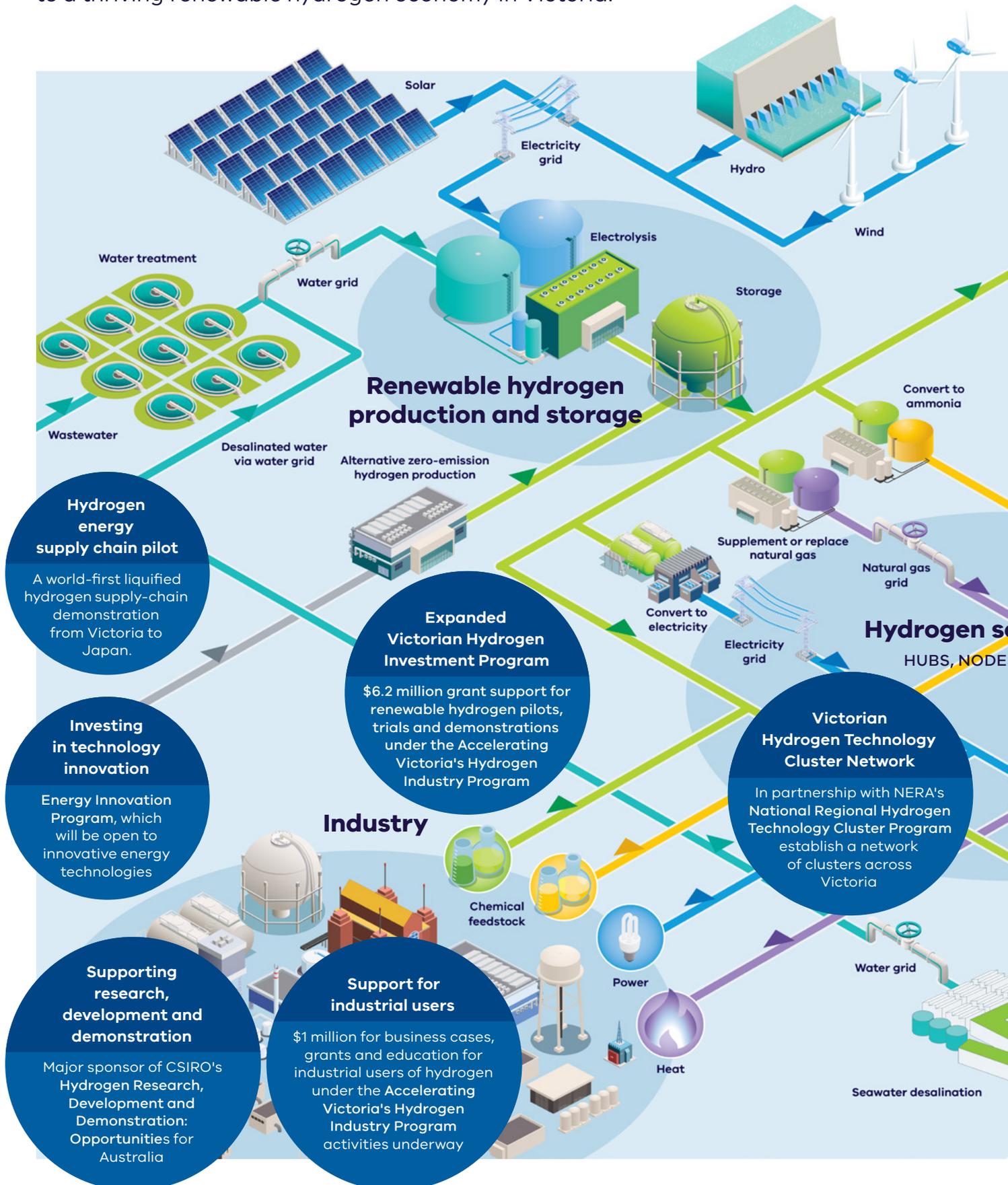
For Victoria, it is the development of a shared value chain across different hydrogen production pathways that advantages our state in developing a renewable hydrogen sector.

Renewable hydrogen as a technology and as an environmental and economic opportunity touches on many parts of our society and a range of industries.

Clear and open dialogue between and across government, industry, communities, research and education is needed to ensure critical decisions are well-informed, evidence-based and fit-for-purpose. The Plan has been informed by each of these stakeholder groups and in alignment with the broader hydrogen policy landscape.

Our hydrogen economy

We are creating the foundations, connecting the economy and leading the way to a thriving renewable hydrogen economy in Victoria.





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Section 1

Our hydrogen economy

Hydrogen is a versatile energy carrier that has the potential to touch on all parts of our economy and energy systems. It can generate positive outcomes for communities through decarbonisation and environmental benefits, as well as bring new jobs and career pathways for Victorians.

The hydrogen economy is interconnected, and Victoria has a role to play in the global hydrogen story. The Victorian Government is working to ensure we are at the forefront of hydrogen development opportunities to decarbonise our economy and see new investment and jobs in this emerging technology.



What is renewable hydrogen?

Renewable hydrogen is a zero emissions and multipurpose energy carrier that can be used as an alternative fuel source across Victoria's industrial and transport sectors, as well as in Victorian households and businesses.

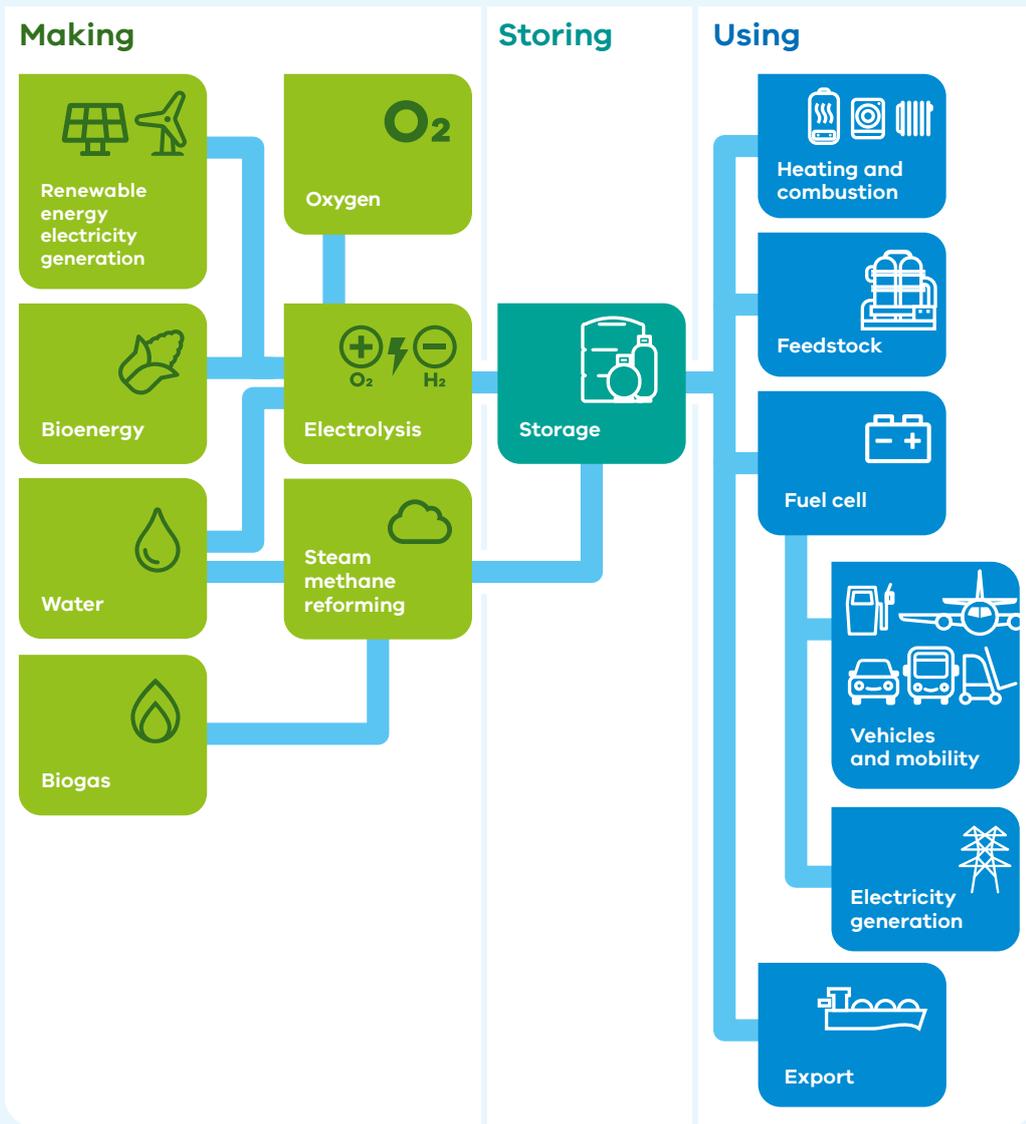
Electrolysis is the process of using electricity to split water into hydrogen and oxygen molecules, using an electrolyser. When renewable energy is used for electrolysis, the hydrogen produced is known as renewable hydrogen. There are other ways to produce renewable hydrogen than electrolysis, for example, using biomethane and bioenergy.

In this document electrolysis is the focus as the most common way to produce renewable hydrogen, but it is important to recognise other zero emissions production methods for hydrogen are available.

Producing hydrogen from renewable sources is not a new idea. Hydrogen as a fuel source was first developed over two centuries ago, and electrolysis technology emerged at a similar time.² As renewable energy becomes more widely available and affordable, production of renewable hydrogen becomes more attractive.

Interest in hydrogen's role as an energy carrier has rapidly increased in recent years because of its extensive application as a zero emissions fuel. Renewable hydrogen can be safely blended with or replace natural gas in our pipelines, used as a form of long-term electricity storage, in industries that can use hydrogen for feedstock, and to power zero emissions vehicles including trains, buses and cars.³

Renewable hydrogen can be an input to other energy carriers, like green ammonia. Hydrogen produced with electrolysis also has oxygen as a by product, and this can be used in many ways, including to treat water at water treatment facilities.

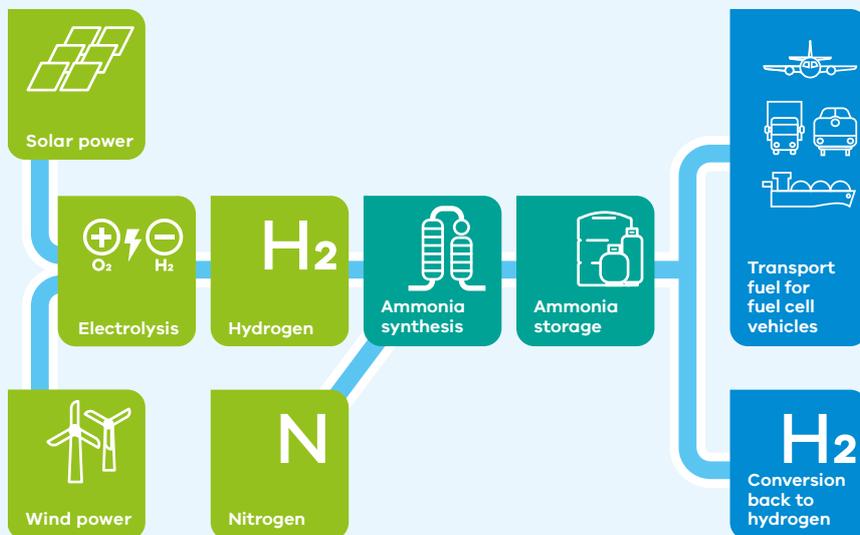




Ballarat Energy Storage System, Victoria Courtesy Spotless Downer

What is green ammonia?

Green ammonia is an emerging sustainable fuel source which is carbon neutral and energy efficient. Currently, ammonia is produced from the conversion of natural gas, coal or liquified petroleum gas and is used in water purification, fertilizer, and as a feedstock in many different industrial applications. Green ammonia is produced by combining hydrogen, produced from electrolysis, and nitrogen from air, in a thermochemical reaction. Green ammonia has potential to be used as hydrogen carrier fuel, as a fuel for transport, or for electricity production.



The national hydrogen agenda

The economic and environmental potential of hydrogen has been recognised not only in Victoria, but also nationally and internationally.

Victoria has played an active role in shaping the direction for clean hydrogen policies through the development of the National Hydrogen Strategy. The National Hydrogen Strategy is the overarching framework to provide focus and coordination of activities led by the Commonwealth, states and territories to deliver optimal outcomes for Australia and meet the vision of being a major global hydrogen player by 2030.

The Victorian Government is working collaboratively and in partnership with industry across multiple states to develop hydrogen demonstrations to progress local use of the technology. The Australian Hydrogen Centre, supported by the Victorian Government, South Australian Government, AusNet Services, Australian Gas Infrastructure Group, and others, is the first of Victoria's collaborations to explore injecting hydrogen into the gas network.

This is an important step toward decarbonising our natural gas supply and an enabler of zero emissions household and business, and industrial, heating and cooking.

Victoria, along with the rest of Australia, has an opportunity to become a significant exporter of hydrogen. The Victorian Government is already demonstrating the world's first liquified supply chain in cooperation with the Japanese Government through the Hydrogen Energy Supply Chain (HESC) pilot project, jointly funded with the Commonwealth Government. The supply chain pilot project will provide Victoria with first mover advantages in hydrogen supply chain development, and if commercialised, could provide shared infrastructure and skills for the renewable hydrogen industry to develop.

H₂ under \$2

The national stretch goal for hydrogen price

The Commonwealth Government has set an aspirational economic goal of producing hydrogen under \$2 per kilogram – or "H₂ under \$2".

That is the price point at which hydrogen will be competitive with alternatives in large-scale deployment across our energy system. The purpose of this goal is to enable the Commonwealth Government to track how hydrogen is progressing on its cost curve.



The National Hydrogen Strategy aims to lay the foundation for Australia to capture the hydrogen opportunity and become a leading player in a growing global market

National Hydrogen Strategy, 2019

Vision for renewable hydrogen in Victoria

Our vision for Victoria is to develop a thriving renewable hydrogen economy by creating the foundation, connecting the economy and leading the way. The renewable hydrogen economy will be underpinned by a safe, innovative and growing hydrogen technologies sector with both local supply and demand, and growing export linkages. This will position us to reach our legislated net zero emissions targets by 2050.

Positioning Victoria

The Victorian Government is committed to maximising our opportunities from being adaptive and resilient to climate change and transitioning to a net zero emissions economy. We are uniquely placed to use our extensive natural resources, skills and capabilities to reduce emissions and create economic advantages for the state.

Renewable hydrogen is a rapidly advancing technology with huge potential for market demand, both in Victoria and as an export nationally and internationally. This opportunity is particularly valuable as economies around the world recover and reposition in the wake of COVID-19.

In the near term, project activity has already commenced establishing pilots and demonstration projects. Projects often touch on multiple value streams and parts of the hydrogen supply chain, establishing localised hubs and nodes.

The next stage of development will see a scaling-up of hubs and nodes as the hydrogen sector grows and becomes more connected. Sector coupling opportunities, linking together a range of energy consuming sectors such as transport and industry to the electricity sector through hydrogen, will become stronger and connectivity between regional hubs will emerge.

In the medium to long term, a thriving, interconnected hydrogen economy will emerge. Regional activity centres will become interconnected across Victoria and links across the supply chain will be strengthened, including exports. Hydrogen opportunities across the state will be linked through market connectivity and a fully integrated supply chain, as well as established education opportunities and clear career pathways.



Establishing renewable hydrogen hubs and nodes



Scaling and sector coupling



Hydrogen economy



Victoria has all the right elements for establishing a renewable hydrogen economy

Loddon Mallee



The Loddon Mallee Region offers some of Victoria's strongest solar energy potential. The region has an intermodal freight network connecting major state and interstate freight corridors. The high concentration of heavy vehicles and heavy vehicle companies in the region presents an opportunity for hydrogen freight vehicles and fuelling.

There are two Renewable Energy Zones in the Loddon Mallee Region – Murray River and Central North Victoria. The region offers Victoria's best quality solar resources with established, large-scale solar photovoltaic projects located near Mildura, Swan Hill and Kerang.

Grampians

The Grampians Region offers several advantages to establishing a local hydrogen sector, including hosting the Western Victoria Renewable Energy Zone. It contains the primary trucking route between Melbourne and Adelaide (South Australia), with an intermodal freight terminal conveniently located between the two state capitals. The region has excellent wind resources, many existing wind farms, several solar farms and a natural gas pipeline to Horsham. The manufacturing and education hub of Ballarat provides a ready market for hydrogen consumption and skilled workers, as well as potential sites for hydrogen production about an hour away from Melbourne's western suburbs.

Barwon South West

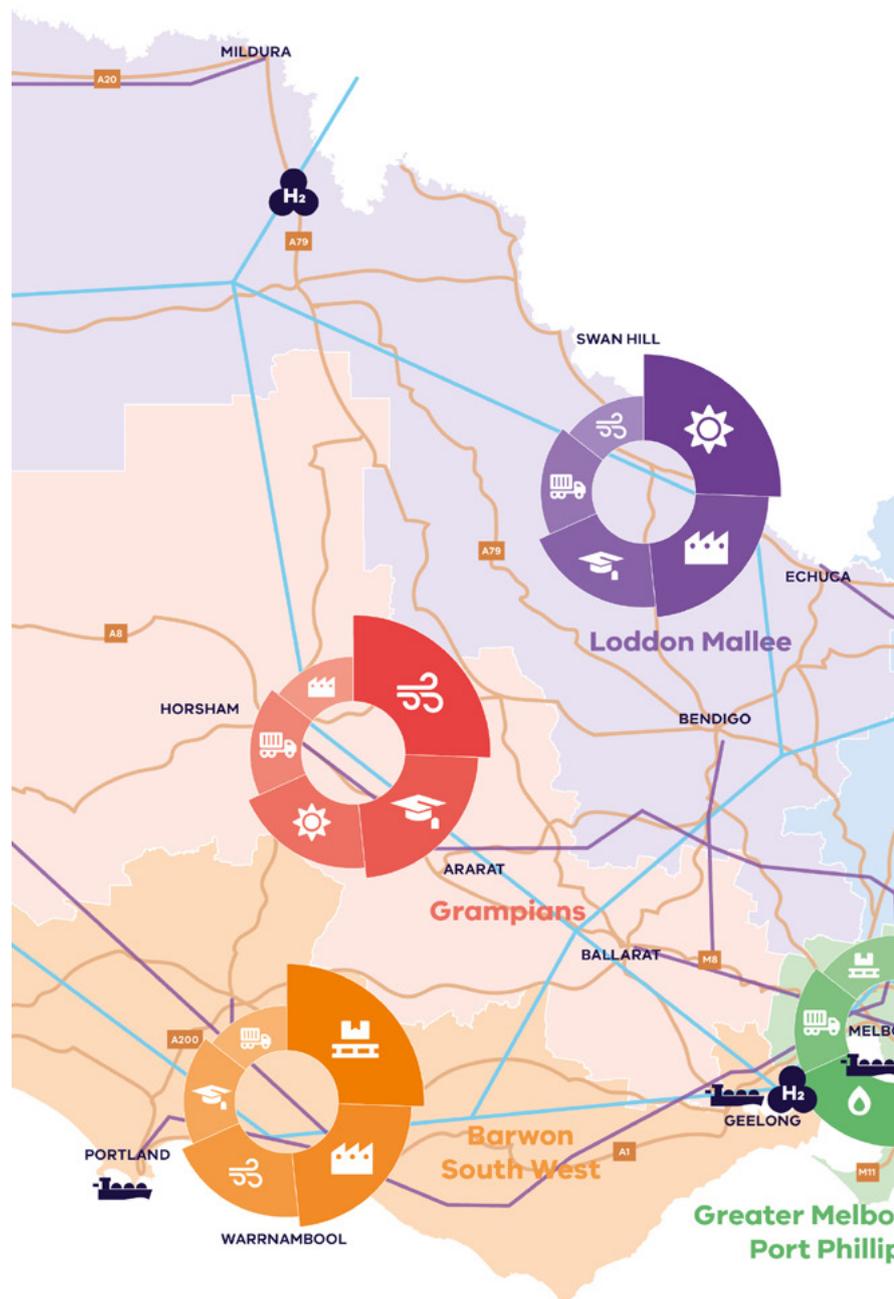


The Barwon South West Region hosts Victoria's largest regional town, Geelong, which is a hub of industry and manufacturing, including refineries. Geelong and other regional towns such as Warrnambool and Portland are also agricultural hubs. Portland and Geelong offer deepwater ports.

The region contains the South West Renewable Energy Zone, has more than ten active wind farms and several more approved or under construction. The Hycel Research Hydrogen Transition Centre is already operational in Warrnambool.

Greater Melbourne/Port Phillip

The Greater Melbourne Region is home to more than 70% of Victoria's population. Melbourne's higher education and research facilities are ranked among the world's best. The region offers industrial parks and technology innovation precincts coupled with a concentrated population of skilled workers.



Hume

The Hume region has three of Australia's most significant freight corridors running through it, including that of Melbourne to Sydney, Melbourne to Brisbane (via Shepparton) and Wodonga to Adelaide.

The region has excellent solar resources and offers close proximity to high voltage transmission lines. This is driving considerable interest in the area for solar farm development.

There are currently several operational solar farms, approved applications and a growing number under consideration.

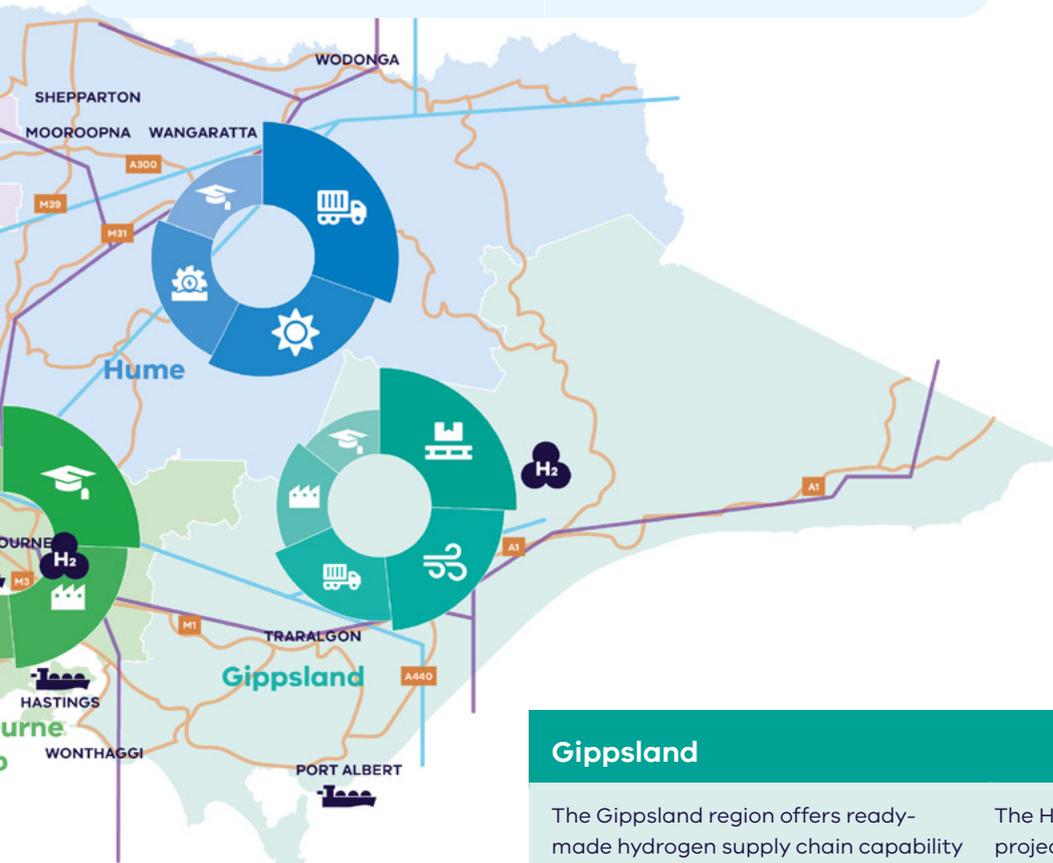
The region generates large amounts of hydroelectricity and is recognised for providing significant opportunity for pumped hydro energy storage.

Hume also has supportive training facilities for renewable energy industries, including universities and TAFEs.

KEY

-  Solar resource
-  Wind resource
-  Hydro electricity
-  Supply chain
-  Industrial area
-  Deep water port
-  Education
-  Hydrogen project
-  Initial Hydrogen Technology Cluster
-  Freight route
-  Gas network
-  Electricity network

SCALE



Gippsland



The Gippsland region offers ready-made hydrogen supply chain capability through use of the NEM grid and gas pipeline infrastructure. A local hydrogen sector would complement other emerging energy initiatives in the area including biomass and marine technologies.

Within the region, the Latrobe Valley is an established industrial energy hub with strong technical skills and trades.

Promoting advanced capability for the hydrogen market is Gippsland Hi-Tech region.

The Hydrogen Energy Supply Chain pilot project has its hydrogen production site in the Latrobe Valley which if commercialised, could provide shared infrastructure and skills for the renewable hydrogen industry to develop.

The Marinus Link will bolster regional energy reserves with up to 1500kw additional capacity. The region offers opportunities to utilise alternative water sources for renewable hydrogen production.

Gippsland is in close proximity to coastal ports, which may facilitate exports.



Significant hydrogen projects are already underway in the region, including CSIRO's Centre for Hybrid Energy Systems (CHES) laboratory, Swinburne University and CSIRO's Victorian Hydrogen Hub, Toyota Australia's Hydrogen Centre in Altona, and the Hydrogen Energy Supply Chain pilot project facilities at the Port of Hastings.



Renewable energy resources and enabling infrastructure

In response to global climate challenges, the Victorian Government has increased the Victorian Renewable Energy Target (VRET) to 50 per cent by 2030, highlighting our commitment to leadership in renewable energy, and providing greater renewable energy support for a renewable hydrogen industry.

The more renewable energy we generate, the greater potential to produce renewable hydrogen. In 2019, Victoria generated 10,811 gigawatt hours (GWh) of renewable electricity or 22.5 per cent of Victoria's total electricity generation.

Victoria has world-class solar and wind resources, and an established renewable energy sector. Victoria has the best offshore wind potential in Australia and amongst the best in the world.

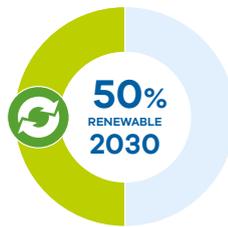
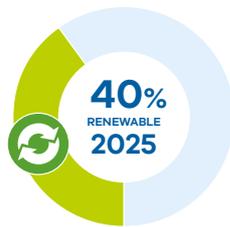
Equally, the advances in renewable energy infrastructure spurred by increased generation will position Victoria to meet increasing production demands for renewable hydrogen.

We have several new transmission infrastructure projects designed to facilitate the connection of solar and wind farms to the grid.

The Victorian Government has facilitated the Australian Energy Market Operator's (AEMO) procurement of a 300 megawatt (MW) battery, to be installed at the Moorabool Terminal Station, near Geelong. The 'Victorian Big Battery' will operate as a virtual transmission line between November and March each year, and participate in the energy markets throughout the year. The additional capacity will lower electricity prices for all Victorians and deliver significant net benefits to our state.

Victoria's renewable energy zones (REZs) will also coordinate further transmission and generation infrastructure to connect our renewable energy resources to the grid.⁴

Net zero greenhouse gas emissions by 2050 Victoria's renewable energy targets



Integration with water

Although water requirements are projected to contribute less than two per cent to the cost of hydrogen production via electrolysis,² access to sustainable and appropriate water supplies will play a part in determining the location of hydrogen production facilities. Victoria has strong alternative water sources, including water recycling and wastewater resources across the state.

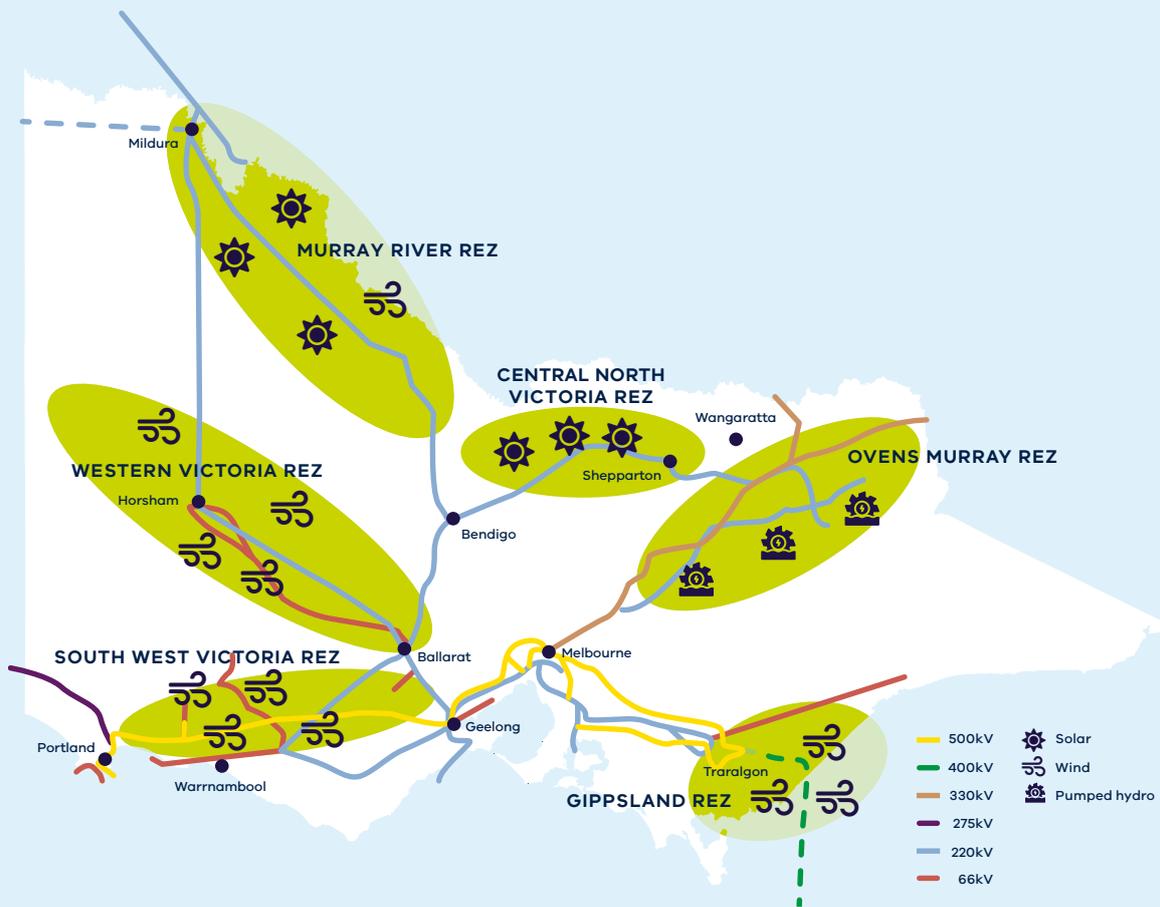


Extensive gas network

Victoria has the most extensive gas main network in Australia and uses a significant amount of natural gas. Renewable hydrogen could become a low-carbon substitute for natural gas, either through gas blending or complete replacement in the long term.

Extensive gas pipelines provide a major advantage for establishing a renewable hydrogen fuel industry. The Victorian transmission system extends over 2,000km covering Melbourne and Central Victoria,⁵ with another 1,280km of pipelines reaching regional Victoria.^{6,7} Our gas distribution pipelines supply gas to 80 per cent of Victorian households.⁸ Victoria's gas pipelines, coupled with the Gas Mains Renewal Project – which converts distribution pipes from steel to polyethylene⁹ – equips us to distribute hydrogen gas around the state.

Renewable energy zones



Renewable Energy Zones. Source: adapted from AEMO, 2019

Australian Energy Market Operator (AEMO) published an Integrated System Plan (ISP) for the National Electricity Market (NEM). The report presented modelling to forecast the transmission system requirements for the NEM over the next 20 years, identifying transmission investments necessary to meet long-term needs.

As part of the plan, dozens of Renewable Energy Zones (REZ) were identified across the NEM. REZs feature existing transmission infrastructure and high-quality renewable energy resources which could be harnessed as a source of electricity to generate hydrogen.

Six of these REZs are located in Victoria including Ovens Murray, Murray River, Western Victoria, South West Victoria, Gippsland and Central North Victoria.

The ISP recognises that hydrogen has the potential to meet some of Australia's energy needs as it becomes more economically competitive with other fuels, and highlights Australia's potential to be a large exporter of hydrogen.



Supporting reliability and security of energy supply

Victoria's electricity system encompasses electricity generation, transmission and distribution infrastructure used to produce, transmit and distribute electricity to end-use customers. The system includes several interconnected networks, as well as embedded and remote power systems.

Renewable hydrogen production sites that are located close to significant renewable generation facilities have the potential to extract value by avoiding network constraints that might otherwise limit the generation of power from renewable sources.

In addition, they could vary their output to deliver wider system services such as grid stabilisation or frequency control.

Renewable hydrogen can also be used as a large-scale storage application solution to support Victoria's electricity generation, including solar and wind. Hydrogen is a flexible energy storage medium and has the highest energy density of any fuel, making it a viable option for holding and distributing energy to match grid power demand.

In the medium-term as technology costs continue to fall, more isolated communities may present opportunities for smaller-scale developments incorporating hydrogen production, storage and conversion of hydrogen back to power. When coupled with renewable generation, this technology could enable remote communities and isolated power grids to reduce their dependence on liquid-fuelled electricity generation.

As Victoria's renewable energy production continues to grow, excess renewable energy can be leveraged and stored as hydrogen, balancing renewable energy intermittency and supporting energy reliability and grid security.



Skilled workforce and world class education institutions

The potential for new jobs and economic development in regional areas can be achieved through all hydrogen production pathways. A renewable hydrogen industry is expected to generate 7,600 jobs in Australia,¹⁰ and more jobs could be found further along the hydrogen supply chain using hydrogen produced in a range of ways. By leveraging our existing skilled workforce, Victoria is well-positioned to establish a thriving local sector.

During a time of critical economic recovery and rebuilding following COVID-19, a hydrogen economy presents an opportunity to bring new jobs and investment to our state. It has the potential to generate jobs across the supply chain, from production, transport and end uses, to skills and training opportunities, advanced manufacturing and export.

Victoria's extensive gas distribution and transmission networks support a workforce with critical expertise and skills.¹¹ The industry has established expert communities, particularly in regional Victorian areas such as the Gippsland Basin area and the Latrobe Valley. Supporting our regional economies to apply skills to new sectors will be vital to successful economic recasting as we move beyond the constraints of COVID-19.

Victoria has access to renowned academic and research centres that position the state as a centre of hydrogen excellence. Eight universities have their central campus concentrated within metropolitan Melbourne,¹² five of which have dedicated energy research centres. The University of Melbourne,¹³ Monash University¹⁴ and Deakin University¹⁵ also have targeted hydrogen research centres that explore hydrogen production, transport, storage, and applications.

Further, Victoria is home to 12 TAFEs and four dual-sector universities, many of which provide free certificates and training for priority courses such as plumbing (including gas fitting) and engineering.¹⁶ Victoria has 28,000 licensed plumbers, of which 20,000 are gas fitters, indicating that our workforce has a strong foundation of capabilities to transition to working with hydrogen.¹⁷



Connected transport networks

Victoria has a well-established and thriving multi-modal transport network with major road and rail freight routes through to South Australia and New South Wales. The 150,000km of roads in Victoria transport 350 million tonnes of goods a year, which amounts to almost all goods in metropolitan Melbourne and 80 per cent of the goods in regional Victoria.¹⁸ Victoria’s extensive use of road freight ensures safety standards for transporting liquid fuels are well established¹⁹ and an experienced workforce has versatility to learn new skills and adapt to transport hydrogen.

Hydrogen has the potential to provide zero-emissions transport across road, rail, air and sea. Hydrogen fuel cell electric vehicles (FCEVs) are an emerging technology potentially well-suited to Victoria’s transport sector. With transport accounting for twenty percent of Victoria’s total emissions, the development and application of FCEVs could be crucial in minimising emissions in this difficult to abate sector of the economy.



Export-ready infrastructure

Our extensive renewable energy resources, history of trade and relations, established infrastructure, and experience with liquid fuel exports make Victoria an attractive exporter.

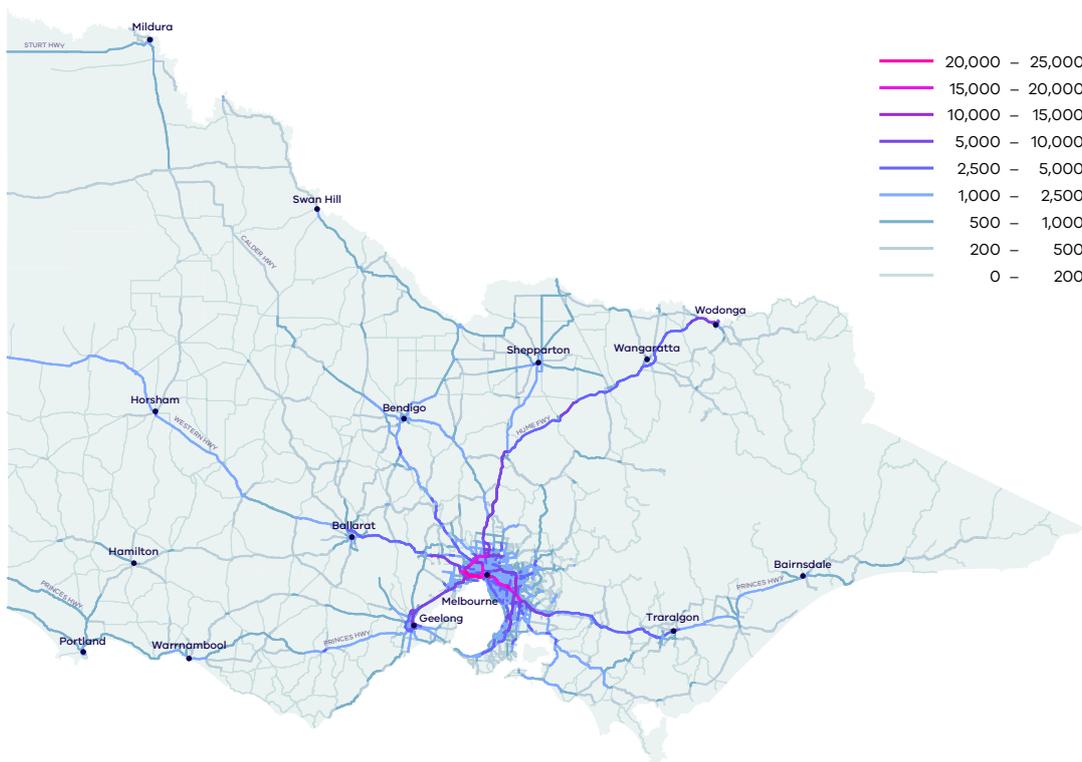
Victoria is well-positioned to export renewable hydrogen as liquid hydrogen, or using a hydrogen carrier like green ammonia, to nearby Asia-Pacific markets and beyond.

The potential demand for hydrogen and green ammonia in these regions is expected to increase exponentially as countries look to transition away from carbon-intensive energy sources in response to global climate challenges.

Pre-existing and suitable deep-water ports with liquid fuel infrastructure will be essential to growing our renewable hydrogen export market. Victoria has four major deep-water ports (Melbourne, Hastings, Geelong and Portland). Assessments²⁰ made during the development of the National Hydrogen Strategy identified that the Port of Melbourne and Port of Hastings in Victoria could be well-suited for renewable hydrogen export with minimal infrastructure developments required.²¹

Two way annual average daily traffic – trucks

DOT 2020 DATA DERIVED FROM TRAFFIC SURVEYS OR ESTIMATES



Strong interest in hydrogen from key global markets



Germany

The share of hydrogen in Europe's energy mix is projected to grow from currently less than 2 per cent to 13-14 per cent by 2050, according to the European Commission.

Germany and others are leading the way in the region with large investments in hydrogen technologies, including supporting international collaborations.

In 2020, Germany announced €9 billion for renewable hydrogen projects, including collaboration with Australia.²²

Japan

Japan has adopted a Basic Hydrogen Strategy, which highlights its commitment of becoming a 'Hydrogen Society' by 2030. The priority for the Japanese Government is for hydrogen to become a cheaper energy carrier, with future reduction costs targets to be the same level as conventional energy sources, such as Liquefied Natural Gas (LNG). Victoria's abundant solar and wind resources will drive down the cost of production and associated technologies of renewable hydrogen, which could help increase its cost-competitiveness and availability to fuel future export demand in Japan.

Victoria could help support expansion of hydrogen in Japan's transport sector, as seen with the recent Hydrogen Energy Supply Chain (HESC) Pilot Project.



Japan

Republic of Korea

Victoria

Republic of Korea

The Republic of Korea has developed a Hydrogen Economy Roadmap, which includes powering 30 per cent of its cities and towns with hydrogen by 2040. Additionally, the Republic of Korea has set ambitious hydrogen mobility targets to produce 6.2 million FCEVs and establish 1,200 hydrogen refilling stations by 2040.

As the Republic of Korea begins to decarbonise its economy, renewable hydrogen presents extensive market opportunities as the nation moves away from fossil fuel imports towards cleaner energy sources. Victoria is well-placed to capitalise on this growing hydrogen demand. Our manufacturing expertise, skilled and deployable workforce, as well as our research and development capabilities could help support the Republic of Korea's hydrogen aspirations in the future.



H2

Section 2

Industry development plan

To establish and accelerate a renewable hydrogen sector, the Victorian Government has identified 18 outcomes across three focus areas. Each of these outcomes has been crafted to indicate where we need to be in order to position Victoria with a thriving renewable hydrogen economy. It will also enable us to reach our legislated net zero emissions targets.

Activities underway that contribute to achieving each outcome are included, mapping out a pathway forward. Focus areas and outcomes have been identified through stakeholder consultation, analysis and assessment of the energy landscape more broadly.

Summary of focus areas and outcomes

 <p>FOCUS AREA 1 Foundation for renewable hydrogen</p>	1	Hydrogen research and development is accelerating innovation
	2	Safety standards and regulations for hydrogen are clear and fit for purpose
	3	Workforce skills and capabilities can pivot to an emerging hydrogen industry
	4	Victoria is a leading hydrogen higher education centre
	5	State-wide planning for hydrogen is clear and consistent to optimise land use and infrastructure developments
	6	Water is used sustainably in renewable hydrogen production
 <p>FOCUS AREA 2 Connecting the economy</p>	7	Gas networks have a pathway to renewable hydrogen
	8	Renewable hydrogen enables the export of renewable energy
	9	Victoria has advanced the integration of renewable hydrogen with the transport sector
	10	Hydrogen is playing a clear role in supporting a secure, reliable and resilient electricity system
	11	Industrial sector is primed for renewable hydrogen
	12	Hydrogen supply chain capitalises on Victoria's advanced manufacturing capabilities
 <p>FOCUS AREA 3 Leading the way</p>	13	Renewable hydrogen pilots, projects and demonstrations are enabled by government support
	14	The community understands and trusts hydrogen
	15	The Victorian Government uses its purchasing power to strengthen our renewable hydrogen sector
	16	The Victorian Government plays a central role in coordinating across government and industry
	17	Victoria is a renewable hydrogen leader as part of Australia's hydrogen powerhouse ambitions
	18	Victoria is promoted as a globally attractive trade and investment destination



FOCUS AREA 1

Foundation for renewable hydrogen

When setting the scene for sector growth, it is critical to ensure early on that the policy environment is fit for purpose. To do this, we need a clear foundation and direction to build up renewable hydrogen. This focus area sets out how we can lay the critical foundations and activate early enablers for a renewable hydrogen economy.

Creating a foundation for a hydrogen economy focuses on the cross-cutting issues that need to be addressed to enable us to make progress. This focus area covers critical aspects such as safety, regulations, educational capability, skills and workforce, planning, and research and development.

These fundamental activities can shape the competitiveness of Victoria's renewable hydrogen sector, creating favourable conditions for scalability and growth as the technology evolves.

Hydrogen research and development is accelerating innovation

Research and development are of fundamental importance to improve efficiency and economies of scale, thereby reducing costs of hydrogen technologies. It enables innovation across hydrogen production, storage, distribution and utilisation technologies.

Innovation driven by research and development helps to reduce capital and operating expenses; deliver breakthroughs in technologies; improve safety; minimise environmental impacts; inform community awareness and provide a clear direction on the demonstration and scale-up requirements for technologies to stimulate investment.²³

With a history of developing world-leading innovations, Victoria’s globally recognised universities and research institutes, along with Australia’s national science agency, the CSIRO, are leading the way in research and development today. Victoria’s innovation ecosystem underpins the state’s research-oriented industries. Through increased opportunities for collaborative coalitions of business and research, renewable hydrogen technologies are becoming more efficient and have a declining cost curve.

Activities underway

- Support pathways to market for emerging technologies through Victorian and Commonwealth research institutions and Cooperative Research Centres to develop and progress hydrogen research.
- Harness the next generation of researchers and optimise links between industry and universities. This includes major collaborative research initiatives underway across industry, government and the research sector through CSIRO’s Hydrogen Industry Mission.
- Explore the potential to establish industry test beds, innovation clusters and precincts focused on hydrogen-enabled advanced manufacturing.
- Expedite research and development in Victoria, including incubators and accelerators by working with Commonwealth agencies.

Researcher checking her data in lab next to a 2.5kW PEM hydrogen fuel cell, CSIRO Centre for Hybrid Energy Systems (CHES), Clayton, Victoria



CSIRO identifies opportunities for hydrogen in commercial aviation

CSIRO has partnered with Boeing to produce a report on how clean hydrogen-based technologies can make a significant contribution to emissions reduction in the aviation sector.

Key findings from 'Opportunities for hydrogen in commercial aviation' show that hydrogen can significantly reduce aviation emissions in the long-term and that growing hydrogen industry momentum can provide an opportunity for airport applications as early as 2025.

CASE STUDY

Hycel Technology Hub Deakin University

Deakin University has established Hycel Technology Hub, a hydrogen research centre for safety testing, manufacturing, and training in new hydrogen technologies. With a focus on hydrogen usage, Hycel is developing technologies and pathways in the areas of transport, gas pipelines, education and social licence; and tackling two sectors of the economy that are difficult to decarbonise: heavy transport and natural gas. Training a skilled workforce and creating jobs for the emerging hydrogen economy are at the core of Hycel.

Hycel's Establishment phase is supported by a \$2 million Commonwealth Government grant and involves developing research, safety, training, and regulatory foundations for hydrogen usage. If fully funded, the subsequent Technology phase will see the construction of a facility at Deakin University's Warrnambool campus in south-west Victoria. The facility will include Australia's first fuel cell assembly and testing pilot plant dedicated to manufacturing hydrogen solutions at scale.

With the support and guidance from partners PACCAR Australia (Kenworth), Warrnambool Bus Lines, Future Fuels CRC, South West TAFE, AusNet Services, Mondo Power, ACCIONA, Warrnambool City Council and International Advanced Research Centre for Powder Metallurgy and New Materials (India), Hycel is developing fuel cell technology for heavy vehicles, optimising refuelling networks for the transport sector, testing the safety and compatibility of gas infrastructure and developing hydrogen gas monitoring systems. Hycel is also supporting the development of training, social licence and safety standards pathways.

An External Advisory Board strengthens cross-sector linkages, comprising members from state and federal government, industry and research institutions.

Embedded in the local community, Hycel is supported by shires in the Great South Coast and South West TAFE, who together as a region have significant interest in hydrogen as prioritised in the Great South Coast Economic Futures strategy. This is a collaborative commitment to regional actions that contribute to state and national hydrogen goals.



Safety standards and regulations for hydrogen are clear and fit for purpose

Safely facilitating the introduction of hydrogen technologies and services is vital to establishing a functioning renewable hydrogen industry. Equally, a positive regulatory environment is one which supports commercial competition while balancing competing priorities.

Hydrogen safety will require a coordinated approach to harmonisation with international standards, development of local standards and regulations, and application and integration of these into practices across industry.

Regulations, standards and codes are already being developed by experts to be fit for purpose. Along with clear and consistent communication, education and training in these standards and regulations is key to safe operations across the hydrogen value chain.

Activities underway

- Support undertaking a review of legislative and regulatory frameworks for safety and standards at national and international levels.
- Establish international partnerships and collaboration with other regulatory authorities and standards-writing bodies to collaborate and share learnings regarding safety, standards and regulation design and implementation.
- Engage with Future Fuels Cooperative Research Centre (CRC) and hydrogen peak bodies to coordinate an approach to communicating with hydrogen users about safety and regulations.
- Support undertaking studies to contextualise hydrogen projects in the regulatory framework and planning approvals processes.
- Collaborate with trade unions and with the Australian Industry and Skills Committee through the Construction, Plumbing and Services Industry Reference Committee on developing training of gasfitters to work with hydrogen.

Developing a new hydrogen standard

Standards are documents that set out the specifications, procedures and guidelines for working with a material, technology or service, especially in relation to safety, quality, performance and efficiency. As we begin to produce and use hydrogen in different ways, our standards need to be updated and modernised.

Work on hydrogen standards is already underway. Standards Australia has constituted a new Technical Committee. The Technical Committee, ME-093 Hydrogen Technologies, will undertake work as the mirror committee to international standard ISO/TC197 Hydrogen Technologies. It will consider the technical properties of hydrogen and how it impacts safety. The standards developed for Australia through this work will either be identical international adoptions or modified to fit the Australian context. In addition, existing Australian standards for natural gas will be further developed to facilitate the blending of hydrogen.²⁴

Workforce skills and capabilities can pivot to an emerging hydrogen industry

As we establish a renewable hydrogen sector, our workforce will need to grow and develop new skills. We can help close the skills gap to meet projected sector needs by preparing workers with the skills and capabilities necessary for roles across the hydrogen value chain through formal training and applied learning. Investing in technical knowledge and capabilities of workers also has the advantage of creating benefits across the economy.

We are exploring ways to support skills development for the emerging hydrogen industry through education and training, including cross-sector knowledge, upskilling and re-skilling. Working with businesses and education and training institutions to get the right training and skills mix will set a strong foundation for a renewable hydrogen economy to grow in Victoria. Building skills can focus not just on hydrogen production, but also all forms of downstream use.

Activities underway

- Work with the Commonwealth and other jurisdictions to ensure a national coordinated approach to determine and meet the skills and training requirements for the emerging hydrogen sector.
- Collaborate with education institutions, trade unions, industry bodies, professional associations and the Clean Economy Skills and Jobs Taskforce to map skills clusters and career pathways for a renewable hydrogen workforce.
- Engage key skills and capabilities stakeholders, including the Clean Economy Jobs and Skills Taskforce, Skills Commissioner and Latrobe Valley Authority, to develop a strategic approach to developing workforce capabilities, particularly in regional areas to boost economic recovery.
- Build capacity in training delivery and the vocational education and training (VET) workforce through the Victorian Clean Economy Workforce Development Strategy and the Clean Economy Workforce Capacity Building Fund.

CASE STUDY

Plumbing Industry Climate Action Centre

Training associations and peak bodies are supporting the move to new energy technologies. The Plumbing Industry Climate Action Centre (PICAC) has trained and upskilled over 10,000 apprentices and working professionals in the plumbing, gas, fire protection and heating, ventilation, and air conditioning (HVAC) industries and is well positioned to upskill Victoria's gas fitters in the specific skills required to develop a renewable hydrogen industry.

PICAC's new facility at Narre Warren in Melbourne also houses the research centre and product testing laboratory of the International Association of Plumbing and Mechanical Officials (IAPMO) which will enable them to convert theoretical, laboratory and demonstration project research into practical real-world environments for the safe deployment of hydrogen.

PICAC's three world-class campuses stationed across Victoria – with their close industry collaborations – stand ready, willing, and able to house future hydrogen research and training and help position Victoria as world-leaders in hydrogen development.

Supporting a Clean Economy workforce

The new \$10 million Clean Economy workforce skills development initiative aligns with the development of workforce skills across the hydrogen value chain, it comprises:

- \$2 million for an independent Clean Economy Jobs and Skills Taskforce.
- \$2 million to develop a Clean Economy Workforce Development Strategy.
- \$6 million in grants as part of the Clean Economy Workforce Capacity Building Fund.

Victoria is a leading hydrogen higher education centre

The rapid establishment of a global hydrogen industry is driving demand for relevant courses and training. Victoria is positioned to become a leader in the hydrogen higher education, training and skills space.

Our education and training institutions offer state-of-the-art facilities, internationally engaged academic staff, access to world-leading research infrastructure and outstanding graduate outcomes.

Victoria’s university and TAFE campuses are located in and around Melbourne, as well as throughout regional Victoria, and are active globally, offering education, training and research solutions to governments, industry partners and students across the world.

This concentration of expertise has drawn leading international companies to establish major research and development operations in the state, offering unique opportunities for successful collaboration and partnership.

The Victorian Department of Education and Training’s Clean Economy Workforce Capacity Building Fund is building capacity in training delivery and in the vocational education and training (VET) workforce.

Activities underway

- Promote our expertise in research, training, skills and best practice for hydrogen to grow Victoria’s reputation as a leader in hydrogen education.
- Work with Victorian universities and TAFEs to position Victoria to be the preferred international destination for hydrogen education.
- Partner with industry bodies to develop the next generation of engineers, designers and technicians, and work closely with industry both in Australia and internationally.
- Support the establishment of the Victorian Hydrogen Hub (VH2), working with Swinburne University and CSIRO through \$10 million funding from the Victorian Higher Education State Investment Fund.

CASE STUDY

Melbourne Energy Institute

The University of Melbourne’s Hydrogen and Clean Fuels Program studies the electrolytic production of hydrogen, as well as the distribution and use of hydrogen in the energy system. With Caterpillar, the Melbourne Energy Institute is undertaking research on advanced hydrogen fuelled engine systems for zero emission power generation and transport. The Program is also working on the safety and economics of hydrogen distribution and export with local industry and government, and the export of liquid hydrogen to Japan.²⁵



State-wide planning for hydrogen is clear and consistent to optimise land use and infrastructure developments

Strategic partnership with project proponents, landowners, development and planning authorities and the community is central to clear and coherent planning. Local government, state government and regulatory bodies all have a role to play in facilitating the implementation of hydrogen projects at the planning and regulatory approvals stage.

To improve 'hydrogen-ready' capabilities it is critical to develop competency in and awareness of hydrogen across government. We will progress this through cross-government working groups. These groups can identify and address regulatory gaps and provide information to proponents of hydrogen projects to ensure compliance with existing requirements. The groups include emergency services personnel and workplace safety, environmental, planning and technical regulation authorities involved in the permitting of hydrogen facilities.

Activities underway

- Ensure a coordinated and sustainable approach to resource planning across land and renewable energy use for renewable hydrogen, including within Renewable Energy Zones (REZs).
- Work across the sector to optimise current use and future development of Victoria's renewable energy resources for renewable hydrogen, including consultation with AEMO on its Integrated System Plan and Gas Statement of Opportunity, and local councils on planning and zoning.
- Review and define hydrogen within a modern planning framework that considers multiple end uses, including commercial and industrial applications, stationary energy including gas and electricity and modes of transport.



Water is used sustainably in renewable hydrogen production

Water is central to every community, powering our industries and economy, improving our quality of life, and nurturing our natural environment.

Sustainable management of our water resources requires coordinated planning across with our water users, including renewable hydrogen as an emerging industry which will consume water.

Although water is a relatively low-cost component of renewable hydrogen, it is a critical input to its production. Securing access to reliable and sustainable supplies of water will be one of several key considerations for locating hydrogen projects.

Activities underway

- Facilitate cross-sector collaboration to investigate the use of recycled or wastewater, stormwater, seawater and traditional sources of water for renewable hydrogen production, and understand the demands of renewable hydrogen production for Victoria’s water resources, including identifying appropriate locations for sustainable production.
- Collaborate with the water corporations, including through the Intelligent Water Network, to develop a long term, sustainable approach to integrating renewable hydrogen production into Victoria’s water management framework and inform stakeholders across the community.

CASE STUDY

Yarra Valley Water

Yarra Valley Water, one of Victoria’s 19 water corporations, is actively exploring a pilot project to produce hydrogen via electrolysis at the Aurora wastewater treatment plant in Wollert, north of Melbourne. Aurora already has access to onsite renewable energy generation from a waste to energy facility, as well as a reliable source of sustainable water from the treatment plant. Pure oxygen produced from the electrolysis would be utilised to assist a more energy efficient wastewater treatment process, while the hydrogen could be sold to re-fuel vehicles locally or blended into natural gas pipelines. A business case is under development, and learnings from this project could be shared with other Victorian water corporations.

Wastewater treatment



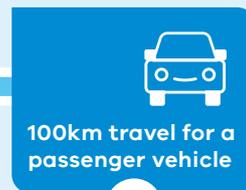
How much water does hydrogen production use?

According to the CSIRO, 9 litres of water could produce 1 kilogram of hydrogen through electrolysis.³³ Using these figures, to produce enough renewable hydrogen for a one-year supply to all of Victoria's gas network of a 10 per cent hydrogen blend requires 448 mega litres (ML) of water. This amount of water, 448ML, equates to less than half of Melbourne's average daily water consumption.³⁴

INPUTS



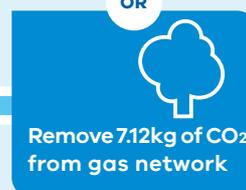
OUTPUTS



OR



OR







FOCUS AREA 2

Connecting the economy

This focus area aims to connect Victoria's advantages, building scale and linking emerging hydrogen hubs, nodes and clusters. As the renewable hydrogen sector develops, different components and regions in the economy need to converge into a coordinated industry. Connecting the economy, or sector coupling, includes maximising value in interactions between supply chain capabilities, gas and electricity networks, export functions, transport sector and industrial use.

Through connecting different parts of the economy, especially different energy sectors, we can enable partnerships and synergies between producers, distributors and users. Recent technological development and interest in the low carbon economy has highlighted the increasing links between sectors such as electricity, gas (natural gas and hydrogen) and opportunities for greater integration with end users, such as transport, industry and households.

Recent research suggests that scale-up will be the biggest driver of cost reduction, notably in the production and distribution of hydrogen and the manufacturing of system components.²⁶ Connecting the economy by linking workers to skills and training opportunities, developing networks across the supply chain, connecting producers with end-users and ensuring active engagement between research, education and industry can drive growth of the sector.

Gas networks have a pathway to renewable hydrogen

Victoria has over 31,000 km of gas mains distribution connecting around 2 million customers or over 80 per cent of the population – the most connections and largest distribution in Australia. Our gas network infrastructure is both extensive and efficient, providing a potential distribution pathway for hydrogen in substitution for natural gas, either as a blend or total replacement.

Renewable hydrogen has enormous potential to support decarbonisation of our gas networks through direct injection of hydrogen into the gas distribution network. In this way, the natural gas network can deliver hydrogen to domestic, commercial and industrial premises. Substituting natural gas with renewable hydrogen will support decarbonisation for residential, commercial and industrial users without requiring electrification of existing gas-based processes and infrastructure.

Victoria’s gas substitution roadmap will establish a strategic framework for the transition of gas to meet Victoria’s emission reduction targets through support for more efficient use of natural gas, reduced fugitive emissions, increased use of hydrogen and biogas and increased electrification of Victorian homes and businesses.

The Victorian Government is already supporting critical research to assess the viability of hydrogen blending in the gas networks, including technical and safety questions surrounding pipeline suitability and risk of embrittlement on pipelines, impacts on appliances and community awareness and social licence. These studies are expected to set out a practical pathway to implementation for hydrogen blends up to 10 per cent and 100 per cent.

Activities underway

- Develop a gas substitution roadmap to support gas efficiency, electrification, and increased use of hydrogen and biogas.
- Undertake feasibility studies to understand the technical requirements of renewable hydrogen as a natural gas substitute.
- Ensure households have access to information and resources for hydrogen-ready appliance switching.
- Investigate opportunities to increase the security and reliability of our natural gas systems using hydrogen, including through collaborating with gas distribution businesses and others in pilot demonstrations.
- Explore the potential for 100 per cent renewable hydrogen in the natural gas network.



What is gas blending?

Gas blending is the process of mixing gases to a specified and controlled concentration and blend. Natural gas currently used in our gas networks for heating and cooking generates greenhouse gas emissions. Blending renewable hydrogen, a zero emissions fuel, into the existing natural gas network could reduce greenhouse gas emissions and support a sustainable, reliable and cost-effective energy transition.

Current research suggests that hydrogen can be blended with natural gas up to a concentration of 10 per cent without the need for significant modifications to distribution pipelines or most household appliances. The injection and blending of renewable hydrogen with natural gas is a low-emissions alternative that could reduce the carbon intensity of the final gas product distributed to households and businesses. Hydrogen blending could also potentially increase renewable energy output by providing hydrogen storage and delivery pathways in the gas distribution networks, balancing renewable energy intermittency and supporting grid security.

CASE STUDY

Australian Hydrogen Centre gas blending feasibility study

The Australian Hydrogen Centre (AHC) was established and is backed by the Australian Renewable Energy Agency (ARENA), the Victorian and South Australian Governments, gas and energy infrastructure businesses. The AHC will assess the feasibility of blending renewable hydrogen into gas distribution networks in Victoria and South Australia, and also assess the feasibility of a transition to 100 per cent hydrogen networks. Feasibility studies will include:

- 10 per cent hydrogen blending into selected regional towns in Victoria and South Australia
- 10 per cent hydrogen blending into gas networks of Victoria and South Australia
- 100 per cent hydrogen networks for Victoria and South Australia

The results from its feasibility studies on injecting renewable hydrogen into the gas network for a Victorian town will be published in 2021.

The work of the AHC will establish a platform for other states to decarbonise their gas consumption by leveraging on the Victorian and South Australian feasibility studies and also raise community awareness on the use of hydrogen and how this technology may be deployed in the future.²⁷



Renewable hydrogen enables the export of renewable energy

Victoria has rich onshore and offshore wind and solar resources backed by ambitious legislated renewable energy targets. We can produce significant amounts of renewable energy that could be capitalised on to become a valuable export commodity while boosting the renewable energy supply to the state.

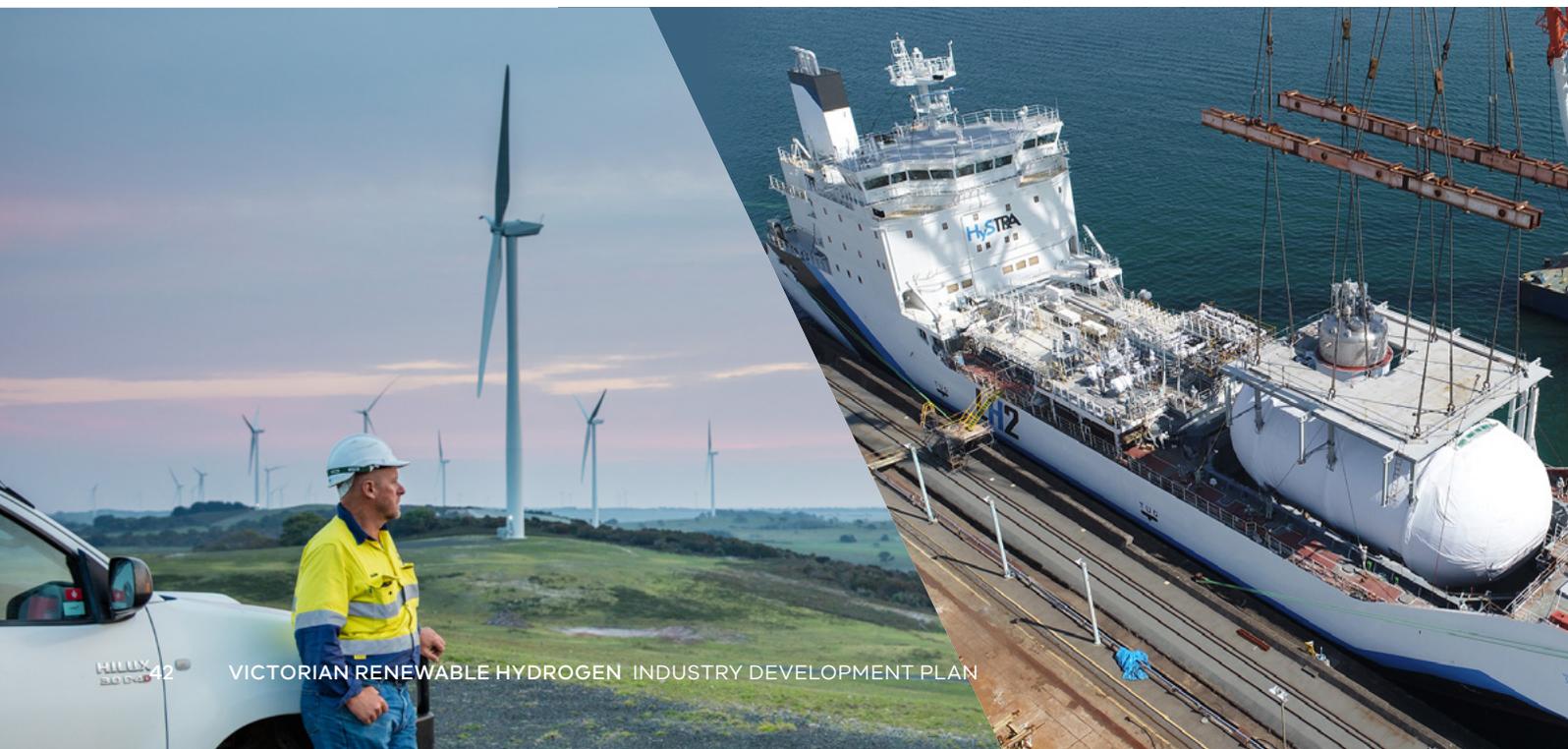
The emerging renewable hydrogen industry provides a significant opportunity for Australia to become a global leader in exporting renewable energy, replacing traditional fossil fuel exports over time. For large energy importers, renewable hydrogen represents an opportunity to import a CO₂-free form of energy to displace the importation of fossil fuels to meet environmental, economic and geopolitical needs and aims. The National Hydrogen Strategy is looking to position Australia as one of the top three exporters of hydrogen to Asian markets,²⁸ and Victorian-made hydrogen has potential to significantly contribute to this goal. Victoria's world class offshore-wind resources are ideally located close to potential renewable hydrogen export hubs.

Enabling the export of our renewable energy through hydrogen will further stimulate investment in renewable energy by enabling renewable energy operators to also trade in the gas and international energy markets – not just domestic electricity. This may also address capacity issues.

The lessons arising from the Hydrogen Energy Supply Chain (HESC) pilot project could also unlock development of an international hydrogen supply chain for Victoria. In particular, the hydrogen industry may be able to leverage the international supply chain developed through HESC.

Recognising the increasing profile of green ammonia and its links with renewable hydrogen, the Victorian Government is a government observer at the Green Ammonia Consortium (GAC). The GAC's mission is the development of a commercial CO₂-free ammonia value chain, toward a low carbon society. The GAC is based in Japan with an international membership base comprising businesses and industry, universities and governments.

Left: Bald Hills Wind Farm, Victoria. Right: credit: HESC Project Partners



Potential hydrogen export locations²⁹



Note: These locations were identified through a National Hydrogen Strategy study, and are a preliminary assessment.

Activities underway

- Collaborate with CSIRO's Team Australia Missions to create a hydrogen industry to generate a new clean energy export industry.
- Promote the potential to export Victoria's expansive renewable energy resources through hydrogen.
- Leverage Renewable Energy Zones (REZs) to maximise renewable energy and renewable hydrogen production potential.
- Develop state-wide expertise in transporting hydrogen across Victoria, Australia and as an international export.
- Monitor the Hydrogen Energy Supply Chain (HESC) pilot project to capture export potential.
- Assess potential of renewable hydrogen as an ammonia feedstock, working with the Green Ammonia Consortium.
- Participate in developing hydrogen certification schemes through the National Hydrogen Strategy working group.

CASE STUDY

Hydrogen certification

The emerging hydrogen industry presents an opportunity for Australia to become a leading exporter. Under action 4.16 of the National Hydrogen Strategy, Australia will seek to play a lead role in the design and development of an international guarantee of origin scheme. The Department of Industry, Science, Energy and Resources (DISER) is working to develop the Guarantee of Origins (GO) scheme for hydrogen (the scheme) in Australia. As far as practicable, the scheme will build on or harmonise with international certification schemes, verify and track aspects including production technology, carbon emissions associated with production (scope 1 and scope 2) and production location. Any subsequent expansion of the scheme may include water consumption and other factors.



Victoria has advanced the integration of renewable hydrogen with the transport sector

Transport is responsible for 20 per cent of Victoria’s greenhouse gas emissions.³⁰ Hydrogen fuel cell electric vehicles (FCEVs) are a zero-emissions mobility option to support decarbonisation of this sector. Hydrogen can be deployed across a broad transport spectrum from heavy vehicles, trains and ships to passenger and small vehicles, to industrial vehicles such as forklifts and as a future pathway for aviation.

FCEVs and battery electric vehicles have complementary rather than competing roles to play in the decarbonisation of transport. Hydrogen-fuelled heavy vehicles, including for freight and marine have advantages over battery electric vehicles in relation to being lighter in weight, able to travel longer distances and faster refuelling time.

A sustainable supply of renewable hydrogen and well-planned enabling infrastructure, including refuelling stations, will establish a viable hydrogen FCEV market in Victoria. This could be a path to economic growth and new jobs for Victorian businesses to manufacture both vehicles and supporting infrastructure, as well as increase opportunities from the associated supply chain and skilled workforce sector. Two FCEV passenger vehicles, the Toyota Mirai and Hyundai Nexo, have been introduced to the Australian market, and other FCEVs including forklifts and trucks are well established in the global market.

Fuel security is an increasing point of interest as our interconnected global supply chains can face risk of disruption. Creating a strong, stable and local supply of renewable hydrogen could help Victoria to become more resilient to potential fluctuations in supply of natural gas, petroleum or diesel, as hydrogen can substitute for these fuels in the transport and other sectors.

Activities underway

- Invest \$20 million in a statewide trial to investigate solutions to achieve a zero-emission bus fleet, including hydrogen buses.
- Consult with local industry and experts to develop an approach to hydrogen heavy transport and freight in Victoria, including optimal refuelling infrastructure.
- Explore fuel security potential of hydrogen as a liquid fuel.
- Release a Zero Emission Vehicle Roadmap setting out Victoria’s priorities for decarbonising the transport sector.





CASE STUDY

Toyota Australia's Hydrogen Centre

Toyota Australia, with funding assistance from the Australian Renewable Energy Agency (ARENA), has finished building the first stage of its \$7.4 million Hydrogen Centre. This educational facility is at the mobility company's former site of car manufacturing at Altona in Victoria's west.

As part of the Hydrogen Centre project, existing manufacturing infrastructure will be repurposed into Victoria's first integrated hydrogen site, and will include an electrolyser, commercial grade hydrogen refuelling station and an education centre promoting the opportunities that exist with the introduction of a hydrogen economy in Australia.

Targeting CO₂ emissions is a major goal of the global Toyota Environment Challenge 2050 and for the longer term, Toyota is committed to developing and promoting hydrogen as a viable fuel for zero-emission transport as well as playing a larger role in the broader energy economy.

CSIRO Hydrogen Technology Demonstration Facility and Refueller

CSIRO is currently developing a small scale hydrogen refuelling station at its Clayton facility as part of its priority to demonstrate emerging hydrogen technologies that target increased hydrogen demand and cost reduction. The refueller will be integrated into CSIRO's hydrogen production and storage research facilities and will be employed to stimulate hydrogen vehicle trial partnerships in Victoria.

Green ammonia could unlock zero emissions shipping

The marine sector is looking for pathways to emissions-free bunker fuel for shipping, and research indicates ammonia could be a solution. Ammonia can be safely and effectively applied as a marine fuel to reduce harmful emissions in the maritime industry, according to the Ammonia Energy Association. The first demonstration vessel was announced in January 2020, the Viking Energy, which will be operating on a 2 MW ammonia-powered fuel cell from 2024.

In March 2020, the Japanese Government announced a roadmap for zero emissions international shipping with an aim of commercial operation of a zero emissions ship by 2028. Increasing numbers of ammonia and hydrogen bunker fuel projects are moving to demonstration phases and momentum in the sector is increasing.

Hydrogen is playing a clear role in supporting a secure, reliable and resilient electricity system

Hydrogen creates a unique connection between the electricity and gas sectors, enabling energy to shift between hydrogen in gas or liquid form to energy storage, electricity generation and potentially back again. This characteristic of hydrogen presents opportunities to enhance the security, reliability and resilience of our electricity system.

Renewable hydrogen can be used as a large-scale electricity storage solution to support Victoria’s electricity system. Hydrogen can provide dispatchable generation to meet peak demand, provide flexible load in times of low demand and operate as a resource in ancillary services markets. Electrolysers and fuel cells can vary their output to deliver flexible supply and demand, for example generation and frequency control, to benefit consumers.

Hydrogen production sites located close to significant renewable generation facilities can help avoid network constraints and defer network investment. Hydrogen is also a flexible energy storage medium and has the highest energy density of any fuel, making it a viable option for holding and distributing energy to match grid power demand.

Activities underway

- Build on the work Victoria led under the National Hydrogen Strategy to investigate hydrogen’s capacity to both improve the integration of renewable energy into Victoria’s electricity grid and increase reliability.
- Actively explore opportunities to support off-grid, end of network and microgrid hydrogen trials, pilots and demonstrations.
- Through the gas substitution roadmap, understand the role of hydrogen in strengthening the relationship between the electricity and gas networks.

Ballarat Energy Storage System, Victoria Courtesy Spotless Downer



Industrial sector is primed for renewable hydrogen

As Victoria’s economy is reshaped following the events of COVID-19, manufacturing will remain an important and growing industry. There is an opportunity to use hydrogen to recast our manufacturing sector to be more modern, effective and environmentally sustainable.

Renewable hydrogen is an emissions-free alternative feedstock for existing industrial applications that are currently using hydrogen derived from fossil fuel as feedstock. Industrial users can also adopt hydrogen as a replacement for natural gas and other carbon-intensive fuel sources used in heating and manufacturing processes where those processes are compatible. Leveraging these opportunities allows industries to decarbonise manufacturing processes and at the same time retooling, upgrading infrastructure and reskilling workers.

Significant early opportunities exist for industrial users that currently use hydrogen as a feedstock to switch to renewable hydrogen. Renewable hydrogen can also be used in industrial processes in place of natural gas. Through this, Victoria can both support decarbonisation and begin to grow the scale of renewable hydrogen production.

Activities underway

- Allocate \$1 million for business cases, grants and education for industrial users of hydrogen under the Accelerate Victoria’s Hydrogen Industry Program.
- Work with industry associations to promote a refresh of our manufacturing base through hydrogen, upgrading infrastructure and re-skilling workers.
- Assist industry to connect to key local services and tools such as NERA’s Regional Hydrogen Technology Clusters and Victoria’s Hydrogen Technology Cluster Network.
- Work with industries to understand their needs and how hydrogen may be used, including switching from traditional hydrogen and natural gas, which are not carbon emissions free.
- Provide \$31 million in simultaneous grant funding to medium and large energy users for both capital works and energy demand management technologies, which may include fuel switching to renewable hydrogen, through the Business Recovery Energy Efficiency Fund (BREEF).



Hydrogen supply chain capitalises on Victoria’s advanced manufacturing capabilities

Globally, the nature of manufacturing is rapidly changing as it becomes increasingly characterised by complex connections across global value chains with final products often shaped by expertise, components and services from around the world. Victoria is placed to take advantage of this trend, and renewable hydrogen has the potential to support a strong advanced manufacturing industry.

Once hydrogen supply chains are in place, and as hydrogen generation from renewables at scale becomes cost effective, the role of renewable energy to supply hydrogen for export will increase. Partnerships, consortiums and collaborative engagements are likely to be key delivery mechanisms for renewable hydrogen products and services.

Building a well-connected supply chain network and at the same time boosting advanced manufacturing capabilities will deliver hydrogen infrastructure, componentry, products and services more efficiently and at a lower cost.

Activities underway

- Demonstrate Victoria’s hydrogen supply chain capabilities through a pilot project.
- Map the renewable hydrogen supply chain in Victoria.
- Establish a Victorian Hydrogen Technology Cluster Network and work with NERA to support the development of Regional Hydrogen Technology Clusters under NERA’s national program, which will support supply chain and advanced manufacturing development capabilities across the state.

CASE STUDY

National Energy Resources Australia hydrogen clusters

National Energy Resources Australia (NERA) is forming a network of industry-led hydrogen clusters around Australia.

The Regional Hydrogen Technology Clusters will facilitate collaboration and growth across the emerging hydrogen supply chain including start-ups, scale-ups and SMEs.

This initiative connects regions, forming a virtual national cluster that aims to establish a global identity and brand for Australian hydrogen technology and expertise. Once formed, clusters will develop, deploy and commercialise technologies to sustain a highly competitive hydrogen industry.

To support this, Victoria is establishing the **Victorian Hydrogen Technology Cluster Network**.

CASE STUDY

Building Victoria's energy supply chain capabilities

The Victorian Government is already testing the hydrogen supply chain in cooperation with Japanese multinational companies and the Japanese Government through the Hydrogen Energy Supply Chain (HESC) pilot program jointly funded with the Commonwealth Government.

The supply chain pilot will provide Victoria with first mover advantage in hydrogen supply chain development, providing Victoria with a unique advantage over other markets.





FOCUS AREA 3

Leading the way

The Victorian Government has set comprehensive targets to transition to renewable energy and navigate a path to net zero emissions. Renewable hydrogen may provide a powerful tool to meet these ambitions, while opening opportunities for new jobs and economic growth.

If Victoria is to attract and retain investment in renewable hydrogen projects, the Victorian Government must play a critical leadership role. We can achieve this by creating domestic demand and making sure the policy settings are right. Early, domestic-focused support will help us develop skills and capabilities that contribute to the scalability of the sector.

The Victorian Government can also support renewable hydrogen through direct action. This area focuses on investment to de-risk the technology, using the government's purchasing powers through procurement, supporting community awareness, and ensuring a coordinated approach that can position Victoria to succeed.

Renewable hydrogen pilots, projects and demonstrations are enabled by government support

Although electrolysis, fuel cells, and many hydrogen technologies are proven technologies, they have limited demonstrated commercial application especially within a Victorian context.

Government plays a critical role in supporting the commercialisation of emerging technologies, such as hydrogen. Targeted support to progress from pilot to commercial deployment of hydrogen technologies will help to de-risk the Victorian application of hydrogen and may open new market opportunities.

This Plan provides the blueprint to guide Victoria’s focus for growing a renewable hydrogen economy over the next five years, and what steps we take to support pre-commercial investment financially. The Victorian Government will also work closely with funding bodies, such as ARENA and the CEFC, to demonstrate commercial capabilities of hydrogen technologies.

Activities underway

- Provide \$6.2 million of grant support for hydrogen pilots, trials and demonstrations under the \$10 million Accelerating Victoria’s Hydrogen Industry Program. This program forms part of the new, broader \$108 million funding package to prepare Victoria for innovative and transformational renewable energy and hydrogen projects.
- Accelerate Victoria’s hydrogen industry through \$10 million for policy and industry development, research and grants as part of the broader \$108 million new funding package to prepare Victoria for innovative and transformational renewable energy and hydrogen projects.
- Use a partnership approach to facilitate Victorian-based renewable hydrogen projects, pilots and trials.
- Work with ARENA and CEFC to ensure investment continues to support new Victorian renewable hydrogen projects.
- Leverage and communicate the learnings from VHIP-supported projects.
- Partner with key players to develop feasibility studies for Victoria.

Funding support opportunities for hydrogen projects

Advancing Hydrogen Fund (CEFC)

The Clean Energy Finance Corporation has launched a \$300 million Advancing Hydrogen Fund, to support the growth of a clean, innovative, safe and competitive Australian hydrogen industry. Eligible projects can include projects aimed at advancing hydrogen production; developing export and domestic hydrogen supply chains, including hydrogen export industry infrastructure; establishing hydrogen hubs; and other projects that assist in building domestic demand for hydrogen.

Renewable Hydrogen Deployment Funding Round (ARENA)

The Renewable Hydrogen Deployment Funding Round by ARENA follows the release of the National Hydrogen Strategy and will fund \$70 million to large scale hydrogen production projects. The projects will focus on electrolysis using renewable energy and on facilitating a pathway to technical and commercial viability of renewable hydrogen in Australia.

The community understands and trusts hydrogen

Community support to operate new technologies is vital to the success and acceptance of these technologies in Victoria. This acceptance is only achieved by early, transparent community engagement.

Community confidence in the safety of hydrogen production processes has been deemed a critical success factor³¹ for the development of an emerging hydrogen industry. In 2018, research showed that the Australian community's understanding of hydrogen is low.³²

The Victorian Government will take a coordinated approach to building community understanding of hydrogen technologies and the environmental benefits of renewable hydrogen, while also working with communities to understand what they see as the opportunities and challenges for hydrogen.

Activities underway

- Ensure a coordinated approach across the Victorian Government in cooperation with key stakeholders to build hydrogen community awareness and education.
- Build community confidence and understanding through hydrogen technology demonstrations.
- Engage with potential early adopter communities to understand their ambitions for local benefits and community outcomes arising from hydrogen developments in their region.
- Support the work of the Australian Hydrogen Council to develop community standards and benefits sharing guidelines and use community engagement techniques to involve the community in the decision making and benefit sharing guidelines.

Developing community trust in hydrogen

The National Hydrogen Strategy Taskforce commissioned a report to inform understanding of community and stakeholder engagement. It was found that stakeholders valued transparency around the costs, benefits, opportunities, risks, and safety for hydrogen projects.

The need to co-exist with different sectors such as agriculture, the resources industry, and large-scale renewable energy projects was also raised as an important consideration. Other considerations included the need for context specific, early engagement that is culturally relevant and appropriate.

Equally, there was recognition of the need for identifying local benefits such as jobs, opportunities for co-ownership and co-contribution as part of the decision-making processes. Such a focus on local outcomes was seen to contribute to perceptions of procedural and distributive fairness which help to build trust in project developers and government regulators.

The Victorian Government uses its purchasing power to strengthen our renewable hydrogen sector

The Victorian Government is the largest procurer of goods, services and construction works in the state. It uses its purchasing power to help develop local industries, create jobs and boost economic activity across Victoria. This purchasing power may present an opportunity to stimulate demand for renewable hydrogen and strengthen the supply chain.

We are committed to ethical, sustainable and socially responsible procurement. As hydrogen technologies enter the market, there are opportunities for Victorian suppliers and government buyers to mutually benefit.

Activities underway

- Support local content requirements in renewable hydrogen technology procurement as outlined through the Local Jobs First Policy.
- Investigate potential for renewable hydrogen technologies for consideration in government procurement and work across government to identify the potential value and benefits of renewable hydrogen technologies in procurement.
- Explore Power Purchasing Agreements (PPA) for renewable hydrogen projects.

Local jobs first

The Local Jobs First Policy supports Victorian businesses and workers by ensuring that SMEs are given a full and fair opportunity to compete for both large and small government contracts, helping to create opportunities including for apprentices, trainees and cadets.

The Local Jobs First policy comprises the Victorian Industry Participation Policy and the Major Projects Skills Guarantee.



The Victorian Government plays a central role in coordinating across government and industry

Hydrogen is potentially a wide-ranging, transformational technology. The challenges and opportunities in creating a hydrogen economy will impact different parts of the energy sector and may reach into other industries.

Hydrogen sector issues cannot be dealt with in isolation and require a comprehensive and coordinated approach.

Coordination across the Victorian Government provides many benefits. It enables cross-sector issues to be considered holistically, for information to be collected and shared consistently, and enables the establishment of periodic reporting to provide transparency, accountability and to ensure the community remains informed.

Activities underway

- Coordinate across the Victorian Government to engage in cross-sector issues.
- Develop a complementary approach to the design of future Victorian funding rounds to enable applicants to access both state and Commonwealth streams of funding for projects.
- Ensure a coordinated approach to storing and sharing hydrogen information, data and resources within government and industry where appropriate, such as the 'HyResource' module from CSIRO's Hydrogen Knowledge Centre, a collaborative initiative with NERA, Futures Fuels CRC and the Australian Hydrogen Council, working with NERA's National Hydrogen Technology Cluster virtual network and the Victorian Hydrogen Technology Cluster Network.
- Track progress on measures of success and undertake five-yearly reviews of the Victorian Renewable Hydrogen Industry Development Plan, to align with the setting of the next five yearly emissions reduction pledges.
- Establish an industry-wide stakeholder forum including businesses and relevant unions to inform the development of renewable hydrogen in Victoria.



Victoria is a renewable hydrogen leader as part of Australia’s hydrogen powerhouse ambitions

For the past two and a half decades, Victoria has been at the forefront of national energy reforms to deliver competitive and well-functioning energy markets across Australia. We are well-positioned to integrate Victorian hydrogen technologies into our competitive market.

The National Federation Reform Council is the peak intergovernmental forum in Australia. Its role is to initiate, develop and monitor the implementation of policy reforms that are of national significance and which require cooperative action by Australian governments, including an emerging hydrogen industry. The Victorian Government is represented at the National Federation Reform Council Energy Committee by the Minister for Energy, Environment and Climate Change. We will maximise the benefit from this forum by providing leadership through Victoria’s role at the National Hydrogen Working Group.

As we look to integrate hydrogen into our energy sector, Victoria will continue to lead reforms in Australian energy markets in partnership with national energy market institutions, the Commonwealth Government, and other states.

Activities underway

- Provide leadership in intergovernmental processes to ensure national consistency in regulatory frameworks governing the hydrogen industry.
- Work collaboratively with all jurisdictions to establish Australia as a major player in the global hydrogen industry.
- Support the Commonwealth Government to publish an annual state of hydrogen report.
- Work with all jurisdictions to develop and communicate coherent policy and provide certainty to Victorian industry.
- Contribute to a consistent national approach to workforce training and skills for the hydrogen economy.

The National Hydrogen Strategy

Victoria was a key player in the development of the National Hydrogen Strategy, leading significant workstreams in its development.

The overarching vision of the National Hydrogen Strategy is to have a clean, innovative, safe and competitive industry that benefits all Australians, and where Australia is a major global player in hydrogen by 2030.

The Strategy coordinates the actions of the States, Territories and Commonwealth to provide a strategic vision for Australia’s national hydrogen industry.

Victoria’s leadership role in workstreams for hydrogen in the gas network and hydrogen for electricity, and strong contributions to hydrogen for industrial users and transport workstreams has enabled an aligned approach between our state and national policy, and the opportunity to progress actions in line with Victorian priorities and areas of strategic advantage.

Victoria is promoted as a globally attractive trade and investment destination

Australia is considered one of the best countries in the world for business, and Victoria remains at the heart of Australia as a premier business and investment destination. Our offering is underpinned by great talent, world class infrastructure, competitive business costs, and connections to the Asia-Pacific region. Victoria is a favoured destination for global investment in renewable energy and storage. The Victorian Government actively assists companies to facilitate investment.

The Victorian Government actively works with companies to attract and facilitate investment by providing companies with tailored support. The Victorian Government can assist with the identification of opportunities and development of business cases, engagement with potential partners, research organisations, suppliers and customers, and provide assistance with site selection and regulations.

With more than 20 offices globally, support is provided to international companies in their home markets and for Victorian companies seeking to expand to new markets.

Activities underway

- Support and leverage Victoria’s global trade networks (VGTIOs) to build international demand for Victorian-produced hydrogen and hydrogen technologies.
- Deliver renewable hydrogen investment attraction material to promote Victoria as an attractive investment destination.
- Foster international collaborations to encourage technological advances and accelerate commercialisation.
- Ensure renewable hydrogen is a fundamental part of Victoria’s new energy technologies sector, attracting investment and recasting our economy post COVID-19.

CASE STUDY

Global Victoria

Global Victoria works with businesses to build their export capabilities and connect them to international opportunities through tailored programs, trade missions and a network of over 20 trade and investment offices around the world. The group advocates for the best policy settings so that Victorian companies can be competitive in the global arena. It also promotes Victoria as the best place for further study and skills development through the state’s world-class universities and training institutions.



H₂

Looking to the future

Victoria is at the beginning of a journey to introduce renewable hydrogen into our economic and energy systems. We will need to work together with businesses, universities, research institutions, industry associations and others to deliver this Plan and forge a pathway to a renewable energy future.

Hydrogen has the capacity to stimulate many parts of Victoria's economy, lead to long term, sustainable economic growth and offer the benefits of reducing our carbon emissions to meet our net zero emissions target.

The outcomes in this Plan signpost our early achievements toward a thriving renewable hydrogen sector in Victoria, bringing down technology costs and opening new markets.

Through this Plan we also aim to contribute to our Climate Change Targets, achieve lasting growth, open export market opportunities and create rewarding, high-value, and secure jobs for Victorians. In alignment with our Climate Change Targets, this Plan will be reviewed after five years.

Glossary

Australian Energy Market Operator (AEMO)	Responsible for operating Australia's largest gas and electricity markets
Australian Renewable Energy Agency (ARENA)	Supports innovative renewable energy technologies and increases the supply of renewable energy
Clean Energy Finance Corporation (CEFC)	The CEFC invests in Australian energy projects to assist the energy transition to lower emissions
Decarbonising	Reducing or eliminating the amount of carbon released to atmosphere from combustion of fossil fuels
Electrolyser	Uses electricity to split liquid water into hydrogen gas and oxygen gas
Feedstock	Hydrogen as a raw material to supply or fuel a machine or industrial process
Fuel cell electric vehicle (FCEV)	An electric vehicle that uses electricity from a fuel cell powered by hydrogen
Cooperative Research Centre (CRC)	An industry-led collaborative research organisation
Green ammonia	Ammonia produced using renewable hydrogen
Hydrogen	The most abundant element in the universe, with a low density and high energy potential
Hydrogen Energy Supply Chain (HESC)	Pilot project to produce and transport clean hydrogen located in the Latrobe Valley
Liquefied natural gas (LNG)	LNG is the form in which natural gas is transported over long distances
National Energy Resources Australia (NERA)	Australia's Industry Growth Centre for the energy resources sector
National Electricity Market (NEM)	A wholesale electricity market that interconnects Queensland, New South Wales, Victoria, South Australia, Australian Capital Territory, and Tasmania
Renewable hydrogen	Hydrogen produced using renewable energy
Standards Australia	Australia's peak standards development body
Victorian Renewable Energy Target (VRET)	Victoria's legislated Renewable Energy Target of 50% by 2030

Endnotes

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- 21 The initial assessment of export hubs in Victoria was based on ARUP's export hub assessment framework. Based on this framework, the Port of Hastings achieved the strongest results due to its history in exporting liquid hydrogen, channel depth, and proximity to Melbourne. The Port of Melbourne's extensive liquid fuel infrastructure and channel depth also make it a valuable export hub for hydrogen. The Port of Geelong has been used extensively for petroleum export, also making it a potential valuable hydrogen export hub.
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