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GREEN HYDROGEN DISCUSSION PAPER

VICTORIAN HYDROGEN INVESTMENT PROGRAM

November 2019

VICTORIA
State Government

Purpose of this discussion paper

The Victorian Government wants to ensure that the potential for growth in green hydrogen technologies is developed through the Victorian Hydrogen Investment Program (VHIP).

The VHIP is informed by the growing expertise of industry, academics and communities, as well as drawing on previous experience and best practice both locally and internationally. This discussion paper is designed to inform the VHIP by building on the information received through the market testing Request for Industry Submissions (RFIS) process undertaken in early 2019. It sets out issues and poses questions designed to help guide submissions that will contribute to the development of a Victorian Green Hydrogen Industry Development Plan (IDP). Submissions containing additional information and issues beyond the scope of questions posed in this discussion paper will be considered in the development of the IDP.

Information gathered through this process will also inform the development of Victorian Government policy.

Make a submission

You are encouraged to make a submission on any or all the matters raised in this discussion paper. You can respond to the discussion paper by uploading a submission through the Victorian Government's online platform, Engage Victoria, at **engage.vic.gov.au**

Submissions will be published online, and may be shared with the National Hydrogen Strategy taskforce or used to inform the development of future DELWP energy strategy and policy. If you do not wish to have your submission published, or do not wish to have your submission shared with the National Hydrogen Strategy taskforce, please advise us in writing at the time of submission.

For inquiries about the submission process, please contact **emerging.energy@delwp.vic.gov.au**

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Cover storage image: Linde Group

Using Victoria's natural resources to reduce emissions and create economic advantages

MINISTER'S FOREWORD

The way we generate, move, store and use energy touches every part of our economy. Victoria, along with the rest of the world, is shifting away from emissions-intensive energy sources to cleaner, more modern ways of operating.

Green hydrogen derived from renewable energy may be an economy-wide solution to facilitate this transition. Our natural energy resources in wind and sun are plentiful, providing a ready supply of renewable energy to power the production of hydrogen by electrolysis. Green hydrogen could diversify revenue streams from renewable energy beyond the electricity markets. This diversification could enable power to gas opportunities that would open new pathways to exporting Victoria's renewable energy, act as a substitute for natural gas, or provide a low-emissions alternative to diesel back-up generation.

The Victorian Government is committed to leadership in renewable energy and has committed to increasing the Victorian Renewable Energy Target (VRET) to 50 per cent by 2030. Legislated renewable energy targets are a key factor in the potential for green hydrogen to support our transitioning energy mix, providing certainty of renewable energy as a core input. Increased renewable energy generation will also drive down the cost of energy production and associated technologies, removing an early barrier to green hydrogen activities.

Green hydrogen may play a significant role in Victoria's decarbonisation pathway. Green hydrogen offers a unique opportunity to support decarbonisation of our gas networks, support a low-emissions transport sector – especially heavy vehicle transport – provide large-scale energy storage, and a range of other domestic and industrial applications such as an alternative feedstock. The versatility of hydrogen's role in our energy system translates to greater opportunities for economic growth in Victoria. Equally, our local manufacturing expertise and skilled workforce are equipped to scale up rapidly. Victoria's extensive gas network, road, rail and port infrastructure are attractive mechanisms for streamlined distribution of green hydrogen and create advantages for our state.

However, green hydrogen is still an emerging technology, and we must ensure we have an informed and strategic approach to developing the sector, drawing on our competitive advantages to create jobs and economic benefits across the state. This discussion paper is an important step in understanding the potential for green hydrogen in Victoria.

We will continue to demonstrate leadership in new energy technologies by exploring the potential of our hydrogen economy, uncovering opportunities for innovation and investment to benefit all Victorians.

The Hon. Lily D'Ambrosio MP

Minister for Energy, Environment and Climate Change

Minister for Solar Homes

Scope

This discussion paper is for stakeholders who would like to shape the development of Victoria's emerging green hydrogen sector, identifying competitive advantages and priority focus areas for industry and the Victorian Government.

The Victorian Government is using this paper to focus on the economic growth and sector development opportunities emerging for a Victorian hydrogen industry powered by renewable energy, also known as 'green' hydrogen. In addition, this paper seeks input from all stakeholders on how, where and when the Victorian Government can act to establish a thriving green hydrogen economy.

Although green hydrogen is the only type of hydrogen production within the scope of this discussion paper, the development of the VHIP aligns with the policies, projects and initiatives which support these other forms of hydrogen production. The VHIP is considering the broad policy landscape and actively coordinating with related hydrogen programs, policies and strategies under development, including the Council of Australian Governments (COAG) Energy Council's National Hydrogen Strategy, to ensure a complementary approach. In Victoria, there are several programs and strategies in development and underway that have linkages with hydrogen and the VHIP.

Types of hydrogen production

Hydrogen can be produced in a variety of ways. Green hydrogen is hydrogen that has been produced using renewable energy and without creating carbon dioxide emissions. The most common way to produce green hydrogen is through a process known as electrolysis. Electrolysis uses electricity to split water into hydrogen and oxygen. Where the electricity used is renewable energy, the process is carbon emission free, and the hydrogen is considered 'green'. Green hydrogen production is the focus of this discussion paper.

Strategic context

Victorian Government context

Victoria has a vision of using our extensive natural resources to reduce emissions and create economic advantages for the state.

The VHIP represents part of how the Victorian Government is promoting the development of a hydrogen industry in our state. It will support the green hydrogen industry in Victoria and is being developed in coordination with other hydrogen initiatives occurring across Victoria and Australia.

The Department of Environment, Land, Water and Planning (DELWP) is exploring the role of gas and alternative low emission fuels in progressing to net zero carbon emissions by 2050, while continuing the supply of affordable, reliable and secure energy to Victorian homes and businesses. The actions arising from the *Climate Change Act 2017* and the Renewable Energy Targets are also important driving policies in Victoria's strategic landscape, reflected as considerations in the VHIP.

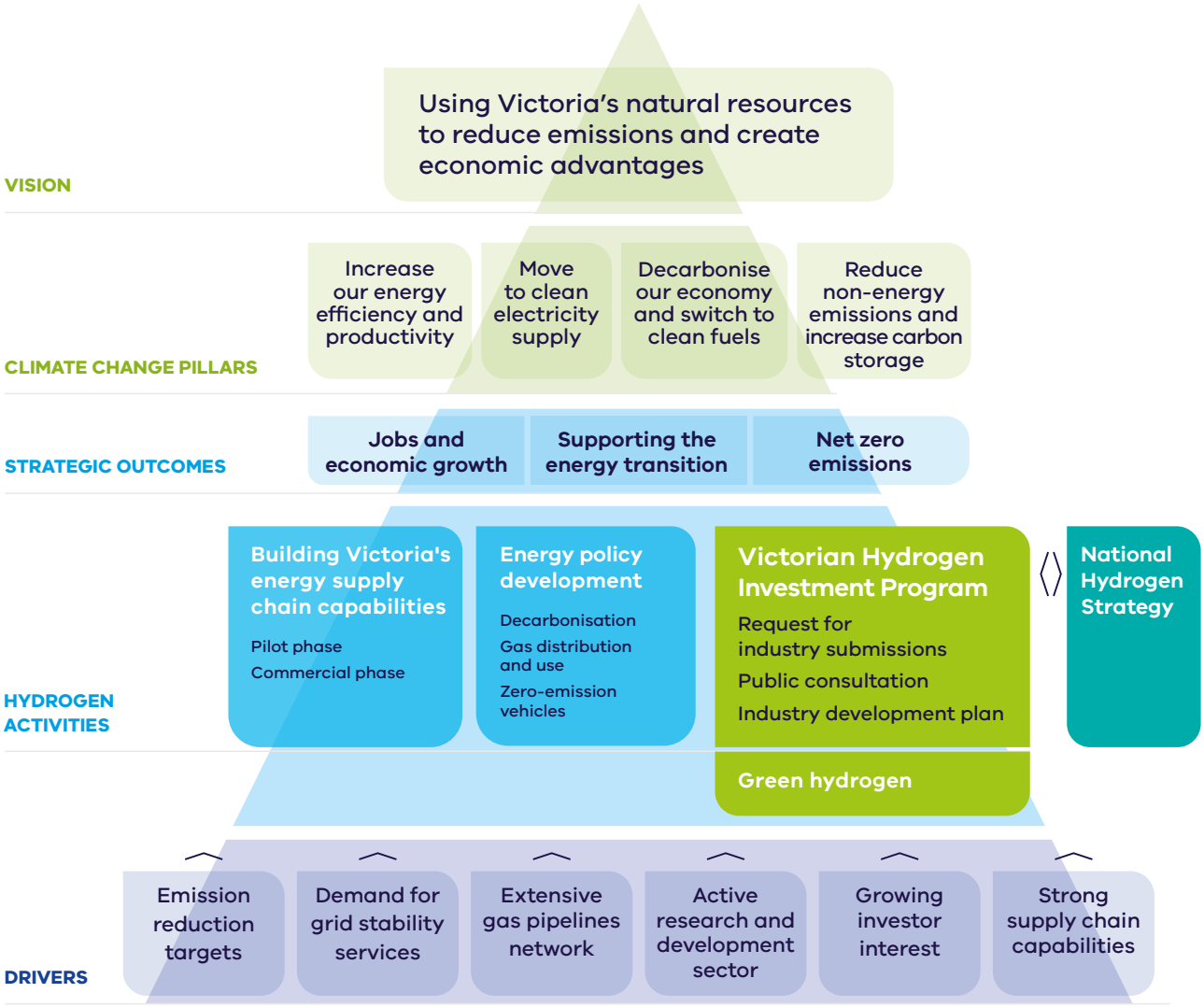
The Victorian Government is also positioning to capitalise on first mover advantages by investigating supply chain development activities. These activities will support green hydrogen production, transport and export. Pilot and demonstration projects such as the Hydrogen Energy Supply Chain (HESC) pilot project, may provide critical learnings to strengthen Victoria's green hydrogen supply chain capabilities.

At a national level, the Victorian Government is actively working with other states through the COAG Energy Council to shape the National Hydrogen Strategy and help Australia capitalise on hydrogen opportunities.

National Hydrogen Strategy

The National Hydrogen Strategy (NHS), intended to be released by the end of 2019, is set to be a comprehensive and ambitious national strategy for the development of an Australian hydrogen industry. The overarching national framework will provide focus and coordination of the activities and actions 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 national Hydrogen Working Group released an Issues Paper Series on 1 July 2019 seeking stakeholder feedback. Stakeholders may wish to forward relevant aspects of those submissions to DELWP in relation to the questions raised in the discussion paper.



See page 2 for types of hydrogen production

Emissions reduction

Victoria has a long-term target of net-zero emissions by 2050, as set out in the *Climate Change Act 2017*. Achieving this long-term target will be supported by a series of five-yearly interim emissions reduction targets, the first two of which (for the period to 2025 and 2030) will be set by 31 March 2020. Achieving these interim targets, as well as the long-term target, will require significant emissions reductions across the whole of the Victorian economy.

Emissions from the energy sector are the single largest source of greenhouse gas emissions in Victoria, followed by transport. Energy emissions include electricity generation and direct combustion of natural gas for domestic heating and commercial and industrial processes.

Victoria has strong policy settings to ensure that we reach our target. The Victorian Government identified the new energy technologies sector as one of the growth sectors vital to the future economic prosperity of Victoria and a priority sector where Victoria is well placed to become a global leader.

We have prioritised investing in clean energy generation technologies, encouraging new consumer markets, building state-wide capabilities and strengthening sector skills, collaboration and innovation.

We are supporting emerging energy industries such as green hydrogen so that Victoria is at the forefront of the transition to clean energy.

Victorian Hydrogen Investment Program

The Victorian Government announced the Victorian Hydrogen Investment Program (VHIP) to support development of a green hydrogen industry through market testing, policy development and a targeted investment program.

The VHIP aims to:

- build an understanding of Victorian industry capability and capacity;
- identify pathways for government, businesses, academics and the community to address barriers constraining development of a hydrogen economy;
- establish a program of support for hydrogen research, trials, pilots and demonstrations, creating a strong base of industry knowledge and skills;
- identify the best way for government to create an enabling environment; and
- align with the National Hydrogen Strategy currently in development by the COAG Energy Council.

This discussion paper, along with our broader stakeholder consultation activities, will inform an Industry Development Plan for Victoria's green hydrogen producers and users. The Industry Development Plan will create the framework to guide our future policies and a program of green hydrogen investment.

VHIP process

VHIP consultation activities

To complement consultation through this discussion paper, the Victorian Government invited a Request for Industry Submissions (RFIS) under the VHIP. The purpose of the RFIS was to determine the current extent of market interest and opportunity for green hydrogen to inform the VHIP investment program and guidelines.

Thirty-four submissions were received from a diverse range of stakeholders covering a broad scope of green hydrogen activities. Six of the submissions were general in nature rather than about a particular project. The remaining submissions described projects or potential projects spanning production, distribution and end-use, including hydrogen for transport. Some submissions described projects which were cross-sectoral or across the value chain; for example, green hydrogen production for vehicle refuelling stations or microgrids.

The RFIS responses indicated an enthusiasm for adopting hydrogen technology solutions across many applications in Victoria. Most proposals considered partnerships across the supply chain, including with local councils and state government agencies, land and site owners, technology providers, industry bodies, universities and other businesses. Many submissions also recognised engaging with communities as a core project activity.

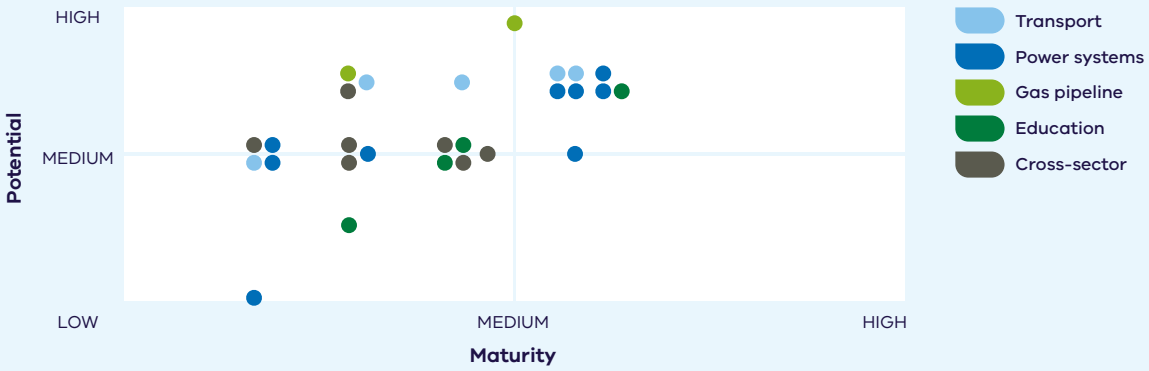
The RFIS responses were analysed and categorised by sector as transport, power systems, gas pipelines, education and cross-sectoral, and then benchmarked according to their potential and maturity, as shown in the graphic. 'Potential' refers to the project's potential to contribute to hydrogen value chain development, and domestic and international market opportunities. 'Maturity' refers to the maturity of the project's technology or technologies, stakeholder acceptance and project stage development.

The market analysis from the RFIS results has informed development of this discussion paper, as well as shaping our future investment program. Where the RFIS process sought details of proposed and emerging green hydrogen projects in Victoria and provided valuable insights into project status across the state, through this discussion paper we are seeking input on the factors driving potential and maturity in the market, and how the Victorian Government can assist project proponents to increase the viability of their projects.

The release of this discussion paper will be followed by stakeholder workshops across the state providing further opportunity for discussion and engagement with the VHIP on green hydrogen potential for Victoria.

We will use these inputs to develop an Industry Development Plan to promote the green hydrogen value proposition for Victoria.

RFIS submissions analysis



Part 1

Decarbonising our economy with hydrogen

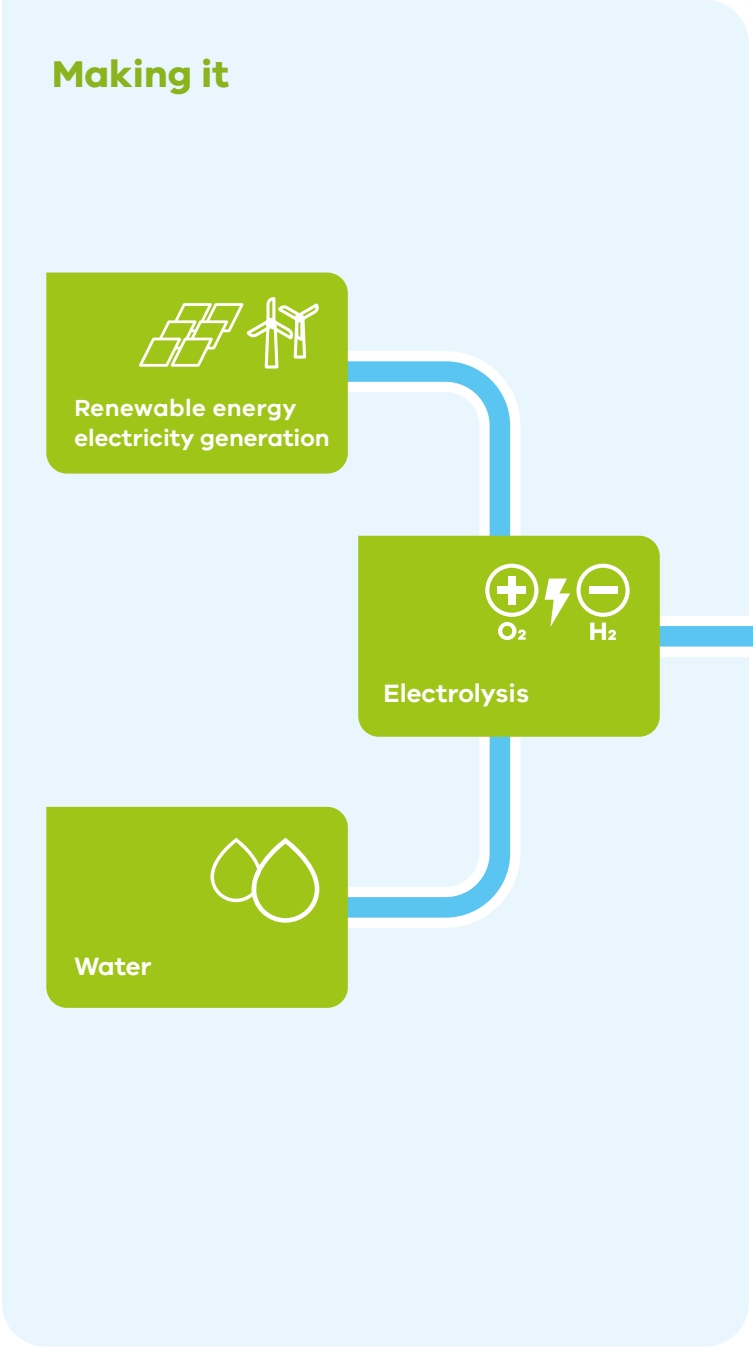
As Victoria's economy decarbonises, green hydrogen may assist us to both meet our emissions reduction obligations and create new cleantech jobs in Victoria.

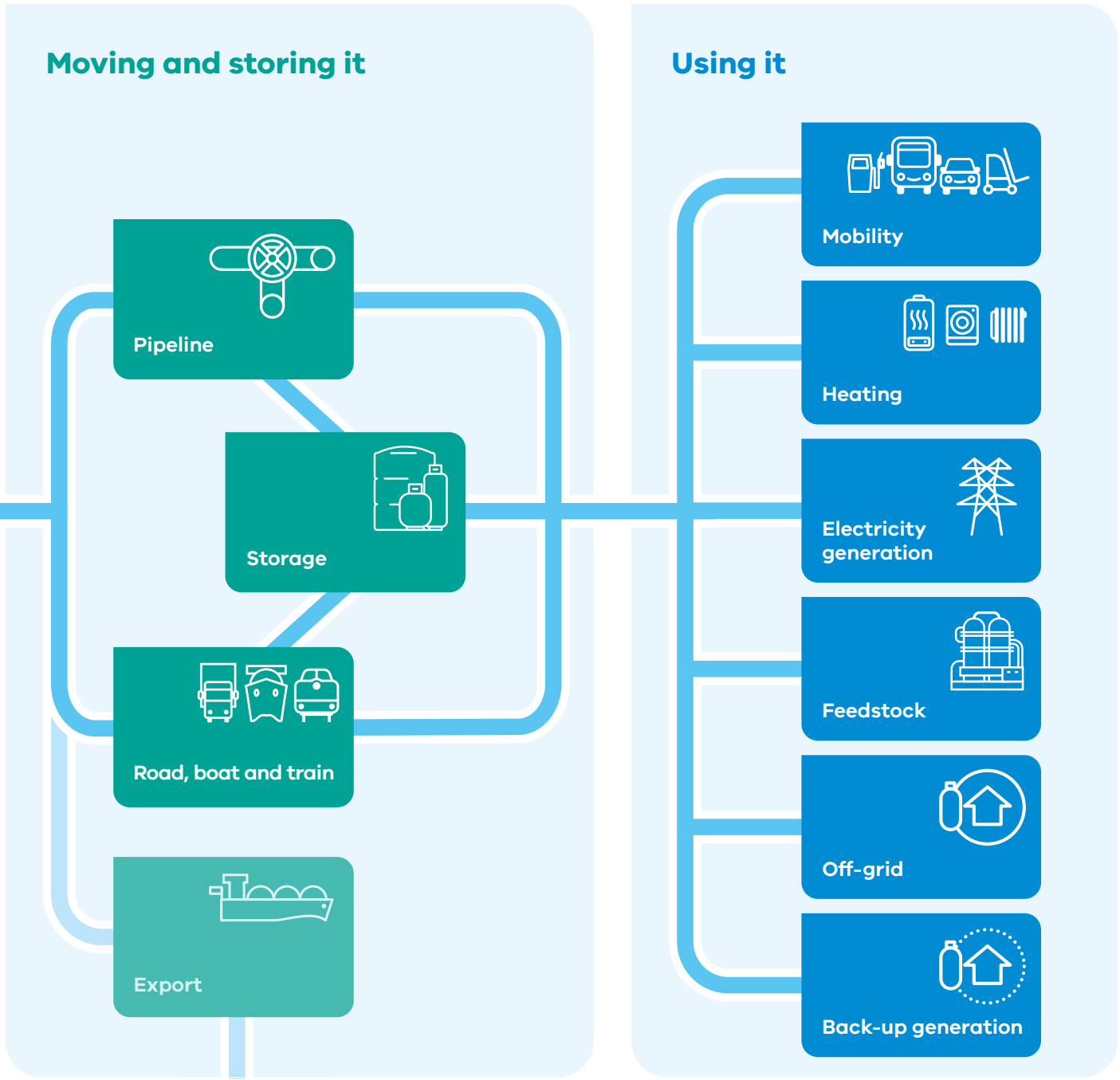
A hydrogen economy is an ecosystem that uses technologies to connect primary energy sources with end-uses such as domestic energy supply, sustainable transport and export. It encompasses the entire hydrogen energy supply chain, from production and storage through to utilisation.

A green hydrogen economy can deliver benefits across Victoria, including boosting our renewable energy penetration, contributing to decarbonisation across difficult to abate sectors and providing an alternative for natural gas and transport fossil fuels.

Victoria's abundant wind and solar resources, skilled workforce and established gas network mean that we are well placed to introduce a sustainable hydrogen economy.

Green hydrogen value chain




Moving and storing it
Pipeline
Storage
Road, boat and train
Export
Using it
Mobility
Heating
Electricity generation
Feedstock
Off-grid
Back-up generation

Setting the foundation for a Victorian hydrogen economy

Uptake of green hydrogen could help Victoria achieve significant greenhouse gas emissions reductions. This alternative fuel source may support several decarbonisation pathways including as a zero-emission substitute in our natural gas network, replacement of diesel generators, new forms of electricity generation, alternative industrial feedstock, and as a zero-emission transport fuel.

For Victoria, green hydrogen as a fuel substitute option is made attractive given our substantive natural gas distribution and transmission pipeline infrastructure. If we make specific changes and upgrades, this option may provide potential to distribute hydrogen, enabling Victoria to decarbonise while maintaining a dual fuel system. Hydrogen fuel cells also have a potential role to play in decarbonising our transport.

The Victorian Government is looking to encourage private investment and create an environment for business innovation and new market development. The new energy technologies sector is a priority sector for development in Victoria.

Image: A researcher checks her data in the lab next to a 2.5kW PEM hydrogen fuel cell, CSIRO Centre for Hybrid Energy Systems (CHES) in Clayton, Victoria

The Government has set comprehensive strategies to transition to renewable energy and drive energy efficiency and productivity. We are ensuring Victoria has the skills and capabilities to capitalise on a global demand for energy, which is set to grow by nearly one third by 2040.

Equally, global demand for hydrogen is expected to increase dramatically over the coming decades, driven by the aspirations of Japan and the Republic of Korea to increase their supply of imported hydrogen for their energy needs.[1] Japan, the world's third largest economy by Gross Domestic Product (GDP), currently imports 94 per cent of its energy as coal, oil and natural gas.[2] These growing international markets for hydrogen present Victoria with new and untapped ability to export our vast renewable energy resources.

We are now turning our attention to what the Victorian Government can do today to position Victoria for future green hydrogen opportunities. The VHIP is a first step to understanding how Victoria can realise the potential of a thriving green hydrogen economy.

Hydrogen research and development

As an emerging energy technology, there is significant scope for innovation in green hydrogen production, distribution and use. Connection and collaboration are key to building our capacity to innovate. We will seek to strengthen new and existing affiliations across energy businesses, advanced manufacturers, the Information Communications Technology (ICT) sector, universities and communities.

The Victorian Government was a sponsor and member of the Government Advisory Group of the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) National Hydrogen Roadmap (Roadmap), released in August 2018.

The Roadmap highlights opportunities for new products, services and systems for hydrogen, including electricity and energy storage, heat, transport and industrial uses along with the commercial models, regulatory frameworks, and research and development investment priorities that will enable hydrogen utilisation to become competitive in local and global markets.

In 2019, the Victorian Government is continuing to support CSIRO's research, and is sponsoring a forthcoming report on research, demonstration and development (RD&D) contributions to hydrogen technologies.

Hydrogen is becoming more cost-competitive

According to the International Energy Agency (IEA),[3] the recent sharp decline in the cost of renewable energy suggests that the production of hydrogen from renewable power may become more affordable. Hydrogen from electrolysis currently accounts for 2 per cent of global hydrogen production.[4] However, there is significant scope for electrolysis to provide more low-carbon hydrogen.

Surplus electricity from variable renewables has low costs, but the number of hours during which this surplus occurs is generally low. Falling costs mean that dedicated renewables for hydrogen production in regions with excellent resource conditions could provide a reliable, low-cost hydrogen production source.

CSIRO estimate that the levelised cost of hydrogen (LCOH) produced using electrolysis, which in 2018 was approximately $5.50/kg, could be reduced to $2.29-2.79/kg by 2025.[5]

Compared to the IEA analysis, this price may be competitive on a levelised basis with petrol and diesel. However, by 2025, it is still likely to be three times the cost of natural gas.

1 'Opportunities for Australia From Hydrogen Exports', ACIL Allen Consulting for ARENA, 2018.
2 'Japan's Energy Supply Situation and Basic Policy', The Federation of Electric Companies of Japan, retrieved from www.fepc.or.jp/english/energy_electricity/supply_situation/
3 International Energy Agency, 'The Future of Hydrogen: Seizing Today's Opportunities', 2019
4 Ibid
5 Bruce S, Temminghoff M, Hayward J, Schmidt E, Munnings C, Palfreyman D, Hartley P (2018) National Hydrogen Roadmap, CSIRO, Australia

Cutting across the economy

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 or reach into other industries. As a result, these issues cannot be dealt with in isolation, and require a comprehensive and coordinated approach.

The Victorian Government is exploring partnership opportunities to embed links between suppliers, manufacturers and distributors to allow for easy use and low-cost distribution. The competitiveness of hydrogen technologies is likely to improve with scale.

Workforce capabilities

A skilled and deployable workforce able to support the technological transition to a green hydrogen economy is needed. The Government is exploring ways to support skills development through education and training to serve the emerging hydrogen industry, including cross-sector knowledge and re-skilling. Working with businesses and education institutions to get the right skills mix will set a strong foundation for a green hydrogen economy to grow in Victoria.

Engaging communities

Communities are at the forefront of the energy transition through adopting new energy technologies. Supporting pre-commercial trials, building public acceptance and engaging with innovation precincts, all help set a path for more widespread and sustained technology deployment.

Community support to operate new technologies is integral for the success and acceptance of these technologies and is only achieved by early, transparent community engagement. Awareness and consumer confidence in safety and reliability of hydrogen technologies will be critical to introducing improved production methods and new applications for green hydrogen.

Responses to the RFIS have shown that local government areas across Victoria are already identifying opportunities for hydrogen-based environmental and transport projects on a local and regional level.

The social and economic benefits from hydrogen projects include environmental and air quality improvements, climate change mitigation, the creation of new jobs and industries and a decarbonised pathway to meet Victoria's growing energy needs. These must be promoted to affected communities to build understanding and acceptance.

Image: Hydrogen storage tanks, CSIRO Centre for Hybrid Energy Systems (CHES) in Clayton, Victoria.

Getting the settings right

A positive regulatory environment is one which supports commercial competition while balancing competing priorities.

The hydrogen economy encompasses production, storage, distribution, and utilisation. Each stage will need appropriate regulatory settings, including infrastructure, land and resource use, safety, pricing, transport and trading.

Work on hydrogen standards is already underway. Standards Australia has recently constituted a new Technical Committee, ME-093 Hydrogen Technologies to undertake work as the mirror committee to international standard ISO/TC197 Hydrogen Technologies.

Victoria may also consider adopting international standards to support the export market and align with international production, storage and utilisation technologies.

As an emerging technology, green hydrogen will benefit from investment in supply chain capabilities and consideration of the outcomes of pilot and demonstration projects underway both domestically and internationally

Building Victoria's energy supply chain capabilities

The emerging green hydrogen industry provides a significant opportunity for Australia to be a global leader in supplying an environmentally friendly energy source internationally, replacing major coal and natural gas exports.

For large energy importing markets like Japan, the Republic of Korea and Taiwan, green hydrogen presents an opportunity to import a CO_2-free form of energy to displace the importation of fossil fuels – meeting environmental, economic and geopolitical needs and aims. Australia already has existing trade relationships with these countries and hydrogen exportation can potentially look to replicate the way Australia already exports LNG.

Pilot and demonstration projects focusing on Victoria's hydrogen supply chain capabilities will be critical to the development of a commercial-scale green hydrogen industry in Victoria.

The Victorian Government is already testing the hydrogen 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 through planning, design, construction and commissioning of hydrogen production and transport infrastructure.

This includes valuable insights ranging from distribution, exports and use right through to skills and workforce development, providing Victoria with a unique advantage over other jurisdictions.

These projects will also assist in exploring regulatory barriers to large scale hydrogen production and export, providing a focus for investment into Victoria in new engineering and technical expertise, industry and academic knowledge transfer and helping build community understanding of hydrogen as a fuel.

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.

Victoria is positioned to move rapidly and take advantage of this opportunity.

CASE STUDY

Using skills and workforce to support green hydrogen

Logan Energy is a UK based engineering and project delivery contractor, specialising in hydrogen energy solutions. The company has drawn on these capabilities to deliver several integrated hydrogen projects.

Logan Energy delivered the Levenmouth Community Energy Project, which demonstrates a fully integrated green hydrogen energy system using a microgrid.

The project generates hydrogen using renewable electricity from a 750kW wind turbine and 160kW solar PV to provide electricity to a commercial park. The hydrogen is used for transport fuel and as a way of renewable energy storage for use in the microgrid precinct. The microgrid is supported by two semi-mobile hydrogen generation and refuelling stations.

The system includes a 250kW electrolyser with hydrogen storage plus a 100kW hydrogen fuel cell. A smart energy management system adjusts hydrogen production based on weather forecasts, predicted consumption and available storage.

This project highlights opportunities for Victorian businesses and suppliers to similarly apply their current skills and capabilities to transition into delivery of integrated green hydrogen projects.[6]

Key questions

1. What are the greatest opportunities for investment and employment in hydrogen?
2. What is Victoria's competitive advantage to capitalising on an emerging hydrogen economy?
3. What lessons can Victoria learn from the global hydrogen agenda and international experience to date?
4. Geographically, where are the most significant clusters for this investment, employment and production?
5. What are the skills and training requirements needed to grow Victoria's hydrogen industry?
6. What are the challenges to developing a hydrogen economy in Victoria?

6 Levenmouth Community Energy Project. Retrieved from www.loganenergy.com/portfolio/levenmouth-community-energy-project/

Part 2

Image: View into a completely assembled hydrogen compressor station, Linde Group

Producing hydrogen

Currently, the global hydrogen production market is approximately 55 million tonnes of production per year, worth over $191 billion (US$135 billion).[7] The clear majority of this is produced from emissions-intensive coal gasification or steam methane reforming.

Producing green hydrogen from renewable sources is not a new idea. To date, the cost of both inputs in the form of renewable energy, and production by electrolysis, have been a barrier, but this is changing as technology prices come down. As production increases, economies of scale can reduce costs.

Hydrogen from renewable energy

Victoria has an abundance of renewable energy sources. As the state's proportion of energy generation from renewables increases and the cost of energy production comes down, hydrogen produced from renewables can support grid reliability and security, economic growth and affordability.

The Victorian Government has legislated renewable energy targets of 25 per cent by 2020 and 40 per cent by 2025, and committed to increase the target to 50 per cent by 2030. The 2020 target is supported by the delivery of Australia's largest ever reverse auction, which has successfully secured an additional 928 megawatts of green power across three solar and three wind projects in regional Victoria.

Electrolysis to create hydrogen

Electrolysis is the process of using electricity to split water into hydrogen and oxygen. Electrolysers are used to manufacture hydrogen molecules via electrolysis.

There are several types of electrolyser, which each contain a different electrolyte material. Electrolysers used in hydrogen production include polymer electrolyte membrane (PEM), which uses a specialised plastic membrane, and alkaline electrolysers, which use a liquid alkaline solution of sodium or potassium hydroxide. Where electricity used in the electrolysis process is from renewable energy sources, carbon-neutral green hydrogen is produced.

Water requirements

Australia's relative water scarcity and the volume required to produce green hydrogen could pose a barrier to developing a large-scale green hydrogen production sector.

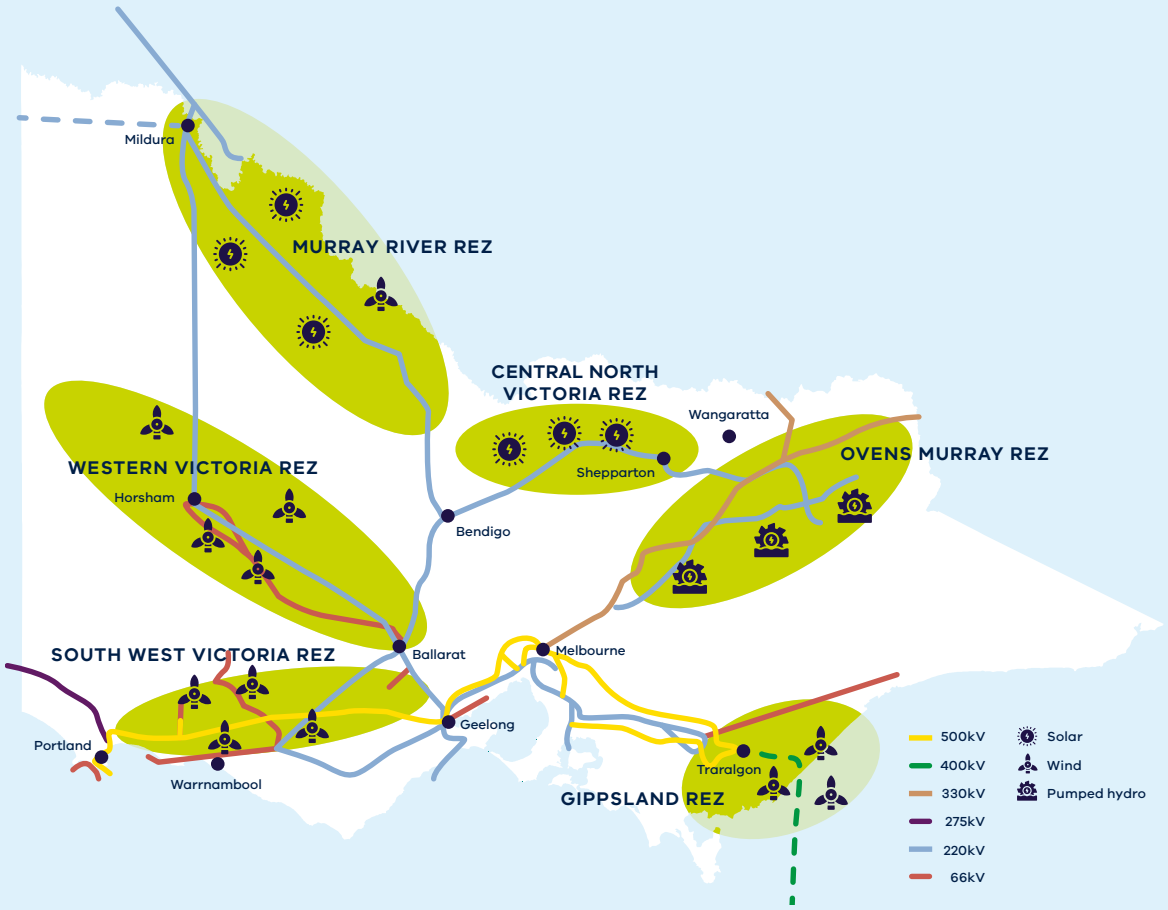
Producing one kilogram of hydrogen by electrolysis requires approximately nine litres of water.[8] The water must be pure to ensure there is no contamination of the electrolysers because it reduces efficiency. Additional energy input is needed for evaporative processes to purify water. Research into the use of salt water as an input to the electrolysers is underway but is still at an early stage.

Given the proposed scale of future green hydrogen production, the need to secure access to reliable and sustainable supplies of water will be a key consideration for locating hydrogen projects in addition to other factors.

7 Hydrogen for Australia's Future, COAG Energy Council briefing, August 2018, page 26; International Energy Agency, 'Global trends and outlook for energy' December 2017

8 Bruce S, Temminghoff M, Hayward J, Schmidt E, Munnings C, Palfreyman D, Hartley P (2018) National Hydrogen Roadmap, CSIRO, Australia

Renewable Energy Zones



Renewable Energy Zones. Source: adapted from AEMO, 2019

In July 2018, the 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.

The report acknowledged the radical changes and transformation underway in the energy system and the investment needed to facilitate a smooth transition of our evolving power system.

As part of the report, several highly valued Renewable Energy Zones were identified across the NEM, six of which are in Victoria, with either good transmission connections, or in need of coordinated investment to accommodate future generating capacity.

These zones include areas of Victoria which possess abundant renewable energy resources which can be harnessed as a source of electricity to generate hydrogen.

Moving and storing hydrogen

Green hydrogen can support a transition to low-emissions electricity and gas systems. This includes long term (seasonal) storage opportunities and grid stability and reliability services,[9] encouraging greater renewable energy penetration in Victoria's energy mix. Hydrogen technologies also support decentralised applications such as microgrids and other off-grid energy technologies, reducing reliance on the electricity network.

Utilising the gas network

Hydrogen has enormous potential to support decarbonisation through direct injection into the gas distribution network. With over 31,000 kilometres of gas mains distribution, the largest in Australia,[10] Victoria's gas network infrastructure is both extensive and efficient, providing a potential distribution pathway for hydrogen substitution of natural gas, either as a blend or total replacement. In this way, the gas network can deliver green hydrogen to domestic, commercial and industrial premises.

Natural gas is an important fuel for Victorian households' heating and cooking and has been a reliable source of fuel for high-temperature industrial and manufacturing uses across the state. Substituting natural gas with green hydrogen will support decarbonisation for residential and industrial applications without requiring electrification of existing gas-based processes and infrastructure. However, transmission pipelines may need to be tested, modified or replaced if increasing volumes of hydrogen are to be introduced to the gas network.

CASE STUDY

Power-to-gas

In Falkenhagen, in the state of Brandenburg in Germany, Uniper Energy Storage has constructed the world's first demonstration plant for storing wind energy as hydrogen in the natural gas grid. The plant stores electricity generated by wind turbines. Around 360 Nm^3/h of hydrogen is generated by means of electrolysis and fed through a 1.6 km hydrogen pipeline into the gas grid. The demonstration operated for one year. In May 2018, the power-to-gas plant successfully expanded to include a methane production plant. The innovative, commercial scale facility will be in operation for analysis by a German technology consortium until 2020.[11]

9 Bruce S, Temminghoff M, Hayward J, Schmidt E, Munnings C, Palfreyman D, Hartley P (2018) National Hydrogen Roadmap, CSIRO, Australia
10 'Victorian Gas Planning Report Update', Australian Energy Market Operator, March 2018, p.3
11 Uniper, 'WindGas Falkenhagen'. Retrieved from www.uniper.energy/storage/what-we-do/power-to-gas

Using rail, road and port infrastructure

Hydrogen is most commonly transported and delivered as a liquid when high-volume transport is needed in the absence of pipelines. The liquefied hydrogen can then be converted back to gas for use as needed. Hydrogen can also be transported in compressed gaseous form in tubes, commonly by truck. Alternative methods of transport include ammonia conversion using nitrogen and conversion to a carrier material such as methylcyclohexane. However, any processes for converting hydrogen into other forms and back again requires more energy.

The HESC Pilot Project will transport compressed hydrogen gas by road and liquefied hydrogen by sea. Learnings from the HESC Pilot Project may create advantages for Victoria in hydrogen transportation.

Supporting the electricity system

Green hydrogen can provide dispatchable generation to meet peak demand and provide flexible load in times of low demand, and ancillary services.

Electrolysers can be quickly scaled up or down to improve grid frequency stability without affecting consumers. Electrolysers can also function as fast-acting demand management. The load can be controlled to respond to frequency variations, maintaining balanced system stability.

Small and medium-scale electrolysers can be useful as distributed power generation resources to deliver grid management, fast frequency response and grid services. Small-scale electrolysers can also be used as a distributed power source to provide green power to remote locations, microgrids, or as a power source during emergency management responses.

Gas turbines for power generation have also been developed that are dual fuel, with the potential to use either natural gas or hydrogen. Such technologies could be a useful transition from the way we use energy today to a hydrogen future.

Storing hydrogen

Economic and at-scale storage will be key to the widespread use and application of hydrogen across the economy, including export. There are many different technologies and processes to enable the storage of hydrogen at varying pressures.

Hydrogen can be transported in the gas network to storage facilities that capture surplus renewable energy. With Victoria's large gas network, the gas pipelines also serve as a form of storage. Stored reserves can then be converted back to electricity or used for domestic or industrial heat in substitute for natural gas.

Hydrogen as an energy storage mechanism shows potential to complement established technologies. It provides large-scale, seasonal and portable storage in situations where other storage options, such as batteries, are not suitable.

Forms of hydrogen storage

Pressurised tanks

The most common way of storing hydrogen. The higher the pressure, the higher the storage volume, but also higher costs and greater energy required.

Line packing

Hydrogen is injected into existing natural gas pipelines. This approach has the advantage of utilising existing infrastructure and can be undertaken at scale.

Liquefaction

Through cryogenic tanks to temperatures of minus 253°C.

Material-based storage

Hydrogen is converted into ammonia with nitrogen via the Haber Bosch process.

Key questions

1. Who are the critical stakeholders needed to support a Victorian hydrogen economy?
2. What does a supportive regulatory environment for a sustainable hydrogen industry look like?
3. Are there barriers to achieving a social licence for hydrogen to operate? What does the Victorian Government need to consider in addressing these?
4. What role can hydrogen play in Victoria's energy system into the future? Are there limits to the role hydrogen can play in Victoria's energy mix?

Hydrogen applications

There are a range of possible uses for green hydrogen across Victoria's commercial, transport and industrial sectors, as well as Victorian households and businesses.

Decarbonising industrial feedstocks

Green hydrogen is an emission-free alternative to existing industrial, chemical, manufacturing and agriculture applications that are currently using hydrogen derived from fossil fuel as a feedstock for ammonia and other chemical production. Hydrogen produced by electrolysis using renewable energy can be used as a direct substitute for emissions-intensive hydrogen derived from steam methane reforming (SMR) in existing and new industrial and agricultural applications.

There is also scope for fuel-switching. Industrial users could use hydrogen as a replacement for natural gas and other carbon-intensive fuel sources in production processes. Further opportunities to introduce hydrogen into industrial, chemical, manufacturing and agriculture activities arise with a cost-competitive and reliable supply of green hydrogen, contributing to a low-emissions economy.

A zero-emission transport system

Transport is responsible for 20 per cent of Victoria's greenhouse gas emissions.[12] Hydrogen fuel cell electric vehicles (FCEVs) are a low-emissions transport option to support the decarbonisation of a difficult to decarbonise sector. The technology can be deployed across a broad transport spectrum from heavy vehicles, trains, aircraft and ships to passenger and small vehicles and industrial vehicles such as forklifts.

We will need a sustainable supply of hydrogen and well-planned and appropriate infrastructure, including refuelling stations, to establish a viable hydrogen FCEV market in Victoria. This could be a growth opportunity for Victorian businesses to manufacture both vehicles and supporting infrastructure, plus contributions from the associated supply chain and skilled workforce sector.

12 Victorian Greenhouse Gas Emissions Report, Victorian Government Library Service, 2018

CASE STUDY

Hydrogen vehicles for 2020 Olympic Games

The Tokyo 2020 Olympic and Paralympic Games will be one of the greenest in history. The official vehicle fleet, supplied by Toyota, aims to achieve the lowest emissions target level of any official fleet used at an Olympic and Paralympic Games. This will help to reduce the environmental impact of the event.

Fuel Cell Electric Vehicles (powered by Hydrogen) will play a major role in the environmentally-friendly fleet. 500 Mirai fuel cell electric vehicles will be the official transport for Games' staff members and officials, transporting them to Olympic venues. Toyota will also use the latest production fuel cell electric bus, the Sora, to transport members of the public around Tokyo and the Games venues.

Hydrogen fuel cell electric vehicles emit only water vapour, eliminating harmful CO_2 emissions when driving.[13]

Households and businesses

Hydrogen can be produced for use on-site with micro-electrolysers. The hydrogen produced could be used to power a wide variety of household appliances. Hydrogen could also be used for heating and cooking in households and businesses, substituting natural gas. Public acceptance of hydrogen gas in households and businesses as a natural gas replacement could play a role building a market for these products and services.

Key questions

1. What does the Victorian Government need to consider attracting investment in the hydrogen supply chain in Victoria?
2. What is the best way for the Victorian Government to support hydrogen research and development, pilot projects and demonstrations? Are there any we should prioritise?
3. What possible uses for hydrogen offer greatest benefit to Victoria?
4. What is the level of hydrogen transport infrastructure needed in Victoria and where are the priority areas for infrastructure and Victorian Government policy (e.g. procurement)?
5. What are the considerations for business and consumers in purchasing a new type of vehicle, such as a hydrogen or battery electric vehicle?
6. Other than cost, what factors help current and potential users of hydrogen in commercial and industrial settings decide how to procure hydrogen? How could the Victorian Government assist commercial and industrial businesses switch to green hydrogen for chemical feedstock and/or heating?
7. What other issues does the Victorian Government need to consider in developing an Industry Development Plan?

13 Toyota Provides Diverse Mobility for Tokyo 2020, including a Full Line-up of Electrified Vehicles.' Retrieved from newsroom.toyota.eu/toyota-provides-diverse-mobility-for-tokyo-2020-including-a-full-line-up-of-electrified-vehicles/

Summary of questions

These questions take into consideration what we have learnt from the request for industry submissions and the questions raised through the National Hydrogen Strategy Consultations

1. What are the greatest opportunities for investment and employment in hydrogen?
2. What is Victoria's competitive advantage in relation to capitalising on an emerging hydrogen economy?
3. What lessons can Victoria learn from the global hydrogen agenda and international experience to date?
4. Geographically, where are the most significant clusters for this investment, employment and production?
5. What are the skills and training requirements needed to grow Victoria's hydrogen industry?
6. What are the challenges to developing a hydrogen economy in Victoria?
7. Who are the critical stakeholders needed to support a Victorian hydrogen economy?
8. What does a supportive regulatory environment for a sustainable hydrogen industry look like?
9. Are there barriers to achieving a social licence for hydrogen to operate? What does the Victorian Government need to consider in addressing these?
10. What role can hydrogen play in Victoria's energy system into the future? Are there limits to the role hydrogen can play in Victoria's energy mix?
11. What does the Victorian Government need to consider attracting investment in the hydrogen supply chain in Victoria?
12. What is the best way for the Victorian Government to support hydrogen R&D, pilot projects and demonstrations? Are there any we should prioritise?
13. What possible uses for hydrogen offer greatest benefit to Victoria?
14. What is the level of hydrogen transport infrastructure needed in Victoria and where are the priority areas for infrastructure and Victorian Government policy (e.g. procurement)?
15. What are the considerations for business and consumers in purchasing a new type of vehicle, such as hydrogen or battery electric vehicle?
16. Other than cost and technology barriers, what factors help current and potential users of hydrogen in commercial and industrial settings decide how to procure hydrogen? How could the Victorian Government assist commercial and industrial businesses switch to green hydrogen for chemical feedstock and/or heating?
17. What other issues does the Victorian Government need to consider in developing an Industry Development Plan?

Make a submission

Visit **engage.vic.gov.au**

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