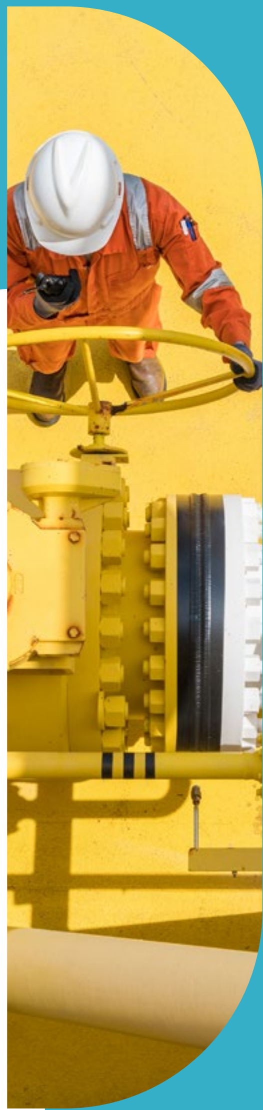
Towards 2050: Gas infrastructure in a net zero emissions economy

Final report



INFRASTRUCTURE VICTORIA

About us

Infrastructure Victoria is an independent advisory body with three functions:

- preparing a 30-year infrastructure strategy for Victoria, which we review and update every three to five years
- providing written advice to government on specific infrastructure matters
- publishing research on infrastructure-related issues.

Infrastructure Victoria also supports the development of sectoral infrastructure plans by government departments and agencies. The aim of Infrastructure Victoria is to take a long-term, evidence-based view of infrastructure planning and inform community discussion about infrastructure provision. Infrastructure Victoria does not directly oversee or fund infrastructure projects.

Aboriginal acknowledgment

Infrastructure Victoria acknowledges the Traditional Owners of Country in Victoria and pays respect to their Elders past and present, as well as Elders of other Aboriginal communities. We recognise that the state's infrastructure is built on land that has been managed by Aboriginal people for millennia.

Sustainability note

Infrastructure Victoria is committed to reducing its impact on the environment. This report is available in accessible version online or in pdf format only.

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1.

Executive Summary

Victoria is endowed with fossil fuel resources, including extensive brown coal reserves, and fields of methane, both onshore and off, also known as natural gas. This abundant but finite supply, coupled with advances in technology, has fuelled the state's development and prosperity just as the gold rush did in the 19th century. But it has not come without a cost. Scientists recognise the harmful role fossil fuels play when burned – creating greenhouse gases which are dangerously warming average temperatures and changing weather patterns. Fossil fuels also contribute to outdoor air pollution, which is harmful to human health and costs Victoria an estimated $1 billion to $2 billion annually.[1]

Victoria is the most gas reliant state or territory in Australia, with gas use representing about one-fifth of the state's total net greenhouse gas emissions. Natural gas is used across the economy, but especially to heat homes and businesses during cold Victorian winters. A vast network of transmission and distribution pipelines pumps this gas where it is needed for a range of purposes, including to make food and beverages, paper, glass, bricks, and chemicals. Victoria is also a net exporter of gas, although this may change as the state's offshore reserves decline.[2]

To limit the harmful impacts of climate change, the Victorian Government has committed to achieving net zero emissions by 2050 and outlined its vision for Victoria as Australia's cheapest, cleanest energy jurisdiction. The scale of decarbonising Victoria's economy, including the gas sector, means immediate and sustained action is needed through to 2050 and beyond. Every sector must play its part. In 2021, the Victorian Government set statewide, interim emissions reduction targets for 2025 and 2030 and published the first round of five-yearly sector pledges for agriculture, energy, industrial processes and products, land use and forestry. Ongoing targets and commitments will help drive transformation to net zero, encouraging businesses to invest in low emissions technologies and consumers to switch to alternatives and adopt new behaviours. Much of the effort to reduce emissions to date has focused on electricity, but this is now changing.

> The scale of decarbonising Victoria's economy, including the gas sector, means immediate and sustained action is needed to 2050 and beyond.

This report, which will also be an input to the Victorian Government's *Gas substitution roadmap,* is the first independent statewide analysis of the implications of the energy transition for Victoria's extensive gas infrastructure assets. It aims to inform the nature and timing of decisions regarding Victoria's gas transmission and distribution networks. At the request of the government, Infrastructure Victoria explored the future of Victoria's gas infrastructure under a range of 2050 net zero scenarios. Scenario modelling involves constructing multiple projections under different assumptions to find common insights and assist long-term planning despite high levels of uncertainty. We have assessed the relative costs and benefits of seven scenarios. Where possible, we have identified the infrastructure decisions that need to be made, and when, to ensure opportunities for existing gas infrastructure can be optimised (see *Terms of reference*). This included exploring the extent to which gas infrastructure can be used for hydrogen, biomethane, and carbon capture and storage.

Our advice, developed over 12 months and informed by evidence, modelling and significant stakeholder engagement, confirms that the gas sector we have today, like the electricity sector, will need to look vastly different in 2050. Its transformation to net zero emissions is a task epic in scale and complexity. For example, if all of Victoria's approximately two million household, business and industry gas connections[3] were to be disconnected from the network by 2050, we would need to disconnect over 250 properties every weekday from now until then. The future of energy use and supply in Victoria is uncertain, making infrastructure planning challenging. There is, at present, no single path to achieve net zero emissions in the gas sector. In addition, gas intersects with other key segments of the economy including electricity, transport, agriculture, waste, and water. For example, the shift towards electric and hydrogen fuel cell vehicles will have huge implications for the energy sector in the decades between now and 2050 and must be considered alongside decarbonisation of gas. These interactions need to be examined together, and collaboratively, to maximise the opportunities of the transition and minimise costs to Victorians.

New partnerships will need to be developed, and policy and business decisions made at key trigger points, in line with technological developments.

Governments, businesses, and industry face a test navigating uncertainty in technology development, economic feasibility, and consumer choice. But this complexity and uncertainty cannot delay action. The scale of the global warming challenge means we must act now. The opportunity for Victoria to be a global leader in the development of low emissions solutions, including biomethane, green hydrogen and other low emissions gases, needs swift action. The world is changing, and Victoria must change with it or risk missing out on a new wave of economic prosperity.

Victoria will need to use a much lower amount of natural gas to reach net zero. But it will not happen quickly. Victoria's electricity sector must decarbonise further, as it is currently more carbon intensive than natural gas and is forecast to remain so until the mid-2030s. The existing gas network will be needed for at least the next ten years. Beyond that, no single low or zero emissions gas is likely to provide the sole solution for Victoria. Several different types of alternative gases – including biomethane and potentially hydrogen – will be needed to replace some natural gas, with an increased role for electricity. Many of Victoria's gas assets can be repurposed, but not without further assessment and working out many complex logistical challenges. Some of our existing gas infrastructure will be decommissioned. Other parts of the network may need to be reconfigured. Smart decisions now will minimise the risk that assets become stranded, wasting resources.

The next decade will be crucial. The challenge to 2030 is to reduce emissions as much as possible with proven methods such as energy efficiency and bioenergy, while also laying the foundations for accelerated emissions reduction in the 2030s, once new technologies are proven at scale and the electricity market has further decarbonised. The early 2030s will be a crucial trigger point to decide the future of renewable gases in Victoria. If they are not economically viable, a further push towards electrification will be required and more investment in energy efficiency will be needed. In the 2040s, remaining infrastructure will need to be repurposed or decommissioned depending on the technological maturity and commercial viability of low emissions gases and other technologies. Planning for this must start now, starting with the Gippsland Basin, where gas production assets are already undergoing or rapidly approaching decommissioning (***Recommendation 4***).

1 Department of Environment, Land, Water and Planning (2016) ***Estimating the Health Impacts of Air Pollution in Victoria***

2 AEMO (2021) ***Gas Statement of Opportunities***

3 Department of Environment, Land, Water and Planning (2021) ***Gas Substitution Roadmap Consultation Paper***

Victoria's gas infrastructure is privately owned, but the Victorian Government has a critical role in driving decarbonisation of the gas sector. The government can contribute to Victoria's emissions reduction targets with more and sustained investment in energy efficiency across residential (especially low income), commercial and industrial sectors – including through education, training, and behaviour change programs (*Recommendations 5*, *6* and *8*). It can immediately remove barriers to all-electric developments to ensure that gas connections are not the default and prepare for increased electrification of transport and buildings in the future (*Recommendation 7*). And it can review its own natural gas use, ensuring all Victorian Government operations – including large energy users such as hospitals and schools – have plans to achieve Victoria's emissions reduction targets (*Recommendation 9*).

By no later than 2030, we recommend the government have completed detailed regional strategic planning and supported trials for a diverse, decentralised low or zero emissions gas supply in Victoria, based on the suitability of gas infrastructure, access to electrical infrastructure and water (necessary for green hydrogen production); and organic feedstocks (necessary for biogas and biomethane production) (*Recommendation 1*). The existing gas network will still be in use, but its expansion should be limited. The government should consider a policy of ending all new gas network connections before 2030 to avoid risks from a potentially stranded asset (*Recommendation 7*). It should also work to align all Victorian Government policy and regulations with the legislated commitment to net zero emissions by 2050 (*Recommendation 10*) and improve data collection and availability on energy use and emissions (*Recommendation 11*). Natural gas use should be incorporated into emissions reduction plans, with progress published regularly (*Recommendation 10*).

Two alternative gases should be the focus for government and private sector investment this decade: biogas (and biomethane) and green hydrogen. Both gases are renewable and show significant potential but have their own challenges and are currently more costly than natural gas. For example, Victoria's existing gas transmission and distribution infrastructure cannot be used to transport hydrogen without modification. Household, business, and industrial natural gas appliances will need to be replaced if switched to electricity or 100% hydrogen for space heating, water heating, cooking, and other uses. Biomethane on the other hand is chemically almost identical to natural gas. Existing infrastructure, including end user appliances, can continue to be used. But there are limits to the amount of biogas and biomethane that can be produced in Victoria. Our analysis suggests biomethane can meet, at most, around a quarter of Victoria's current gas use by 2050. Significant barriers will need to be removed, and planning and coordination efforts increased to reach this scale (*Recommendation 2*).

The government can build on the work outlined in its *Renewable hydrogen industry development plan*.[4] Our analysis suggests green hydrogen use would need to ramp up by 2030 for it to make a significant contribution to Victoria's 2050 net zero emissions target. Substantial effort to develop the industry in Victoria over the next decade is required, and its impacts on water and electricity must be better understood. Consideration should be given to a Victoria-wide target for green hydrogen production supported by grants for pilots, trials and demonstration projects. Use of existing natural gas production, processing and storage facilities for hydrogen distribution will require significant planning (*Recommendation 4*) and major modifications. In some cases, it may introduce added risks. But its flexibility as a source of heat, energy and chemical feedstock matched with its zero emissions profile (when produced by 100% renewable energy) make it worth pursuing (*Recommendation 3*). Existing projects seeking to establish a supply chain from hydrogen production in the Latrobe Valley, together with carbon capture and storage, will complement investment in green hydrogen. Green hydrogen has significant potential as a relatively decentralised, affordable, zero emissions energy source, enabling private sector investment and job creation in multiple regions across Victoria.

Government will need to assess the merits and risk of alternative fuels on a region-by-region basis, identifying areas best suited to new investment. Detailed planning now will position Victoria to maximise the job and export opportunities of decarbonisation and respond to changing carbon policies in global markets. The equity impacts of the gas transition on Victorians will need to be managed, as well as the differing access to gas supply across the state (*Recommendation 6*).

In addition to supporting the expansion and commercialisation of these alternative gases, the government should increase investment in energy efficiency starting immediately. Our analysis finds high levels of investment will likely be needed through to 2040. Reducing demand for energy is a proven, low-cost solution. It curbs emissions, cuts energy costs for households and businesses, and limits the need for expensive new infrastructure. Reducing draughts and improving thermal performance in homes and buildings improves human health and comfort, provides job opportunities (such as retrofitting older housing stock), can boost property values and reduce peak demand on the energy system. Our advice identifies specific short, medium and long-term targets and measures to reduce both gas and overall energy demand across households, businesses, and industry. Reducing gas demand ensures dwindling local supply can be reserved for hard-to-abate industries, and gas-fired electricity generation. Burner and boiler upgrades, heat recovery and installation of heat pumps across the industrial and large commercial sectors can also achieve significant savings this decade (*Recommendation 5*).

There are potential opportunities to repurpose gas production facilities and pipelines for carbon capture and storage (CCS) in Gippsland and Western Victoria due to their proximity to potential carbon storage sites. This would require modifications to existing infrastructure, especially to production facilities. Existing initiatives in Victoria include the CarbonNet and the CO2CRC projects. A trial is underway to establish an export supply chain for hydrogen produced from brown coal in Gippsland. In its commercial phase, the carbon dioxide produced will be captured and stored underground. Some locations in Victoria may also prove suitable for direct air CCS, a developing technology which removes carbon dioxide directly from the atmosphere rather than capturing it from a specific source (*Recommendation 4*).

Regardless of which options prove most effective to reduce emissions, significant change and investment is inevitable. Natural disasters already cost the Australian economy an average of $38 billion a year. We are already on a path to reach 1.5 degrees warming in the early 2030s.[5] A high emissions scenario, where emissions continue to rise and global temperatures average 3 degrees above pre-industrial levels, would see these costs more than double by 2060, to $94 billion – around 30% higher than cost estimates under a low emissions scenario.[6] Three degrees average warming would be devastating for Australia's economy, society, and ecology. A 3 degrees warmer world would render many more properties and businesses uninsurable. A warmer planet also has direct and indirect impacts on human health, livelihoods, and communities. The elderly, young, unwell, and those from lower socio-economic backgrounds are at increased risk.[7]

Victorian Government leadership is needed given our state's far more significant reliance on gas compared with other jurisdictions. Good progress has been made towards decarbonising the electricity sector over the past decade. The same attention now needs to be paid to gas. With coordinated planning and sustained action, Victoria can not only meet its energy needs but also drive the transition to net zero emissions and a prosperous future.

Victoria's gas infrastructure is privately owned, but the Victorian Government has a critical role in driving decarbonisation of the gas sector.

4 Department of Environment, Land, Water and Planning (2021) *Renewable Hydrogen Industry Development Plan*

5 IPCC (2021) *Technical Summary*, in *Climate Change 2021: The Physical Science Basis: Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*

6 Deloitte Access Economics (2021) *Special Report: Update to the Economic Costs of Natural Disasters in Australia*

7 Australian Academy of Science (2021) *The Risks to Australia of a 3°C Warmer World*

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Terms of reference

In December 2020, the Treasurer requested Infrastructure Victoria provide advice on the future of Victoria's gas networks under a range of 2050 net zero emissions energy sector scenarios.

The Victorian Government requested advice on the nature and timing of decisions regarding Victoria's gas transmission and distribution networks in a future where:

- Victoria's carbon emission reduction targets are achieved
- sufficient and suitable energy and chemical feedstocks are available for domestic, commercial and industrial use, and,
- an option is available for hydrogen and/or biomethane to be part of the future energy mix.

Infrastructure Victoria was asked to engage with industry, regulators, the community, government and other key stakeholders in developing this advice, and to draw on international comparators and research. We were asked to develop scenarios for a net zero emissions energy sector in 2050, and assess the implications for gas production, electricity generation, and transmission and distribution networks under each.

The advice was requested in two parts:

1. An interim report, within six months of the request, setting out key early findings and evidence, significant risks and/or opportunities, key issues for further consultation and the proposed strategic direction of the final advice. The *interim report* was published in July 2021.
2. A final report (this report).

   The final advice is supported by evidence and analysis detailing the potential role for gas in Victoria's future energy mix. It considers the regulatory, policy and market settings that underpin gas production, transmission and distribution, and identify potential timings of decisions needed to optimise opportunities for existing gas infrastructure.

   The full *Terms of reference* are available on our website.

A note on methodology

To inform our advice, we commissioned and undertook detailed technical analysis across a range of subject matter areas. A summary of our approach to this work can be found in *Section 6* of this report. All technical analysis can be found in the full set of reports available at infrastructurevictoria.com.au

Glossary

Gas infrastructure is defined as infrastructure across the entire value chain of production, processing, transmission and distribution, storage, consumption, export and end use.

Net zero refers to a balance between greenhouse gas emissions produced and removed from the atmosphere by offsets, avoided emissions, reductions or carbon removal.

Renewable or **zero emissions gases** are gases from renewable resources such as biogas/biomethane and green hydrogen that do not generate greenhouse gas emissions.

Low emissions gases also refers to biogas/biomethane and green hydrogen, but includes gases such as blue hydrogen, which produce greenhouse gas emissions during production. These emissions can be captured and/or offset to achieve net zero emissions.

The term **energy gas** is used in this report to denote all gasses used for household, commercial and industrial use – including biogas, biomethane, hydrogen and natural gas.

Other terminology used in this report includes:

ACCU Australian Carbon Credit Unit

AEMC Australian Energy Market Commission

AEMO Australian Energy Market Operator

AER Australian Energy Regulator

Agroforestry offsets A land or farm management system which uses trees and plants to sequester carbon emissions. Some landowners can be paid for keeping habitat rather than clearing land for grazing.

Behind the meter Energy generated onsite, not measured by the energy meter of a residence, business, or other facilities.

Biogas The raw gaseous product from anaerobic digestion of organic matter in an oxygen-free environment, consisting of about 60% methane along with carbon dioxide and small quantities of other gases. We have also used this term to cover biogas and biomethane in situations where both are likely to be used, or where the use of one or the other is yet to be determined.

Biomethane Upgraded and purified biogas, consisting of near-pure methane. Biomethane has chemically similar properties to fossil fuel derived methane and can be used as a direct substitute for natural gas.

Blue hydrogen Hydrogen produced using natural gas through the process of steam methane reforming. Carbon dioxide emissions generated during production are not necessarily captured and stored. Carbon dioxide emissions generated during production may be captured and stored via carbon capture and storage, or offset if low or net zero emissions are to be achieved.

Brown hydrogen Hydrogen produced using coal gasification. If the carbon dioxide emissions generated during production are captured and stored, it is considered blue hydrogen.

Carbon capture and storage (CCS) Removal of carbon emissions from flue gases (produced at fuel power stations, energy intensive industries, or oil and gas fields) or the atmosphere, for storage permanently underground (as a gas or liquid) or in solid form (through a reaction with metal oxides to produce stable chemical compounds). Natural processes which remove and store carbon dioxide from the atmosphere, such as biomass, soils and oceans, are not included in the definition of CCS.

Carbon dioxide equivalent (CO_2e) A measure used to compare the emissions from greenhouse gases based on their global warming potential.

Carbon sequestration Natural capture of carbon from the atmosphere through biological, chemical, and physical processes for storage in vegetation like grasslands, forests, soils and oceans. Changes in land use and agricultural practices such as reforestation, soil farming or seaweed farming can accelerate the process.

CO_2 Carbon dioxide

Combined heat and power (CHP) Also known as cogeneration, CHP is an energy efficient technology that generates electricity or mechanical power. It recovers thermal energy usually lost in the power generation process to provide additional space and water heating, or cooling, for domestic and industrial processes.

Decarbonisation The reduction of carbon dioxide emissions to zero or net zero.

DELWP Department of Environment, Land, Water and Planning

DISER Department of Industry, Science, Energy and Resources (Commonwealth)

Distributed energy resources Renewable energy units or systems, such as rooftop solar photovoltaic panels, that are commonly located at houses or businesses to provide and/or store power.

Distribution infrastructure (gas) Includes pipelines to transport gas from transmission pipelines to the end-users (businesses and homes) in major demand centres.

Electrification The process of shifting to electricity as an energy source in place of other fuels such as oil or natural gas. When renewable sources are used to generate electricity, electrification can reduce carbon emissions.

ESC Essential Services Commission

ESV Energy Safe Victoria

Feedstock A raw material used to supply or fuel an industrial process or converted to another form of energy.

Firming capacity Provides backup for intermittent power sources such as wind or solar using an additional energy source (such as gas) or storage (such as batteries).

Green ammonia Ammonia is a compound of nitrogen and hydrogen which can be used as a chemical energy carrier and a potential fuel. Green ammonia is synthesised by renewable energy sources.

Green hydrogen Hydrogen produced through electrolysis, using renewable electricity such as wind or solar, to split water into hydrogen and oxygen. Green hydrogen production generates no greenhouse gas emissions.

Greenhouse gases Greenhouse gases include carbon dioxide, methane, nitrous oxide, which are released by human activities such as burning fossil fuels for electricity, heat, and transportation. Greenhouse gases trap heat in the atmosphere and contribute to global warming. Greenhouse gas emissions are commonly measured in carbon dioxide equivalent (CO_2e).

H_2 Hydrogen

Hard-to-abate industries Energy-intensive industries, dependent on natural gas as a chemical feedstock and high-temperature process heat, where substitutes are currently unavailable or unaffordable.

Heat pump A device that uses the refrigeration cycle to cool and heat spaces, or water, by transferring thermal energy from a cooler environment to a warmer environment or vice versa.

Heat recovery An energy efficient technology used in commercial and industrial processes, such as burning gas, to reduce energy demand by optimising the existing process heating flows. It recovers wasted heat and uses it to pre-heat air at the combustion burner intake. Heat recovery is implemented through moderate modifications of the gas ductwork.

km Kilometres

kt Kilotonnes

MJ Megajoule or one million joules (unit of measurement for energy)

Mt Million tonnes (metric)

National Gas Rules The National Gas Rules govern the access to natural gas transmission and distribution pipeline services and elements of broader wholesale and retail natural gas markets in north and east Australia. Together with the National Gas Law, the National Gas Rules are a schedule to the *National Gas Act 2008*.

NEM National Electricity Market

NOPSEMA National Offshore Petroleum Safety and Environmental Management Authority (Commonwealth)

NOPTA National Offshore Petroleum Titles Administrator (Commonwealth)

OECD Organisation for Economic Co-operation and Development

PJ Petajoule or one million billion joules (unit of measurement for energy)

PV Solar photovoltaic panel

REZ Renewable Energy Zone

Stranded assets Investments which are likely to see their economic life cut short due to a combination of technology, regulatory and/or market changes.

Transmission infrastructure (gas) Includes pipelines to transport gas from production and storage facilities to the entry point of the distribution network. Some large gas users are directly connected to the transmission pipeline.

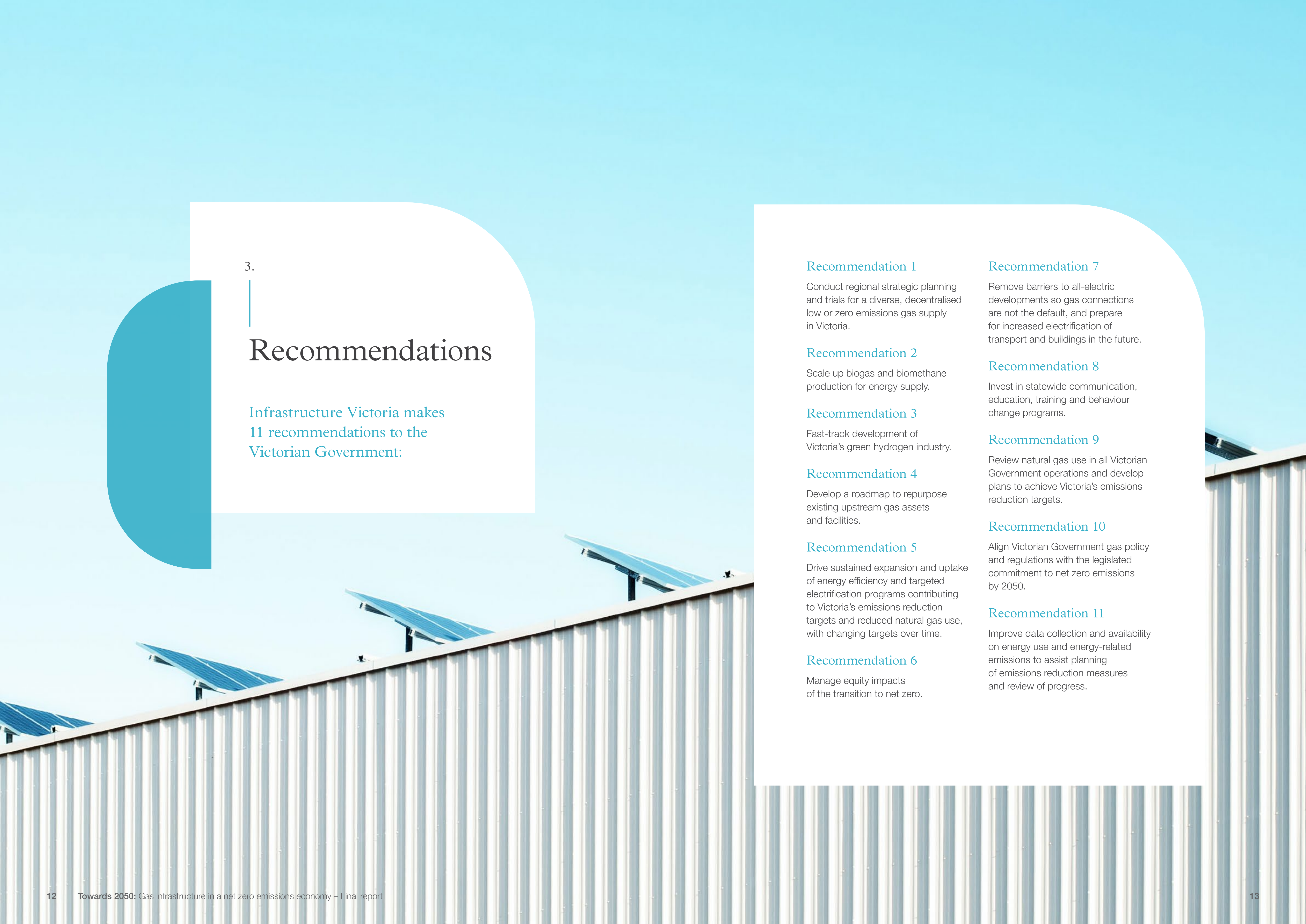
Upstream / midstream / downstream Upstream natural gas industry assets include production facilities and production pipelines needed to explore potential underground or underwater natural gas fields, to drill and operate the wells that recover raw natural gas. Upstream is followed by midstream processes (processing and transportation) and downstream processes (refining and distribution).

VEU Victorian Energy Upgrades

VEEC Victorian Energy Efficiency Certificate

VRET Victorian Renewable Energy Target

Waste-to-energy The process of generating energy such as electricity, heat or fuels from waste.



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Recommendations

Infrastructure Victoria makes 11 recommendations to the Victorian Government:

Recommendation 1

Conduct regional strategic planning and trials for a diverse, decentralised low or zero emissions gas supply in Victoria.

Recommendation 2

Scale up biogas and biomethane production for energy supply.

Recommendation 3

Fast-track development of Victoria's green hydrogen industry.

Recommendation 4

Develop a roadmap to repurpose existing upstream gas assets and facilities.

Recommendation 5

Drive sustained expansion and uptake of energy efficiency and targeted electrification programs contributing to Victoria's emissions reduction targets and reduced natural gas use, with changing targets over time.

Recommendation 6

Manage equity impacts of the transition to net zero.

Recommendation 7

Remove barriers to all-electric developments so gas connections are not the default, and prepare for increased electrification of transport and buildings in the future.

Recommendation 8

Invest in statewide communication, education, training and behaviour change programs.

Recommendation 9

Review natural gas use in all Victorian Government operations and develop plans to achieve Victoria's emissions reduction targets.

Recommendation 10

Align Victorian Government gas policy and regulations with the legislated commitment to net zero emissions by 2050.

Recommendation 11

Improve data collection and availability on energy use and energy-related emissions to assist planning of emissions reduction measures and review of progress.

Timeline for government action

Immediate and ongoing

- Strong and sustained investment in energy efficiency across residential (especially low income), small commercial and large commercial sectors – including education, training and behaviour change programs (*Recommendations 5* and *8*).
- Manage equity impacts of the transition to net zero (*Recommendation 6*).

Immediate – for completion by 2024

(within one to two years)

- Develop a gas production and storage asset repurposing roadmap (*Recommendation 4*).
- Remove barriers to all-electric developments, to ensure that gas connections are not the default, and prepare for increased electrification of transport and buildings in the future (*Recommendation 7*).
- Review natural gas use in all Victorian Government operations and develop plans to achieve Victoria's emissions reductions targets (*Recommendation 9*).

Immediate – for completion by 2030

(over the next three to eight years)

- Conduct regional strategic planning and trials for a diverse, decentralised low or zero emissions gas supply in Victoria (*Recommendation 1*).
- Scale up regional biogas and biomethane production by supporting co-investment in biogas development and demonstration with industry, local government and other stakeholders (*Recommendation 2*).
- Fast-track development of Victoria's green hydrogen industry (*Recommendation 3*).
- Existing gas network still in use but expansion is limited. Consider policy of ending all new gas network extensions and connections (*Recommendation 7*).
- Align government policy and regulations with the legislated commitment to net zero emissions by 2050 (*Recommendation 10*).
- Improve data collection and availability on energy use and energy-related emissions to assist planning of emissions reduction measures and review of progress (*Recommendation 11*).

2030 to 2040

- Review future of existing gas network in line with emissions reduction goals and technology cost/commercial viability (*Recommendations 1* and *7*).
- Evaluate the commercial viability of renewable gas options, aligned with emissions reductions goals, and reconfigure or decommission the gas network (or sections thereof) (*Recommendations 1, 2* and *3*).
- Implement large-scale appliance switching for household, commercial and industrial gas users (*Recommendations 1, 2* and *3*).

2040 to 2050

- Complete implementation of renewable gas at scale, if commercially viable, including decommissioning/retrofit or new pipelines as applicable (*Recommendations 1, 2* and *3*).
- Complete implementation of large-scale appliance switching for household, commercial and industrial gas users (*Recommendations 1, 2* and *3*).

2050

- Net zero emissions for Victoria's gas sector achieved.

Recommendation 1

Conduct regional strategic planning and trials for a diverse, decentralised low or zero emissions gas supply in Victoria.

Context

- **Emissions from natural gas use will need to decline significantly for Victoria to meet its emissions reduction targets. A range of actions can contribute to reducing emissions from current natural gas use, including energy efficiency, and substituting natural gas for low or zero emissions energy gases and/or electricity generated from renewable sources. A combination of approaches will likely be needed for the gas sector to achieve net zero emissions.**
- The future energy mix will be influenced by breakthroughs in lower emissions energy technologies and their ability to be rapidly and cost-effectively scaled up. It will also be influenced by changing consumer preferences, including the uptake of rooftop solar panels, household battery storage and energy efficiency improvements.
- Our scenario analysis has explored a range of plausible future energy mixes to consider the direction, extent and impact of change which may be required while seeking to maximise use of existing gas infrastructure. While the scenarios have made simplifications and assumptions to deal with the uncertainties that surround future energy technologies, they highlight that the most cost-effective way to achieve net zero emissions by 2050 may be to have significantly lower gas use for energy than is currently the case. Our analysis also indicates that no single low or zero emissions gas is likely to provide the solution for Victoria, but that multiple energy sources will be needed.
- Natural gas will continue to play a critical role in providing a reliable source of energy to Victorians while commercialisation efforts play out for alternatives. This means that the existing gas network will be needed into the 2030s and likely beyond. However, its long-term future – at least in its current form – is uncertain.
- Planning for low and zero emissions gases needs to start now, building on the technical studies that support this advice, if they are to make a significant contribution to Victoria's 2050 and interim emissions reduction targets.
- Biogas, biomethane and hydrogen are potential energy substitutes for natural gas which may allow for continued use and/or repurposing of existing gas infrastructure. However, these energy sources are currently unproven at a network-scale in Australia and are not yet cost competitive with natural gas or electricity.
- Victoria's gas system is part of a national network. Changes to Victorian settings will need to consider implications for other states who are connected to and may rely on gas supplies from Victoria.
- The Australian Energy Market Operator (AEMO) facilitates planning in Victoria's Declared Transmission System for gas through the *Victorian gas planning report*. It is also responsible for Victoria's electricity transmission planning, and undertakes the integrated system plan every two years to prepare for efficient development of the National Electricity Market. The *Draft 2022 integrated system plan* analyses various scenarios exploring the pace of economy-wide decarbonisation and the extent of transport and industry electrification. To date, gas planning has not had the same focus on the transition to net zero.

Emissions from natural gas use will need to decline significantly for Victoria to meet its emissions reduction targets.

Recommendation

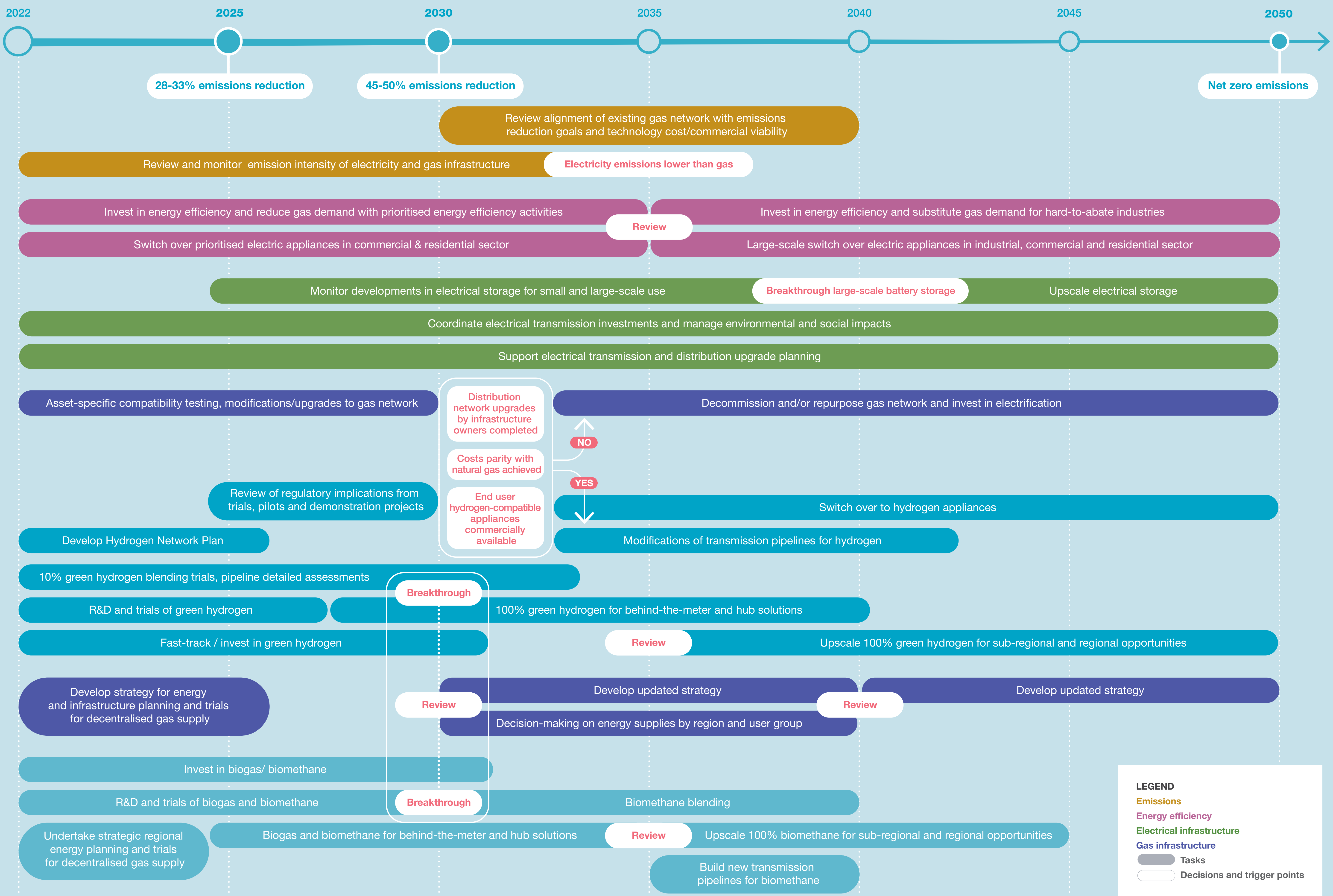
- **Within the next five years, the Department of Environment, Land, Water and Planning (DELWP) should lead completion of detailed regional strategic energy planning. Planning should identify and facilitate the implementation of low or zero emissions gas supply across Victoria, based on reduced energy demand resulting from energy efficiency improvements; the most promising candidates for low or zero emissions energy gas in each region; and additional electricity demand, including from transport and green hydrogen production (see also *Recommendations 2, 3* and *5*). This should include:**
  - Support for trials of biogas, biomethane, hydrogen blending and pure hydrogen at site, local hub and sub-regional scales with comprehensive monitoring, evaluation, review and sharing of information.
  - A detailed assessment of infrastructure implications by region, considering both gas and electricity infrastructure and the various gas decarbonisation pathways that may emerge over time, which can be adapted if low or zero emissions gases do not become technically feasible and/or economically competitive.
  - Detailed identification of cross-sectoral impacts and opportunities in each region, including water, waste, transport and agriculture.
  - Pre-feasibility assessment for biogas and biomethane production from food and agricultural waste, particularly in northern and western Victoria, and Melbourne, in collaboration with Recycling Victoria.
  - Detailed assessment of the implications for different user groups, including residential, commercial and industrial:
    - Options for hard-to-abate industries such as chemical production and heavy transport, to determine the appropriate decarbonisation pathway on a case-by-case basis
    - Options and required actions for the different gas user groups depending on the decarbonisation pathway(s) available to them
    - Any safety implications associated with the proposed changes to gas supply
  - Options for staged implementation of low or zero emissions energy gases into the gas distribution and/or transmission networks, identifying the region-by-region schedule for infrastructure upgrades, potential blending, or switchover from natural gas. This involves coordinating with private sector operators, local governments and other stakeholdersto map out logistics for each option and how each party will interface with one another in any transition.
  - Consideration of the potential impact on other jurisdictions of any changes in Victoria's natural gas production and use, as well as the impact on Victoria of possible policy changes in other jurisdictions.

If, by the early 2030s, efforts to coordinate, incentivise and scale up biogas and biomethane production have been successful (see *Recommendation 2*), plans to separate parts of the network to be run on biomethane can be implemented.

In the early 2030s, the Victorian Government should assess the success of efforts made to decarbonise gas and electricity, in consultation with industry. At this point, a decision on the ongoing role, if any, fornatural gas in each region of Victoria can be made.

- Modification and/or decommissioning of gas distribution, transmission and production infrastructure will need to be planned in accordance with this decision. Some gas infrastructure may be repurposed (see *Recommendation 4*).
- This decision will have a significant impact on consumers, which will need to be planned for and managed (see *Recommendation 8*).

Figure 1: Nature and timing of gas infrastructure decisions



Key findings

\ Our analysis has indicated that natural gas has a role to play in Victoria's energy supply for at least the next 10 years and that existing gas infrastructure may have an ongoing role, depending on production costs of alternative gases relative to other energy sources, and consumer, business and industry acceptance:

- Commercialisation at scale of energy technologies which may allow for ongoing use of existing gas infrastructure, such as hydrogen and biomethane, is still being explored. Low and zero emissions gases are likely to be more expensive than natural gas for some time to come. For example, the *National hydrogen strategy* aims for a competitive clean hydrogen (i.e. hydrogen produced using renewable energy or using fossil fuels with substantial carbon capture and storage) industry by 2030.[8]
- The electricity network is designed to meet Victoria's current electricity demand. It is not yet able to also deliver the energy demand currently supplied by gas. Our scenario analysis has modelled a future where electricity consumption increases from around 200 PJ in 2020 to between 650–810 PJ in 2050, depending on the scenario – an increase of more than three times.[9]

\ Transitioning the gas sector to net zero emissions will require significant planning and investment. Our analysis indicates that:

- Victoria's offshore natural gas production is declining, and early consideration will be needed on potential constraints to natural gas supply which may affect the capacity for hydrogen blending during the transition.[10]
- Most of the gas transmission network is not compatible with pure hydrogen transportation without significant modifications.[11] The distribution network will require modification to be repurposed for high concentrations of, or pure, hydrogen.
- Gas supply in the future may be less centralised, potentially produced in more and different locations to natural gas production today. Changes to the way gas is supplied and distributed would require modifications to the gas network which need further assessment and planning.

\ Significant scaling up of electrical infrastructure will be required regardless of the future energy mix. The scale of the transition suggests there is likely to be a significant need to accommodate more projects within each Renewable Energy Zone – including wind and solar generation, battery and other storage, bioenergy plants, and green hydrogen plants. It will be necessary to coordinate transmission investments and manage the cumulative environmental and social impacts of these energy projects.[12] Electricity distribution networks will also be impacted.

\ For Victoria to achieve its emissions reduction targets, the 2050 gas network will need to look substantially different to the gas network of today. The future energy mix may incorporate:

- Increased reliance on renewable electricity for many uses, including transport: Scenario analysis suggests that Victoria's electricity consumption increases significantly by 2050, with Greater Melbourne expected to experience the greatest change.[13]
- Significantly reduced or no natural gas use: From the 2030s, available natural gas could be used to support hydrogen blending and/or hard-to-abate uses (including any sub-regions of the distribution network for which a lower emissions solution is not feasible). Any ongoing role past 2050 for natural gas will require carbon sequestration, offsets and/or carbon capture and storage to reach net zero emissions.
- Additional biogas and biomethane supply: There are significant bioenergy resources in Victoria (see *Recommendation 2*). However, these resources are widely distributed and, in the case of those in the northern and western parts of the state, far from existing gas transmission pipelines.[14] As biomethane is chemically similar to natural gas, its use is compatible with existing gas infrastructure, including end user appliances. Some reconfiguration of the gas transmission network may be needed to maximise use of biomethane across Victoria.
- Hydrogen production: The location of potential green hydrogen production sites will be influenced by proximity to electricity infrastructure and gas networks, as well as availability of suitable land and water resources.[15] Hydrogen can be a distributed energy resource, meaning it can be produced locally or close to demand centres.[16] However, models of delivery will depend on supply side costs and end user dynamics.[17] In Gippsland, it may be possible to use hydrogen produced from brown coal or natural gas in conjunction with carbon capture and storage and offsets. Hydrogen can be blended at up to 10% by volume with natural gas into the distribution network, or used to displace natural gas for industrial purposes. Moving to 100% hydrogen requires substantial changes to gas transmission and distribution networks including operating pressure, meters, valves and joints as well as a coordinated switch to hydrogen end user appliances.

\ The transition will likely be far more complex than other transitions, such as implementation for the National Broadband Network or the digital television transition, due to safety hazards associated with gas and the need for households to purchase and swap out large, fixed appliances. It will require detailed planning, identification and resolution of many issues for infrastructure delivery across multiple parties.

\ Various Victorian Government departments and agencies, as well as Victoria's water corporations and Recycling Victoria, are responsible for planning for other sectors. This planning needs to integrate considerations relating to the gas transition. For instance, producing green hydrogen at scale requires significant water resources. Victoria is water-constrained, meaning green hydrogen production should use wastewater, storm water or sea water to avoid competition for water resources. This may entail additional desalination, adding to the electricity requirement.

8 COAG Energy Council (2019) *Australia's National Hydrogen Strategy*

9 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

10 Advisian (2021) *Asset Life and Adaptability Review*

11 Advisian (2021) *Asset Life and Adaptability Review*

12 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

13 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

14 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

15 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

16 Australian Energy Regulator (2021) *Regulating Gas Pipelines Under Uncertainty*

17 Advisian (2021) *Australian Hydrogen Market Study Sector Analysis Summary*

Recommendation 2

Scale up biogas and biomethane production for energy supply.

Context

- **Biogas and biomethane are renewable gases that can contribute to gas sector decarbonisation.**
  - Biogas can be used for onsite combustion as a gas in some applications, or to produce clean electricity. Its production can reduce emissions from the waste and agricultural sectors.
  - Biomethane is upgraded and purified biogas, which can be injected into existing gas distribution and transmission networks without the need for infrastructure upgrades.
  - Biogas and biomethane do release carbon dioxide when burned, but this comes from organic matter that has absorbed a similar amount when growing. They are therefore considered carbon neutral.
- Several existing projects in Victoria use biogas to supply energy, including wastewater treatment plants and food processing businesses. These include:
  - a biogas power station at Ravenhall which uses landfill gas to generate electricity for the grid
  - a waste-to-energy facility at Wollert which converts food waste to energy to power both the facility and a sewage treatment plant[18]
  - Barwon Water's Renewable Organics Network in Colac, which converts organic trade waste into renewable electricity to power their water reclamation plant[19]
  - biogas facilities at Melbourne Water's Western Treatment Plant and Eastern Treatment Plant to power each plant's energy usage, with excess at the Western Treatment Plant site exported to the grid to offset usage at other sites.
- There are limits to the amount of biogas and biomethane that can be produced in Victoria as both rely on organic waste streams from other activities such as fruit and vegetable waste, animal manure (cattle, chickens, piggeries), plantation waste and straw chaff. Supply can also fluctuate due to changing weather conditions, in particular drought. Estimates indicate that Victoria's total biogas and biomethane supply could reach around 40 PJ a year by 2050 – approximately one quarter of current natural gas use.[20]
- Our analysis suggests biogas production needs to ramp up significantly by 2030, utilising current technology and building on the success of existing Victorian projects and extensive use in Europe. Acting now will enable biogas and biomethane to reach their full potential in Victoria.

Recommendation

Over the next three years, the Victorian Government should accelerate the role of biogas and biomethane in the future energy mix by addressing identified barriers and strengthening support for their development and uptake. For biomethane, the role is to maximise its potential to displace natural gas in distribution networks. For biogas, the role is to maximise its potential to displace grid electricity. Both can be used in onsite applications (behind the meter).

Actions include:

- Develop a 2030 target for biogas and biomethane production. Our scenario analysis modelled 14–17 PJ of biogas and biomethane energy being consumed by 2030,[21] which could inform the setting of a target.
- As part of regional planning (see *Recommendation 1*), identify and plan both behind the meter and local area solutions, cost-sharing and coordinating with multiple parties, including those involved in managing organic feedstocks.
  - Assess the suitability of sustainable feedstocks in each region.
  - In metropolitan Melbourne, coordinate the provision of dedicated organics recovery hubs and build anaerobic digestion capacity to process food organics.
  - In regional Victoria, co-locate facilities with existing wastewater treatment plants and food production hubs that generate significant volumes of food waste.
- Advocate to the Australian Government for additional methods within the Emissions Reduction Fund to support biogas and biomethane uptake.[22]
- Review and coordinate Victorian Government energy, water, waste, agriculture and industry infrastructure grants and funding to incorporate and incentivise biogas and biomethane projects.
- Request DELWP, in consultation with the Environment Protection Authority and Sustainability Victoria, review legislation and regulations around anaerobic digestion and digestate (the material left after the anaerobic digestion of organic materials) to remove unnecessary regulatory burdens. The review should:
  - focus on the classification of anaerobic digestate as a reportable priority waste, which creates additional obligations and limits reuse
  - consider the potential for a Hazard Analysis and Critical Control Point regulatory framework for anaerobic digestion, which would support feedstock supply and the beneficial use of digestate in agriculture.

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18 Advisian (2021) *Asset Life and Adaptability Review*

19 Barwon Water (2021) *Renewable Organic Networks (website)*

20 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

21 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

22 ENEA and Deloitte (2021) *Australia's Bioenergy Roadmap*

Key findings

\ Biogas and biomethane production have the potential to be a part of Victoria's future net zero energy mix. Our scenario analysis estimates potential bioenergy resources in Victoria of around 140 PJ in 2020, growing to around 190 PJ in 2050.[23] Other studies suggest Victoria's bioenergy resource potential could be more than 300 PJ a year. However, these resources are widely distributed across the state, and vulnerable to drought and bushfire. It will not be technically, commercially and sustainably possible to realise the full potential.[24] Biomethane demand is limited at around 40 PJ by 2050 in our scenario analysis.

\ Biogas production can contribute to emissions reduction targets across a range of sectors – including energy, waste, water and agriculture, noting that any fugitive methane emissions would need to be managed and accounted for. Our scenario modelling shows around 11 million tonnes (Mt) of carbon dioxide equivalent (CO_2e) emissions can be avoided annually by using bioenergy to generate electricity. However, several barriers currently inhibit development at a larger scale:

- Projects tend to have higher capital and operating costs compared to natural gas.[25] They can be challenging to coordinate and attract investment given the multiple parties involved in both feedstock supply and biogas use.
- With carbon accounting, facilities that receive waste or recover materials record increases to their emissions, which creates a hurdle for new activities, particularly if the timing of benefits from offsets cannot align with the costs incurred.
- Biomethane produced from waste and agricultural methods is currently not eligible under the Emissions Reduction Fund. A new method is under development,[26] but stakeholders have raised concerns that current drafts do not meet industry needs.[27]
- Energy innovation funds could help overcome some cost barriers. However, grants programs (for instance the Victorian Government's Energy Innovation Fund) tend to require a grid connection,[28] while biogas and biomethane projects may be more suitable for industrial onsite applications.
- There are limits to the amount of residual waste that can be used across Victoria in thermal waste-to-energy facilities,[29] which constrains the market potential for bioenergy.
- Current regulations classify anaerobic digestate as a reportable priority waste.[30] This creates additional obligations and rules, and limits reuse as a fertiliser or potential upgrade to biochar (charcoal produced from biomass), which has potential to help with carbon storage.

\ The Malabar Biomethane Project in Sydney, partly funded by the Australian Renewable Energy Agency, is Australia's first biomethane-to-gas project. The project aims to demonstrate the technical viability and commercial considerations when upgrading biogas to biomethane for injection into the gas distribution network. The lessons from this project will be useful for Victoria.[31]

23 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*
24 ENEA and Deloitte (2021) *Australia's Bioenergy Roadmap*
25 BioEnergy Australia (2021) *Submission to Infrastructure Victoria's Gas Advice*
26 Clean Energy Regulator (2021) *Biomethane (website)*
27 BioEnergy Australia (2021) *Submission to Infrastructure Victoria's Gas Advice*
28 Department of Environment, Land, Water and Planning (2020) *Energy Innovation Fund: Program Guidelines*
29 Department of Environment, Land, Water and Planning (2020) *Recycling Victoria: A New Economy*
30 Environment Protection Authority Victoria (2021) *Waste Determinations: Questions and Answers*
31 Jemena (2021) *Malabar Biomethane Project (website)*

Recommendation 3

Fast-track development of Victoria's green hydrogen industry.

Context

- Hydrogen can be used instead of natural gas as a source of heat, energy and chemical feedstock for a range of purposes. The transport, storage and use of hydrogen would in many cases require modification to, or replacement of, existing gas infrastructure including end user appliances.
- Technical and commercial barriers to uptake of green hydrogen exist. Production is not yet cost competitive with natural gas, and it requires large amounts of renewable electricity and water – potentially increasing competition for Victoria's fresh water supplies unless produced with recycled wastewater or desalinated water.
- The Victorian Government released its *Renewable hydrogen industry development plan* in 2021, outlining how it can support development of Victoria's green hydrogen industry. The $10 million Accelerating Victoria's hydrogen industry program includes $6.2 million of grant support to hydrogen pilots, trials and demonstration projects.[32] The *NSW hydrogen strategy* has been funded with up to $3 billion in incentives, targeting up to $80 billion in private sector investment.[33] The Australian Government's Renewable hydrogen industry development funding round committed up to $70 million to help accelerate industry development.[34]
- Our scenario analysis suggests green hydrogen production would need to scale up by 2030 for it to make a significant contribution to Victoria's 2050 net zero emissions target.[35] Substantial efforts over the next decade to develop the green hydrogen industry in Victoria and resolve implementation issues will enable good decision-making for gas infrastructure based on the longer-term viability and scale of hydrogen use in Victoria.

Recommendation

The Victorian Government should increase its focus on green hydrogen development **over the next five years**, collaborating with industry, researchers, the transport sector and the Australian Government to determine whether production can reach cost-competitive commercialisation at scale, for which uses, and by when.

In the early 2030s, the overall role of hydrogen in the energy sector (i.e., the scale of supply to one or more of industry, large commercial, small commercial, residential and export) will be clearer and better gas infrastructure decisions can be made. To meet net zero by 2050, Victoria's energy strategy will need to pivot to other solutions if cost-competitive production of hydrogen has not been achieved by this time, or if implementation challenges cannot be overcome, such as consumer acceptance, appliance switchovers and maintaining hydrogen-natural gas blending limits.

- In implementing Victoria's *Renewable hydrogen industry development plan*, the government should provide additional support for green hydrogen trials, pilots and demonstration projects in strategic locations, to fast-track development and better understand technical and regulatory implications.
  - Support should help identify strategic locations, and coordinate and streamline development and regulatory processes, particularly as hydrogen projects currently traverse both gas and electricity requirements with complex governance settings
  - Support should encourage projects which use wastewater, seawater and saline groundwater, and projects seeking to improve electrolyser efficiency and/or drive cost reduction
  - In 2025, a proactive review should be undertaken of regulatory implications from the trials, pilots and demonstration projects to support a fit-for-purpose regulatory environment for hydrogen projects
- Consideration should be given to a Victoria-wide target for green hydrogen production supported with grants or incentives, allowing achievement of the target through various emissions reduction opportunities. This includes industrial onsite use and hubs, transport applications and potentially blending in networks where infrastructure cost implications are resolved.

A Hydrogen Network Plan should be completed by DELWP within **three to five years**. The Hydrogen Network Plan should identify end users likely to be dependent on hydrogen for a cleaner energy source (such as heavy transport) and applications where electrification is difficult (for example, industries requiring high grade heat), should hydrogen production at scale become technically feasible and cost competitive. This plan should build on the *Renewable hydrogen industry development plan* and be integrated with the regional planning in *Recommendation 1*, and consider:

- Suitable locations for green hydrogen production and use, factoring in access to sustainable water supplies, electricity supply and potential injection points into the gas distribution network. Integrated planning should consider electricity system planning, including Renewable Energy Zone and offshore wind developmenst, transmission needs and interconnection, and any distribution needs.
- A preferred approach for introducing hydrogen will need to be developed, whether via blending or complete replacement, in collaboration with the hydrogen and natural gas industries and with strong consumer engagement.
- If, by 2030, hydrogen becomes cost-competitive with other sources of energy, the distribution network upgrades for hydrogen compatibility planned by infrastructure owners are completed,[36] end user hydrogen-compatible appliances are commercially available, it is logistically feasible, and the economic case is established at that time, detailed switchover planning for suitable parts of the network can be finalised and implemented.

32 Department of Environment, Land, Water and Planning (2021) *Renewable Hydrogen Industry Development Plan*
33 Department of Planning, Industry and Environment (2021) *NSW Hydrogen Strategy*
34 Australian Renewable Energy Agency (2021) *Renewable Hydrogen Deployment Funding Round (website)*
35 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*
36 Australian Gas Infrastructure Group (2021) *Submission to Victoria's Gas Substitution Roadmap*

Key findings

- Existing projects seeking to establish a supply chain from hydrogen production in the Latrobe Valley, together with carbon capture and storage, will complement investment in green hydrogen. Green hydrogen has significant potential as a relatively decentralised, affordable, zero emissions energy source, enabling private sector investment and job creation in multiple regions across Victoria.
- Our strategic assessment of repurposing opportunities for gas infrastructure indicates that existing gas pipelines can be repurposed to transport hydrogen. The distribution network requires limited modifications to be repurposed to transport hydrogen at blends up to 10%. Around 60% of existing transmission pipelines would require modifications to be compatible with 10% hydrogen blends, in that they may need to be operated at lower pressure than their design pressure. Detailed assessment and potentially major modifications would be required to all pipelines to transport pure hydrogen.[37] In some cases, it may be cheaper to replace, rather than modify, existing infrastructure.
- Before hydrogen blending in existing gas networks can occur, cost arrangements need to be resolved such as who should bear the costs of network upgrades or how cost risks should be shared between network owners, hydrogen producers and consumers.
- Our scenario analysis has explored the implications of green hydrogen as a dispersed solution, to minimise the need for costly upgrades to the gas transmission system. It suggests that green hydrogen has significant potential, particularly where production and consumption can be closer together.[38]
  - Production closer to demand centres would avoid the need for major upgrades to the gas transmission pipelines which would be required to handle 100% hydrogen.
  - Electricity represents a significant portion of green hydrogen production costs.[39,40] Considerable renewable electricity generation and storage capacity would be required to support large-scale roll out of green hydrogen projects across Victoria.
- Hydrogen has the lowest implementation barriers for industrial and transport use as it does not need to be connected to a fixed network and there is familiarity with hazardous materials.[41] Implementation barriers are more significant for users on distribution networks, given the modifications required to pipelines for 100% hydrogen and mass replacement of end user appliances and equipment, many of which are not yet commercially available.
- A hydrogen blending target with natural gas places emphasis on network infrastructure and may support scale up of production,[42] but it will have limited impact on overall emissions and can therefore be only a temporary or transition solution. The main policy objective for a target should be to reduce emissions, and there are cross-sectoral opportunities to do so, for example leveraging hydrogen use in transport to increase the scale of production. Any hydrogen production target should therefore be inclusive of all emissions reduction opportunities.
- Maintaining hydrogen blending at 10% by volume may become difficult if natural gas supply declines.
- Current green hydrogen production technology requires electrolysers to use high-quality water as a feedstock, which requires additional water treatment. The maximum water efficiency of electrolysers is about 9 litres of water per kilogram of hydrogen. However, with the added process of water de-mineralisation, the ratio can range from between 18 litres to as much as 30 litres per kilogram.[43] A technology breakthrough for electrolyser water efficiency is required to avoid competition for Victoria's limited water resources.
- The amount of change required for large-scale roll out of hydrogen indicates that further work is needed to ensure sufficient resilience at regional and system levels. For example, major power outages could prevent production of green hydrogen, and this would have significant impacts on users if there is inadequate storage. However, the role low or zero emissions hydrogen could play in helping to meet Victoria's emissions reduction targets, combined with the potential benefits of a diversified energy mix for energy security and reliability, mean that an ongoing focus on hydrogen development is warranted this decade.

37 Advisian (2021) *Asset Life and Adaptability Review*

38 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

39 International Renewable Energy Agency (2020) *Green Hydrogen Cost Reduction*

40 Environmental Clean Technologies Limited (2020) *How Can Green Hydrogen Slash Costs by 75%? (website)*

41 DORIS Engineering (2021) *Net Zero Emission Scenario Analysis (Phase 1)*

42 Finkel A (2021) *Getting to Net Zero, published in Quarterly Essay*

43 Lampert D, Cai H and Elgowainy A (2016) *Wells to wheels: water consumption for transportation fuels in the United States, in Energy & Environmental Science, Issue 3*

Recommendation 4

Develop a roadmap to repurpose existing upstream gas assets and facilities.

Context

- Victoria's natural gas production is forecast to fall 43% from 360 PJ to 205 PJ between 2021 and 2025 as several fields in Gippsland cease production.[44] When gas production ceases, options for upstream assets (depleted gas fields, gas production, processing plants and pipelines) include repurposing, or decommissioning and rehabilitation.
- Decommissioning and rehabilitation will likely be a significant cost impact for the current asset owner and operator.
- Instead of decommissioning and rehabilitation at the end of field life, depleted gas fields and processing facilities can be repurposed to process CO_2, with some modifications, and utilised as carbon capture and storage (CCS) facilities.[45] Right now, there is a narrow window of opportunity as some existing production assets are already undergoing decommissioning. However, there is no clear overall strategy for potential asset repurposing.
- Many production assets are in Commonwealth waters and are not regulated by the Victorian Government. Collaboration with the Australian Government and regulators will be required.
- CCS has the potential to contribute to Victoria's emissions reduction targets by capturing and storing greenhouse gas emissions from energy-intensive industries which may otherwise find it difficult to reduce their emissions. It is part of the Victorian Government's *Climate change framework*, which outlines the government's approach to achieving net zero by 2050,[46] and the Commonwealth Government's whole-of-economy *Long-term emissions reduction plan*.[47] Existing initiatives in Victoria include the CarbonNet project and the CO2CRC initiative.

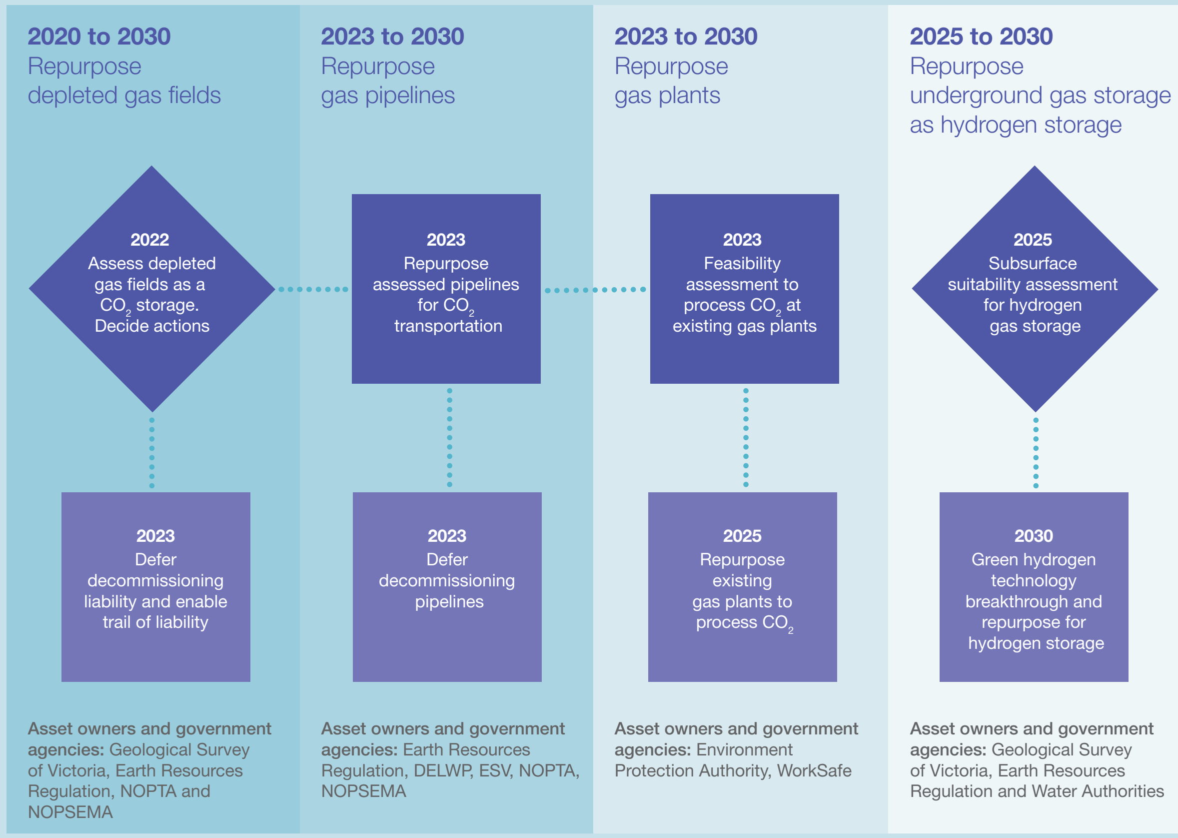
Recommendation

The Victorian Government, in collaboration with state and federal regulators and infrastructure owners, should develop a gas infrastructure asset repurposing roadmap for upstream assets **within the next two years**. Building on the work completed as part of this advice, identify priority assets in strategic locations that are suitable for repurposing and work with regulators and asset owners to preserve identified opportunities. This should start with the Gippsland Basin gas production assets which are already undergoing or rapidly approaching decommissioning stage:

- Undertake a suitability assessment ranking of depleted gas fields as potential CCS storage facilities, to include a technical assessment of surface and subsurface facilities.
- Determine the extent and timing of modifications required to cost-effectively repurpose each asset.
- Prepare for early engagement with existing operators and infrastructure owners to facilitate CO_2-ready applications when upgrading/modifying existing gas infrastructure.
- Collaborate with infrastructure owners to assess, in more detail, the potential for processing and underground storage facilities to be repurposed for hydrogen blends and pure hydrogen gas processing and storage operations.

44 AEMO (2021) *Victorian Gas Planning Report 2021*
45 Advisian (2021) *Asset Life and Adaptability Review*
46 Department of Environment, Land, Water and Planning (2016) *Victoria's Climate Change Framework*
47 Department of Industry, Science, Energy and Resources (2021) *Australia's Long-Term Emissions Reduction Plan*

Figure 2: Decision timeline to repurpose upstream gas infrastructure-government and asset owners



Key findings

- Our strategic analysis of Victoria's existing gas infrastructure has identified opportunities to repurpose gas production facilities and pipelines for CCS in Gippsland and the Otway Basin. This would require major modifications to existing infrastructure, especially on production facilities where equipment would need to be replaced to enable CO_2 injection.[48]
- Locations may also prove suitable for direct air CCS, a developing technology which aims to remove CO_2 directly from the atmosphere, rather than capturing it from the source of production.[49]
- As oil and gas production continues to decline, it is anticipated that operators will decommission and remove infrastructure to fulfil their decommissioning obligations. To enable repurposing, this could be deferred until CO_2 storage locations in the vicinity are proven. The feasibility of using existing production facilities for CCS should be assessed on a case-by-case basis.
- Under the *Offshore Petroleum and Greenhouse Gas Storage Act*,[50] existing petroleum production licence holders have the right to apply for greenhouse gas injection licences. Infrastructure owners may be considering repurposing their assets and may already have undertaken suitability assessments. Development of an asset repurposing roadmap would require the Victorian Government to work with petroleum licensees to build an understanding of, and agreement on, potential opportunities.
- Where existing facilities are identified as potential CCS locations, minimum inspection and maintenance activities should continue in place of decommissioning. Early engagement with existing operators and owners will be required to determine appropriate maintenance, decommissioning and/or rehabilitation action for each facility.
- Detailed and rigorous assessments will be required for any planned repurposing of infrastructure. Operators will need to work closely with the National Offshore Petroleum Safety and Environmental Management Authority to ensure future intentions are aligned while ensuring compliance with offshore safety and environmental regulations.
- Liability for asset decommissioning and rehabilitation would transfer to the incoming CCS operator. Legislation updates may be required to enable a deferred decommissioning plan and title transfer process for the ageing gas assets. The process will have to assess how to transfer the decommissioning liability to the incoming titleholder from the current owner/operator.
- There may be an opportunity to repurpose some natural gas processing and storage facilities to support hydrogen blending and hydrogen gas processing and storage. Further work is required, building on the technical studies completed for this advice, given the different chemical and physical properties of hydrogen compared to natural gas and uncertainties related to geological storage formations.
- Hydrogen storage underground is not currently provided for by legislation. There will need to be an additional workstream to establish a legislative framework if this is to be an option. There may be interactions with existing petroleum licensees that currently have existing rights over petroleum reservoirs which need to be appropriately respected.

48 Advisian (2021) *Asset Life and Adaptability Review*

49 CO2CRC (2021) *Direct Air Capture (website)*

50 *Offshore Petroleum and Greenhouse Gas Storage Act 2006 (Cth), s.392*

Recommendation 5

Drive sustained expansion and uptake of energy efficiency and targeted electrification programs contributing to Victoria's emissions reduction targets and reduced natural gas use, with changing targets over time.

Context

- **Whatever the current and future energy mix, reducing demand for energy through improved thermal performance of residences and energy efficiency of heating and cooling appliances helps curb emissions, save energy costs for households and businesses and limits the need for more infrastructure.**
- Victorian households account for 40% of Victoria's total natural gas use, a higher share than any other state or territory.[51] Space heating, such as wall heaters and ducted heating systems, comprises more than half (57%) of total household energy consumption in Victoria, and 29% of Victorian household greenhouse gas emissions.[52]
- Most homes and commercial buildings that will be standing in 2050 have already been built, making efficiency retrofits critically important.[53] In 2050, approximately 45% of Australia's housing stock will have been built prior to planned improvements to the National Construction Code's energy efficiency requirements, due to be included in the 2022 update.[54]
- The Victorian Energy Upgrades (VEU) program aims to improve energy efficiency in homes and businesses. Under the current program, relevant activities replace an electric appliance for a more efficient electric or gas appliance. There are no activities for replacing a gas appliance with an electric appliance.[55]
- Large industrial facilities that participate in the Environment Protection Authority's Environment and Resource Efficiency program are exempt from the VEU, unless they choose to opt in, and pay Victorian energy efficiency certificate (VEEC) charges on their bills.[56] VEECs represent one tonne of greenhouse gas saved when certain energy efficiency activities are undertaken. Annual targets have been set through Victorian legislation for up to 7.3 million VEECs in 2025.[57]
- *Victoria's infrastructure strategy 2021-2051* includes five recommendations to support energy efficiency and reduce associated greenhouse gas emissions from energy use, which the government has supported, partly supported, or supported in principle.[58]
  - Require 7-star energy-rated new homes by 2022, and increase afterwards
  - Mandate a home energy disclosure scheme
  - Strengthen minimum energy efficiency standards for rented homes
  - Make Victorian Government buildings more energy efficient
  - Make social housing suitable for changing local climates.

51 Department of Industry, Science, Energy and Resources (2021) *Australian Energy Update 2021*

52 Sustainability Victoria (2019) *Comprehensive Energy Efficiency Retrofits to Existing Victorian Houses*

53 European Council for an Energy Efficient Economy, Alliance for an Energy Efficient Economy and American Council for an Energy-Efficient Economy (2019) *12 Strategies to Step up Global Energy Efficiency: Advice from three expert NGOs to IEA's High-Level Commission on Energy Efficiency*

54 Wood T and Carter L (2014) *Fair Pricing for Power* and COAG Energy Council (2019) *Report for Achieving Low Energy Existing Homes*

55 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

56 Essential Services Commission (2021) *Specifications (website)*

57 Essential Services Commission (2021) *Victorian Energy Efficiency Certificates (VEECs) (website)*

58 Infrastructure Victoria (2021) *Victoria's Infrastructure Strategy 2021–2051*

Recommendation

The Victorian Government should immediately expand the scope, scale and coverage of Victoria's energy efficiency efforts to accelerate uptake of energy efficiency measures across Victoria's residential, commercial and industrial sectors. The expansion of the VEU program can help households and businesses access discounted energy-efficient products and services that will deliver significant greenhouse gas emissions reductions. Currently, the program creates new VEEC targets each year until at least 2030. We have identified the opportunity to target an additional 3.9 million VEECs across all sectors by 2040 at the latest. An earlier target, increasing annual targets from 7.3 million VEECs in 2025 to 11.2 million by 2030, will lead to greater long-term emissions savings. Alternatively, opportunities for program expansion could be explored through additional targets and expanded eligible activities.

We have identified the following high priority initiatives within each sector for immediate focus to realise energy and emissions savings and help meet interim and 2050 emissions reduction targets:

Immediately

- Support initiatives which replace gas appliances with high efficiency electric appliances to reduce gas demand and carbon emissions across all sectors:
  - Target replacement of commercial and residential gas-powered space and water heating with electric heat pumps
  - Target replacement of low temperature gas-powered water heating with electric heat pumps in the industrial and large commercial sectors.
- Support improvements to residential buildings' thermal shell performance:
  - Target improved draught sealing in the residential sector
  - Consider targeted measures to upgrade insulation in low-income households.
- Discontinue initiatives that increase gas demand in the commercial and residential sectors and increase the risk of future redundant appliances:
  - Discontinue all activities that incentivise replacement of appliances with gas-powered appliances, for example water and space heating.
- Support initiatives to reduce gas demand for large industrial energy users:
  - Support uptake of burner and boiler upgrades and heat recovery in the industrial sector
  - Include large industrial energy consumers, currently exempt, in energy efficiency schemes to support investments in transformational projects
  - Increase industry participation in existing programs that increase energy efficiency, such as use of the VEU Measurement and Verification method.
- Support research and development for electric appliances in high temperature, hard-to-abate industrial processes and gain a better understanding of changes in maintenance and life-cycle costs of electric appliances.
- Introduce review points to observe technological changes (at least every three to five years) and correct initiatives that are not achieving expected emissions reduction results.

In addition to the priority initiatives identified for immediate action, we recommend the Victorian Government provide long-term policy direction for energy efficiency programs to ensure ongoing funding certainty, with a focus on:

In the medium-term (the 2030s)

- As the emissions intensity of the electricity grid reduces and investment costs become competitive, introduce initiatives (for example, as an eligible activity under the VEU) to replace gas cooking appliances with high efficiency electric appliances to reduce gas demand in the residential and commercial sectors. Alternatively, cooking appliances could be converted to support hydrogen if that pathway has been proven viable by then (see *Recommendation 3*).
- Introduce initiatives to reduce natural gas demand for harder-to-abate industrial and large commercial uses. Depending on the relative costs and benefits at the time, this could be electrification, hydrogen, biomethane or other new low emissions technologies.

In the medium to long-term (the late 2030s and early 2040s)

Introduce initiatives (for example, as an eligible activity under the VEU) to reduce or replace natural gas demand in hard-to-abate industries including chemical, glass and metal production. This could include high temperature heat pumps (over 90°C), electric induction furnaces, microwave and electric resistance heating, and infrared drying across industrial sub-sectors.

Energy efficiency is a 'no regrets' approach which has clear and immediate benefits.

Key findings

- Energy efficiency is a 'no regrets' approach which has clear and immediate benefits. It reduces demand for energy without constraining future policy choices. It is the cleanest and most economical way to meet growing demand. It can help to increase business competitiveness, generate employment, boost energy security, reduce poverty, and benefit development.[59]
- Improved energy efficiency (resulting in either reduced electricity or gas demand) significantly reduces the amount of new energy generation and transmission infrastructure required, delivering financial, environmental, land use and social benefits.
- The Victorian Government has been focusing on energy efficiency. Since its inception in 2009, the VEU program has avoided over 75 Mt CO_2e.[60] However, more can be done – especially in the short term where gas decarbonisation pathways are still unproven. Immediate and sustained focus on improving energy efficiency in households and businesses will contribute towards meeting Victoria's net zero emissions targets and reduce the cost of the energy transition for consumers.
- Our analysis has identified six energy efficiency opportunities that would deliver significant gas reduction and can be implemented in the short to medium term for acceptable financial returns. These are: improved heat recovery; upgrades to burners and boilers; air to air heat pumps; air (and water) to water heat pumps; draught sealing; and electrification of cooking with induction. Improved insulation in the residential sector also has benefits but variable payback periods.
- The analysis suggests that across the residential, commercial and industrial sectors, these energy efficiency options could achieve 112 PJ in annual gas reduction by 2040 and save 4 Mt CO_2e in 2040.[61]
- Investing in these six high-value energy efficiency opportunities could reduce gas demand by 66%, with more than half contributed by the residential sector. Translated into VEECs, this is an additional 3.9 million VEECs in 2040 across all sectors.

59 Singh J (2016) *Why Energy Efficiency Matters and How to Scale it Up, in Live Wire, 2016/53*

60 Essential Services Commission (2021) *Victorian Energy Upgrades Data Dashboard (website)*

61 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

Recommendation 6

Manage equity impacts of the transition to net zero.

Context

- Our analysis has demonstrated that all future energy mix scenarios represent change. As natural gas is a major energy source for Victoria, the transition to lower emissions energy sources will be significant and incur costs that are likely to be passed on to energy users – regardless of the specific pathway leading to net zero emissions.[62]
- Equity is a guiding principle within the *Climate Change Act 2017*, which stipulates that government policies and programs should consider opportunities to increase the capacity of those most vulnerable to climate change impacts to adapt.[63]
- The Victorian Government's Victorian Energy Saver program includes targeted provisions for low-income households, including $335 million to deliver heating and cooling systems for low-income households and $112 million for energy upgrades to social housing properties.[64]
- *Victoria's infrastructure strategy 2021-2051* recommends that the Victorian Government strengthen minimum energy efficiency standards for rented homes and improve the energy efficiency and energy affordability of social housing.[65]

62 Energy Consumers Victoria (2021) *Submission to Infrastructure Victoria's Gas Advice*

63 *Climate Change Act 2017 (Vic)*

64 Department of Environment, Land, Water and Planning (2021) *Victoria's Household Energy Savings Package (website)*

65 Infrastructure Victoria (2021) *Victoria's Infrastructure Strategy 2021–2051*

Recommendation

To manage the equity implications of the energy transition, the Victorian Government should **immediately**:

- Increase the scope and scale of energy efficiency programs (or components of broader programs) specifically targeting low-income households
- Increase the scale of improvements in energy efficiency to existing social housing properties
- Increase minimum energy efficiency requirements in the minimum standards for rental properties to reduce energy use and costs, and regularly review and update to reflect new cost-effective measures
- Mandate all-electric appliances for new social housing to minimise energy bills for residents.

The Victorian Government should increase the scope and scale of energy efficiency programs specifically targeting low-income households.

In developing targeted energy efficiency programs for low-income households, the Victorian Government should:

- Ensure nil or minimal upfront contributions by low-income households to electrify, reduce emissions and/or move off the gas network
- Consider opportunities to link into Victoria's concession program for low-income households, noting that additional targeting may be needed within the broad cohort of concession holders
- Undertake further analysis of energy concessions usage and needs to better inform program design and targeting
- Address the different and often conflicting incentives for landlords and tenants in the rental market as they relate to the thermal and fixed appliance energy efficiency of rental properties
- Explicitly consider the range of benefits of thermal improvements to residential buildings, such as energy savings, avoided infrastructure build, health benefits, environmental benefits (such as reduced pollution and climate risk), more comfortable and higher quality homes suitable for a changing climate
- Consider alignment to other programs (in particular, energy efficiency programs such as Victorian Energy Upgrades – see *Recommendations 5*) as part of program design and evaluation
- Tailor program design and supporting communications to specific groups, such as the elderly, high-energy users, culturally and linguistically diverse communities and/or renters.

Key findings

\ Several pathways are available for the gas sector to reach net zero emissions, including substituting natural gas with a low emissions gas and/or electrification. Each of these has costs and implications for existing gas users:

- Energy efficiency upgrades, while potentially reducing household energy bills in the long run, require an upfront investment
- Switching from gas to pure hydrogen would mean households have to change their appliances
- Switching from gas to electricity would also require households to change appliances (for example, induction cooktops and split system air conditioning), as well as remove gas supply to their home. In some instances, they may need to upgrade their power supply.[66]

\ If significant numbers of households and businesses disconnect from the gas network, remaining customers would bear more of the network costs. This would increase affordability concerns for those who are less able to make changes in the first place, such as low-income households and renters.

\ Low-income households are more likely to experience energy affordability stress,[67] and can benefit the most from energy efficiency upgrades. In addition, there is evidence of significant health benefits from improvements to the thermal performance of houses, especially for low-income households.[68] However, the upfront cost of improving energy efficiency is often a barrier for low-income households.[69]

\ There are also significant opportunities to improve the thermal quality of social housing. A Sustainability Victoria report indicated that over 60% of Victorians in public housing felt their home was too hot in summer and/or too cold in winter.[70]

\ Developing subsidy programs with an equity objective is especially challenging for rental properties. This is due to the relatively longer payback periods of many energy efficiency upgrades in comparison to tenancy agreements; the risk of creating perverse incentives for landlords to raise rents following energy efficiency upgrades; and the risk the benefits of government subsidies unfairly flow to private landlords. However, without government support low-income renters are at high risk of being disadvantaged in the energy transition. Support for this cohort should be an immediate and ongoing focus for the Victorian Government.

\ The Victorian Government has implemented minimum energy efficiency standards for rental properties requiring a minimum 2-star heater. As rented homes comprise around 29% of Victorian homes,[71] significant energy and emissions savings could be achieved by increasing the rental standards for space heaters to require energy efficient heat pumps.

\ Renew Australia's consumer principles regarding fuel choice recommend that the best economic decision in Melbourne under a number of scenarios is to build or switch to all-electric.[72]

\ Government energy efficiency programs are not linked or delivered via the concession program, even though concession holders are lower income households that need special focus to support a just energy transition.[73] There is currently limited information about concession household composition, home and appliance age, and energy use and spending (see *Recommendation 11*). This information would help with better program design, delivery and evaluation for targeted energy efficiency initiatives (see *Recommendations 5*).

66 Allison L (2021) *Submission to Infrastructure Victoria's Gas Advice*

67 COAG Energy Council (2019) *COAG Report for Achieving Low Energy Existing Homes*

68 Daly D, Halldorsson J, Kempton L and Cooper P (2018) *Targeted Review of Evidence of Direct and Co-benefits of Energy Efficiency Upgrades in Low Income Dwellings in Australia*

69 Berg W, Cooper E and Molina M (2021) *Meeting State Climate Goals: Energy Efficiency Will Be Critical*

70 Sustainability Victoria (2020) *Linking Climate Change and Health Impacts – Social Research Exploring Awareness Among Victorians and our Healthcare Professionals of the Health Effects of Climate Change*

71 Australian Bureau of Statistics (2016) *2016 Census QuickStats – Victoria*

72 Alternative Technology Association (trading as Renew Australia) (2018) *Household Fuel Choice in the National Energy Market*

73 Noting not all low-income or disadvantaged households will hold a concession card

Recommendation 7

Remove barriers to all-electric developments so gas connections are not the default, and prepare for increased electrification of transport and buildings in the future.

Context

\ **New technologies will shape energy use and generate more options to reduce greenhouse gas emissions and manage the energy system. While the electricity sector has a potential pathway for achieving net zero emissions with renewable energy such as solar and wind, the transition to a low emissions or renewable future is less clear for natural gas.**

\ Increased energy efficiency, improved energy management by large energy users, and the growing use of electrical appliances in new high-density developments are reducing Victoria's overall natural gas consumption.[74] If additional energy efficiency and/or electrification measures are adopted, natural gas use may decrease further.

\ However, the trend for residential users is not the same in each area of Victoria. Some residential gas use is projected to increase, driven by growth in regional towns and connections in new developments in Melbourne's growth areas.[75] Some new housing estates have rolled out reticulated gas networks, like the Quandong Precinct in Wyndham, while others, like Mirvac's 'The Fabric' in Altona North, are all-electric.

\ Infrastructure projects are an investment for the long term. Continued expansion of the existing gas network today can create a bigger transition problem in the future – either through creating a bigger asset base that may need to be altered or decommissioned or locking in natural gas use and associated emissions for end-users. Embedding long-term natural gas use does not align with Victoria's 2050 net zero emissions goal.

\ If there is to be a shift towards greater electrification, a better understanding of the electricity network's capacity is required, particularly at the distribution level, and resolution of the implications for existing gas infrastructure investment.

\ In the *Victorian infrastructure plan 2021*, the Victorian Government states their support of policy adjustment so as not to encourage or embed future residential gas use. We think this should be done immediately.

74 AEMO (2021) *Victorian Gas Planning Report*

75 AEMO (2021) *Victorian Gas Planning Report*

Recommendation

To ensure that gas infrastructure is no longer the default in new housing developments, and to prepare for increased electrification in the future, the Victorian Government should:

\ **Immediately** remove any requirements for gas infrastructure and connections from the planning, building and plumbing system. Key regulations for revision include:

- Victorian Planning Provision clause 56.09 Utilities, which needs clarification that residential subdivisions do not require new gas infrastructure
- Victorian Planning Provision clause 66.01 Subdivision referrals, which requires change to limit gas network businesses' ability to specify reticulated gas for residential subdivisions as part of its 'determining referral authority'
- Plumbing Regulations 3.12.0(a), which requires change to remove the requirement for a gas connection (or a rainwater tank) for solar hot water systems.

\ Consider a policy of ending new gas network extensions and connections before the start of the 2028–2032 access arrangement process. Any policy should be developed in consultation with the Australian Energy Regulator, gas and electricity distributors, developers, local governments and consumer groups and include commercial considerations for gas network businesses and implications for consumers.

\ **Within two years**, review frameworks governing electricity distribution network investment to check that they facilitate planning for, and investment to support, all-electric buildings across residential, commercial and light industrial sectors.

\ Improve transparency of existing electricity infrastructure capacity to help developers identify suitable locations for new electricity-intensive developments, as well as to help streamline connections processes.

Consumer, developer and builder education will be needed to support any policy change, as well as enhanced consumer education on energy choice implications when buying a new home (see *Recommendation 8*).

Key findings

- Some local governments and parts of the development industry are interested in moving away from providing gas infrastructure in new developments. However, there are planning, building and plumbing regulations that impede building all-electric homes. New gas networks could lock in potential future emissions if alternative low or zero emission gases are not available via the existing gas network.
- There are some compelling consumer reasons for all-electric homes:
  - A dual fuel home results in paying for two types of infrastructure
  - Research examining detached or semi-detached homes found that all-electric new homes in Victoria can save households money compared to dual fuel, particularly when combined with solar panels[76]
  - Heat pumps, such as reverse cycle air conditioners, can use less energy than gas heaters to heat a home.[77]
- The capacity and cost of upgrading electricity networks outside of a development site varies widely depending on the site, the existing capacity of the electricity network, and the timing of other developments.[78] As there is no transparency around the capacity of the electricity network at particular locations to support higher electrical load or planned and possible upgrades and costs to support this, there is a cost risk to developers.
- Rules surrounding the economic framework create obligations for gas network businesses to connect customers and increase gas consumption, and do not adequately consider decline, repurposing or net zero emissions goals. A policy which halts new connections to existing gas infrastructure, such as in the Australian Capital Territory, could have implications for other users on the gas network. Existing gas networks have been built with a forecast of increasing customer numbers.[79] If those forecasts are not achieved, the costs are recovered among a smaller customer base – affecting affordability.
- Our scenario analysis points to increased electrification, from direct gas substitution, green hydrogen production and/or transport electrification.[80] Electricity businesses will need to be prepared for increased scale of demand on their networks, particularly distribution networks which tend to have more localised constraints. Further work is needed to understand the electricity distribution system's capacity and preparedness for a significant step up in electricity demand.

76 Alternative Technology Association (trading as Renew Australia) (2018) *Household Fuel Choice in the National Energy Market*

77 Your Home (2020) *Heating and Cooling (website)*

78 Infrastructure Victoria (2019) *Infrastructure Provision in Different Development Settings: Technical Appendix Volume 2*

79 APA Group (2021) *Submission to Infrastructure Victoria's Gas Advice*

80 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

Recommendation 8

Invest in statewide communication, education, training and behaviour change programs.

Context

- The International Energy Agency indicates that the transition to net zero emissions by 2050 can only be achieved with the sustained support and participation of individuals, households and businesses.[81] Their research suggests that a combination of end-use efficiency gains, electrification and behaviour change is required to meet the target of net zero emissions.[82]
- Whichever pathway leads to gas sector decarbonisation, Victorian homes and businesses will need to update appliances so that they are more energy efficient and/or use a different fuel. While many Victorian households connected to gas say they prefer to use natural gas for cooking (64%), our research shows that over half of households (54%) are likely to reduce their gas use over the next five years. Once informed about the contribution of natural gas to climate change, this increased to 64%. The fact that new gas supplies may need to be imported or developed due to declining Victorian gas reserves was also a strong motivator for change (63%).[83]

81 International Energy Agency (2021) *Net Zero by 2050: A Roadmap for the Global Energy Sector*

82 International Energy Agency (2021) *The Potential of Behavioural Interventions for Optimising Energy Use at Home*

83 Quantum Market Research (2021) *Gas Infrastructure Community Sentiment*

84 Quantum Market Research (2021) *Gas Infrastructure Community Sentiment*

Recommendation

The Victorian Government should **immediately** invest and sustain long-term, targeted and coordinated communication, education, training and behaviour change programs to highlight the impact of fossil fuels on climate change and encourage households and businesses to consider lower emissions energy sources. Campaigns and programs should also emphasise potential energy bill savings through more efficient appliances and buildings. The combination of these components will be most effective.[84]

Communication and behaviour change mechanisms should be targeted and tailored to meet the needs of different audiences, and consider relevant retail, trades, property managers and investors in addition to households and businesses. The scope and coverage should include:

- a statewide, targeted communication program which builds understanding of the climate impacts of different energy sources including natural gas, the benefits of more efficient appliances, the benefits of energy efficient buildings and available energy efficiency incentive programs
- education tools, for example to enable simple calculation of energy, cost and emissions savings estimates from investing in more efficient appliances, insulation and other high impact energy efficiency measures
- targeted behaviour change initiatives to encourage energy efficient behaviours in households and businesses
- targeted training programs for the trades and service sectors.

The scale of change required, and the need to achieve fast emissions reduction quickly from proven technologies such as energy efficiency, indicates that these initiatives are required immediately and should be ongoing. The programs should be monitored and evaluated over time and have the flexibility to evolve in response to changing technologies.

Key findings

- Awareness and information are a barrier to households and businesses being energy efficient. Information on energy efficiency can be highly technical, making it difficult for consumers to understand the different benefits and costs, such as payback periods, thermal comfort and health. They may also lack awareness of their own energy use, energy costs or the available energy efficiency measures that would best meet their needs.[85]
- Consumers value simple, practical and accessible information on energy efficiency from an independent trusted source, including clarity on different technologies and how they can save money and make a positive impact.[86]
- Education, training and behaviour change programs should be targeted to specific audiences[87,88,89] to ensure maximum impact, including households, businesses, the service industry, property managers and investors. Further, energy efficiency education and training should promote both energy savings and other benefits, such as reduced costs, health, comfort improvements and climate to maximise their effectiveness.[90]
- Internationally, interventions aimed at promoting behaviour change are often found to be cheaper to implement relative to policies that seek to encourage investment. Such measures also tend to be relatively quick to design and implement.[91]
- Government energy efficiency communication campaigns are often time-limited[92] and run by individual agencies rather than co-ordinated at a whole-of-government level, which can limit their effectiveness.
- An examples of a successful behaviour change program in Victoria is the TAC Towards Zero road safety campaign, which has a long-term focus, consistent messaging and regular funding.

85 COAG Energy Council (2019) *COAG Report for Achieving Low Energy Existing Homes*

86 Energy Consumers Australia (2019) *A Future Energy Vision Consumer Expectations Research*

87 White K, Habib R, and Hardisty DJ (2019) *How to SHIFT Consumer Behaviours to be More Sustainable: A Literature Review and Guiding Framework, in Journal of Marketing, Vol. 83(3) 22-49, 2019*

88 COAG Energy Council (2019) *COAG Report for Achieving Low Energy Existing Homes*

89 Department of State Development Business and Innovation (2014) *Business Impact Assessment Victorian Energy Efficiency Target*

90 US Department of Energy and US Environmental Protection Agency (2006) *Energy Efficiency Program Best Practices, in National Action Plan for Energy Efficiency*

91 International Energy Agency (2021) *The Potential of Behavioural Interventions for Optimising Energy Use at Home*

92 Department of State Development Business and Innovation (2014) *Business Impact Assessment Victorian Energy Efficiency Target*

Recommendation 9

Review natural gas use in all Victorian Government operations and develop plans to achieve Victoria's emissions reduction targets.

Context

- The Victorian Government has committed to sourcing 100% renewable electricity for all Victorian Government operations by 2025. This includes electricity consumption for Victorian hospitals, schools, police stations, Melbourne's metropolitan train network and a range of other government infrastructure, operations and services.
- The second Victorian Renewable Energy Target Auction (VRET2) aims for at least 600 MW of new renewable energy capacity in Victoria and will play a key role in fulfilling the government's renewable electricity commitment.[93]
- There is no equivalent program to target government's gas use and associated emissions.

93 Department of Environment, Land, Water and Planning (2021) *VRET2 (website)*

94 Department of Treasury and Finance (2021) *Greener Government Buildings (website)*

Recommendation

Over the next two years, the Victorian Government should work to gain better understanding of natural gas use in all Victorian Government organisations and operations by:

- Improving data collection and data sharing of natural gas use between all levels of the Victorian Government to improve transparency, enable analysis and support decision-making.
- Introducing mandatory data reporting on energy consumption and greenhouse gas emissions in all Victorian Government non-office-based operations.

Alongside efforts to better understand its own natural gas use, the Victorian Government should also:

- Incorporate emissions reduction plans and targets for natural gas use within sector net zero plans, introduce Victorian Government operations interim emissions reduction targets specific to natural gas and publish regular progress reports for all Victorian Government organisations.
- Prioritise immediate energy efficiency activities to achieve emissions and energy savings through space and water heating electrification, with a focus on schools and TAFEs, hospitals and public buildings, including through the Greener Government Buildings program.[94]
- Provide or increase funding to target energy efficiency activities and ensure ongoing funding certainty.
- Continue to monitor and evaluate the existing net zero plans and activities of public organisations, incorporating any lessons learned from other relevant Victorian programs such as alternative gas trials, targeted electrification policies and energy efficiency retrofits.

Key findings

- While Victoria has a legislated long-term commitment to net zero by 2050, interim emissions reduction targets and sector pledges, significant components of the government's own gas use are not well understood and lack plans to achieve net zero.
- Current initiatives to reduce government gas use through energy efficiency and/or to replace natural gas with lower emissions alternatives have limited access to funding.
- Barriers to full electrification, which has the potential to reach net zero through the VRET program, include insufficient funding, electricity grid constraints and existing building design.
- Schools and hospitals are estimated to be among the largest government gas consumers in Victoria.[95]
- Under the *Climate Change Act 2017*, all Victorian Government organisations and operations are committed to a net zero target by 2050. However, the development and implementation of net zero plans varies across departments.

Education

- Schools and TAFE institutes are the largest public sector gas consumer in Victoria, primarily for space and water heating.[96] However, there is no mandated environmental management reporting of greenhouse gas emissions and energy consumption for schools, and no central database to provide an overview.[97]
- The Victorian School Building Authority intends to phase out natural gas to new and existing school sites in the future, although no specific timeframe has been set.[98] This may require capital-intensive upgrades in existing schools. Further work is required to assess costs against benefits. There is currently no funding available to support efforts to reduce natural gas use in schools.

Hospitals

- The healthcare sector, including public hospitals, is the second largest public sector natural gas consumer in Victoria. The greatest uses are space heating and on-site cogeneration of electricity and steam, to provide security of energy supply.[99]
- The Victorian Health Building Authority expects all new public health facilities built in Victorian under 10,000 square metres to be all-electric to support the net zero 2050 target.
- Their sustainability guidelines do not require all-electric for sites greater than 10,000 square metres but do require these projects to minimise gas use as much as possible and future proof an all-electric design.[100]

Social housing

- The government's housing services including high-rise dwellings and other social housing, which have a significant gas use for heating.[101] Within the Big Housing Build package, new housing will meet 7-star energy efficiency standards and include solar PV and all-electric appliances where possible.[102,103] There are design exceptions if third parties are involved in rapid construction development. In these cases, designs allow gas connections.
- There are several existing energy efficiency programs to reduce energy consumption in existing social housing. The EnergySmart Public Housing program, which concluded in 2020, delivered energy efficiency upgrades to 1,500 low-rise public housing properties. The program aimed to reduce energy costs and improve thermal comfort for participating public housing tenants by replacing gas space and water heaters with heat pumps and upgrading the building thermal shell.[104] The Victorian Government should continue to promote and fund these programs for the foreseeable future.

95 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

96 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

97 Department of Climate Change and Energy Efficiency (2012) *Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia – Part 1 – Report*

98 Department of Education and Training (2021) *VSBA Building Quality Standard Handbook*

99 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

100 Victorian Health and Human Services Building Authority (2021) *Guidelines for Sustainability in Health Care Capital Works*

101 Department of Health and Human Services (2020) *Annual Report 2019-2020*

102 Premier of Victoria The Hon Daniel Andrews (2020) *Victoria's Big Housing Build (media release)*

103 Department for Environment, Land, Water and Planning (2021) *Energy Sector Emissions Reduction Pledge (website)*

104 Housing VIC (2021) *EnergySmart Public Housing Project (website)*

Recommendation 10

Align Victorian Government gas policy and regulations with the legislated commitment to net zero emissions by 2050.

Clear policy and regulatory settings from government that align with net zero emissions commitments provide industry and consumers more certainty to invest, plan, innovate, and deliver emissions reductions.

Context

- **The infrastructure that Victoria builds now will exist for decades. Clear policy and regulatory settings from government that align with net zero emissions commitments provide industry and consumers more certainty to invest, plan, innovate, and deliver emissions reductions.**
- The Victorian Government's sector pledges go some way to advancing this, but legislation, regulation and/or incentives are required to drive further change across the economy.
- The long-term future for any new and existing natural gas infrastructure is uncertain. When considering government or regulatory approvals for natural gas infrastructure, the processes should account for emissions reduction goals and potentially shorter asset lifespans. This may span a range of regulatory activities, including development approvals and regulatory determinations.
- Following release of *Recycling Victoria: A new economy policy,*[105] the Victorian Government revised or initiated several complementary policies to assist their waste reduction and recycling targets. This effort is part of aligning policy and regulation to new overarching objectives for the industry: the same needs to be done for gas.

Recommendation

The Victorian Government should align its gas policies, regulation and decision-making across departments and agencies over the next five years, to coordinate the efficient achievement of emissions reduction targets, particularly as it relates to infrastructure decisions within its jurisdiction:

- Any new gas exploration, import and production proposals should include a plan to reduce, offset or capture and store emissions in line with Victoria's emissions reduction targets.
- Gas sector facilities, and major gas users, should be required and incentivised to reduce emissions in line with the government's emissions reduction targets. The most suitable mechanism should be identified and could include the Victorian Energy Upgrades program or operating licences. Requirements or incentives to decarbonise should be staged over the transition to net zero emissions and should consider industry specific requirements, the impact to regional communities, capital costs and asset lifespan.
- Environmental Effects Statements for fossil fuel supply, and planning approval and operating licence applications for industrial facilities, should explicitly include information on carbon emissions in construction and operation, including proposed management and reduction, so that statutory decision-makers are better informed when deciding if a project should proceed and under what conditions.
- Climate scenarios and carbon value should be specified in assessing government's infrastructure proposals, in line with our recommendation in *Victoria's infrastructure strategy 2021–2025.*[106]

The Victorian Government, in collaboration with the Australian, state and territory governments, should also seek national energy laws and rules that enable decarbonisation of the energy market. This could include incorporating emissions considerations into national energy objectives or more explicit guidance to the Australian Energy Market Commission and the Australian Energy Regulator for their decisions to be consistent with, and promote achievement of, net zero emissions by 2050.

105 Department of Environment, Land, Water and Planning (2020) *Recycling Victoria: A New Economy*

106 Infrastructure Victoria (2021) *Victoria's Infrastructure Strategy 2021–2051*

Key findings

- Policy analysis has highlighted gaps and inconsistencies in Victoria's approach to net zero. While making an excellent start on the complex problem of achieving net zero emissions, the Victorian Government's first round of sector pledges do not yet address the decarbonisation of gas use. It is expected that these will continue to grow and evolve, including with the actions arising from the *Gas substitution roadmap*.
- Within Victoria, there are some clear areas for review:
  - The Victorian Energy Upgrades program currently subsidises gas hot water systems, which have a typical appliance life of 15 years. New gas hot water systems installed now will likely still be operating in 2035, when lower emissions alternatives will be available.[107]
  - The objective of the *Petroleum Act 1998* is to encourage exploration for petroleum in Victoria and to promote petroleum production for the benefit of Victorians. The Petroleum Regulations, which govern new fossil fuel development, have recently undergone public consultation ahead of implementation. The accompanying Regulatory Impact Statement includes as a key problem: 'Victoria's social and environmental interests are insufficiently protected'. The preferred regulatory option includes a requirement to provide estimates of hydrocarbon emissions and how they will be minimised,[108] but does not include the impact of carbon emissions from production and ongoing natural gas use on climate change. Section 33(j) of the draft regulations provides for the assessment and minimisation of emissions directly arising from new gas production 'to the extent practical' but does not require that these are reduced or offset over time.[109] Regulations in Victoria last for 10 years unless remade.
  - See also the land use, building and plumbing regulations identified in *Recommendation 7*.
- For distribution and transmission networks, the National Gas Law is relevant. It includes the following objective: 'to promote efficient investment in, and efficient operation and use of, natural gas services for the long-term interests of consumers of natural gas with respect to price, quality, safety, reliability and security of supply of natural gas.'
- The Australian Energy Regulator (which approves access regimes for the Victorian Transmission System and the three distribution networks) and the Australian Energy Market Commission (responsible for making and amending national gas market rules) must perform their functions with regard to the National Gas Objective.
- The National Gas Objective does not explicitly incorporate long-term climate risks or net zero emissions considerations.
- Current Victorian Government infrastructure investment guidance observes the *Climate Change Act 2017* requirement to consider climate risk but does not provide detailed advice on doing so. The guidance for government agencies investing in infrastructure should be updated to explicitly advise on the appropriate method of calculating the value of avoided carbon emissions, for use in calculating emissions reduction benefits. It should also determine climate scenarios for assessing infrastructure resilience, such as a future with 1.5 degree of warming and potentially more extreme scenarios.[110]

107 AEMO (2020) *2020 Integrated System Plan*

108 Deloitte Access Economics (2021) *Proposed Petroleum Regulations – Regulatory Impact Statement*

109 Draft Petroleum Regulations 2021 s.33(j)

110 Infrastructure Victoria (2021) *Victoria's Infrastructure Strategy 2021–2051*

Recommendation 11

Improve data collection and availability on energy use and energy-related emissions to assist planning of emissions reduction measures and review of progress.

Context

- **The Victorian Government's planning and policy decisions need to be informed by reliable data on energy use and emissions. Reliable data helps improve energy analysis, forecasting, predict demand peaks and patterns, and monitor and manage progress towards emissions reduction targets.**
- The energy sector is a complex regulatory environment. Government bodies and organisations which collect energy and emissions data include:
  - The Clean Energy Regulator collects, analyses and publishes emissions and energy information across all sectors.[111] Australian facilities and corporations that meet certain production and consumption thresholds must report their emissions and energy data.[112] Under the *National Greenhouse and Energy Reporting Act 2007*, the National Greenhouse and Energy Reporting scheme provides a national framework for company information about greenhouse gas emissions, energy consumption and production. The non-public data informs Australian Government policy and is shared between states and territories to avoid duplication of corporate reporting requirements.[113]
  - The Department of Industry, Science, Energy and Resources (DISER) publishes an annual update on Australian energy consumption, production and trade. The Australian Energy Statistics is Australia's official source of energy statistics to support decision-making and international reporting.[114]
  - The Australian Energy Market Operator (AEMO) reports and provides forecasts for the gas and electricity markets to inform the planning and decision-making of market participants, new investors, and jurisdictional bodies. The *Gas statement of opportunities* provides AEMO's forecast of annual gas consumption and maximum gas demand.[115] The *Electricity statement of opportunities* provides technical and market data for the National Electricity Market.[116]
  - In Victoria, the Commissioner for Environmental Sustainability publishes an annual strategic audit of environmental management systems in mandated Victorian Government entities. The audit details how departments and agencies are improving environmentally sustainable practices. This includes reporting on energy use and greenhouse gas emissions.[117]
- We have identified data gaps and complex data sharing arrangements between stakeholders, which hinder informed decision-making. There is significant scope to improve the quality and coverage of data.

111 Clean Energy Regulator (2021) *What We Do (website)*
112 Clean Energy Regulator (2021) *Reporting Thresholds (website)*
113 *National Greenhouse and Energy Reporting Act 2007*
114 Department of Industry, Science, Energy and Resources (2021) *Australian Energy Update 2021*
115 AEMO (2021) *Gas Statement of Opportunities*
116 AEMO (2021) *2021 Electricity Statement of Opportunities*
117 Commissioner for Environmental Sustainability Victoria (2021) *Strategic Audit of Environmental Management Systems*

Recommendation

Over the next five years, the Victorian Government should improve energy data governance and data collection to enhance decision-making and policy development across government and industry:

- Implement enhanced, timely data analysis and provide clear governance for a data improvement program.
- Improve quality control in existing data collections and systems of environmental management reporting.
- Ensure Victorian data quality standards align with other Australian jurisdictions.

Further, the Victorian Government should address data and knowledge gaps in:

- Energy demand and technology forecasting:
  - Seek to achieve detailed breakdown of industrial sub-sector gas consumption
  - Disaggregate commercial and residential gas consumption and provide consistent definition of the commercial sector
  - Coordinate research regarding technology developments, including potential timing, techno-economic performance and engineering requirements (for example thresholds and compatibility of hydrogen blending in transmission networks)
  - Provide a periodic overview of developments in low and zero emissions gas technologies, to include progress monitoring of low and zero emissions pilots, trials and demonstration projects.
- Energy performance in the built environment:
  - Collaborate with AEMO and the private sector to improve daily load profile data for gas appliances in the commercial sector
  - Further invest in data collection to improve existing models of energy performance in the built environment including commercial gross floor area, residential dwelling stock and energy uses by building type.
- Benefits from thermal building shell improvements:
  - Collect, analyse and publish data from energy efficiency trials and improvement programs for thermal building shell performance (for example, draught sealing, ceiling and wall insulation) in the commercial and residential sectors, including data on long-term, non-energy benefits.
- Concessions' data:
  - Improve data collection on concession household composition, home and appliance age, energy use and spending (see *Recommendation 6*).

Key findings

- Preparatory work to source data inputs for this advice highlighted significant opportunities to improve the completeness and quality of input data, particularly in energy demand forecasting, vehicle fleet transition, energy efficiency, employment transition and emissions offset factors.[118]
- To overcome difficulties sourcing segmented emissions and energy data, our energy efficiency technical analysis relies in part on estimates and assumptions. Data and knowledge gaps exist in industrial sector gas consumption and facility numbers; commercial and residential building stock and turnover; detailed breakdowns of Victorian residential and small commercial facility gas consumption; non-energy benefits of draught sealing and insulation; and thermal building performance in the commercial sector.[119]
- Government organisations report annually on energy use and greenhouse gas emissions. However, there is no detailed breakdown on natural gas use (space or water heating or other gas uses) and data for non-office-based operations such as schools and hospitals are missing:
  - There is no mandated environmental management reporting of greenhouse gas emissions and energy consumption for schools. There is no central database to provide a complete overview[120]
  - There is uncertainty about the floor area definitions and energy performance of buildings in the health sector.[121]

118 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

119 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

120 Department of Climate Change and Energy Efficiency (2012) *Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia – Part 1 – Report*

121 Department of Climate Change and Energy Efficiency (2012) *Baseline Energy Consumption and Greenhouse Gas Emissions in Commercial Buildings in Australia – Part 1 – Report*

4.

What we found

4.1

Natural gas use needs to change if Victoria is to meet its emissions reduction targets.

Natural gas is a fossil fuel which, when burned to generate heat and energy, releases greenhouse gases which contribute to climate change. Victoria currently relies heavily on natural gas for energy use in households, business and industry, and some electricity generation. Natural gas use represents around one-fifth of Victoria's total greenhouse gas emissions.[122]

The Victorian *Climate Change Act 2017* established a system of coordinated, whole-of-economy initiatives to achieve a net zero emissions, climate resilient state. It legislates a target for net zero emissions by 2050. Actions included developing rolling five-year pledges, plans and targets to reduce emissions and adapt to climate change impacts, and obliging all government policies, plans and decisions to consider climate change.[123]

In 2021, the Victorian Government set interim emissions reduction targets for 2025 and 2030, and produced the first round of five-yearly sector pledges. The interim targets aim to reduce Victoria's emissions by 28–33% by 2025, and 45–50% by 2030, based on a 2005 baseline.[124] The 2020 target, to reduce emissions by 15–20% below 2005 levels, was met ahead of schedule.[125] The *Energy sector emissions reduction pledge* includes actions to reduce Victoria's emissions by an estimated 2.2 million tonnes of carbon dioxide equivalent (Mt CO_2e) in 2025 and 3.7 Mt CO_2e in 2030.[126] Reducing greenhouse gas emissions at the scale needed to meet a net zero emissions target requires an economy-wide response, including the gas sector.

Under the 2015 Paris Agreement, Australia committed to reduce greenhouse gas emissions by 26–28% below 2005 levels by 2030.[127] The Australian Government recently set a target for net zero emissions by 2050,[128] joining around 60 other countries with legislated or policy commitments to reduce emissions to net zero by mid-century. Many more are considering it.[129] Meanwhile, the Glasgow Climate Pact has advised that the opportunity to avoid some of the worst impacts of climate change will likely be lost within 10 years, shifting the focus for action from 2050 to 2030.[130]

122 Department of Environment, Land, Water and Planning (2021) *Victorian Greenhouse Gas Emissions Report 2019 (approximate estimates only)*

123 *Climate Change Act 2017 (Vic)*

124 Department of Environment, Land, Water and Planning (2021) *Victorian Greenhouse Gas Emissions Report 2019*

125 Premier of Victoria The Hon Daniel Andrews (2021) *Victoria Continuing to Cut Greenhouse Gas Emissions (media release)*

126 Department of Environment, Land, Water and Planning (2021) *Cutting Victoria's Emissions 2021-2025: Energy Sector Emissions Reduction Pledge*

127 Department of Industry, Science, Energy and Resources (2021) *International Climate Change Commitments (website)*

128 Department of Industry, Science, Energy and Resources (2021) *Australia's Long-Term Emissions Reduction Plan*

129 Energy and Climate Intelligence Unit (2021) *Net Zero Emissions Race (website)*

130 United Nations Framework Convention on Climate Change (2021) *Draft Decision 1/CMA.3 – Glasgow Climate Pact*

131 European Commission (2021) *Carbon Border Adjustment Mechanism: Questions and Answers (website)*

132 Ai Group (2021) *Swings and Roundabouts: The Unexpected Effects of Carbon Border Adjustment on Australia*

133 Deloitte Access Economics (2021) *Special Report: Update to the Economic Costs of Natural Disasters in Australia*

134 Australian Academy of Science (2021) *The Risks to Australia of a 3ºC Warmer World*

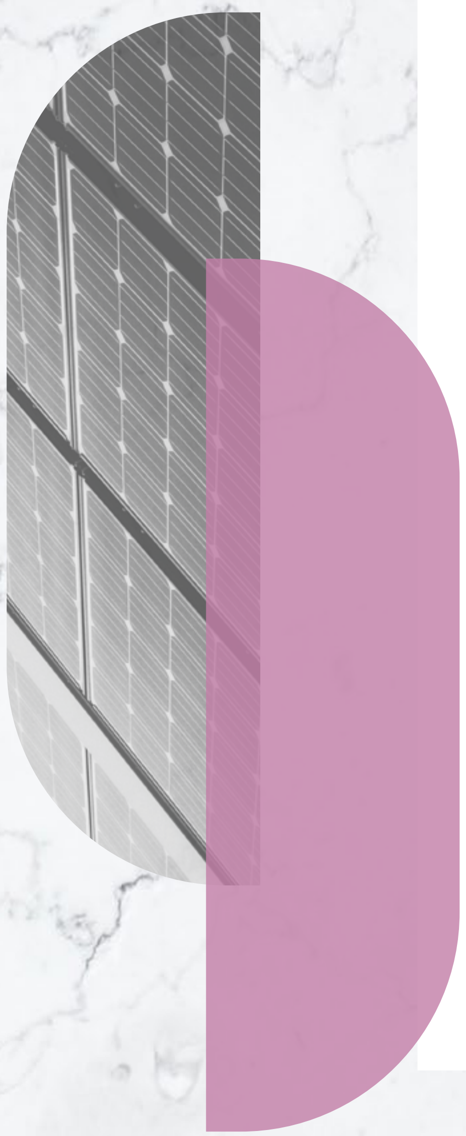
135 The Global Commission on Adaptation (2019) *Adapt Now: A Global Call for Leadership on Climate Resilience*

Major trading partners are starting to consider climate change and decarbonisation requirements within trade and export agreements. The European Union's Carbon Border Adjustment Mechanism, for example, will impose a tax equivalent to the EU's carbon price on imported goods, unless importers can show that they have already paid a carbon price elsewhere.[131] Other countries, including the United Kingdom, Japan and the United States, are considering similar mechanisms.[132]

It will require significant investment across all sectors of the economy to reach net zero emissions, but the costs of inaction on climate change will be even higher. Natural disasters already cost the Australian economy an average of $38 billion a year, taking a huge toll on ecosystems, infrastructure, communities and health. A high emissions scenario, where emissions continue to rise and average global temperatures reach 3 degrees above pre-industrial levels, would see these costs more than double by 2060, to $94 billion – around 30% higher than cost estimates under a low emissions scenario.[133] Three degrees average warming would be devastating for Australia's economy, society, and ecology. A 3 degrees warmer world would render many more properties and businesses uninsurable. A warmer planet also has direct and indirect impacts on human health, livelihoods, and communities. The elderly, young, unwell, and those from lower socio-economic backgrounds are at increased risk.[134] The Global Commission on Adaptation emphasises the economic benefits of adapting now to climate change, finding that the rate of return on investments in improved resilience is very high, with benefit-cost ratios ranging from 2:1 to 10:1, and in some cases even higher.[135]

To reach net zero, significant investment across all sectors of the economy will be required, but the costs of inaction on climate change will be even higher.

Victoria's household and commercial gas use is the highest in Australia, driven by its cold winters and reliance on gas for heating.



4.1.1 Natural gas in Victoria

Natural gas is an important part of Victoria's current energy mix. It is used in residential and commercial buildings, for electricity generation and in transport. Gas is also used as a raw material and a source of heat for some manufacturing and industrial processes.

Natural gas production

Victoria produced 361 PJ of natural gas in 2020. Victoria's production has historically been greater than its gas use, meaning Victoria has been a net exporter of gas to other states. However, production is forecast to fall 43% to 205 PJ by 2025 as several fields in Gippsland cease production. Gas demand in Victoria is expected to fall 7% overall from 207 PJ to 192 PJ over the same period, as energy efficiency and electrification measures are implemented.[136] Despite this, Victoria may need to import gas to meet peak winter demand in the near future.

Natural gas use

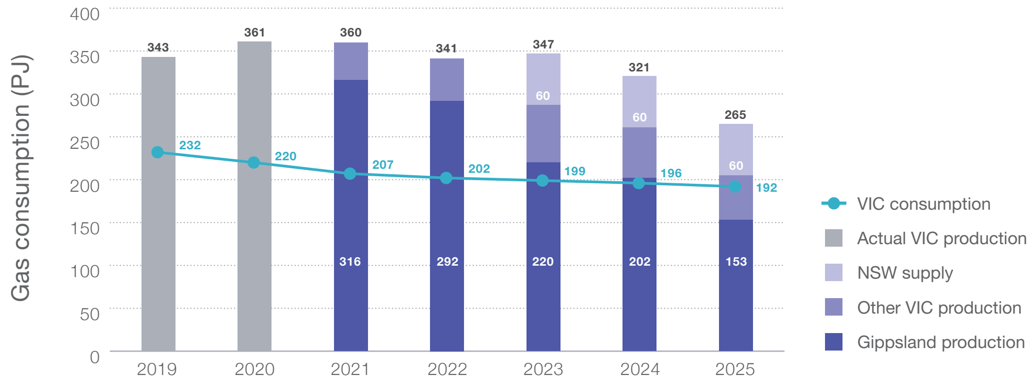
Over 2 million Victorian households and businesses use natural gas to meet their energy needs. Collectively, Victorians used 214 PJ of natural gas in 2020. Households and small commercial users accounted for the largest share of Victoria's gas use (61%). Industrial and large commercial use comprised 31% while electricity generation accounted for 8% of Victoria's gas use in 2020.[137]

Household and small to medium commercial use

Victoria's household and commercial gas use is the highest in Australia, driven by its cold winters and reliance on gas for heating. Altogether, Victoria accounts for around two-thirds of Australia's total household and commercial gas use.[138]

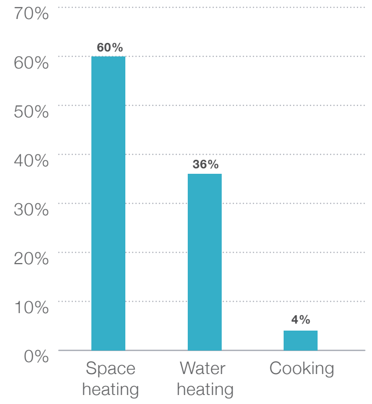
We commissioned more detailed analysis of Victorian gas use to examine the potential for energy efficiency within different sectors.[139] Findings are available in the technical report on our *website*. Within the household and small to medium commercial sector, households account for the majority of gas use (around 80%), predominately in detached houses and townhouses.[140] We know from previous research that space heating comprises more than half of total household energy use in Victoria, and 29% of Victorian greenhouse gas emissions from household energy use.[141] The prevalence of ducted gas heating in Victorian households means that winter gas use is about three times higher than during the summer. Other uses of gas in Victorian households include water heating and cooking.

Figure 3: Annual actual and anticipated gas production and consumption – 2019 to 2025 (PJ)



Sources: AEMO (2021) *Victorian gas planning report*

Figure 4: Estimated share of natural gas consumption by use, Victorian households – 2020



Sources: Northmore Gordon and Energeia (2021) *Cost benefit analysis of energy efficiency activities in the gas sector*

136 AEMO (2021) *Victorian Gas Planning Report 2021*

137 AEMO (2021) *National Electricity and Gas Forecasting, Gas Annual Consumption, Gas Statement of Opportunities 2021 – Victoria, Central Scenario Total (website)*

138 AEMO (2021) *National Electricity and Gas Forecasting, Gas Annual Consumption, Gas Statement of Opportunities 2021 – Victoria, Central Scenario Total (website)*

139 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

140 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

141 Sustainability Victoria (2019) *Comprehensive Energy Efficiency Retrofits to Existing Victorian Houses*

Our modelling indicates that space heating accounts for almost two-thirds (60%) of Victoria's household gas use, while water heating accounts for around one-third (36%). Cooking makes up just 4% of total household use, as illustrated in Figure 4.[142] Victoria's existing housing stock is considerably less energy efficient than new buildings, which are required to achieve a 6-star rating, and tend to have less energy efficient lighting, heating and cooling, and other appliances.[143]

The largest consumers of natural gas in the small to medium commercial sector are schools (accounting for an estimated 22% of small to medium commercial gas use), offices (16%), restaurants (15%) and hospitals (12%). Across all small to medium commercial segments, gas is primarily used for space heating (more than 50% of annual gas use) followed by water heating and cooking. Exceptions are restaurants (where most gas use is for cooking), hotels (where a significant share is used for pool heating) and hospitals (where gas is used for combined heat and power generation and equipment sterilisation).[144]

Industrial and large commercial use

Manufacturing is the biggest industrial user of natural gas, making up around 80% of Victoria's industrial and large commercial gas use. Most gas in the industrial sector is used for producing heat. Gas is also used as a chemical input for some manufacturing processes, including ammonia and polyethylene production.

Some industrial gas uses, such as process heating at very high temperatures, cannot be readily substituted for alternative energy sources. Technological solutions may be available in some instances, but these are developing technologies and are likely to require significant investment. As technology improves, more cost-effective solutions may become available to support hard-to-abate industries to lower their emissions.

Within the industrial sector, our analysis indicates that the largest gas users are food and beverage manufacturing (24% of industrial and large commercial gas use) followed by pulp and paper manufacturing (14% of industrial and large commercial gas use) and petroleum and coal product manufacturing (11% of industrial and large commercial gas use), as illustrated in Figure 6. Large commercial users account for around one-fifth (19%) of total gas use in the industrial and large commercial segment.[145]

Electricity generation

Gas plays a relatively small but critical role in electricity generation in Victoria, providing additional supply particularly when there are prolonged coal fired plant outages or to satisfy peak demand across the National Electricity Market. As the proportion of electricity supplied from renewable energy sources grows, gas-powered generation can provide a stabilising role with its ability to quickly ramp up and down to balance variations in supply.[146] Victoria has eight gas-powered generation plants, which collectively meet around 2% of Victoria's grid-supplied energy over the last year.[147]

142 Wood T and Dundas G (2020) *Flame Out: The Future of Natural Gas*

143 Sustainability Victoria (2015) *Energy Efficiency Upgrade Potential of Existing Victorian Homes*

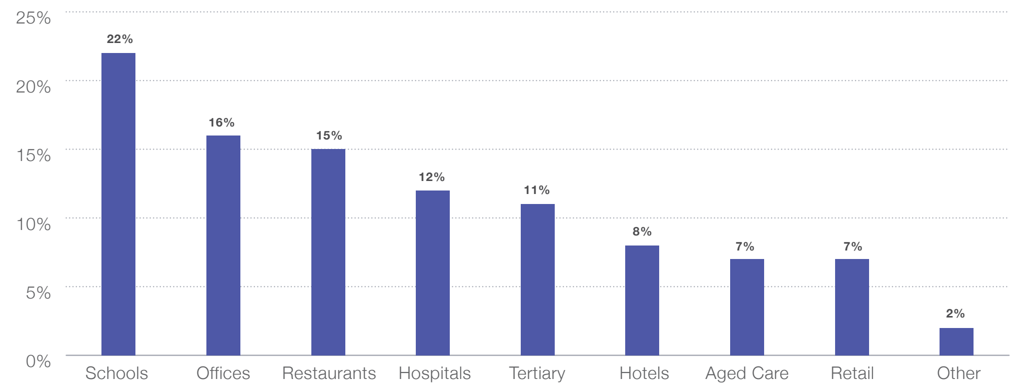
144 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

145 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

146 AEMO (2021) *Victorian Gas Planning Report 2021*

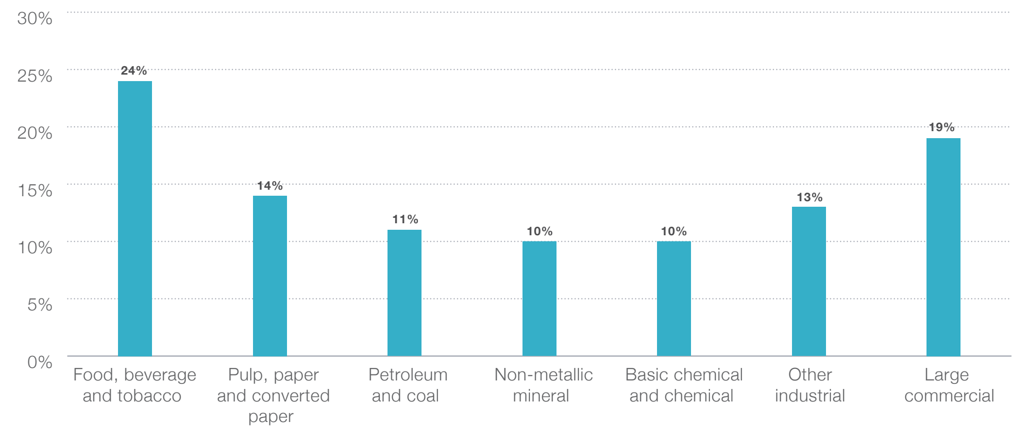
147 AEMO (2021) *National Electricity Market Dashboard (website)*

Figure 5: Estimated share of natural gas consumption, Victorian small to medium commercial – 2020



Sources: Northmore Gordon and Energeia (2021) *Cost benefit analysis of energy efficiency activities in the gas sector*
Note: 'Other' includes law courts, public buildings and warehouses

Figure 6: Estimated share of natural gas consumption, Victorian industrial and large commercial – 2020



Sources: Northmore Gordon and Energeia (2021) Cost benefit analysis of energy efficiency activities in the gas sector
Note: 'Other industrial' includes metal and metal product manufacturing, textile, leather, clothing and footwear, wood product, polymer product and rubber, printing, transport equipment and machinery manufacturing, and mining. 'Large commercial' includes aquatic centres, health care and social services, large education, commercial office and large retail. The industrial and large commercial sector does not include gas-powered generation.

Natural gas infrastructure

Victoria's gas infrastructure has been developed over eight decades, from the 1950s to date. Most of the state's natural gas is sourced from the offshore Gippsland Basin and produced at the Longford processing plant. Over the years, Victoria has sourced additional gas from other fields in Gippsland, the Otway and Bass basins and interstate. Six processing plants produce natural gas, including Longford in Gippsland and plants in the Otway Basin.

An extensive gas network crosses the state, with storage facilities to help meet demand peaks, and significant interconnections with other states. The network includes high-pressure gas transmission pipelines that transport gas around the state, and lower-pressure distribution pipelines that deliver gas to customers. The largest storage facility is at Iona in Victoria's south-west.[148] Figure 7 shows the location of Victoria's gas infrastructure.

In developing this advice, we undertook a high level strategic assessment of Victoria's gas infrastructure across the Victorian gas value chain to determine its current status and any potential opportunities to repurpose for alternative energy mixes. This assessment is necessarily high level and aims to guide the Victorian Government's further work and engagement with the gas industry and regulators.

The current status of natural gas infrastructure is summarised below, by type of infrastructure, while findings from the repurposing assessment are outlined in Section 4.2.2. For gas transmission and distribution pipelines, the pipeline materials and gas pressure, capacity and flow direction are all important when assessing repurposing options. Detailed findings can be found in the technical report,[149] available on our *website*. Gas infrastructure owners are conducting their own more detailed assessment of their infrastructure's adaptability.

148 Australian Energy Regulator (2020) *State of the Energy Market 2020*

149 Advisian (2021) *Asset Life and Adaptability Review*

Figure 7a: Map of Victoria's gas infrastructure

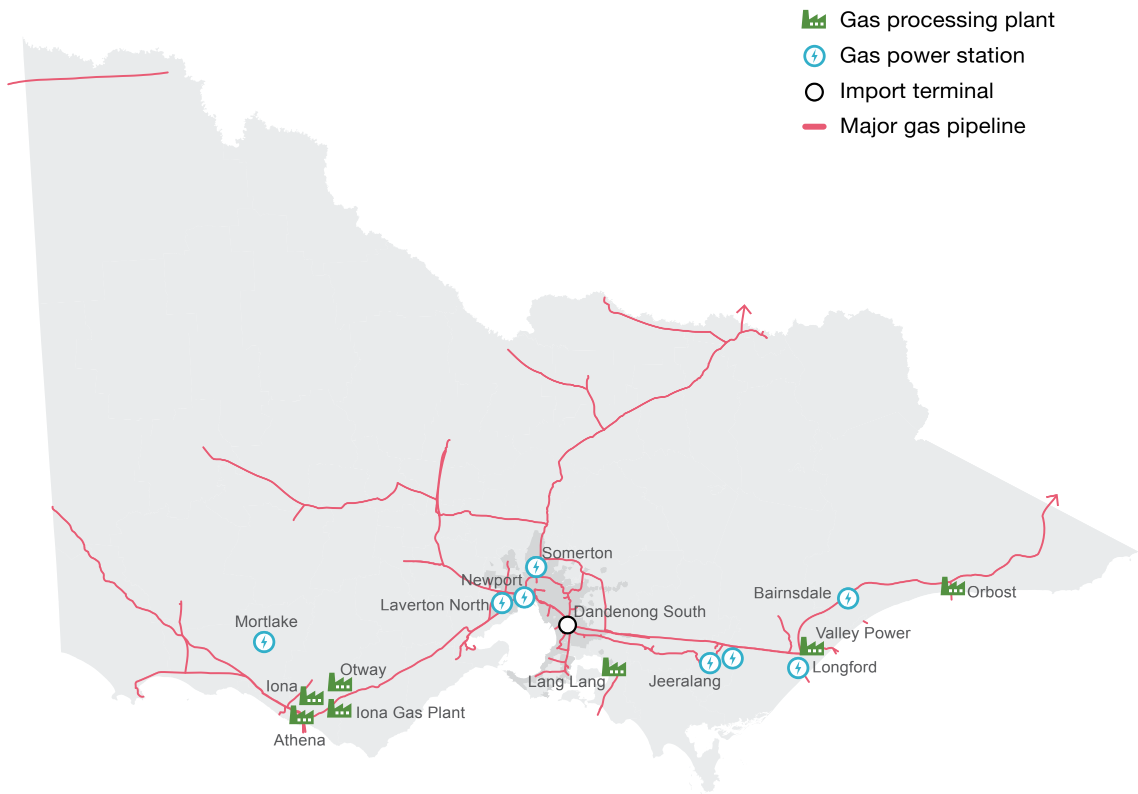


Figure 7b: Otway Basin

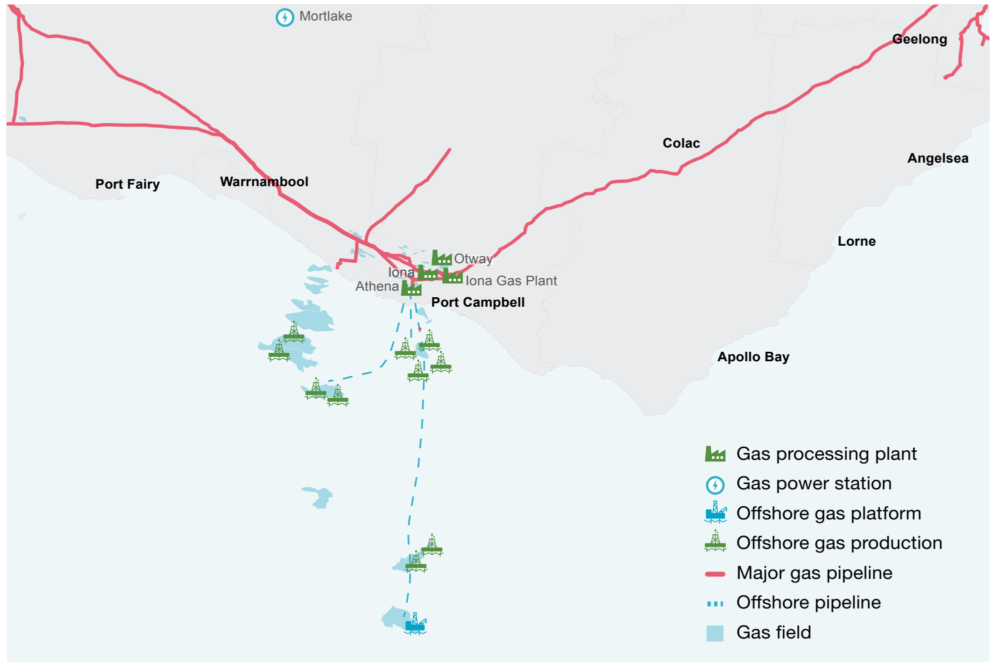
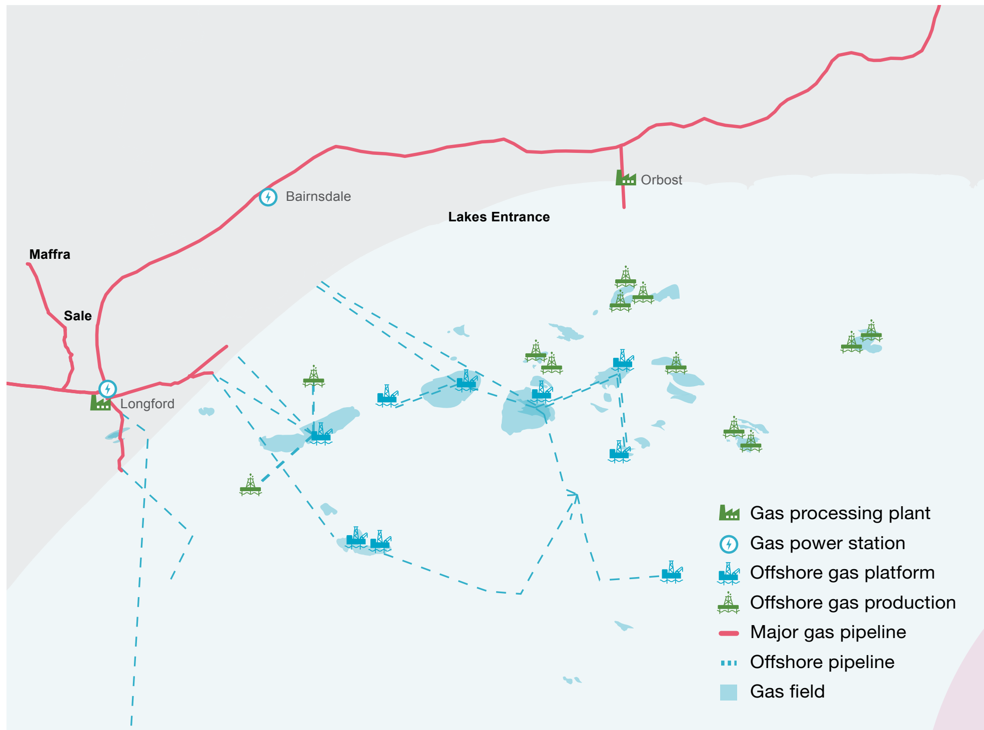


Figure 7c: Gippsland Basin



Source: Advisian (2021), GeoVic and Infrastructure Victoria

Production facilities

The major gas resources in the Gippsland Basin were discovered in the initial drilling campaign from 1965 to 1970. Field development was phased to match gas demand from the Victorian market. Subsequent gas discoveries were made in the 1980s and 1990s. The Bass Basin has a single producing field, originally discovered in 1985 although commercial gas production only began in 2006.

Figure 8 highlights the age and production status of facilities in Gippsland. Two-thirds (67%) of the assets are aged 30 years and older. A majority (60%) are not in production, with a further 16% due to cease production by 2025.

Onshore commercial gas production in the Otway Basin (Western zone) began in 1978. There have been further gas discoveries onshore from the early 1990s into the 2000s, while larger gas discoveries have occurred in the offshore section of the Otway Basin.

There are only a few production facilities in the Western zone. These facilities are relatively new, less than 20 years old, while 29% have been installed in the last 10 years. Most facilities (71%) are still in production. The remaining 29% have been taken out of operation due to field depletion.

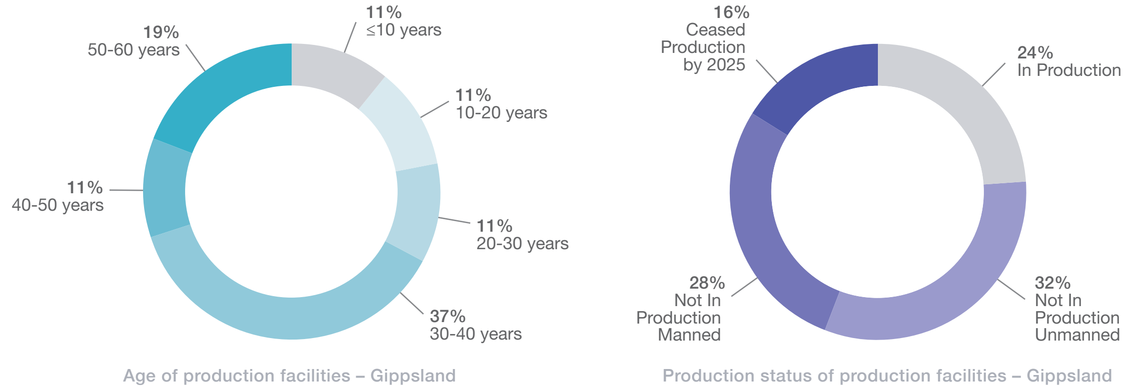
Production pipelines

Production pipelines transport raw or wet gas and crude oil from the offshore production facilities to onshore processing facilities. These pipelines are located mainly within Gippsland, with a limited number in the Western, Melbourne and Geelong zones. A total of 15 production pipelines cover more than 500km.

The Gippsland zone contains more than 450km of production pipelines. Around one-third of assets are over 40 years old, as shown in Figure 10. Most of these pipelines (75%) operate at pressures above 7.5 megapascals.

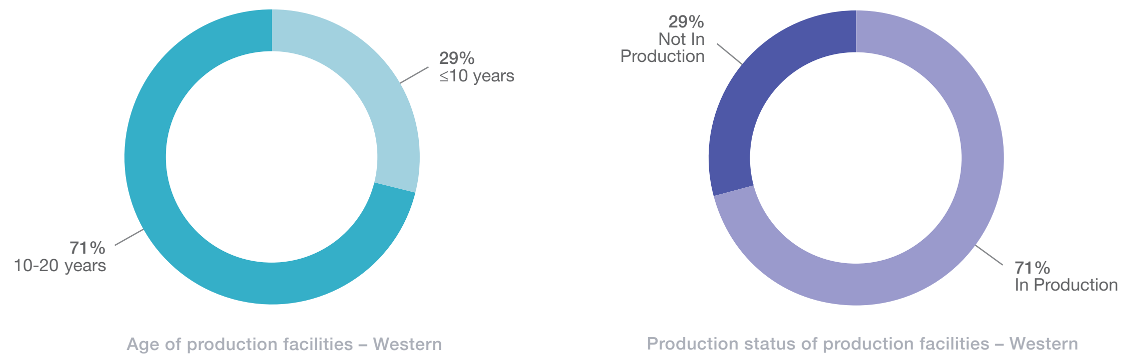
The Western zone contains two production pipelines, both built after 2000, with a total length of 27km. They operate at pressures beyond 15 megapascals. The Melbourne zone contains one 20km production pipeline, which is an older oil pipeline. The Geelong zone contains two short liquid and gas lines with a total length of 12km.

Figure 8: Production facilities: age and production status – Gippsland



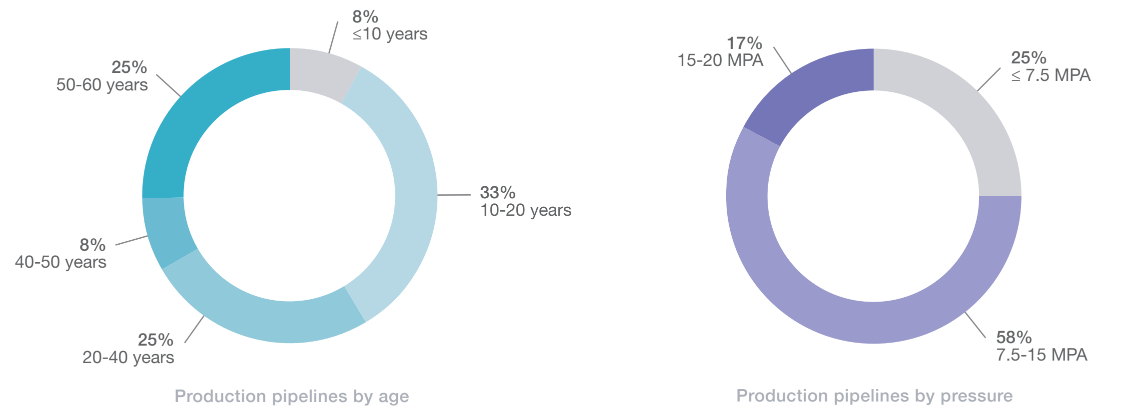
Source: Advisian (2021) *Asset life and adaptability review*

Figure 9: Production facilities: age and production status – Western zone



Source: Advisian (2021) *Asset life and adaptability review*

Figure 10: Production pipelines: age and pressure – Gippsland



Source: Advisian (2021) *Asset life and adaptability review*

Gas processing and storage facilities

Victoria has six existing gas processing plants and one decommissioned facility, extending across the state from Orbost in the east to Port Campbell in the west.

- **Longford gas plants:** these comprise the crude stabilisation plant, gas plants 1, 2 and 3 and the gas conditioning plant. The crude stabilisation plant recovers associated gas from oil production and boosts it into the gas plant inlet. Some of the older facilities are being decommissioned as production declines at Longford. The gas conditioning plant will remain online to process the fields with higher carbon dioxide content which will dominate late life production.
- **Orbost gas plant:** repurposed twice, most recently to process gas from the Sole gas field in the Gippsland Basin.
- **Lang Lang gas plant:** processes gas from the Yolla platform, located in the Bass Strait.
- **Otway gas plant:** located adjacent to the Iona gas plant, the Otway plant processes gas from Thylacine platform for supply to the higher-pressure SEA Gas pipeline.
- **Iona gas plant:** located above the Iona gas field, the Iona gas plant serves multiple purposes (including gas processing, injection and withdrawal from gas storage reservoirs) and connects to multiple pipelines. The plant has progressively expanded since its construction in 1999.
- **Athena gas plant:** with the cessation of production from the Minerva field, the plant is currently being re-purposed to process Casino gas in the Otway Basin.
- **Heytesbury gas plant:** processed gas from a number of small gas fields in the Timboon area but with their depletion the plant was shut down in the early 2000s. The plant has since been decommissioned.
- **Iona underground gas storage:** Australia's largest independent east coast gas storage facility. The storage facility can store up to 23.5 PJ of gas underground, which can then be extracted for later use.[150]

150 AEMO (2018) *Keeping You Warm – The Importance of Gas Storage Explained (website)*

151 Advisian (2021) *Asset Life and Adaptability Review*

Gas transmission network

There are 53 natural gas transmission pipeline licences in Victoria, managed by six licensees. Together, these licensees operate 4,200km of transmission pipelines, spread across Victoria but with a larger share in Gippsland and the Western zone due to their proximity to production facilities.

The Victorian Transmission System (VTS) comprises just over half of Victoria's gas transmission network (2,000km). It includes multiple pipeline licences that transport gas to customers in Victoria and connect to New South Wales and South Australia.

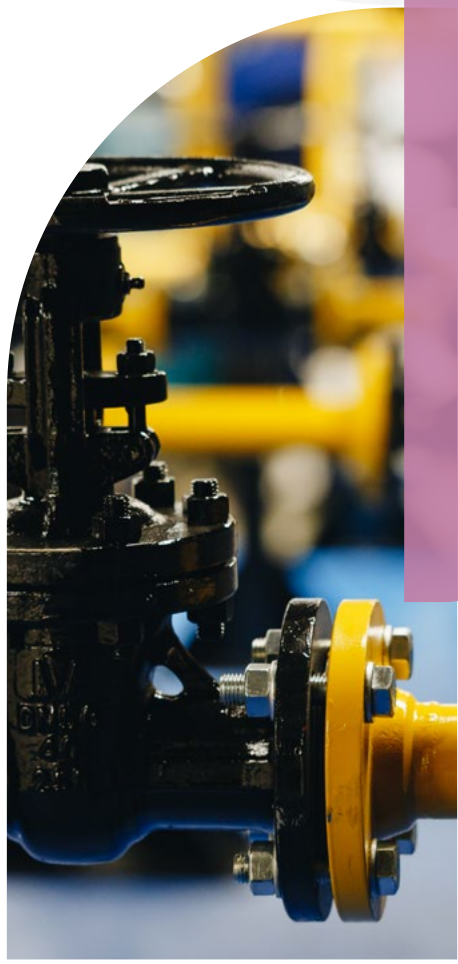
A summary of the transmission pipeline status by zone is as follows:

- **Gippsland:** 17 lines with a total length of over 1,400km. Three-quarters of pipelines are less than 20 years old. A similar proportion are designed for pressure of 7.5 megapascals and over.
- **Melbourne:** 13 lines with a total length of over 300km. The majority (97%) are over 40 years old, while around 40% are designed for pressure of 7.5 megapascals and over.
- **Northern:** 14 pipelines with a total length of over 740km. All pipelines are over 20 years old, with 26% over 40 years. Just over half the lines (54%) are designed for pressure of 7.5 megapascals and over.
- **Ballarat:** three lines of 140km in total. All pipelines are over 40 years old. All lines are designed for maximum allowable operating pressure of less than 10 megapascals.
- **Geelong:** three pipelines of 3km in total. Pipelines are aged 10–30 years. A majority of lines (90%) are designed for pressure of 10–15 megapascals.
- **Western:** 10 lines with a total length of over 1,100km. Most lines (67%) are less than 20 years old. Almost all lines (99%) are designed for pressure of 7.5 megapascals and over.[151]

Gas distribution network

The natural gas distribution system consists of over 650km of high-pressure licensed pipelines (with maximum allowable operating pressure greater than 1,050 kilopascals) and more than 38,000km of low-pressure pipelines and mains. The low-pressure distribution network operates with three different pressure ranges: low (up to 7 kilopascals); medium (up to 210 kilopascals); and high (up to 500 kilopascals).

Melbourne has the largest network of high-pressure pipelines (55% of the total), followed by the Northern and Gippsland zones. Melbourne also has the largest network of low-pressure pipelines (47%), while the Western, Ballarat and Geelong zones collectively make up 52% of the low-pressure network. Polyethylene materials comprise the majority of low-pressure pipelines (63%), while 7% of the network is a combination of cast iron, unprotected steel and polyvinyl chloride (PVC). Cast iron and PVC are proposed to be replaced as part of network replacement programs. A small part of the network (2%) is unprotected steel. Half of the low-pressure distribution network is less than 20 years old.



The natural gas distribution system consists of over 650km of high-pressure licensed pipelines and more than 38,000km of low-pressure pipelines and mains.

Switching from natural gas to electricity produced using renewable sources can help to reduce Victoria's energy-related emissions.

4.1.2 Key emissions reduction pathways for the gas sector

There are a range of options available to help reduce emissions associated with natural gas use. These include energy efficiency, fuel switching from natural gas to electricity from renewable sources, substituting natural gas with low emissions or renewable gases such as hydrogen or biomethane, and other technologies such carbon capture, utilisation and storage.

These are each outlined in brief below. Further details on these decarbonisation options and associated risks and opportunities are outlined in our interim report and in the technical reports which accompany this advice, available at infrastructurevictoria.com.au

Energy efficiency

Measures to reduce demand for gas (and electricity) by improving energy efficiency can contribute to reducing emissions associated with energy use. This includes efficiency measures in industry, buildings and appliances. These are cost-effective 'no regrets' measures that can be put into place immediately and have a positive impact in reducing demand for energy regardless of how Victoria ultimately achieves net zero emissions.

Energy efficiency measures include incentives to install more efficient equipment and appliances, improved building standards, and upgrades to existing buildings. They can reduce the need for more energy supply infrastructure, support better use from the infrastructure we already have and deliver energy cost savings for industrial, business and household gas users. Measures to reduce energy demand overall are worthwhile under all future energy scenarios.

152 Bruce S, Temminghoff M, Hayward J, Schmidt E, Munnings C, Palfreyman D and Hartley P (2018) *National Hydrogen Roadmap*

153 Wouters C, Buseman M, van Tilburg J, Berg T, Cihlar J, Villar Lejarreta A, Jens J, Wang A, Peters D, van der Leun K (2020) *Market State and Trends in Renewable and Low-carbon Gases in Europe*

154 Jemena (2021) *Malabar Biomethane Project (website)*

155 Deloitte Access Economics (2017) *Decarbonising Australia's Gas Distribution Networks*

156 Earth Resources (2021) *The CarbonNet Project (website)*

157 CO2CRC (2021) *About Us (website)*

Electrification

Switching from natural gas to electricity produced using renewable sources can help to reduce Victoria's energy-related emissions. In addition, some electrical appliances can be more energy efficient than the equivalent gas appliance, meaning switching from gas to electricity can save on energy costs in the long run.

Electrical alternatives are available for a range of household, commercial and industrial gas uses. However, electrification options are not currently viable for all industrial processes – for example, process heating at very high temperatures. Increased electrification will also increase demand for electricity, particularly in winter due to the need for heating. When combined with growth in demand associated with electric vehicles, this would require significant investment in electricity infrastructure.

Substitution with hydrogen

Hydrogen can be used instead of natural gas as a source of heat and energy for a range of purposes, including in homes, businesses and industry, as well as energy generation and transport. It can also be used as an industrial feedstock for chemical production.

Hydrogen can be produced from water by electrolysis. It can help the gas sector decarbonise if production is powered by electricity from renewable sources (green hydrogen). Hydrogen can also be produced from coal (brown hydrogen) or natural gas (blue hydrogen). Greenhouse gas emissions produced during the brown or blue hydrogen production process would need to be captured and stored, or fully offset to contribute to Victoria's emissions reduction targets.

Hydrogen is currently more expensive to produce than natural gas. Green hydrogen production would also require reliable high-quality water and renewable electricity supply, increasing demands on Victoria's electricity network and water resources. However, if production costs come down in future, it could become more widely available as a substitute for natural gas.

Hydrogen can be blended with natural gas at low levels in the existing gas distribution system for household and business use (up to 10% by volume, although higher blends may be possible in some instances[152]) as a first step in reducing emissions. However, pure hydrogen cannot be used in domestic gas appliances or transported in the existing gas transmission network without additional assessment and/or modifications. Blending of hydrogen in natural gas networks is limited to what end use appliances can take.

Substitution with biogas

Biogas is produced from the anaerobic digestion Aof organic matter – for example, food waste, wastewater and agricultural waste. It can be used as a renewable alternative to natural gas in some settings and can further contribute to Victoria's emissions reduction targets by capturing methane emissions from organic matter that would otherwise be released, contributing to global warming. If upgraded to biomethane, it can be injected into the existing gas network without the need for modification.

There are several projects in Victoria using biogas to supply energy for their own use, including wastewater treatment plants and food processing businesses. There is currently no biomethane plant operating in Australia with injection to a gas network, but biomethane production is increasing in Europe, helping to bring down production costs.[153] The Malabar Biomethane Project is aiming to develop Australia's first biomethane production facility for injection into Sydney's gas network in 2022.[154]

The potential for biogas and biomethane to substitute for natural gas will depend largely on the availability of organic matter and the costs of production. Estimates indicate that Victoria's biogas supply potential is around one quarter of its current gas consumption.[155]

Other technologies

There are several other technologies which have the potential to play a role in gas sector decarbonisation, including some which are at a relatively early stage of technical and/or commercial development. Technologies which have been considered as part of our technical analysis include:

- Carbon capture and storage (CCS) involves capturing, transporting and storing greenhouse gas emissions from fossil fuel power stations, energy intensive industries, and oil and gas fields. It removes carbon emissions from the source or directly from the atmosphere (known as direct air CCS), and stores carbon permanently underground (as a gas or liquid), or in solid form. Existing CCS projects in Victoria include CarbonNet, which aims to establish a commercial-scale CCS network in the Gippsland Basin,[156] and CO2CRC, a CCS research organisation based in south-west Victoria.[157]

- **Concentrated solar thermal** is a solar energy technology that uses mirrors to concentrate a large area of sunlight onto a targeted location to create high temperatures. The heat is captured by a heat transfer fluid, such as molten salt, which can then be used to create steam to power a turbine and generate electricity. The thermal energy can also be cost-effectively stored for periods of several hours or more, so that power generation can continue when the sun is not shining. The RayGen solar thermal project in north-west Victoria aims to demonstrate the application of solar thermal technology at scale.[158]
- **Green ammonia** is produced catalytically from air and green hydrogen using renewable electricity. It may be used directly as a fuel, for example in power stations, or converted back into hydrogen for injection into the gas distribution networks. Ammonia is easier to liquify than hydrogen and is therefore easier to store and transport.
- **Iron-air batteries** are an emerging technology with the potential to provide low-cost, safe, multi-day electricity storage to stabilise an electricity grid predominantly supplied by variable renewable energy – meaning renewable energy can be made available as needed, even during multiple days of extreme weather or grid outages.
- **Offshore wind** generates electricity using offshore wind turbines. It is stronger and more consistent than onshore wind, meaning that the average amount of power that can be generated is greater and there is less variability in power delivery. Offshore wind technology is proven in other parts of the world, including the UK and Scandinavia. Star of the South is Australia's first proposed offshore wind project, located off the coast of Gippsland.[159]
- **Fuel cells** convert hydrogen to electricity via an electro-chemical reaction and are widely used in hydrogen fuel cell vehicles. Fuel cells have the potential to be used as a form of long-term energy storage and fast reacting energy supply to help stabilise the electricity grid.

158 Australian Renewable Energy Agency (2021) *RayGen Solar Power Plant Demonstration (website)*

159 Star of the South (2021) *Project Overview (website)*

4.2

Victoria's emissions reduction targets are clear, but the path to achieve them is not.

This advice aims to inform the nature and timing of decisions regarding Victoria's gas transmission and distribution networks. Future energy use in Victoria, including gas, is being considered against a backdrop of significant uncertainty. The exact evolution of technology is unpredictable, as is its impact on long-lived assets, making planning for infrastructure challenging.

Scenario planning involves constructing multiple projections under different assumptions. It improves understanding of the value of infrastructure investments in different possible futures. It also helps document the value of keeping options open under different possible circumstances and identifies situations where infrastructure could become redundant.

4.2.1 Scenarios have explored potential energy mixes in a net zero emissions future

Our scenario analysis has modelled different energy futures as part of the evidence base underpinning this advice. Infrastructure projects are an investment for the long term, but the long-term outlook can vary markedly. The future energy mix will be determined by the availability of technologies, commercial considerations, environmental and health impacts, energy security and reliability requirements, and community acceptance.[160] For this advice we modelled scenarios considering a wide range of energy futures, including full electrification, large-scale hydrogen roll out and a diversified energy mix.

Approach

The four scenarios constructed by us and examined in our first round of scenario analysis (see detailed discussion in our *interim report*), suggested limited opportunity to use existing gas infrastructure beyond 2040.[161] Based on learnings from this first study and stakeholder feedback, and to further explore the range of potential futures facing Victoria's gas sector, the second phase of our scenario analysis has compared seven scenarios generated by a purpose-built model which specifically consider how gas infrastructure use could be maximised while also providing a secure supply of low emissions energy during the transition to net zero by 2050.

In developing these scenarios, several simplifications and assumptions have been made to deal with the many uncertainties surrounding future technology development and energy use. The intent of the scenarios is not to determine a precise answer or to define the future energy mix. Instead, in developing multiple scenarios we compare potential infrastructure costs, emissions and energy mixes to meet demand, and consider the timing and support needed to further develop low emissions energy. It is high level, strategic modelling to help inform future planning, and more detailed modelling and analysis would need to be done before any investment decisions are made.

The scope of the scenario analysis included electricity, natural gas and road vehicles to holistically consider the impact of the transport transition on renewable electricity and gas infrastructure, but excluded agriculture, aviation and shipping. In maximising use of existing gas infrastructure, the scenarios aim to minimise the need for new gas and electricity transmission infrastructure, which would require greatly increased levels of cost (as demonstrated in our first round of scenario analysis).

The model was constrained by Victoria's emissions targets, including current interim targets. It is a static energy balance model with analysis conducted at five-year time steps, incorporating published electricity generation infrastructure retirement dates. The model assumes a baseline annual energy demand in Victoria of around 730 PJ in 2020, with a forecast increase in energy demand of approximately 25% to 2050, to around 910 PJ (except for the energy efficiency scenario, which has a forecast demand increase of 8% over the period). Population growth forecasts are in line with the Department of Environment, Land, Water and Planning's *Victoria in future 2019* population projections.[162] New energy supply capacity choices are driven by the model, constrained by the emissions targets, energy supply emission factors, and costs to meet 115% of the forecast demand. Peak demand is met by interconnectors. Subsequent gas spatial analysis determined when changes to the transmission system would be required, and a simplistic representation of the electricity transmission system was used. It was assumed the electricity transmission system would expand as required to meet the new generation requirements.

Using multiple input databases covering energy demand, natural gas production forecasts, interconnector capacity, energy efficiency improvements, low emissions vehicle uptake, infrastructure costs and emissions factors for new energy supplies, the model identified several non-unique solutions. It has not been optimised and does not consider broader economic impacts. It is intended to guide further detailed analysis that would be required prior to decision-making on any specific infrastructure.

More detailed information can be found in the technical report, *Net zero emissions scenario analysis stage 2*, available on the Infrastructure Victoria *website.*[163]

The seven scenarios, and associated technology breakthroughs, are summarised in Table 1.

160 International Atomic Energy Agency (2010) *Nuclear Energy Development in the 21st Century: Global Scenarios and Regional Trends*

161 DORIS Engineering (2021) *Net Zero Emission Scenario Analysis (Phase 1)*

162 Department of Environment, Land, Water and Planning (2019) *Victoria in Future 2019*

163 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

Table 1: Summary of scenarios and technology breakthroughs

Scenario	Description	Primary breakthrough technologies	Secondary breakthrough technologies
Current energy technology scenario	Uses low emissions technologies, primarily solar PV and wind, that are currently capable of delivering commercially competitive energy at an industrial scale.	Current energy technology	Green hydrogen (energy gas generation)
High green ammonia scenario (breakthrough by 2040)	Uses primarily green ammonia to replace natural gas entirely, and allows electrical generation and transmission infrastructure in the Latrobe Valley to be used beyond 2050.	Green ammonia (energy gas, electrical generation)	Iron-air batteries (electrical storage)
Solar thermal scenario (breakthrough by 2030)	Uses primarily solar thermal and molten salt deep duration storage to provide an enhanced level of high-quality electrical power in the mix, with the potential to reduce firming infrastructure.	Solar thermal, molten salt (electrical generation and storage)	Offshore wind, fuel cells (electrical generation, electrical storage)
Combined solar thermal/ammonia scenario (breakthrough by 2030/40)	Investigates the potential of achieving multiple technology breakthroughs, along with the associated cost implications. This scenario was constructed by combining technology breakthroughs from both the high green ammonia and solar thermal scenarios.	Green ammonia, solar thermal, molten salt (energy gas, electrical generation, electrical storage)	Iron-air batteries, offshore wind, fuel cells (electrical generation, electrical storage)
Low green ammonia scenario (breakthrough by 2040)	A variation of the high green ammonia scenario, with the objective of calibrating ammonia demand to identified supply prospects, e.g. Western Green Energy Hub (WA).	Green ammonia (energy gas, electrical generation)	Iron-air batteries (electrical storage)
Energy efficiency scenario	Investigates the influence of energy efficiency on transition costs and benefits. Energy efficiency improvement levels in the current energy technology scenario were adjusted from 5% to 20% per decade.	Current energy technology	Green hydrogen (energy gas generation)
Green hydrogen scenario (breakthrough by 2030)	Investigates how a high proportion of green hydrogen in the energy mix would affect transition costs, emissions and use of existing energy infrastructure. Constructed from the low green ammonia scenario, the green hydrogen scenario aims to more fully explore the potential role of green hydrogen in the transition to net zero.	Green hydrogen (energy gas generation)	Solar thermal, molten salt, offshore wind, fuel cells (electrical generation, electrical storage)

Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*[164]

164 The seven scenarios listed above are named to highlight the key energy technology breakthrough in each case. DORIS Engineering's *IV128 net zero emissions scenario analysis stage 2 – study report* uses the following naming conventions: high probability technology scenario (current energy technology); mid probability technology scenario (high green ammonia); low probability technology scenario (solar thermal); sensitivity 1 (combined solar thermal/ammonia); sensitivity 2 (low green ammonia); sensitivity 3 (energy efficiency); sensitivity 4 (green hydrogen).

Energy mix

Common to all scenarios, and driven by the logic of the model, is a gradual decline over time in the consumption of fossil fuels for energy generation, notably brown coal (primarily electricity), diesel and gasoline (primarily transport). Natural gas use declines significantly in all scenarios, but some use is retained in most cases, to further explore options to reuse existing energy infrastructure and to allow the planning, build and costs of new infrastructure to happen over time. The exceptions are the high green ammonia and the combined solar thermal/ammonia scenarios, where use of ammonia (converted to hydrogen for distribution) allows for complete replacement of natural gas.

All scenarios see an increasing proportion of Victoria's energy demand being met by electricity in the years to 2050. Electricity generation and storage account for 30% of total energy consumed in 2020, rising to 70–90% in 2050, depending on the scenario. The solar thermal scenario has the greatest degree of electrification, with electricity accounting for 90% of energy consumed by 2050 compared with 10% for gas. Breakthroughs in electrical generation and storage technologies are required to support this energy mix. For such scenarios to evolve, increases in electricity transmission and distribution infrastructure would also be required, though these were not explicitly modelled (see section 4.2.3).

Based on findings from the first phase of our scenario analysis, all seven scenarios include a significant increase in the use of bioenergy resources to accelerate progress to net zero. As well as enabling continued use of existing gas infrastructure to distribute biomethane, bioenergy is used to generate renewable electricity and can contribute to emissions reduction across a range of other sectors – including waste, water and agriculture.

Other sources of energy in the 2050 energy mix include renewable gases (green hydrogen and green ammonia), renewable electricity generation (including solar PV, onshore and offshore wind) and electricity storage, and a significantly reduced proportion of natural gas in most scenarios.

Figures 11–13 summarise how energy demand (including for road vehicles) is met under each scenario in 2030, 2040 and 2050, illustrating relative reliance on natural gas, renewable gases (green hydrogen, green ammonia and biomethane), electricity generated using fossil fuels and renewable sources, and gasoline and diesel.

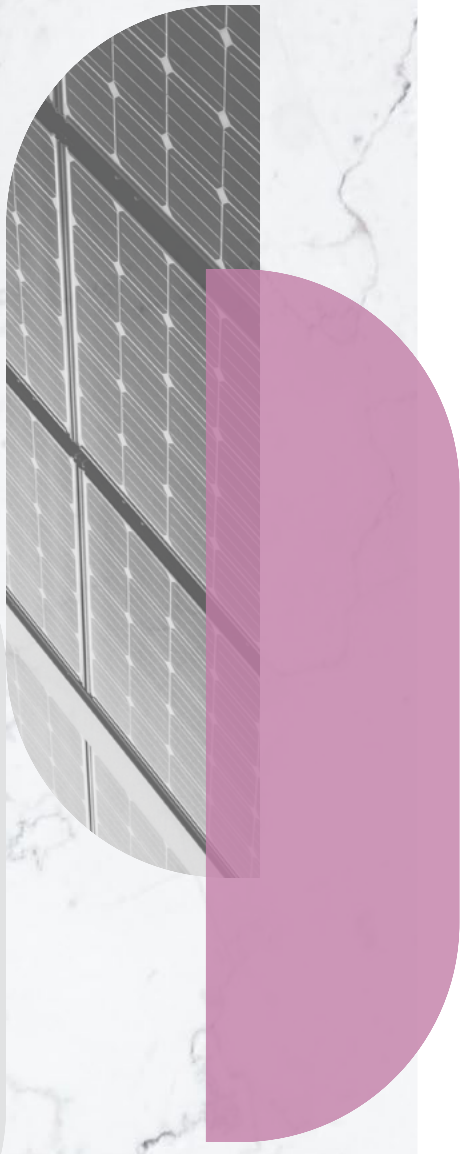


Figure 11: Energy mix by scenario and energy type – 2030 (PJ)

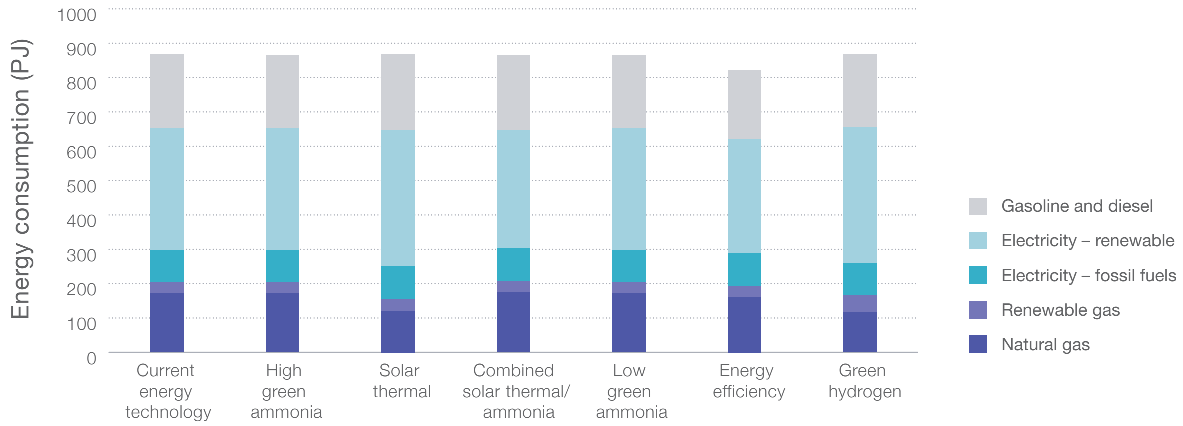


Figure 12: Energy demand by scenario and energy type – 2040 (PJ)

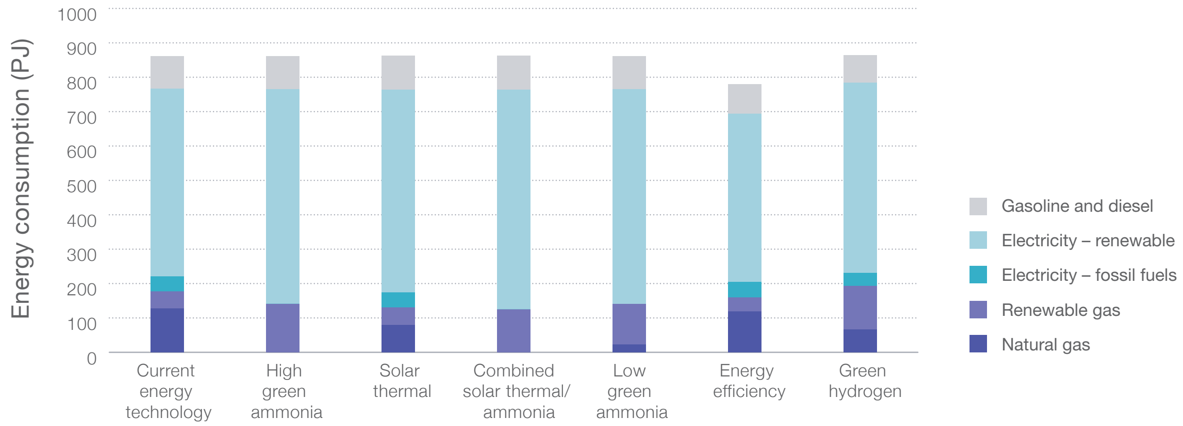
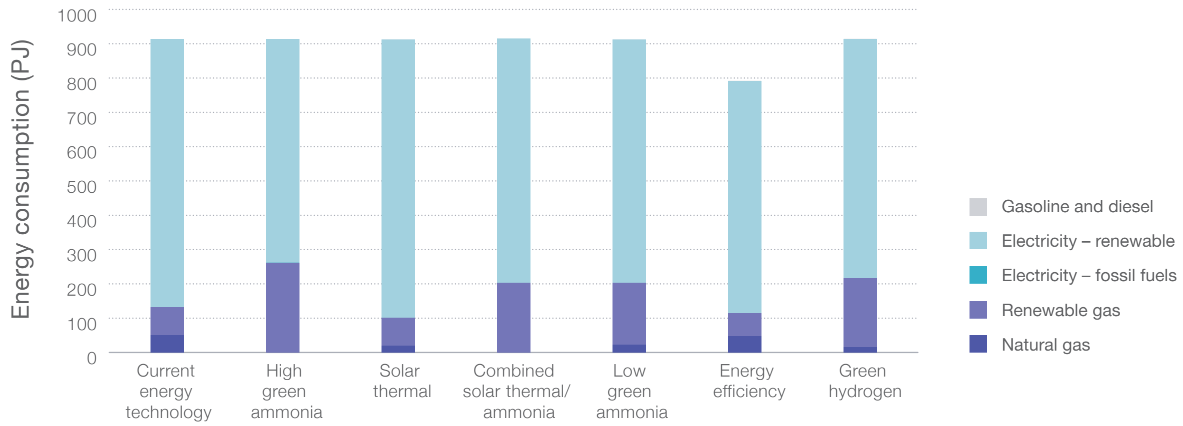


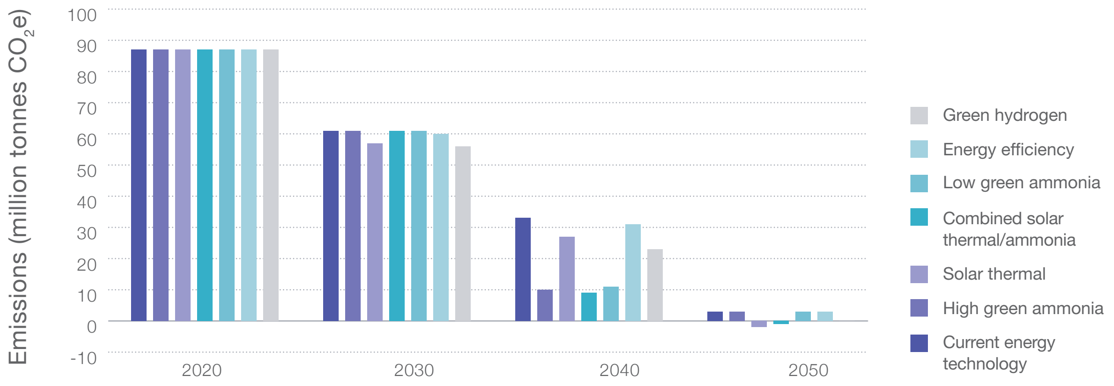
Figure 13: Energy demand by scenario and energy type – 2050 (PJ)



Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

Notes:
- Renewable gas includes green hydrogen, green ammonia, and biomethane.
- Renewable electricity includes generation (ammonia, hydropower, solar PV, solar thermal, wind, bioenergy, fuel cells) and storage (pumped hydro, batteries).
- Fuel for low emissions vehicles is included in renewable gas and renewable electricity.

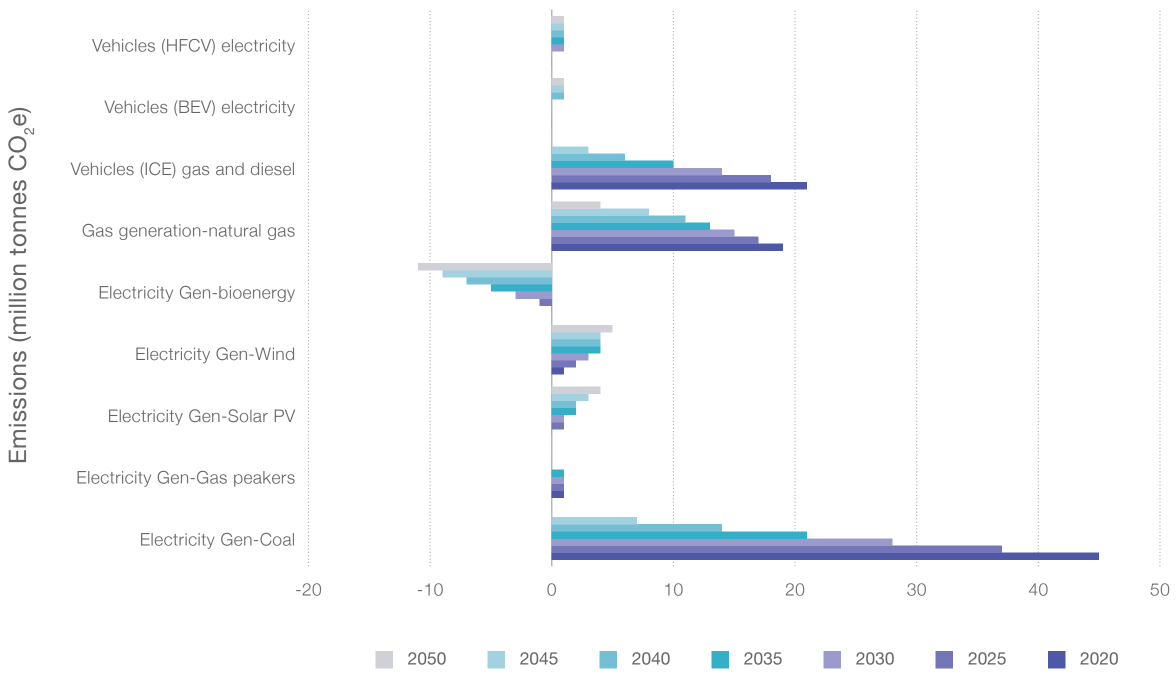
Figure 14: Emissions profile by scenario – 2020 to 2050 (Mt CO_2e)



Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

Notes:
- Emissions in scope include electricity, energy gas and road vehicles (i.e. only a component of total reported emissions across the Victorian economy).
- In scenarios with positive emissions in 2050, offsets are required to achieve net zero. A negative emissions result in 2050 indicates net zero can be achieved prior to 2050.

Figure 15: Emissions profile, current energy technology scenario – 2020 to 2050 (Mt CO_2e)



Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

Emissions and time to net zero

Figure 14 shows the estimated annual greenhouse gas emissions at ten-yearly intervals for each of the scenarios. The current energy technology, solar thermal, energy efficiency and green hydrogen scenarios have a relatively linear decline in emissions to 2050. While similar in 2030, the high and low green ammonia and combined solar thermal/ammonia scenarios show an accelerated reduction in emissions from the mid-2030s through to 2050.

As illustrated in Figure 14, four of the scenarios – the current energy technology, high green ammonia, low green ammonia and energy efficiency scenarios – have a tail of residual greenhouse gas emissions in 2050, approximately 3 Mt CO_2e. In these scenarios, offsets have been used to achieve net zero emissions by 2050.

Each of the scenarios meet Victoria's interim emissions reduction targets of 28–33% below 2005 emissions by 2025, and 45–50% by 2030. Emissions decline by around 40% by 2025 and around 50–55% by 2050, compared with 2005.

Figure 15 shows the relative change in emissions over time for the current energy technology scenario (i.e. use of currently commercially available energy generation technologies). This demonstrates that the overwhelming amount of emissions reduction comes from declining fossil fuel use (coal, natural gas and vehicle fuel), but that negative or avoided emissions from bioenergy also make a significant contribution.

Individual scenarios

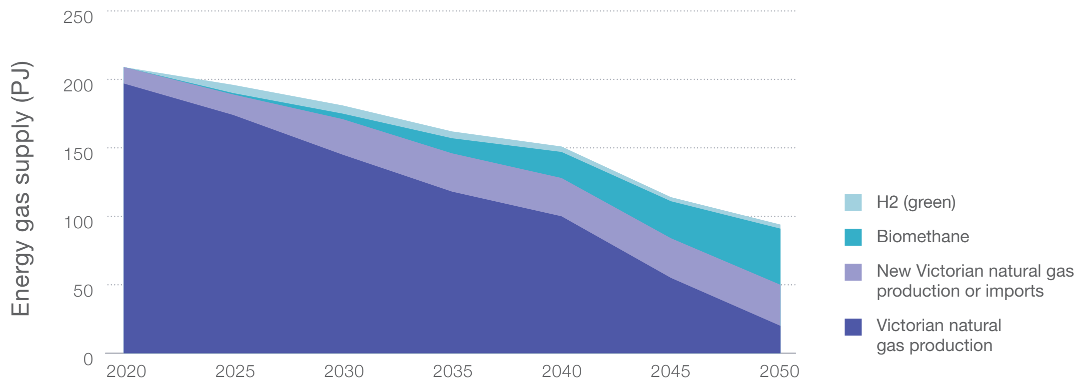
Current energy technology scenario

The current energy technology scenario uses low emissions energy technologies, primarily solar PV and wind, to meet Victoria's energy demand. The scenario achieves net zero with little technical risk compared with other scenarios, as these technologies are currently capable of delivering commercially competitive energy at an industrial scale.

This scenario relies on the continued supply and distribution of natural gas, including imports or new local supplies, to support harder-to-abate industries. A declining tail of natural gas is maintained in the energy mix along with other energy gases (biomethane and green hydrogen), while renewable electricity from onshore wind and solar PV continues to grow to meet the electricity demand and produce green hydrogen. Offsets are required to achieve net zero emissions, generated by investment in soil farming projects equating to a cumulative total of 2,400 hectares in 2050. Greenhouse gas emissions of approximately 3 Mt CO_2e are anticipated in 2050.

The current energy technology scenario assumes that green hydrogen production at scale becomes technically viable and commercially competitive by 2025, although hydrogen's small contribution to the overall energy mix means that this timing is not critical. Production is dispersed across the state, preferably located close to electrical transmission and gas pipeline infrastructure. A small amount of hydrogen is blended in the existing gas transmission and distribution systems, limited to 10% by volume. Biomethane production is concentrated in Melbourne and Victoria's northern and western regions. New gas transmission pipelines would be required to transport biomethane produced in north-western Victoria around the state.

Figure 16: Energy gas supply, current energy technology scenario – 2020 to 2050 (PJ)



Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

These changes to the energy gas supply mean that gas flows in the transmission system reduce significantly between 2020 and 2050 (see Figure 16). In some sections of the transmission network, as biomethane supplies are brought onstream and specific regions become self-sufficient in gas and then have surplus, the gas flow direction will need to be reversed. Excluding transport, demand for gas declines by over 50% between 2020 and 2050, from around 210 PJ to 90 PJ, with natural gas comprising over 50% of energy gas in 2050. Around 20% of existing gas transmission infrastructure and 10% of gas distribution infrastructure could be decommissioned by 2050.

The current energy technology scenario has a high proportion of electrification, with 85% of energy demand supplied by electricity by 2050 compared with 15% gas. It has a high level of variable renewable energy (solar PV and onshore wind), requiring the highest level of storage using lithium-ion batteries compared with the other scenarios. In 2050, solar PV and wind represent 85% of the electrical mix.

Key investments to achieve net zero emissions by 2050 under the current energy technology scenario include:

- Compared to 2020, 18 times more solar PV, 4.5 times more wind capacity, and 190 times the level of battery support.
- Significant investments in biomethane, bioenergy and hydrogen production.
- By 2050, 3 Mt per year of agroforestry offsets to offset emissions.
- Additional gas transmission pipelines to transport biomethane from the north to demand centres in Echuca and Bendigo and then onto other centres.
- A strengthened electricity grid to support large amounts of renewable generation capacity.

High green ammonia scenario

The high green ammonia scenario uses primarily green ammonia plus other low emissions energy technologies to replace natural gas entirely by 2040. This scenario assumes technology breakthroughs in:

- Green ammonia – used in two ways in this scenario:
  - Transported via existing transmission pipelines to industrial users and conversion plants located close to the gas distribution network. These plants will convert ammonia to hydrogen for injection into the gas distribution system. The scenario assumes that existing gas transmission pipelines can transport liquid ammonia with minimal modifications, and that any upgrades needed to transport pure hydrogen in the distribution system will have been carried out by 2040.
  - Used to generate electricity via ammonia gas-fired turbine generation systems, to be located in the Latrobe Valley.
- Iron-air batteries – can store renewables-sourced electricity for a long period of time
- Fuel cells – electricity generation from hydrogen, which could be fast reacting dispatchable energy supply and a source of storage

This scenario represents the highest proportion of energy gas in the mix (30% compared with 70% of energy demand satisfied by electricity) due to the introduction of green ammonia. It provides the opportunity to maximise use of natural gas pipeline infrastructure, and the potential to use the Latrobe Valley's electricity generation and transmission infrastructure by converting coal-fired power stations to ammonia (although new ammonia-fired power generation capacity would be required if reuse of existing infrastructure proves unfeasible). Ammonia was assumed to be imported to the Latrobe Valley rather than produced locally, due to the amount of energy required to produce ammonia. Appropriate import infrastructure would therefore need to be developed. Green ammonia projects are currently in development in other Australian states.

A significant degree of planning would be required to manage this transition successfully. Implementation would likely occur in a staged manner, region-by-region, commencing with the most suitable locations (based on locations for siting conversion plants, readiness of existing infrastructure and requirements for any new infrastructure).

The high green ammonia scenario has a different emissions decline profile over time compared to the current energy technology scenario, with a sharp decline in 2040 due to the introduction of ammonia and iron-air batteries which allow no further use of natural gas and coal. Similar to the current energy technology scenario, this scenario anticipates greenhouse gas emissions of approximately 3 Mt CO_2e in 2050, but requires slightly lower levels of offsets – a cumulative total of 2,100 hectares in 2050.

Unlike other scenarios, overall demand for energy gas increases slightly, by 10% from between 2020 and 2050 due to the addition of ammonia to the energy mix. Biomethane production is concentrated in Melbourne and Victoria's northern, western and north-eastern regions. Biomethane production is mostly limited to injection into the local gas distribution networks, so that from 2040 onwards ammonia can be distributed via the gas transmission system. Due to the high concentration of biomethane production in the north west of the state, the north western transmission system could be separated and used exclusively to transport biomethane to meet demand in major regional centres. As in the current energy technology scenario, new gas transmission pipelines would be required from biomethane production sites in the north west to regional centres. These pipelines would also be suitable for hydrogen.

In this scenario, gas users consume a combination of hydrogen and biomethane, with the mix dependent on their location and proximity to local biomethane production sources. Hydrogen production is relatively low, as use is limited to 10% hydrogen by volume in the gas mix until 2040. After 2040, consumers in many locations will use pure hydrogen, which will be injected into the distribution system after conversion from ammonia. Under this scenario, around one-third of existing gas transmission infrastructure and up to 15% of gas distribution infrastructure could be decommissioned by 2050.

The main electrical generation infrastructure in the high green ammonia scenario is solar PV and onshore wind, with storage provided primarily by lithium-ion batteries. In 2050, wind and solar PV represent around 70% of the electrical mix. Compared to the current energy technology scenario, solar PV represents a much smaller proportion of electricity generation capacity (approximately one-third compared with over 50% in the current energy technology scenario) due to the use of ammonia to generate electricity.

Key investments to achieve net zero emissions by 2050 under the high green ammonia scenario include:

- Compared to 2020, 10 times more solar PV, four times as much wind capacity, and around 100 times the level of battery support.
- Significant investments in biomethane, bioenergy, and hydrogen production, as well as electrical generation from ammonia.
- High volumes of ammonia imports (and investment in associated infrastructure).
- Construction of new pipelines to transport imported ammonia to the gas distribution grid and the Latrobe Valley, as well as new ammonia storage and ammonia-to-hydrogen conversion plants.
- By 2050, just under 3 Mt per year of agroforestry offsets to offset greenhouse gas emissions.
- Additional pipelines to transport biomethane.
- A strengthened electricity grid to support large amounts of renewable generation capacity.

Solar thermal scenario

The solar thermal scenario uses solar thermal and deep duration storage (molten salt) to provide electrical power into the energy mix. This scenario assumes technology breakthroughs by 2030 in:

- \ Solar thermal – electricity generation from industrial scale solar energy, assumed to be integrated with thermal energy storage using molten salt providing longer duration storage
- \ Offshore wind – electricity generation using offshore wind turbines providing larger scale generation.

The solar thermal scenario reaches net zero before 2050, unlike the current energy technology and high green ammonia scenarios, and does not require offsets. This outcome is due to the high level of electrification (10% energy gas compared with 90% electricity in the energy mix, the highest level across all scenarios), through the use of solar thermal electricity generation with molten salt storage providing a steadier supply of power with better yields compared to firmed solar PV.

In this scenario, overall gas consumption (excluding transport) declines by 70% between 2020 and 2050, from around 210 PJ to 60 PJ. Natural gas supply is supplemented by biomethane and hydrogen (up to 10% by volume). The overall demand for biomethane and hydrogen is similar to the current energy technology scenario, while demand for natural gas is significantly lower (less than half the demand in the current energy technology scenario by 2050).

Biomethane production means that certain regions become self-sufficient in renewable gas and can export excess capacity to other parts of the state. As a result, the flow direction of gas in pipelines will need to be reversed. As with the current energy technology and high green ammonia scenarios, two new transmission pipelines would be required by 2035, to transport biomethane produced in north-western Victoria to regional centres and around the state. Green hydrogen production is dispersed across the state, preferably located close to electrical transmission and gas pipeline infrastructure and water supplies. Under this scenario, around one-third of existing gas transmission infrastructure and up to 30% of gas distribution infrastructure could be decommissioned by 2050.

The main electrical generation infrastructure in the solar thermal scenario includes solar thermal, wind (onshore and offshore) and solar PV, while the main electrical storage technologies are lithium-ion batteries and the molten salt storage associated with solar thermal generation. In 2050, solar PV and wind represent around 50% of electricity generated, while solar thermal generates 34%.

Key investments to achieve net zero emissions by 2050 under the solar thermal scenario include:

- \ Compared to 2020, 7.8 times more solar PV, 4.5 times more wind capacity, and 100 times the level of battery storage.
- \ Roll out of substantial solar thermal capacity and associated molten salt storage.
- \ Significant investments in biomethane, bioenergy and hydrogen production, including additional gas transmission pipelines to transport biomethane from the north of the state to demand centres.
- \ A strengthened electricity grid to support large amounts of renewable generation capacity.

Combined solar thermal/ammonia scenario

The combined solar thermal/ammonia scenario combines the technology breakthroughs of the high green ammonia and solar thermal scenarios (i.e. offshore wind, solar thermal, fuel cells, ammonia and iron-air batteries). This scenario achieves a time to net zero like the solar thermal scenario (i.e. slightly before 2050), without requiring offsets. Achieving a more significant reduction in the time to net zero might be achieved in this scenario by implementing an aggressive, near-term (to 2030) improvement in residential and commercial energy efficiency, alongside a significant increase in the uptake of low emissions road vehicles.

Overall demand for energy gas declines by around 20% in the combined solar thermal/ammonia scenario, from around 210 PJ in 2020 to 170 PJ in 2050. By 2050, green ammonia comprises almost 80% of Victoria's energy gas. Compared with the previous scenarios, biomethane demand is slightly reduced and is supplied in regions close to existing gas distribution networks. There is therefore no need for additional gas transmission infrastructure in this scenario. As in other scenarios, green hydrogen production is dispersed across the state, and limited to 10% blending in existing gas networks. Ammonia distribution is similar to the high green ammonia scenario, and requires similar investment in infrastructure. Around 40% of existing gas transmission infrastructure could be decommissioned by 2050.

The main electrical generation infrastructure includes solar thermal, wind (onshore and offshore), solar PV and ammonia, while the main electrical storage technologies are the molten salt storage associated with solar thermal generation, iron-air and lithium-ion batteries. In 2050, solar PV and wind represent around 55% of electricity generated.

Key investments to achieve net zero emissions by 2050 under the combined solar thermal/ammonia scenario include:

- \ Compared to 2020, six times more solar PV, 3.5 times more wind capacity, and 100 times more battery storage.
- \ Roll out of solar thermal capacity and associated molten salt storage. Most of the solar thermal capacity is deployed before 2040.
- \ Investment in infrastructure to support ammonia imports and electricity generation, including construction of new pipelines to transport ammonia to the gas distribution grid and the Latrobe Valley.
- \ Significant investments in biomethane, bioenergy and hydrogen production.
- \ A strengthened electricity grid to support large amounts of renewable generation capacity.

Low green ammonia scenario

The low green ammonia scenario is based on the high green ammonia scenario, but with demand for green ammonia reduced (by around 25% for electricity generation and by 40% for conversion to hydrogen and blending in the gas network), with the objective of calibrating ammonia demand to identified supply prospects. In contrast to the high green ammonia scenario, this scenario maintains use of natural gas through to 2050 to offset the lower levels of ammonia. Increased energy is also supplied from onshore wind and battery storage.

Similar to the high green ammonia scenario, this scenario sees a sharp decline in emissions in 2040 as ammonia and iron-air batteries are introduced, allowing no further use of coal. Greenhouse gas emissions of approximately 3 Mt CO_2e in 2050 are anticipated, which are offset via soil farming projects. This requires a cumulative total of 2,400 hectares in 2050, slightly higher than the high green ammonia scenario as a result of a higher level of natural gas in the energy mix.

Overall demand for energy gas declines by almost 20% in the low green ammonia scenario, from around 210 PJ in 2020 to 170 PJ in 2050. Natural gas is supplemented by biomethane and green hydrogen production from 2025, and with green ammonia from 2040. By 2050, green ammonia comprises almost two-thirds of Victoria's energy gas. Biomethane and green hydrogen production is the same as the combined solar thermal/ammonia scenario, with the same implications for infrastructure.

The main electrical generation infrastructure includes solar PV, onshore wind, and ammonia, while the main electrical storage technologies are lithium-ion and iron-air batteries. In 2050, solar PV and wind represent just under 80% of electricity generated.

Key investments to achieve net zero emissions by 2050 under the low green ammonia scenario include:

- Compared to 2020, 10 times more solar PV, 4.7 times as much wind capacity, and around 140 times the level of battery support.
- Investment in infrastructure to support ammonia imports and electricity generation, including construction of new pipelines to transport ammonia to the gas distribution grid and the Latrobe Valley.
- Significant investments in biomethane, bioenergy and hydrogen production.
- By 2050, 3 Mt per year of agroforestry offsets to offset greenhouse gas emissions.
- A strengthened electricity grid to support large amounts of renewable generation capacity.

Energy efficiency scenario

The energy efficiency scenario is based on the current energy technology scenario. It includes no technology breakthroughs so the impact of increased energy efficiency can be more clearly identified. In this scenario, the energy efficiency improvement rate was increased to 20% per decade for both electricity and gas, in comparison to the 5% improvement included in the current energy technology scenario.

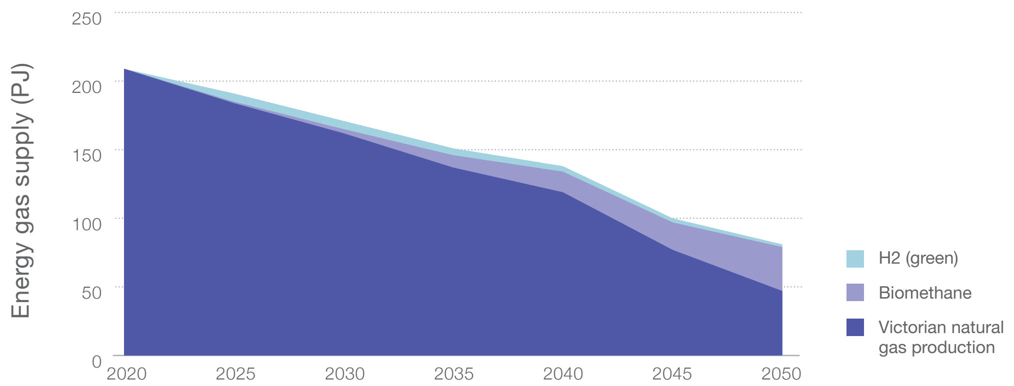
The increased rate of energy efficiency improvement did not have a significant impact on the time taken to reach net zero, but it did have a significant impact on energy generation requirements, associated infrastructure costs and environmental and social impacts. Total energy demand is reduced by around 15% compared with the current energy technology scenario. As a result, the need for large-scale solar PV is reduced by 13%, wind by 17%, battery storage by 13% and bioenergy by 20%.

Improving energy efficiency has little impact on reducing emissions in this scenario because the largest sources of emissions (i.e. coal and natural gas) tail off as energy efficiency improvements become significant. Results indicate that a greater increase in residential and commercial energy efficiency improvements before 2030, combined with a greater uptake of low emissions vehicles, would deliver a greater impact on emissions reduction and the time required to reach net zero.

The energy efficiency scenario has a very much lower net cost compared to any of the other scenarios due to the avoidance of some energy generation infrastructure resulting from reduced energy demand.

This scenario has a similar emissions decline profile to the current energy technology scenario. Greenhouse gas emissions of approximately 3 Mt CO_2e are anticipated in 2050, requiring a cumulative total of 2,400 hectares of offsets in 2050.

Figure 17: Energy gas supply, energy efficiency scenario – 2020 to 2050 (PJ)



Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

Demand for energy gas declines by over 60% in the energy efficiency scenario, from around 210 PJ in 2020 to 80 PJ in 2050. Natural gas comprises over 50% of energy gas, supplemented by biomethane production and a small amount of hydrogen for blending in the network at 10%. Energy efficiency enables the local resource use to be extended without requiring imports or new production (see Figure 17). Around 25% of existing gas transmission infrastructure could be decommissioned by 2050.

Solar PV and onshore wind accounts for the majority of electrical generation infrastructure, while the main electrical storage technologies are lithium-ion batteries. By 2050, solar PV and wind represent approximately 80% of electricity generated.

Key investments to achieve net zero emissions by 2050 under the energy efficiency scenario include:

- Compared to 2020, 16 times more solar PV, 3.8 times more wind capacity, and 160 times more battery storage.
- Significant investments in biomethane, bioenergy and hydrogen production.
- By 2050, 3 Mt per year of agroforestry offsets to offset greenhouse gas emissions.
- A strengthened electricity grid to support large amounts of renewable generation capacity.
- Increased investment in energy efficiency improvements across the economy relative to other scenarios.

Green hydrogen scenario

The green hydrogen scenario investigates the role green hydrogen could play in the energy transition, should production at scale become cost competitive. A key assumption in this scenario is that the gas distribution system will transition from natural gas to pure hydrogen by 2035. The gas transmission and distribution systems are segregated, with the transmission system transporting biomethane, a limited tail of natural gas and hydrogen blends limited to 10%. The distribution system is progressively converted to transport green hydrogen from 2025, with the transition complete by 2035.

This scenario is based on the solar thermal scenario and assumes the same technology breakthroughs in solar thermal and offshore wind by 2030. It also assumes a breakthrough in high efficiency and high productivity electrolysis in green hydrogen production. The green hydrogen scenario has higher uptake of hydrogen fuel cell vehicles compared with all other scenarios, offset by a reduced uptake of electric vehicles. As with the solar thermal scenario, the green hydrogen scenario achieves net zero by 2050 without the need for offsets.

Demand for energy gas declines by around 10% in this scenario, from around 210 PJ in 2020 to 180 PJ in 2050 (see Figure 18). Green hydrogen comprises three-quarters of energy gas demand, supplemented by biomethane production and a small tail of natural gas (15 PJ in 2050). Hydrogen will be produced via multiple green hydrogen production plants in each region, and injected into local gas distribution systems. Each plant will require electrical connection and sufficient supply of water.

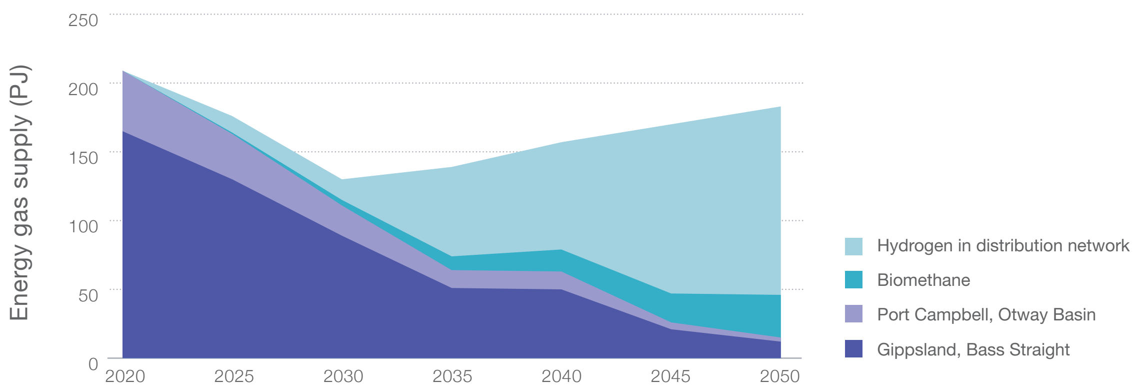
Biomethane is used locally in the region it is produced, removing the need for new gas transmission lines. Similarly, green hydrogen is produced close to where it will be consumed (further investigation is needed into feasible locations, given the requirement for access to the electricity network and water). As a result, use of the gas transmission system declines over time and as much as 85% of existing transmission infrastructure could be decommissioned by 2050.

Solar PV, wind (offshore and onshore) and solar thermal accounts for the majority of electrical generation infrastructure, while the main electrical storage technologies are lithium-ion batteries and the molten salt storage associated with solar thermal generation. In 2050, solar PV and wind represent approximately 60% of electricity generated, while around one-third of total electricity generated is required for green hydrogen production.

Key investments to achieve net zero emissions by 2050 under the green hydrogen scenario include:

- Compared to 2020, 12.5 times more solar PV, six times more wind generation, and up to 100 times more battery storage.
- Major investment in green hydrogen production for injection in the existing gas network, along with any modifications required to the existing gas distribution system to accommodate hydrogen use.
- Significant investment in solar thermal, bioenergy and biomethane production.
- A strengthened electricity grid to support large amounts of renewable generation capacity.

Figure 18: Energy gas supply, green hydrogen scenario – 2020 to 2050 (PJ)



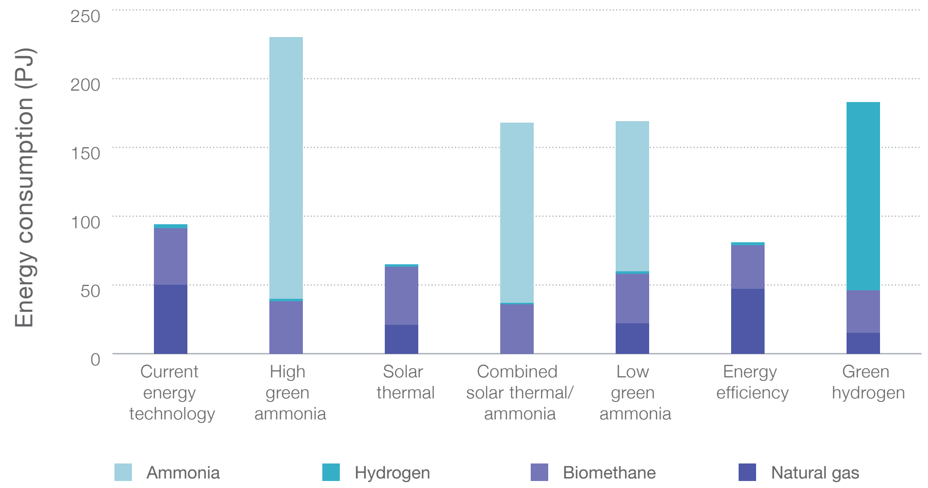
Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

4.2.2 The future for existing gas infrastructure is linked to the cost-competitive development of natural gas substitutes

The scenario analysis has looked at ways in which natural gas infrastructure can continue to be used and/or repurposed. As illustrated in Figure 19, all scenarios see a significantly reduced role for natural gas by 2050 due to declining supply and the need to meet emissions reduction targets. Natural gas supply reduces from around 200 PJ in 2020 to between 0–50 PJ in 2050, depending on the scenario. However, natural gas continues to play a critical role in providing energy until at least the 2030s in all scenarios, as technology breakthroughs and commercialisation efforts for alternative energy sources play out.

Most scenarios also see a reduced role for energy gas (including hydrogen, biogas and biomethane) compared to current levels of natural gas use. The ultimate mix of gases in the energy mix will depend on the ability of other energy technologies to become cost competitive in time to make a material contribution to net zero by 2050. The scenarios indicate that no single low or zero emissions gas is likely to fully replace natural gas in Victoria.

Figure 19: Energy gas supply by scenario and energy type – 2050 (PJ)



Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

Some existing gas infrastructure is decommissioned under each scenario

In the current energy technology, high green ammonia and solar thermal scenarios new transmission pipelines are assumed to move biomethane produced in the west and north west of the state to centres of demand, as bioenergy resources are not close to existing pipelines. This comprises 360km of transmission pipeline to be installed in 2035 in these three scenarios.

Table 2 shows a summary of the decommissioning of existing gas transmission pipelines under the different scenarios. This occurs in scenarios where local production of biomethane and/or green hydrogen could meet local demand. In the green hydrogen scenario, most of the high-pressure gas transmission system (85%) is decommissioned by 2050 as green hydrogen is produced closer to demand centres.

Initial estimates of the extent of decommissioning of existing gas distribution pipelines indicate that by 2050 2,500km of pipeline could be decommissioned under the current energy technology scenario (around 7% of the existing network), 4,000km under the high green ammonia scenario (12% of the network) and 8,000km under the solar thermal scenario (around 25% of the network).

Several scenarios assume pure hydrogen will be transported in the distribution system and/or pure ammonia will be transported in the transmission system. The scenarios assume that pure ammonia can be transported as a liquid in the existing transmission pipelines with minimal modifications required. In scenarios which rely on the distribution system to transport pure hydrogen, it is assumed any necessary upgrades to existing infrastructure will have been undertaken by 2030.

Table 2: Estimated decommissioning – gas transmission pipelines

Scenario	2030	2040	2050	% total 2050
Current energy technology	–	–	850km	18%
High green ammonia	–	1,700km	–	36%
Solar thermal	–	1,700km	–	36%
Combined solar thermal/ammonia	–	1,200km	700km	40%
Low green ammonia	–	1,200km	700km	40%
Energy efficiency	–	1,200km	–	26%
Green hydrogen	–	2,000km	2,000km	85%

Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

To inform our advice, we commissioned an assessment of the current condition of Victoria's existing gas infrastructure, to better understand the opportunities for potential repurposing. The assessment considered all gas infrastructure across the Victorian gas value chain, and the extent of upgrades required to repurpose for carbon dioxide (carbon capture and storage), biomethane or hydrogen. As indicated earlier, our assessment is necessarily high level and is intended to guide future government work and engagement with the gas industry and regulators. Infrastructure owners will conduct their own more detailed assessment of their infrastructure's adaptability.

The assessment findings, summarised in Figure 20, indicate that:[165]

\ All existing gas infrastructure can be repurposed to introduce biomethane with no or minor modifications. Opportunities to repurpose processing and storage facilities may be limited by local availability of biomass resources in some instances.

\ All distribution pipelines can be repurposed to transport hydrogen blends at 10% with minor modifications. The gas distribution network could also be repurposed to transport pure hydrogen, but major modifications would be required.

\ Around 60% of transmission pipelines would require detailed assessment and/or modifications before they could be repurposed for hydrogen blending at 10% volume (an estimated 38% would require minor modifications), to allow for pipelines operating at a lower pressure than their design pressure. The transmission network could also be repurposed to transport pure hydrogen, but detailed assessment and/or modifications would be required to all of the network.

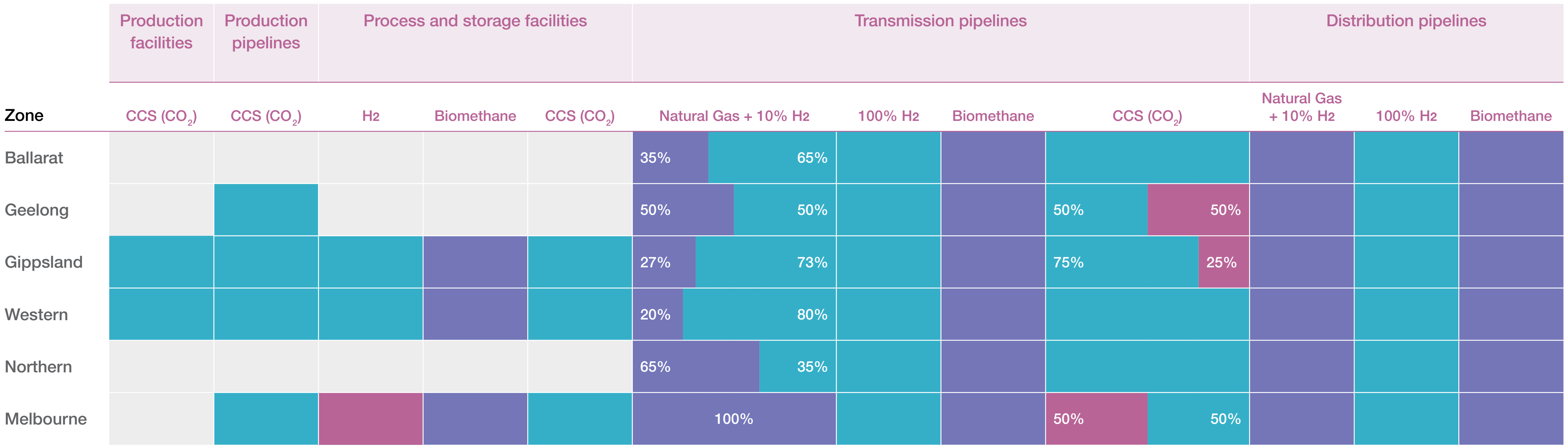
\ Use of existing natural gas production, processing and/or storage facilities for hydrogen would require extensive modifications and, in some instances, may not be feasible.

\ There are opportunities to repurpose existing natural gas production facilities, pipelines, processing and/or storage facilities in Gippsland and the Otway Basin for carbon capture and storage. Feasibility would need to be assessed on a case-by-case basis, with some likely to require major modifications before they can be repurposed – especially on production facilities where equipment would need to be replaced to enable carbon dioxide injection.

The full results from the gas infrastructure asset life and adaptability assessment are available in the *Asset life and adaptability review* technical report on our *website*.

165 Advisian (2021) *Asset Life and Adaptability Review*

Figure 20: Victoria's gas infrastructure – summary of repurposing assessment by asset type and region



Source: Advisian (2021) *Asset life and adaptability review*

Repurposing category definitions:

Category	Definition
Limited modifications required	The compatibility issues for repurposing are well defined and understood and the asset is generally capable of handling the new mixture with some minor additional changes/modifications.
Assessment and/or modification required	The compatibility issues for repurposing are generally defined and understood but detailed assessment is required. The asset may need to be modified, in parts replaced, requalified or redesigned to ensure suitability.
Non-compatible	The compatibility issues for repurposing are will defined and understood and the asset is not capable of handling the new mixture. Large sections of the asset require major changes and replacements.
Not applicable	

These results indicate that a relatively high proportion of existing gas infrastructure can be repurposed, although it may be cheaper in some instances to replace existing infrastructure rather than modify it. Continued use of existing assets can reduce overall capital expenditure on new energy infrastructure, as well as the potential environmental and social impacts associated with construction and decommissioning works. However, our analysis shows that the opportunity to use or repurpose existing infrastructure will come with challenges and that some decommissioning of assets is likely. Our scenarios have modelled energy futures where between 18–85% of the gas transmission network and between 7–25% of the gas distribution network could be decommissioned.[166] More detailed planning will be required, in collaboration with the private sector, building on the findings of this work.

166 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

Natural gas consumption should be reduced now and targeted beyond the 2030s

Many of the scenarios developed to accompany this report have explored an ongoing, but much reduced role for natural gas to 2050, in part to examine how the use of existing gas infrastructure could be maximised. It also aims to allow time for emerging technologies to be further developed and become cost competitive. Too rapid a transition away from natural gas as a fuel source will place significant additional demands on the electricity network, which is not yet ready to reliably assume Victoria's full energy load.

However, natural gas use for residential, commercial and industrial purposes will need to decline significantly or cease for Victoria to reach net zero. Our analysis indicates that from the 2030s, available natural gas should be used to support hydrogen blending and/or hard-to-abate gas uses (including any sections of the distribution network for which a low emissions solution is not viable). Natural gas also plays a role in electricity generation, and this may need to continue to maintain system reliability, noting other solutions can also play a similar role such as batteries and pumped hydro. Victoria's declining natural gas production means that additional gas may need to be sourced, either imported from other states or via new local production. The *National gas infrastructure plan* highlights that new natural gas supply will be needed by the end of this decade to avert future shortages. However, any new gas supply will need to be carefully balanced against Victoria's emissions reduction commitments.

Any emissions associated with ongoing natural gas use will require carbon sequestration and/or offsets for Victoria to reach its net zero 2050 target. Several of our scenarios result in greenhouse gas emissions of around 3 Mt CO_2e in 2050 from hard-to-abate sectors, meaning offsets play a small role in achieving net zero emissions. The study assumes agroforestry offsets, specifically soil farming, are used to offset emissions – but other forms of offsets could be used, as well as carbon capture and storage. A cumulative total of around 2,000–2,500 hectares are required in by 2050, depending on the scenario, or approximately 0.01% of Victoria's total land area.[167] These offset figures are indicative, as the analysis considers only the gas, electricity and road transport sectors. However, they do provide some context for considering changes in land use and investing in the forestry sector as a natural sink.

There is likely to be competing demand for offsets from a range of hard-to-abate sectors which will find it difficult to eliminate emissions, including aviation and heavy transport, as well as some manufacturing and agriculture.[168] Offsets may become prohibitively expensive for any sector with significant reliance on them to reach net zero.

Biomethane can be used in existing gas infrastructure, but there are supply constraints

Each of our scenarios has explored a greater role for biogas and biomethane in the energy mix, following on from findings in our previous analysis that these gases could contribute to Victoria's emissions reduction targets. Biomethane production ramps up from 1 PJ in 2025 to supply between 30–40 PJ per annum by 2050, depending on the scenario. The modelling also shows around 11 Mt CO_2e emissions being avoided from the agriculture and waste sectors by using bioenergy to generate electricity.

Biomethane represents an excellent opportunity to continue to use existing gas transmission and distribution infrastructure as it is chemically almost identical to natural gas. Existing networks can be repurposed to transport biomethane, and without the need to replace end-use appliances. However, as noted above, Victoria's potential biomethane production will not be enough to fully replace Victoria's existing natural gas use, with total future production estimated at around 25% of current gas use. Supply of feedstocks may fluctuate with variable weather conditions, in particular drought. In addition, there may be competition for bioenergy resources from other sectors.

Considerable investment and policy support will be required to develop biomethane production in Victoria. In each of our scenarios, natural gas use is maintained in the early phases of the energy transition to allow time to put in place the necessary supply chain infrastructure. To make best use of production, biogas and biomethane facilities would need to be strategically located near available biomass feedstock and, unlike current natural gas production, these resources are dispersed across Victoria. In some regions, for example Gippsland and Melbourne, biomass resources are located close to existing gas transmission and distribution infrastructure, potentially allowing biomethane to be injected into the gas network. However, there are significant resources that could be used to produce biogas in Victoria's north-west (such as digestion of animal manure, fruit and vegetable wastes, canola residue, and gasification of straw residue[169]) which are not close to the existing network. Investment would be needed to enable biomethane produced in Victoria's north-west to be transported to other parts of Victoria.

167 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

168 Wood T Reeve A and Ha J (2021) *Towards Net Zero: Practical Policies to Offset Carbon Emissions*

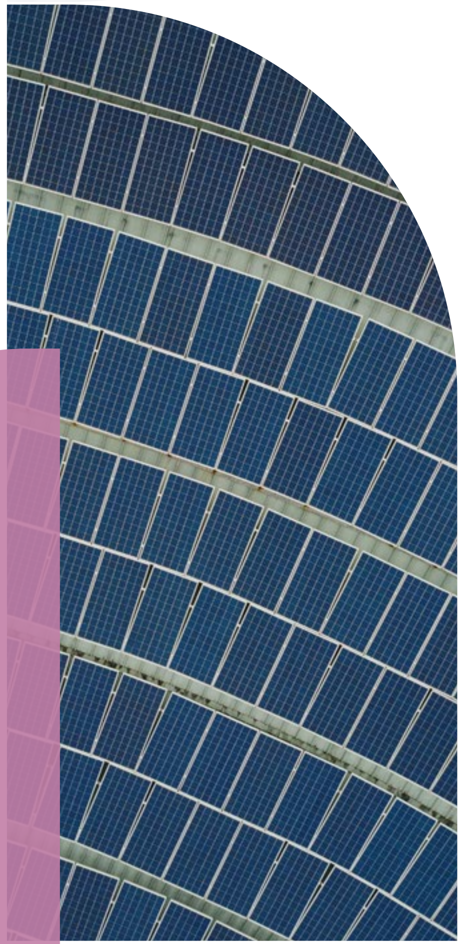
169 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

Our scenarios have explored the possibility of certain regions with readily available biomass resources becoming self-sufficient in gas supply and potentially exporting biomethane to other regions. Localised production would mean significant changes to the way existing gas networks are used. For example, the gas flow in Victoria's transmission system is currently from south to north. Although biomethane can be transported in existing transmission pipelines, additional investment would be required to change the flow direction on certain pipelines to deliver gas to customers in southern Victoria from biomethane produced in the north.

Bioenergy production can further contribute to Victoria's emissions reduction targets by helping to reduce emissions associated with waste and agriculture. Emissions factors for bioenergy projects vary based on feedstock and use, the technology applied and the end product (such as electricity or biomethane). Biomass combustion and gasification projects producing electricity have emissions factors close to zero, because the carbon dioxide emitted during energy production is similar in quantity to that consumed during plant growth. Landfill gas projects producing electricity can have net emissions factors which are negative, because they avoid the methane emissions which would otherwise be produced.[170] The contribution biogas can make towards Victoria's emissions reduction targets suggests its further development should be prioritised.

170 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

Bioenergy production can further contribute to Victoria's emissions reduction targets by helping to reduce emissions associated with waste and agriculture.



Large scale roll out of hydrogen will depend on technical and commercial breakthroughs

Our scenarios have explored a range of different options for hydrogen in the future energy mix, including blending at 10% and supply of pure hydrogen in networks, to explore potential implications for existing gas infrastructure should hydrogen production and delivery become cost competitive with other energy sources.

As highlighted in our asset adaptability assessment, existing distribution pipelines can be repurposed to transport hydrogen at 10% blends with relatively minor modifications. However, more substantial modifications may be required to transport 100% hydrogen in the gas distribution network. Major modifications may be required to existing gas transmission pipelines to allow transportation of 100% hydrogen, as well as to parts of the transmission network to allow blending at 10%.

Our scenarios explored hydrogen production in various locations across Victoria, as with biogas/biomethane production, to minimise the need for costly upgrades to the gas transmission network. In each of our scenarios, green hydrogen production facilities are located across Victoria, close to electrical transmission and gas pipeline infrastructure. The size and location of future hydrogen production in Victoria is currently unclear and will be driven by economic factors. Demonstration projects are currently small in scale, but there are large projects underway interstate (the Western Green Energy Hub) and overseas in the UK and the Netherlands.

In Victorian coastal areas there may be potential to use desalinated seawater for green hydrogen production; in inland areas, this would require use of wastewater or saline groundwater to avoid increased competition for limited water resources. In Gippsland, it may be possible to use hydrogen produced from brown coal in conjunction with carbon capture and storage, but this would likely also require use of additional offsets for residual carbon emissions.

The analysis suggests hydrogen production would need to be scaling up by 2030 for it to make a significant contribution to Victoria's 2050 net zero emissions target. To blend hydrogen with natural gas at 10% by volume, sourcing sufficient natural gas supplies may raise future challenges due to the forecast decline in locally produced natural gas. Blending 10% hydrogen by volume equates to an energy share of around 3% hydrogen compared to 97% natural gas, meaning that to use 1 PJ of hydrogen will require 34 PJ of natural gas to maintain the 10% blend.[171] A system wide approach will be necessary to ensure sufficient natural gas is available to maintain acceptable blending levels without causing upsets in the system and to downstream users. Low volume hydrogen blending projects may also have a relatively short project life due to the need to reduce the emissions associated with Victoria's natural gas use.

Blending hydrogen into the network will require careful consideration of the positioning of blending facilities, to ensure adequate and consistent hydrogen-natural gas blends can flow to customers. As discussed above, gas flow in the Victorian transmission system is currently from south to north. If hydrogen is produced in Victoria's north, for example, based on the current flow regime hydrogen produced in this region will only flow to northern gas customers.

Our green hydrogen scenario has explored the opportunity to maximise the use of hydrogen in Victoria's existing gas networks. In this scenario, hydrogen transportation in transmission pipelines is limited to blending at 10%, due to the constraints identified in the existing gas transmission network. The distribution network would be segregated from the transmission network and converted for 100% hydrogen use in a staged approach over time. A breakthrough is required in high-efficiency and high-pressure hydrogen electrolysis to allow for hydrogen to be rolled out by 2035. A consequence in this scenario of allowing natural gas supply to decline, replaced in the low-pressure distribution system with hydrogen and biomethane, is that use of the gas transmission network declines over time. This scenario assumes that as much as 80% of the existing gas transmission network could be decommissioned.

Significant change would be needed for the existing distribution network to supply pure hydrogen directly to consumers. This approach would also include replacing cooking, hot water and heating systems for households, commercial and industrial users. Implementation barriers for industrial and transport hydrogen use may be lower, as hydrogen would not necessarily need to be connected to a fixed network of pipelines, but they remain significant. The scale of change required – across gas, electricity and transport systems – indicates that further work is required to ensure resilience at region and system levels. For example, major power outages could prevent production of green hydrogen, which would have significant impacts on households if it occurred during the winter months.

However, the role low or zero emissions hydrogen could play in helping to meet Victoria's emissions reduction targets, combined with the potential benefits of a diversified energy mix for energy security and reliability, mean that an ongoing focus on hydrogen development is warranted this decade.

Carbon capture and storage could provide further opportunities to repurpose gas infrastructure

Our analysis has highlighted potential opportunities to repurpose existing production facilities, pipelines, processing and/or storage facilities in Gippsland and the Otway Basin for carbon capture and storage. Detailed and rigorous assessments of the assets on a case-by-case basis would be required, with some assets likely to require major modifications before they can be repurposed. Others may be determined unfit for repurposing and replacement would be required.

The opportunity to use existing production facilities and pipelines to transport and compress carbon dioxide is threatened by the imminent decommissioning and removal of potentially suitable facilities due to declining oil and gas production. This risk can be partly mitigated by ensuring minimum inspection and maintenance activities continue, especially on mothballed equipment.

To enable the repurposing of existing production infrastructure for carbon dioxide, decommissioning and removal of assets would need to be deferred until the potential storage locations in the vicinity of existing infrastructure have been proven. Any plans to repurpose infrastructure will require operators to work closely with regulators to ensure future intentions are aligned alongside compliance with safety and environmental regulations (see *Recommendation 4*). The economic viability of these CCS repurposing uses is likely to be influenced by any introduction of a carbon pricing mechanism in Australia.[172]

171 Advisian (2021) *Asset Life and Adaptability Review*

172 House of Representatives Standing Committee on Science and Innovation (2007) *Between a Rock and a Hard Place: The Science of Geosequestration*

All scenarios suggest a shift in demand for gas over time

In each of the scenarios modelled, there is a shift in the energy mix from gas to electricity over time. Excluding energy use associated with transport, the proportion of gas in the energy mix shifts from approximately 50% in 2020 to between 13–33% in 2050, depending on the scenario. By 2050, energy gas includes a combination of biomethane, hydrogen, ammonia and/or natural gas, depending on the scenario. As illustrated in Figure 21, the high green ammonia scenario has the highest proportion of gas in the energy mix by 2050.

The shift in energy mix over time is consistent across the different types of consumer. In 2020, natural gas accounts for around 70% of household and commercial energy consumption, and around one-third of industrial energy consumption. By 2050, gas consumption (including biomethane, hydrogen, ammonia and/or natural gas) among household and commercial users has fallen to around 20–50% of energy consumed. Among industrial users, gas has fallen to around 5–20% of energy consumed.

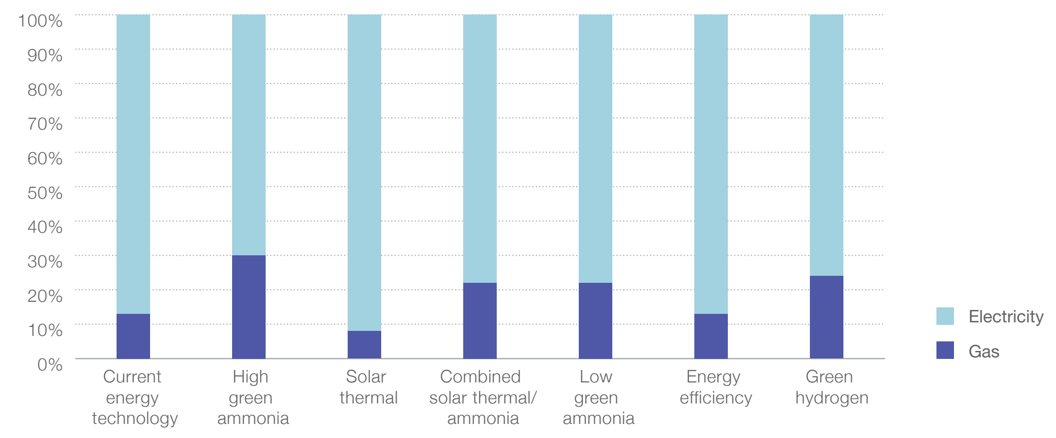
Although all scenarios see a declining share of gas in the energy mix, some scenarios (for example the high green ammonia and green hydrogen scenarios) see its use maintained or even increased as biomethane, hydrogen and/or ammonia production begin to contribute to the energy mix. The decline in the share of energy gas is due to a steady increase in electricity consumption between 2020–50 across all scenarios, for both household/commercial and industrial users.

Figures 22 and 23 show the change in energy mix over time for household/commercial and industrial users across Victoria's regions, using the current energy technology scenario as an example.

While energy gas consumption declines to some extent in all regions across most scenarios, gas supply is increasingly decentralised as production shifts from natural gas to a more diverse gas supply. Existing natural gas production is concentrated in Gippsland and the Otway Basin, whereas the scenarios have modelled the potential for biomethane and green hydrogen production to be more distributed across Victoria. Figure 24 indicates the potential regional shift in gas supply between 2020 and 2050, using the current energy technology scenario as an example.

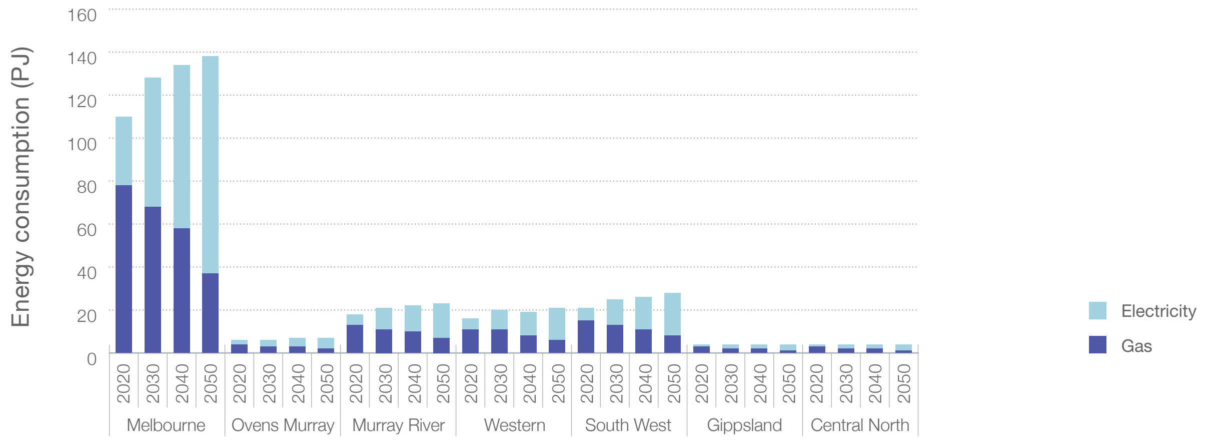
In this scenario, the Loddon Mallee, Grampians Central West and Goulburn Valley regions can produce enough renewable gas (largely biomethane) to meet regional needs, and potentially export excess gas to supply other regions. A more dispersed gas production would have implications for existing gas pipelines, potentially requiring parts of the network to be sectioned off, or changes in gas flow so that gas produced in regional areas can be transported via pipeline to centres of demand.

Figure 21: Energy mix by scenario – 2050 (%)



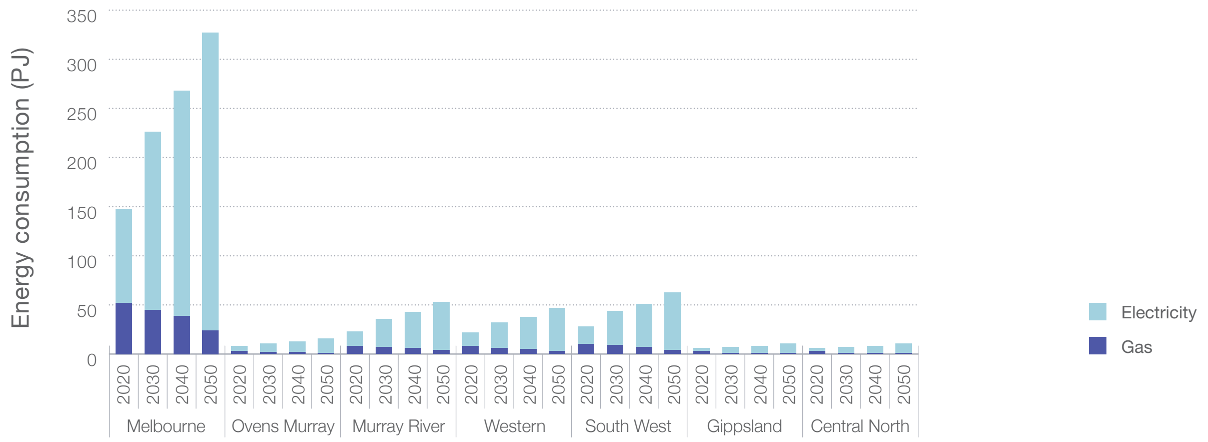
Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*
Note: chart excludes energy use associated with transport

Figure 22: Energy mix, household and commercial users current energy technology scenario – 2020 to 2050 (PJ)



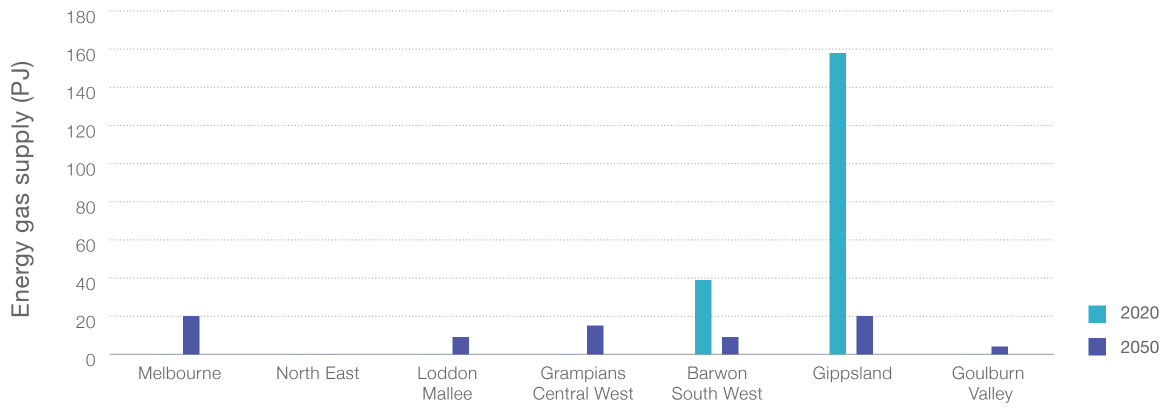
Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

Figure 23: Energy mix, industrial users, current energy technology scenario – 2020 to 2050 (PJ)



Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*
Note: chart excludes energy use associated with transport

Figure 24: Energy gas supply by region, current energy technology scenario – 2020 and 2050 (PJ)



Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

4.2.3 The electricity sector faces unprecedented change under all future energy scenarios

Regardless of the future energy mix, significantly greater demands will be placed on Victoria's electricity system. This may arise from fuel switching, from hydrogen production and/or from uptake of electric vehicles. These changes will occur against a backdrop of ongoing change in electricity generation, as large-scale and distributed renewable energy sources continue to develop rapidly and coal-fired generators retire.[173]

Our scenario analysis has modelled a future where electricity consumption increases from around 200 PJ in 2020 to between 650–810 PJ in 2050, depending on the scenario – an increase of more than three times. This includes electricity generation (including the renewable electricity required for green hydrogen and ammonia production) and storage requirements as well as demand associated with electric and hydrogen fuel cell vehicles, as illustrated in Figure 25.

The modelling focused on generation and storage infrastructure and assumed that Victoria, in the main, is electrically self-sufficient and interconnectors would be used to support system peaks only. Transmission infrastructure was estimated on an order of magnitude basis, linking Victoria's Renewable Energy Zones and Melbourne. These are simplifying assumptions, which allow a high level indication of implications for the electricity system in each scenario.

Under our scenarios, electricity consumption associated with low emissions vehicles represents around 15–20% of total electricity by 2050. In addition, considerable renewable electricity generation and storage capacity could be required for green hydrogen production, if technological and commercial breakthroughs allow hydrogen to become a significant part of Victoria's energy mix. The green hydrogen scenario, which explores large-scale roll out of green hydrogen across Victoria, suggests that as much as one-third of the 2050 electrical mix could be needed for green hydrogen production. The Australian Energy Market Operator (AEMO) has acknowledged that a rapid uptake of green hydrogen could significantly increase demands on the electricity grid.[174]

The increased demand for electricity will have a significant impact on associated infrastructure requirements. Table 3 illustrates the relative extent of new or upgraded electricity generation and storage infrastructure required for each scenario, over and above existing and committed electrical infrastructure. Values are a relative index, where 1 is the lowest level of electrical infrastructure required. All scenarios begin with the same amount of additional electrical capacity in 2025 (i.e. 1.0).

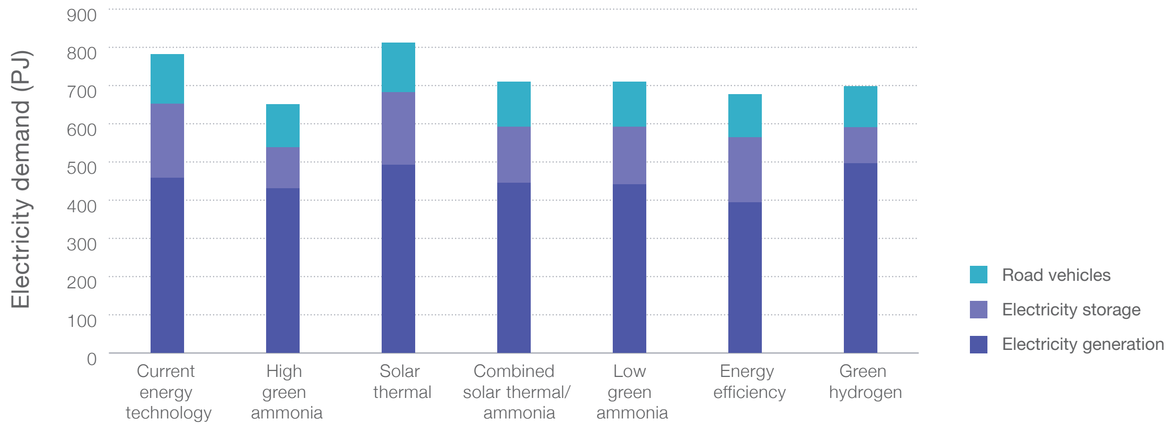
Differences begin to emerge between scenarios from 2035, with the largest difference in electrical generation capacity between the current energy technology and the high green ammonia scenarios, with index values of 3.3 and 2.1 respectively, compared with the 2025 base. The largest differences in electrical storage infrastructure can be seen in the solar thermal and green hydrogen scenarios.

Scaling up of infrastructure will need to be rapid in some instances. Storage will be essential to ensure stability of the electrical grid as the proportion of variable renewable electricity generation increases. Figure 26 illustrates the anticipated electrical storage capacity required under each of the scenarios, rising off a very low base in 2020 to between 95–190 PJ per annum by 2050. Storage requirements are met by a combination of new and existing technologies, depending on the scenario (for example, standard batteries, iron-air batteries, pumped hydro, virtual power plants and molten salt).

The modelling assumed interconnectors were only used for peak purposes and did not consider proposed transmission projects. In reality, interconnectors play a very important role. Interconnection allows consumers in a high price zone to access lower priced generation from another zone. It allows resource sharing across states, balancing renewables across the National Electricity Market, and enhancing system resilience and security. In Victoria's case, the proposed VNI-West and Marinus Link interconnectors will allow access to significant storage capacity from Snowy 2.0 and Tasmania's Battery of the Nation which is not reflected in the model. AEMO's *Draft 2022 integrated system plan* provides insights on the role of electrical interconnectors under a range of scenarios.

173 AEMO (2021) *2021 Electricity Statement of Opportunities*
174 AEMO (2021) *2021 Electricity Statement of Opportunities*

Figure 25: Electrical consumption by scenario – 2050 (PJ)



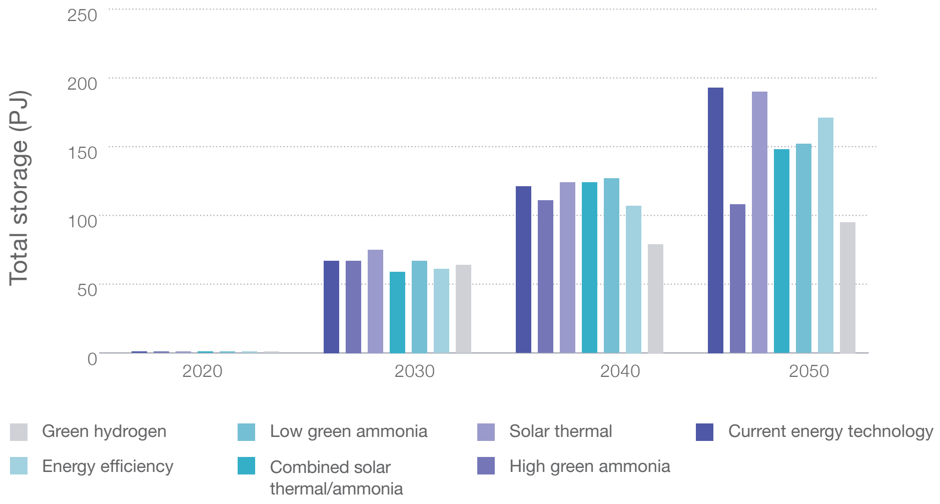
Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*
Note: 'Road vehicles' includes demand for electricity from both battery electric vehicles and renewable hydrogen generation for hydrogen fuel cell vehicles. Other forms of transport (aviation, shipping) are excluded from the scope of this analysis.

Table 3: Estimated indexed upgrades relative to 2025 – electrical infrastructure

Scenario	2025	2030	2035	2040	2045	2050
Electricity generation capacity						
Current energy technology	1.0	1.5	2.0	2.3	2.7	3.3
High green ammonia	1.0	1.5	1.8	2.2	2.2	2.1
Solar thermal	1.0	1.5	1.8	1.9	2.1	2.6
Combined solar thermal/ammonia	1.0	1.5	1.8	2.1	2.4	2.3
Low green ammonia	1.0	1.5	2.0	2.2	2.6	2.5
Energy efficiency	1.0	1.5	1.8	1.9	2.2	2.8
Green hydrogen	1.0	1.2	1.8	2.1	2.4	2.5
Electrical storage infrastructure						
Current energy technology	2	7	11	16	21	29
High green ammonia	2	7	10	13	15	19
Solar thermal	2	11	15	19	23	33
Combined solar thermal/ammonia	2	6	9	16	19	23
Low green ammonia	2	7	11	12	13	23
Energy efficiency	1	6	9	12	15	22
Green hydrogen	2	5	5	5	5	12

Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

Figure 26: Electrical storage requirements by scenario – 2020 to 2050 (PJ)



Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report*

All scenarios represent a shift to greater electrification, with the proportion of electricity in the 2050 energy mix ranging from 70–90% compared with around 30% in 2020. This takes place as the electricity system increasingly shifts towards renewable generation. Our *interim report* for this advice highlights potential reliability issues associated with a high proportion of variable renewable sources of generation in the energy mix, as they are weather-dependent.

Gas-powered generation could play a critical role in maintaining reliability and security of the electricity system,[175] particularly as coal-fired generators close and the energy system becomes more exposed to extreme weather events.[176] Associated emissions would need to be offset or captured to reach net zero, or breakthroughs in other technologies (such as storage) may allow natural gas use in power generation to be replaced – as modelled in our scenario analysis. The scale of change, both in increased demand and in the generation mix, will require careful planning – coordinated with other sectors – to ensure energy reliability and security is maintained.

The increase in electricity infrastructure – including solar PV, wind and storage – has land use and development implications across Victoria, particularly within Renewable Energy Zones. Future development of potential hydrogen, bioenergy and ammonia production plants will have further environmental and safety considerations. It will be essential to build social licence for changes ahead.

175 Infrastructure Victoria (2021) *Towards 2050: Gas Infrastructure in a Zero Emissions Economy – Interim Report*

176 AEMO (2021) *2021 Electricity Statement of Opportunities*

4.2.4 All future energy mix scenarios will require infrastructure investment

Our scenario analysis modelled the potential capital, operating and decommissioning costs associated with gas and electricity infrastructure in each of the net zero 2050 energy mix scenarios we considered. Instead of providing an absolute cost estimate, individual scenario costs were compared to a control scenario, to allow a comparison of relative net costs. This approach was adopted due to the uncertainties involved in estimating costs over such a large timeframe, and recognising the study's assumptions and scope (e.g. certain sectors and cost categories have been deliberately excluded from the scope of analysis).

The control scenario, which does not achieve net zero emissions, assumes that Victoria's existing and planned energy mix, and associated infrastructure, continues through to 2050. Table 4 illustrates the net cost (compared to the control scenario and discounted to 2021 dollars) for each scenario. It also provides a comparative cost of abatement ratio (in comparison to the current energy technology scenario) which accounts for the differing emissions profiles for each scenario (see Figure 14 in section 4.2.1).

The results suggest the energy efficiency scenario has the lowest costs to achieve net zero emissions while meeting energy demand of all the scenarios modelled and it also has the lowest comparative cost of abatement. While specific energy efficiency measures were not costed due to the wide range of possibilities, the very large gap in the comparative net cost and cost of abatement between this scenario and the rest allows for significant investment. This is followed by the current energy technology scenario and the solar thermal scenario (which have a broadly similar comparative cost of abatement). The combined solar thermal/ammonia scenario has the highest net cost due to the capital and operating expenditure costs associated with solar thermal and offshore wind, combined with the costs related to green hydrogen and ammonia development. The combined solar thermal/ammonia scenario also has the highest comparative cost of abatement.

These results suggest that energy efficiency improvements can have a significant impact on energy requirements and their associated infrastructure costs. This aligns with external findings indicating energy efficiency is a source of cheap, reliable and clean energy capacity.[177] These benefits from energy efficiency are regardless of the future energy mix and can be maximised through cross-sectoral planning to identify the best solutions to achieve economy-wide emissions reductions. The energy efficiency scenario is based on the current energy technology scenario, but with energy efficiency improvements increased 20% per decade (from 5% in the current energy technology scenario). These energy efficiency improvements, combined with changes to the overall energy mix, contributed to an estimated threefold improvement in net cost estimates between the current energy technology and energy efficiency scenarios.

177 Murray-Leach R (2019) *The World's First Fuel: How energy efficiency is reshaping global energy systems*

Table 4: Comparative transition cost analysis by scenario

Scenario	Comparative net cost estimate ($m)	Comparative cost of abatement
Current energy technology	$1,587	1.0
High green ammonia	$3,563	2.0
Solar thermal	$1,896	1.1
Combined solar thermal/ ammonia	$5,280	2.9
Low green ammonia	$2,679	1.5
Energy efficiency[178]	$482	0.3
Green hydrogen	$2,792	1.5

Source: DORIS Engineering (2021) *IV128 net zero emissions scenario analysis stage 2 – study report and IV analysis*

Note: The comparative net cost estimate is in comparison to the control scenario, where positive net costs indicate the scenario has a higher cost than the control scenario. The comparative cost of abatement is the ratio of the cost of abatement for each scenario compared to the current energy technology scenario, where cost of abatement is the net cost estimate divided by the cumulative emissions reductions from 2020 emissions.

To assess the potential impact of continued emissions on generation operating costs, costs for each scenario were remodelled with the additional assumption of a hypothetical price on greenhouse gas emissions. This assumes a notional dollar value per tonne of carbon dioxide emissions, allocated to estimated total emissions for existing and new generation in each scenario, including the control scenario. Including a price on greenhouse gas emissions in our analysis can also be interpreted as a representation of the cost to society associated with greenhouse gas emissions.

All the net zero scenarios modelled in this analysis have higher cost estimates than the control scenario (as shown in Table 4 above). However, the introduction of an emissions price suggests the relative costs of the control scenario could be significantly greater than each of the net zero scenarios modelled in this analysis. Our findings are consistent with Australian and international evidence that the economic costs of climate change inaction far exceed the economic costs of moving to net zero by 2050.[179,180]

178 The cost estimates do not include behind the meter costs associated with improving energy efficiency such as upgrades to appliances.

179 Deloitte Access Economics (2020) *A New Choice – Australia's Climate for Growth*

180 Department of Environment, Land, Water and Planning (2021) *Victoria's Climate Change Strategy Economic Analysis*

4.2.5 The future energy mix will present both opportunities and challenges for Victoria

There are economic opportunities as Victoria transitions to net zero emissions. These include potential new business opportunities relating to the development, design, production, construction, installation and maintenance of renewable energy and other energy technologies. In particular, there are potential economic opportunities in hydrogen production (electrolyser manufacturing, hydrogen production and supply chain); hydrogen-fired or ammonia-fired energy generation (operational roles similar to gas generators); carbon capture and storage services (long-term operational, maintenance, technical and support jobs including contract services); installation of solar and wind energy generation technologies (operational, maintenance and engineering jobs); and manufacturing (whole of or component parts for) solar photovoltaic cells, wind turbines and battery storage. These opportunities could create economic growth and employment directly and in the supply chain and broader economy. There are also businesses that will need to transition to new business models including gas producers, gas distributors, gas retailers, gas appliance and equipment manufacturers, and other businesses in the gas industry supply chain.

The transition to net zero emissions will impact the nature and distribution of employment in Victoria. Direct employment in the natural gas industry will reduce as local gas production declines and Victoria transitions to alternative energy sources. However, the transition will also offer new employment opportunities. Our scenario analysis indicates that employment will be higher where the energy mix includes higher complexity energy generation facilities (such as ammonia gas-fired power generation or solar thermal generation technology with integrated molten storage facilities). While not unique to the energy sector, current large-scale renewable generation generally uses a transient contracted workforce, rather than ongoing secure employment.[181] These changes are in addition to other structural changes in the economy that may impact the gas industry under any scenario, such as automation and globalisation. For example, in a highly automated LNG plant, National Energy Resources Australia estimated the workforce could shrink by 20% compared to today.[182]

The distribution of economic activity and employment across Victoria will also change. The gas extraction industry in regional areas is largely concentrated in a small number of locations. However, new energy generation will be more distributed and located in different parts of the state, for example, renewable energy generation will primarily be in places with good sun and wind resources. Our analysis indicates there may be opportunities to repurpose existing facilities in Gippsland and the Otway Basin for carbon capture and storage[183] which would generate local economic activity and jobs to help mitigate the adverse local impacts of the transition away from natural gas. Any repurposing of gas processing facilities would involve acquiring extra land. In addition, converting coal-fired power stations to ammonia could reduce both the local economic (particularly in the Latrobe Valley) and environmental impacts of the energy transition by providing local employment opportunities and utilising current infrastructure and land use.[184]

While the gas industry represents a relatively small proportion of state-wide Victorian employment,[185] the different future employment distribution within Victoria may have an impact on specific regional communities including employment, consumption (i.e. demand for goods and services from local businesses), migration/population and social fabric. Where the gas industry comprises a significant portion of local employment (such as Longford where the gas industry represents 14% of the local workforce[186]), alternative local employment opportunities will need to be created. Without this, local regions may experience increases in unemployment, reduced demand for local goods and services in the supply chain, reduced consumption at local businesses (for example, cafes and retail shops) and population decline as people leave to pursue employment elsewhere. This can have a detrimental social and economic impact on the local community and highlights the importance of pursuing economic diversification opportunities in these local economies. Conversely, other regions linked to the development of alternative energy sources are likely to experience economic growth, increased employment and population growth which will also need to be managed to ensure it is sustainable and positive for the local community.

There are also some economic risks for Victoria in the transition to net zero emissions for the gas sector. As Victoria transitions from a net exporter to potential net importer of gas, Victoria may become reliant on importing gas from other states to meet demand. In addition, most renewable energy generation products are currently manufactured internationally, particularly in China.[187] Global demand for renewable energy generation technology is likely to increase as economies around the world transition to net zero emissions, potentially posing risks for Victoria in accessing the technology infrastructure it needs for its own transition. Any disruptions to supply will have a negative impact on the Victorian economy. The Australian Government is fostering partnerships with Germany, Japan, the Republic of Korea, Singapore and the United Kingdom to advance development of low emissions technologies,[188] and developing local industries to manufacture, assemble and/or maintain these technologies could also mitigate potential supply risks.

The uncertainty in the preferred pathway to net zero for gas makes it more challenging for companies to appropriately plan and respond. This is particularly the case regarding infrastructure investments which often have long asset lives and if investment cases are uncertain.

Rising energy costs also pose economic risks. Gas prices are already rising globally and this is forecast to continue. Rising gas prices may affect business competitiveness, but this may also encourage them to consider alternative energy sources or to invest in energy efficiency or energy management initiatives. However, for hard-to-abate industries, rising gas prices may undermine their viability.

Rising gas prices will also affect residential consumers. As with industrial consumers, this may encourage them to consider alternative energy sources or to invest in energy efficiency or energy management initiatives. However, as some are less able to adapt, this further highlights the importance of immediately focusing on energy efficiency measures and ensuring equity through the transition (see *Recommendations 5* and *6*).

181 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

182 National Energy Resources Australia (2018) *Preparing Australia's Future Oil and Gas Workforce – Three Scenarios for Workforce Change*

183 Advisian (2021) *Asset Life and Adaptability Review*

184 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 - Study Report*'

185 The gas industry directly employs 2,870 people in Victoria, comprising 0.11% of total Victorian employment (source: ABS Census 2016 TableBuilder Pro, employed persons place of work by industry of employment at the ANZSIC 2-digit level for subdivisions Oil and Gas Extraction and Gas Supply). Noting this does not include all employment associated with the gas industry. A National Energy Resource Australia report (NERA 2018) estimated that each worker directly employed in oil and gas extraction in Australia currently sustains another ten jobs across the supply chain and wider economy, generating five times more indirect employment than an average worker in other industries.

186 Employed persons place of work for Longford – Loch Sport SA2 and Oil and Gas Extraction industry of employment at the ANZSIC 2-digit level, ABS Census 2016, sourced from ABS TableBuilder Pro.

187 International Energy Agency (2020) *Photovoltaic Power Systems Programme Annual Report 2020 and Bloomberg (2021) Global Wind Industry Had a Record, Near 100GW, Year as GE, Goldwind Took Lead From Vestas* (website)

188 Department of Industry, Science, Energy and Resources (2021) *Low Emissions Technology Statement 2021*

4.3

The scale of change requires immediate action combined with longer term planning.

4.3.1 Focusing now on energy efficiency will deliver benefits regardless of the future energy mix

In our interim report for this advice, we identified energy efficiency as a no-regrets measure which had significant potential benefits, particularly in the short term, regardless of the specific pathway to achieve net zero emissions.[189] Our subsequent analysis has confirmed this view, and emphasised the importance of immediate action for maximum benefit. The scenario analysis suggests that a significant increase in residential and commercial energy efficiency improvements before 2030, combined with a much greater uptake of low emissions vehicles, would deliver a greater impact on emissions reduction.[190] This opportunity will not return.

The Victorian Government has a strong focus on energy efficiency, but there is more to be done

The Victorian Government's *Energy sector emissions reduction pledge* outlines the government's energy efficiency and demand management initiatives, including the Victorian Energy Upgrades program which promotes energy efficiency for households and businesses and proposed reforms to its exemption framework to incorporate large energy users. Some targeted investments are also made for low-income households, renters, social housing and high energy consuming businesses.[191] These measures are expected to reduce gas consumption in Victoria's residential, commercial and industrial sectors to 2025, and the Australian Energy Market Operator has revised its gas demand forecasts to reflect these improvements.[192]

Our work has explored the potential for additional energy efficiency measures to reduce or replace gas demand in the residential, commercial, and industrial sectors, to better understand the opportunities with greatest impact on gas use and associated emissions. The analysis focused on initiatives that are not covered by, or are not currently a major focus of, the Victorian Energy Upgrades program.[193]

This work identified six energy efficiency opportunities across the three sectors that could deliver significant gas savings for acceptable financial returns: improved heat recovery; upgrades to burners and boilers; air to air heat pumps; air (and water) to water heat pumps; draught sealing; and electrification of cooking.[194] If fully implemented, these opportunities could deliver up to 112 PJ in annual gas savings by 2040, over half of Victoria's current gas usage. This equates to a net greenhouse gas emissions reduction of 4 Mt CO_2e in the year 2040.

189 Infrastructure Victoria (2021) *Towards 2050: Gas Infrastructure in a Zero Emissions Economy*

190 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

191 Department of Environment, Land, Water and Planning (2021) *Cutting Victoria's Emissions 2021-2025: Energy Sector Emissions Reduction Pledge*

192 AEMO (2021) *Gas Statement of Opportunities*

193 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

194 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

Table 5: Potential annual energy and emissions savings of energy efficiency measures in 2040

Sector	Annual gas savings (PJ)	Energy savings (PJ)	Net emissions reduction (kt CO_2e)
Industrial	23	20	966
Commercial	19	15	614
Residential	71	53	2,400
Total	112	87	3,980

Source: Northmore Gordon and Energeia (2021) *Cost benefit analysis of energy efficiency activities in the gas sector*
Note: Energy savings refer to the net energy saved from swapping gas appliances to more energy efficient electric appliances

We have identified priority energy efficiency opportunities for immediate focus

We have used this analysis to identify priority energy efficiency measures targeted towards gas users in the industrial, commercial and residential sectors. Measures were prioritised based on their potential impact on overall gas use and emissions reduction, cost-effectiveness, ease of implementation and timeframe for implementation (with priority given to those which could be implemented immediately). These initiatives should be actioned now to have maximum impact on reducing Victoria's gas use (see *Recommendation 5*).

Table 6: Immediate energy efficiency priorities for industrial and large commercial gas users

	Annual gas savings (PJ)	Annual energy savings (PJ)	Annual emissions reduction (kt CO_2e)	Payback period (years)
Burner and boiler upgrades	6	6	301	3
Low temperature heat pumps	12	10	440	7
Heat recovery	4	4	225	4
Total	23	20	966	

Source: Northmore Gordon and Energeia (2021) *Cost benefit analysis of energy efficiency activities in the gas sector*
Note: gas, energy and emissions data represent total annual savings in the industrial and large commercial sector

Three priority initiatives have been identified in the industrial and large commercial sector for immediate focus:

- **Burner and boiler upgrades:** modifications to existing appliances to improve combustion efficiency and reduce demand for natural gas. Boiler and burner upgrades could provide total annual gas savings of around 5 PJ across industrial manufacturing sectors including food and beverages, petroleum, and coal. In large commercial offices, retail and aquatic centres, burner and boiler upgrades could provide annual gas savings of up to 1 PJ.
- **Low temperature heat pumps:** new appliance installations to substitute natural gas use for electricity. This could provide annual gas savings of up to 8 PJ in industrial manufacturing sectors including food and beverages and textiles. In the large commercial sector, low temperature heat pumps including reverse cycle chillers and packed units can be used in offices, retail, aquatic centres or hospitals, providing potential gas savings of around 5 PJ a year.
- **Heat recovery:** recovers and reuses otherwise wasted heat to reduce demand for natural gas. Heat recovery can provide potential gas savings of around 4 PJ a year in industrial manufacturing sectors including food and beverages, pulp and paper, and non-metallic minerals.

Additional near-term opportunities to reduce natural gas use in the industrial and large commercial sectors include low-cost gas efficiency activities, furnace improvements, low temperature furnace and ladle heating electrification, and building fabric upgrades. Based on high level estimates, these energy efficiency initiatives have a combined potential gas saving of 6 PJ.

Two priority initiatives have been identified in the small commercial and residential sectors for immediate focus:

- **Heat pumps:** new appliance installations to replace natural gas use with electricity for space and water heating. In the small commercial sector, electrification of space heating could have annual gas savings of 220 GJ per thousand square metres, while water heating electrification could generate annual gas savings of 82 GJ per thousand square metres.[195] In the residential sector, space heating electrification could generate annual gas savings of around 14–33 GJ per dwelling, depending on dwelling type, while water heating electrification could generate annual gas savings of 9–19 GJ per dwelling.[196] Estimated payback periods vary according to the type of housing (detached house/townhouse or apartment) but do not include any rebates, reduced energy bills or cost of carbon emissions, which if included would shorten the payback period. Without additional incentives, the best opportunity to start generating these savings is when appliances are being replaced at end of life or when undergoing major renovation.
- **Draught sealing:** Draught sealing, a type of thermal upgrade, has a relatively small impact on overall gas savings, with potential annual savings of 9 GJ in the residential sector, but it promises the shortest payback period of the priority measures identified. We recommend draught sealing measures (such as sealing gaps around doors, windows, and in walls and floors) in the residential sector to provide cost-effective thermal improvements to buildings.

195 Small commercial gas, energy and emissions savings have been modelled per one thousand square metres, based on a total small commercial building floor area in Victoria of 50 million square metres

196 Residential gas, energy and emissions savings are modelled per dwelling, with separate estimates provided for detached houses/townhouses and apartments

Table 7: Immediate energy efficiency priorities for small commercial and residential gas users

	Annual gas savings (GJ)	Annual energy savings (GJ)	Annual emissions reduction (t CO_2e)	Payback period (years)
Small commercial gas users (per one thousand square metres)				
Space heating	220	191	9	11
Water heating	82	66	3	7
Total	302	257	12	
Residential gas users – detached houses/townhouses (per dwelling)				
Space heating	33	30	6	17
Water heating	19	11	1	10
Draught sealing	6	6	2	4
Total	58	47	9	
Residential gas users – apartments (per dwelling)				
Space heating	14	13	2	40
Water heating	9	7	1	17
Draught sealing	3	3	1	2
Total	26	23	4	

Source: Northmore Gordon and Energeia (2021) *Cost benefit analysis of energy efficiency activities in the gas sector*
Note: gas, energy and emissions data represent annual savings per thousand square metres (commercial) and per household (residential)

Our analysis has also identified additional energy efficiency opportunities for action in the medium to long term, based on a high level analysis of energy efficiency activities. The medium to long-term opportunities include current technology solutions which are available now, but which may be relatively immature and/or require significant investment to action:

- **Biomass and biogas** use as a substitute for natural gas has already been adopted in the industrial sector, but uncertainty around access to viable biomass resources has limited its uptake. It offers a low emissions alternative for waste-producing sectors such as wood product manufacturing, pulp and paper, and food and beverage manufacturing. Further uptake of biogas could provide total potential gas savings of 36 PJ a year in the industrial sector.
- **Electrification** can be used to power many industrial heat processes. Industrial electric solutions are available today but have not been applied on a large scale. Significant capital investment and the rebuild of industrial facilities are required that limit uptake, particularly for high temperature industrial processes. Technologies such as high temperature heat pumps (for temperatures over 90 degrees Celsius), microwave and electric resistance heating, electric induction furnaces and infrared drying could provide potential annual gas savings of 31 PJ in the industrial sector – noting that a significant shift towards electrification will place greater demands on the electricity system.
- The **electrification of cooking** with induction cooktops can deliver gas savings, but may not deliver significant emissions reduction until the mid-2030s, depending on the changing emissions intensity of both the electricity and gas sectors. In addition, the current high cost of induction cooktops leads to relatively long payback periods. Changes in costs and emissions intensity should be monitored to determine the appropriate time to target electrification for domestic and small commercial cooking. This could provide potential annual gas savings of 52 GJ per thousand square metres in the small commercial sector and 2–3 GJ per dwelling in the residential sector, depending on the type of dwelling.

Further details of this analysis are available in the technical report which accompanies this advice, *Cost benefit analysis of energy efficiency activities in the gas sector.*[197]

197 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

Case Study

Securing the energy future for Opal Australian Paper's Maryvale Mill

Opal Australian Paper's Maryvale manufacturing facility in the Latrobe Valley is Victoria's largest industrial user of natural gas. Natural gas is needed to create high-pressure steam to generate onsite electricity and low temperature process heat, and as an input in the high-temperature lime kiln pulping process. To reduce its natural gas demand, Opal Australian Paper committed to significant infrastructure and energy efficiency investments within its annual capital investment and replacement program (around $20 million per annum), responding to a direction to reduce energy consumption from their parent company.

The program targeted boiler and burner upgrades and improvements in heat recovery at the site which is one of the Latrobe Valley's largest employers. With these improvements, the paper mill was able to reduce its natural gas consumption by 25%, from around 8 PJ to the current level of 6 PJ per annum, saving 100,000 tonnes of CO_2 emissions per annum and resulting in a return on investment within 1–3 years. Upgrades were scheduled during the mill's maintenance program to limit disruption.

In addition, the company is investing over $500 million in an energy from waste project, with completion expected in 2025. The facility will combust residual waste to generate high efficiency combined heat and power (CHP), supplying both steam and electricity to the mill. This major regional infrastructure investment would achieve a 58% efficiency compared to standalone electricity generation of 27%. Stage 1 of this project would produce enough energy to displace approximately 2 PJ of natural gas per annum, in addition saving a combined total 270,000 tonnes of net CO_2 emissions annually.[198]

Opal Australian Paper is also investigating a co-located aquaculture farm, to get full value from all thermal energy used. Waste heat and spare capacity from the mill's operations would be utilised to supply water heating, oxygen generation and water treatment services.[199] Maximising the capacity of underutilised infrastructure and available low-grade heat is consistent with Opal Group's sustainability principles and aligned with circular economy thinking.

Alternative options cannot fully replace the mill's gas consumption at this time due to technology constraints, commercial realities and grid import capacity constraints. Despite current viability issues, biomethane and hydrogen remain potential future areas of interest, which would complement the mill's existing energy supply infrastructure. In the meantime, continued focus will remain on future energy efficiency programs in conjunction with the energy from waste and aquaculture projects to further decrease the mill's reliance on natural gas. These future energy initiatives will also support Opal Group's target of net zero emissions by 2050.

198 Opal (2019) *Energy from Waste Feasibility Study Summary*

199 Opal (2021) *Future: Aquaculture (website)*

▷ **Figure 27:** Upgrade work during a recent annual maintenance shut down at Maryvale Paper Mill

Source: Opal (2021) *Opal Australian Paper's Maryvale Mill maintenance* (website)

Assessments often focus on energy and cost savings, but energy efficiency measures have other benefits

Heating is the main area of energy use in Victorian houses. Improvements to the thermal performance of dwellings and the energy efficiency of appliances associated with heating are therefore valuable areas to focus energy efficiency efforts. Thermal improvements to existing buildings can be achieved through the installation of insulation (in ceilings, walls and floors), draught sealing, window glazing and installation of drapes or curtains.

Although the energy efficiency of Victoria's housing stock has been improving, this is largely driven by building standards for new dwellings. The existing housing stock generally has poor energy efficiency. Houses built prior to 1990 have an average House Energy Rating of 1.6 stars, compared with houses constructed after 2011, which are required to achieve a 6 star rating.[200] There is a significant opportunity to improve energy efficiency in Victoria's existing dwellings. However, when considering only energy bill savings, many energy efficiency upgrades appear to have long payback periods.[201]

There is strong evidence that non-energy benefits of thermal improvements to residential buildings, such as improved health outcomes, can be significant. Thermal improvements to existing buildings can reduce energy use and associated greenhouse gas emissions. They can also provide health and wellbeing benefits,[202] contribute to increased property values[203] and energy network benefits (including energy security and affordability,[204] improved system reliability[205] and ability to manage peak demand[206]). Studies from the UK, the European Union and New Zealand suggest that health savings of energy efficiency improvements could be around three times larger than the energy bill savings and, if considered, would significantly increase overall savings and dramatically lower the payback period.[207] Improved thermal comfort of homes also prepares Victorians for a warmer climate. One study found residents of 0.9 energy star rated homes in Melbourne were about 50% more vulnerable to experiencing heat stress during a heatwave compared with residents of 5.4 energy star rated homes.[208]

Managing demand to reduce peaks and optimise distributed energy becomes even more important in the energy transition

The energy transition will involve increased demands on the electricity network through greater use of electric vehicles and the potential for gas substitution. Electricity infrastructure is typically designed and built to service peaks which occur a few times each year. Running an air conditioner at peak times has been estimated to add $1200 to $1550 to the cost of the electricity network.[209] Electric vehicle charging which coincides with this peak could alone add around $2.5 billion in electricity infrastructure.[210]

Off-peak pricing can help reduce demand during peak times and, if combined with thermal improvements to homes, has more potential to allow people to shift their energy use, such as pre-cooling before the hottest part of a summer day or using heaters on a lower setting in the winter through improved insulation. One estimate of peak savings suggests that if a family reduced peak energy use by 1 kilowatt – about enough to run a small oil heater – almost $1000 in electricity infrastructure investment would be saved.[211]

Demand management pricing, also known as cost-reflective pricing, is already in place for industry and large businesses, and partially in place for residential and small business customers. As we have already recommended in *Victoria's infrastructure strategy 2021-2051*, the Victorian Government should support continued network tariff reform and encourage existing customers to switch to demand management pricing.[212]

Further pricing reforms can better signal the costs of using infrastructure and help to integrate distributed energy resources, such as rooftop solar and batteries. Rooftop solar is creating new minimum demand on the system, which can create issues for operating networks securely, but gives consumers more control over their emissions. There is significant opportunity to optimise consumer demand and their participation in energy services to get the best use out of existing infrastructure and cost-effectively integrate new infrastructure. The Energy Security Board has developed a Distributed Energy Resource Implementation Plan which seeks to:

- Reward consumers for their demand and generation flexibility, including options for how they want to engage with the energy market and a suitable consumer protections framework.
- Develop wholesale market arrangements that support innovation, the integration of new business models such as demand aggregators, and a more efficient supply and demand balance.
- Allow networks to accommodate continued uptake of distributed energy resources, two-way energy flows and manage network security in a cost-effective way.
- Provide the Australian Energy Market Operator with more system visibility and tools to continue safe, secure and reliable operations.[213]

The Energy Security Board estimates the potential benefits of flexible demand and better integration of distributed resources could be around $6.3 billion over the next 20 years across the National Electricity Market.[214]

200 Sustainability Victoria (2015) *Energy Efficiency Upgrade Potential of Existing Victorian Homes*

201 Sustainability Victoria (2015) *Energy Efficiency Upgrade Potential of Existing Victorian Homes*

202 Sustainability Victoria (2019) *Comprehensive Energy Efficiency Retrofits to Existing Victorian Houses*

203 Department of the Environment, Water, Heritage and the Arts (2008) *Energy Efficiency Rating and the House Price in the ACT*

204 COAG Energy Council (2019) *COAG Report for Achieving Low Energy Existing Homes*

205 ACIL Allen Consulting (2017) *Multiple Impacts Framework*

206 COAG Energy Council (2019) *COAG Report for Achieving Low Energy Existing Homes*

207 Sustainability Victoria (2019) *Comprehensive Energy Efficiency Retrofits to Existing Victorian Houses*

208 Alam M et al (2018) *Mitigation of Heat Stress Risks Through Building Energy Efficiency Upgrade: A Case Study of Melbourne Australia*

209 Wood T and Carter L (2014) *Fair Pricing for Power*

210 Infrastructure Victoria (2018) *Advice on Automated and Zero Emissions Vehicles Infrastructure*

211 Australian Sustainable Built Environment Council (2018) *Built to Perform: An Industry-led Pathway to Zero Carbon Ready Building Code*

212 Infrastructure Victoria (2021) *Victoria's Infrastructure Strategy 2021–2051*

213 Energy Ministers (2021) *Summary of the Final Reform Package and Corresponding Energy Security Board Recommendations*

214 Energy Security Board (2021) *Post-2025 Market Design Final Advice to Energy Ministers Part A*

Thermal improvements to existing buildings can reduce energy use and associated greenhouse gas emissions.

4.3.2 Efforts now to scale up biogas and develop the hydrogen industry will enable further changes in a decade.

The International Energy Agency's *Net zero by 2050 study* highlighted that many of the emissions savings needed to reach net zero by 2050 will rely on technologies that are not yet commercially available.[215] The approach taken in our scenario analysis is consistent with this view, as many of the scenarios rely on new or emerging low emissions energy technologies which are not yet ready to be deployed at scale. It will be necessary for breakthroughs to occur in the performance and cost competitiveness of these technologies for them to contribute to Victoria's emissions reduction targets.[216]

Our analysis has focused on the potential for biomethane and hydrogen in the future energy mix, in line with our *Terms of reference.* Our analysis indicates that both of these energy gases can play a role in helping to reduce emissions associated with natural gas use, but that some commercial, technical and regulatory barriers exist (see ***Recommendations 2*** and ***3***). Our scenario analysis suggests that biogas and hydrogen production would need to scale up significantly to contribute to Victoria's emissions reduction targets from 2030.[217] This would allow time for low emissions gases to reach their full potential and/or to transition natural gas users to alternative energy sources by 2050.

Biogas can contribute to emissions reduction across a range of sectors

Biogas production can contribute to emissions reduction targets across a range of sectors – including energy, waste, water and agriculture – with estimates that future biogas production could comprise up to one quarter of Victoria's current gas use.[218] Resources are widely distributed across the state and to make best use of production opportunities, facilities would need to be strategically located near to organic feedstocks and to end-users, and/or to potential injection points into the gas network.

Feedstock scale and reliability is required to generate energy, which needs a level of coordination and access to large amounts of source materials. Our analysis in developing this advice has identified opportunities to better support development of biogas and biomethane in Victoria. For example, the Emissions Reduction Fund (ERF) provides incentives for organisations and individuals to adopt new practices and technologies to reduce their emissions. Biomethane produced from waste and agricultural methods is currently not eligible under the ERF. A new method is under development,[219] but there is industry concern that current drafts do not allow agricultural waste as a feedstock and that the crediting period for Australian Carbon Credit Units needs to be extended.[220]

There are limits to the amount of residual waste that can be used across Victoria in thermal waste-to-energy facilities.[221] Current government policy seeks to avoid competition between energy recovery and waste avoidance, reuse and recycling objectives. However, prescriptive policies may limit innovation by restricting competition. The limit constrains the market potential for bioenergy, including behind the meter applications for hard-to-abate applications. This policy will be reviewed by the Victorian Government in 2023.

Strict regulations around digestate may restrict further revenue streams to make biomethane projects viable. Current regulations classify anaerobic digestate as a reportable priority waste. This means it can be composted by a licensed composter or a new permit for supply and use will be needed.[222] This creates additional obligations and rules, limiting reuse as a fertiliser or potential upgrading to biochar (charcoal produced from biomass), which has potential to help with carbon storage.

Low emissions hydrogen could contribute to the gas sector's transition to net zero emissions

Our scenario analysis explored the potential implications of green hydrogen production in various locations across Victoria. In addition, Victoria's Hydrogen Energy Supply Chain project is exploring the potential for producing hydrogen using the Latrobe Valley's brown coal resources, for export to Japan. CCS will be used to capture and store emissions for the commercial phase of the project.[223]

Our analysis has focused on energy supply within Victoria, and on implications for existing gas infrastructure, in line with our *Terms of reference*. We have therefore considered opportunities to repurpose existing gas assets and facilities for future uses, including CCS (see **Recommendation 4**). These opportunities could support future expansion of the Hydrogen Energy Supply Chain project, should the commercialisation phase prove successful.

If hydrogen production at scale in Victoria becomes technically feasible and cost competitive, hydrogen could be used in turbines to generate electricity and could provide additional support to the electricity system. Development of hydrogen hubs, where hydrogen is produced and used in a small area, can minimise the need for distribution and transmission pipeline upgrades. Hydrogen can also contribute to decarbonisation of the transport sector in hydrogen fuel cell vehicles, particularly heavy transport like trucks.

Blending of hydrogen in existing natural gas networks is limited to what end use appliances can take. Current domestic appliances can operate with a hydrogen blend of up to 10% by volume in natural gas networks. Blending hydrogen with natural gas at greater than 10% by volume would require new appliances, changes to some pipelines and to metering. Research is underway to confirm the upper limits of safe blending.[224] Local and international trials, research and pilot projects will contribute significantly to understanding this issue over the next few years.

If connected to electricity networks, hydrogen could also provide services back to the electricity grid to help integrate wind and solar. Hydrogen facilities connected to electricity transmission can help:

\ absorb large amounts of renewable energy, acting as a sink for excess energy when it is sunny or windy

\ relieve electricity network congestion issues

\ provide system services such as frequency response and significant flexible demand response

\ increase options for the electricity market operator to maintain power supplies in an emergency.[225]

In essence, hydrogen projects could operate in both gas and electricity markets, potentially deriving revenue from both and taking advantage of varying prices. It will also mean that hydrogen facilities could have obligations under both the gas rules and electricity rules, as well as gas supply and electricity supply registration and licensing requirements.

Business models for hydrogen production are not yet confirmed, such as whether it would connect to the transmission or distribution network for electricity supply, have a standalone power source, or locate in a place where it only operates when there is excess electricity from existing infrastructure. For instance, Countrywide Renewable Hydrogen and the Melbourne Market Authority are investigating creating a renewable hydrogen hub co-located with the Melbourne Market Authority's facilities. The Melbourne Market Authority would have rooftop arrays behind the meter which electricity surplus to requirements would be available for hydrogen production.[226]

Many regulatory barriers and frameworks are being worked through by Australian, state and territory governments. For example, Energy Safe Victoria has worked with the Future Fuels CRC on the safety impacts of hydrogen and provides input to standards technical committees.[227] Energy Ministers have agreed to reform the national gas regulatory framework to bring hydrogen blends, biomethane and other renewable gases within its scope.[228] Reforms aim to provide regulatory certainty to support investment in low emissions gas projects, while ensuring existing regulatory provisions and consumer protections will remain in place when hydrogen blends and renewable gases are supplied in the gas network. It will also be important to ensure that renewable gas projects have appropriate incentives, such as the Australian Carbon Credit Unit system. This will help support decarbonisation of the gas sector.

215 International Energy Agency (2021) *Net Zero by 2050: A Roadmap for the Global Energy Sector*

216 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

217 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

218 Deloitte Access Economics (2017) *Decarbonising Australia's Gas Distribution Networks*

219 Clean Energy Regulator (2021) *Biomethane* (website)

220 BioEnergy Australia (2021) *Submission to Infrastructure Victoria's Gas Advice*

221 Department of Environment, Land, Water and Planning (2020) *Recycling Victoria A New Economy*

222 EPA Victoria (2021) *Waste Determinations: Questions and Answers*

223 HESC (2021) *About HESC (website)*

224 Bruce S, Temminghoff M, Hayward J, Schmidt E, Munnings C, Palfreyman D and Hartley P (2018) *National Hydrogen Roadmap*

225 AEMC (2021) *Hydrogen: The New Australian Manufacturing Export Industry and the Implications for the National Electricity Market* (website)

226 CSIRO (2021) *Melbourne Hydrogen Hub (website)*

227 Energy Safe Victoria (2020) *ESV Annual Report 2018-19*

228 Department of Industry, Science, Energy and Resources (2021) *Extending the National Gas Regulatory Framework to Hydrogen Blends and Renewable Gases* (website)

Cost barriers exist for both biomethane and hydrogen production

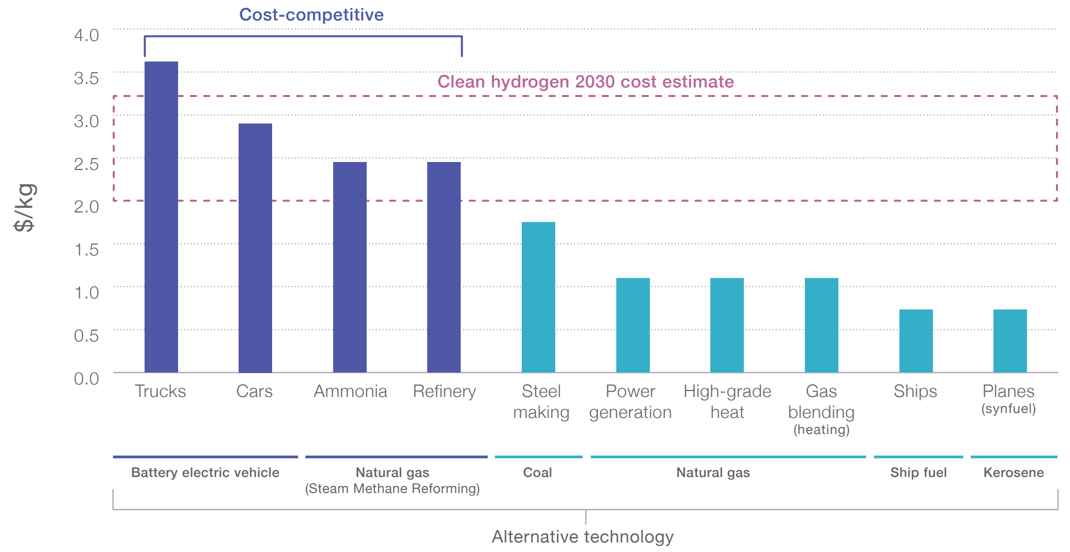
Biogas production for electricity generation and combined heat and power is already being practiced on a small scale in Victoria, but projects tend to have higher capital and operating costs compared to using natural gas.[229] While there is no local biomethane production, international examples suggest that the cost of producing biomethane for injection into the gas network could range from around $7–$50 per gigajoule, with costs depending on the type of feedstock and the size of the production unit.[230] Biomethane costs in Europe are around two to three times Victoria's current wholesale gas prices.[231] However, the dispersed nature of some bioenergy resources may mean that cost-competitive production may not be possible for all feedstocks.[232]

Hydrogen is also more expensive to produce than natural gas. Current green hydrogen production costs are estimated at around $8 per kilogram,[233] while the *National hydrogen strategy* identified that hydrogen production needs to get to around $1.20 per kilogram to break even with natural gas in distribution networks. The breakeven point will likely be region-specific, and different when comparing to other alternatives such as electricity.[234]

Hydrogen blending may support scale up of production[235] but will have limited impact on overall emissions and can therefore be only a temporary or transition solution. This relatively short project life for low volume blending projects may mean that investment costs to modify infrastructure to accommodate hydrogen blends are prohibitive. While 100% hydrogen projects will require higher capital investment, longer project lifetimes can ensure payback times are reasonable and contribute to overall viability.[236]

229 BioEnergy Australia (2021) *Submission to Infrastructure Victoria's Gas Advice*
230 ENEA Consulting (2019) *Biogas Opportunities for Australia*
231 Wood T and Dundas G (2020) *Flame Out: The Future of Natural Gas*
232 ENEA and Deloitte (2021) *Australia's Bioenergy Roadmap*
233 Department of Planning, Industry and Environment (2021) *NSW Hydrogen Strategy*
234 COAG Energy Council (2019) *Australia's National Hydrogen Strategy*
235 Finkel A (2021) *Getting to Net Zero, published in Quarterly Essay*
236 Advisian (2021) *Asset Life and Adaptability Review*

Figure 28: Breakeven cost of hydrogen against alternative technology for major applications, in 2030



Source: COAG Energy Council (2019) *National hydrogen strategy*

Lessons from the electricity transition could be applied to the gas sector

The National Electricity Market is undergoing one of the fastest renewable transitions in the world as it decarbonises.[237] Support for renewable electricity has brought down global costs for wind and solar technologies,[238] and various policy mechanisms have been used or are in place in Australia. These include:

- Victorian Renewable Energy Target (VRET) and Victorian Renewable Energy Auction Scheme. VRET is the Victorian Government's legislated target for renewable energy generation (25% of electricity generation by 2020, rising to 50% by 2030). The auction scheme supports VRET by awarding long-term contracts to renewable energy projects.[239]
- Renewable Energy Target scheme, which encourages renewable electricity generation via two programs:
  - Large-scale Renewable Energy Target (LRET) which incentivises the development of renewable energy power stations through a market for the creation and sale of large-scale generation certificates.
  - Small-scale Renewable Energy Target (SRET) which incentivises individuals and small businesses to install small-scale renewable energy systems such as rooftop solar panels or small-scale wind systems by legislating demand for small-scale technology certificates.[240]
- Grants and funding, for example innovation funding from the Australian Renewable Energy Agency designed to accelerate the renewable energy transition.[241]
- Clean Energy Finance Corporation, an Australian Government-owned bank established to accelerate investment in renewable energy projects on behalf of the government.[242]

Gas sector decarbonisation could be incentivised in a similar way, with a combination of policy and financial support for the industry to lower emissions. There are lessons from the electricity transition that could be applied. For example, the second VRET auction incorporates strengthened network requirements and support from the Australian Energy Market Operator to mitigate previous grid connection risks, such as projects seeking to connect in weaker or congested parts of the network.[243] Should existing gas networks be used to transport low emissions and renewable gases in future, similar consideration will need to be given to network reliability, infrastructure reconfiguration and upgrades – in particular for hydrogen.

237 AEMO (2020) *2020 Integrated System Plan*
238 International Renewable Energy Agency (2019) *Overview of Global and Regional Renewable Energy Policy Landscape*
239 Department of Environment, Land, Water and Planning (2021) *Victoria's Renewable Energy Targets (website)*
240 Department of Industry, Science and Resources (2021) *Renewable Energy Target Scheme (website)*

Implementation challenges will need early planning and resolution

Any move to repurpose gas distribution networks will be a major undertaking that will require considerable lead time. Victoria needs to get ahead of where it is today to be in a position ready to transition networks and users, should this option be preferred (see *Recommendations 1* and *3*).

Other network transitions should be examined to identify any applicable lessons, such as recent switchovers from bottled gas to reticulated gas, the rationalisation of water infrastructure in northern Victoria, tram and train network rationalisation, the NBN rollout and the digital television switchover. Any gas network transition will likely be far more complex than other transitions due to the safety hazards associated with gas and the need for households to purchase and swap out large, fixed appliances.

In the Netherlands, where buildings are switching from natural gas to other energy sources, local authorities are responsible for solutions for their communities. It is a process that takes time, expertise and funding support. For instance, 50 natural gas-free districts are piloting alternative technologies supported with €400 million of government funding.[244] All gas distribution networks are owned by regional or local governments, and seven out of eight operate electricity and gas networks.[245]

A switch to 100% hydrogen would require highly coordinated implementation across many private parties and could raise significant logistical challenges. Planning for the sequence and staging of gas network upgrades combined with building changes, including appliances, will require identification and resolution of many issues for infrastructure delivery across multiple parties. There will be competing commercial interests at play. Interfaces between gas and electricity businesses, appliance installers, local governments, and building owners and occupiers will be needed to support infrastructure changes.

The role of the Victorian Government is to coordinate and facilitate change. Planning for the different transition options should begin now, mapping out logistics to understand how each could be implemented, and examining potential interactions between service providers. The government would need to negotiate and establish governance arrangements with clear roles and responsibilities across parties. It may also need to produce firm timelines for delivery and regulation to protect consumers. Any cutover dates should be set well in advance.

241 Australian Renewable Energy Agency (2021) *Funding (website)*
242 Clean Energy Finance Corporate (2021) *Mission and Values (website)*
243 Department of Environment, Land, Water and Planning (2021) *VRET2 Industry Briefing Questions and Answers Summary*
244 BBC (2021) *How the Netherlands is Turning its Back on Natural Gas*
245 International Energy Agency (2020) *The Netherlands 2020 Energy Policy Review*

4.3.3 Targeted electrification now will allow time for decarbonisation technologies to mature

The National Electricity Market is undergoing rapid transformation and the scale of change still to come is significant.[246] Our scenario analysis has modelled energy futures where electricity demand increases more than threefold between 2020 and 2050 due to gas sector decarbonisation and electrification of sectors such as transport.[247]

The electricity network is not ready to reliably assume Victoria's full energy load. The Latrobe Valley's remaining coal-fired power stations are forecast to close within the next 30 years,[248] and while this will make a major contribution to Victoria's emissions reduction targets, managing the closure of these power stations while developing affordable, reliable low emissions replacement energy will be a challenge.

Victoria's electricity transmission infrastructure has historically been configured to carry power from centralised power stations to places with high energy use, such as Melbourne. It is transitioning to diverse renewable and distributed generation, supported by energy storage and network solutions.[249] Victoria will need to coordinate new transmission and generation infrastructure to help bring new renewable electricity online in the right place at the right time, and planning is underway for more renewable generation, greater interconnection and enhanced system services.

Any major shift from natural gas to electricity for household use will place greater demands on the electricity system. Electricity networks are built to accommodate peak demand, which is a handful of days in summer. Victoria's winter gas energy loads are higher than the summer electricity peak load, with estimates ranging from about 40% higher to more than double.[250,251] Transport electrification and green hydrogen production would add further to the demands on the electricity system. Energy efficiency measures will be vital to help manage demand, while incentives to switch fuels will need to be carefully selected and timed – and these will need to be regularly reviewed as both the gas and electricity sectors decarbonise. Continued use of natural gas in the medium term will allow time for the electricity system to be strengthened while maintaining reliability.

Victoria's reliance on coal-fired power stations to generate electricity means that the electricity system is currently more emissions intensive than the natural gas network. This will not be the case in the medium term. Victoria's electricity system is projected to become cleaner than natural gas from the mid-2030s.[252]

Some electrical appliances are already more energy efficient than the equivalent gas appliance, meaning that targeted measures towards electrification now can contribute towards Victoria's emissions reduction targets, even allowing for the relative emissions intensity of the gas and electricity systems.[253,254] Targeted electrification efforts now (which will roll out over the next decade or more rather than being a large-scale instantaneous change), combined with a strong and sustained focus on energy efficiency (see *Recommendation 5*) and continuing decarbonisation of the electricity network, will lay the groundwork for greater electrification in the next decade and allow time for gas sector decarbonisation technologies to mature. This targeted approach aligns with the recently released *Heat and buildings strategy* in the United Kingdom, which emphasises the importance of improved thermal performance in existing buildings, scale up of heat pump use and phase out of fossil fuel heating in both residential and non-residential buildings.[255]

246 AEMO (2020) *2020 Integrated System Plan*
247 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*
248 AEMO (2021) *Generating Unit Expected Closure Year – October 2021 (website)*
249 AEMO (2020) *2020 Integrated System Plan*
250 AusNet Services (2021) *Submission to Infrastructure Victoria's Gas Advice*
251 Wood T and Dundas G (2020) *Flame Out: The Future of Natural Gas*
252 Wood T and Dundas G (2020) *Flame Out: The Future of Natural Gas*
253 Department of Environment, Land, Water and Planning (2021) *Victoria's Gas Substitution Roadmap Consultation Paper*
254 Wood T and Dundas G (2020) *Flame Out: The Future of Natural Gas*
255 UK Government (2021) *Heat and Buildings Strategy*

4.3.4 Infrastructure decisions made now need to consider long-term implications

Infrastructure is a long-term investment. Many of the buildings and assets built today will still be here in 2050. The infrastructure decisions Victoria makes now will have implications for the gas sector transition ahead.

Household use of natural gas will need to change for Victoria to meet its emissions reduction targets. One potential option is to replace natural gas with hydrogen in the distribution network, but this is still unproven. It relies on key assumptions, including that:

- hydrogen will become cost competitive in the future, allowing widespread use
- the network will link future hydrogen supply locations with future demand locations
- networked infrastructure will be the best form of energy transport
- it is logistically possible and cost effective to change appliances and transition the existing network to hydrogen.

Decarbonisation of Victoria's electricity grid means that all-electric homes and developments represent an emissions reduction pathway which is available now. Many homes in Australia are already all-electric. The increasing energy efficiency of many electrical appliances suggests that gas users can reduce their emissions by switching to electricity even ahead of the mid-2030s, when the electricity network is expected to reach similar levels of emissions intensity to natural gas.[256] The electricity system currently has a clearer pathway towards net zero emissions than natural gas.

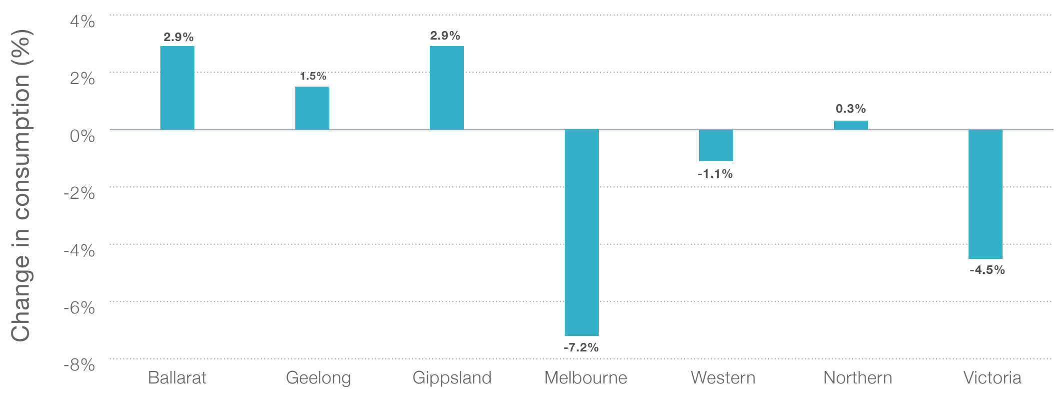
Household natural gas use is continuing to expand in parts of Victoria

Most of Victoria's natural gas consumption is from residential and small commercial customers. Its use is forecast to decline slightly to 2025, due to increased energy efficiency and the use of electric appliances in new high-density developments. However, this trend is not the same across Victoria, as illustrated in Figure 29. Increasing natural gas use is forecast in population growth corridors on the fringe of Melbourne due to new gas connections, and regional towns are expected to continue to install mainly gas appliances.[257]

Some new housing developments include a requirement for gas infrastructure. For instance, the land-use and infrastructure plan for Beveridge Central, a new development in Melbourne's northern growth corridor, mandated that all lots should be provided with reticulated gas.[258] Similar provisions were included in plans for Minta Farm in Melbourne's outer south-east.[259] This effectively locks in future gas connections and use when long-term useability of gas infrastructure is uncertain.

256 Energy Networks Australia (2021) *What to do When Electrification Will Increase Emissions, in 2021 Energy Insider*
257 AEMO (2021) *Victorian Gas Planning Report*
258 Victorian Planning Authority (2018) *Beveridge Central Precinct Structure Plan*
259 Victorian Planning Authority (2018) *Minta Farm Precinct Structure Plan*

Figure 29: Gas consumption growth by zone 2021-25: residential and small commercial users



Source: AEMO (2021) *Victorian gas planning report*

Market drivers, land use planning and building regulations encourage new gas infrastructure

Cost is one market driver which potentially makes gas infrastructure attractive from a developer's perspective. Our previous analysis of building infrastructure in different development settings across Melbourne found that gas infrastructure in new housing appears to be less expensive to build, operate and maintain on average than electricity infrastructure.[260] While housing estates that incorporate gas will also need electricity, incorporating gas can reduce the amount of electricity infrastructure needed overall.

In general, gas and electricity infrastructure to new developments is delivered by energy distributors with a contribution paid by the developer. For electricity, this contribution can vary significantly as electricity is generally more incrementally managed and expanded compared to gas. Table 8 presents a comparison of electricity and gas infrastructure costs.

Within a new housing estate or a large urban renewal development site, gas mains are supplied at no cost to the developer or through a supply funding arrangement.[261] When supplied at no cost to the developer, infrastructure costs are passed on to the home buyer through their future gas bills. By comparison, electricity infrastructure in new subdivisions is funded by the developer, suggesting electricity infrastructure costs are passed through to home buyers in the purchase price of the home. As gas can substitute for electricity in space heating, water heating and cooking, incorporating gas in a development reduces the amount of electricity needed and could therefore reduce costs to the developer. Developers can potentially offer initially 'more affordable' house prices by including gas in a development.

However, a homeowner could be paying more for running a dual fuel home over the longer term compared to all-electric housing. Existing research examining detached or semi-detached homes found that all-electric new homes in Victoria can save between $1,000 and $4,000 over 10 years for a household, compared to dual fuel. When combined with solar, this increases to around $10,000 to $14,000.[262]

Land use planning and building regulations encourage new gas networks where there may otherwise be some appeal for the residential development sector to move away from providing gas to new developments – saving time, planning and permit costs.[263] One key barrier is the role gas network companies play in residential subdivision approvals. They act as a 'determining referral authority', meaning that all conditions they specify must be included in any permit granted. This effectively gives gas networks the ability to mandate gas supply infrastructure in new subdivisions.[264] Elements within the land use planning and building regulations which encourage new gas networks and connections are outlined in Table 9.

260 Infrastructure Victoria (2019) *Infrastructure Provision in Different Development Settings: Technical Paper Volume 1*

261 SMEC (2019) *Infrastructure Provision in Different Development Settings: Metropolitan Melbourne – Costing and Analysis Report*

262 Alternative Technology Association (trading as Renew Australia) (2018) *Household fuel choice in the National Energy Market*

263 Urban Development Institute of Australia (2021) *Submission to Infrastructure Victoria's Gas Advice*

264 Victorian Planning Authority (2021) *Submission to Gas Substitution Roadmap Consultation Paper*

Table 8: Capital costs of infrastructure for new dwellings in undeveloped and established areas

Infrastructure sector	Established areas		Undeveloped areas (greenfield)	
	Low	High	Low	High
Electricity	$2,300	$17,000	$7,500	$21,200
Gas	$1,700	$8,400	$2,800	$3,400

Source: Infrastructure Victoria (2019) *Infrastructure provision in different development settings*

Note: Figures represent the average cost of infrastructure per dwelling for low and high cost scenarios, in 2018 prices

Table 9: Land use planning and building regulations which encourage gas network expansion

Regulation	Description	Impact
Victorian Planning Provision Clause 56.09 Utilities[265]	For residential subdivisions, where available, the reticulated gas supply system must be designed in accordance with the requirements of the relevant gas supply agency and be provided to the boundary of all lots in the subdivision to the satisfaction of the relevant gas supply agency.	Planning regulations have likely caused new developments to build gas networks. Gas connections are increasing in Melbourne's growth corridors.
Victorian Planning Provision Clause 66.01 Subdivision referrals[266]	Gas network businesses are determining authorities for residential subdivisions. If a determining referral authority objects to the subdivision plans, the local government (or the responsible authority) must refuse to grant a permit, and if a determining referral authority specifies conditions, those conditions must be included in any permit granted.	This clause requires the gas network business to be part of the referrals process, where it can use the opportunity to add a condition to include reticulated gas in new developments.
Plumbing regulations 3.12.0(a)	Requires gas boosted solar hot water systems or a rainwater tank.	Requires a gas connection for solar hot water. Developments that wish to be all-electric, and cannot install a rainwater tank, have to apply to the Victorian Building Authority for an exemption.

Removing barriers to all-electric housing is a sensible first step

Many local governments are pursuing zero or net zero emissions policies and seeking changes to planning settings to allow them to achieve this. For example, the City of Moreland's *Zero carbon Moreland 2040 framework* includes a vision for homes and businesses to be powered by renewable electricity alone, following a supported phase-out of natural gas.[267] Brimbank City Council also supports all-electric homes and advocates for the Victorian Government to enable gas-free, climate friendly buildings and precincts through its *Brimbank climate emergency plan 2020-2050*.[268] The City of Melbourne supports changes that will not lock new buildings and urban renewal precincts into natural gas infrastructure,[269] while the City of Yarra is transitioning council buildings to be all-electric powered by renewable energy by 2030.[270]

265 Department of Environment, Land, Water and Planning (2021) *Victorian Planning Provisions*

266 Department of Environment, Land, Water and Planning (2015) *Referral and Notice Provisions*

267 Moreland City Council (2021) *Submission to Infrastructure Victoria's Gas Advice*

268 Brimbank City Council (2021) *Submission to Infrastructure Victoria's Gas Advice*

269 City of Melbourne (2021) *Submission to Infrastructure Victoria's Gas Advice*

270 Yarra City Council (2020) *Yarra Climate Emergency Plan 2020–2024*

Case Study

Transitioning from gas to electric in the ACT

The ACT Government removed the mandate for gas connections in new suburbs in its 2019-2025 climate change strategy.[271] It subsequently announced it would legislate to prevent new gas mains connections to future stages of greenfield residential developments in 2021-22, and begin a transition towards no new gas mains network connections for future infill developments from 2023.[272]

The ACT policy had flow-on effects for the territory's gas distribution network business, Evoenergy, and its options for investing in and maintaining the network. As a regulated network (the same as Victoria's distribution networks), its revenue requirements are assessed and approved by the Australian Energy Regulator. These costs can then be passed on to gas users, which appear as network charges on bills.

The policy change raised challenging conversations for the network business and economic regulator:

- Increased uncertainty in demand forecasts to support investment in new and existing assets
- Concerns about cost recovery
- Stranded asset risks – that is, an asset no longer able to provide an economic return despite not yet reaching the end of its technical life
- Use of accelerated depreciation – that is, shortening the asset life from 50 years to 30 years for new infrastructure; this brings forward costs to align economic life with a reduced technical life, but makes no change to the full recoverable amount
- Debate about whether new infrastructure (market expansion) should proceed with shortened asset life, or not at all
- Fewer customers remaining on the network to recover asset costs, affecting affordability for gas users
- How to provide for intergenerational equity so costs are fairly shared between current and future consumers
- Sharing the risk of low demand forecasts between consumers and the network business
- Whether taxpayers, in the absence of a large gas customer base, could or should cover the costs of stranded assets
- Concerns about the ability of the electricity network to cope with increased demand, requiring additional investment
- National Gas Rules which create obligations for gas network businesses to connect customers and increase gas consumption, and do not adequately consider decline, repurposing or net zero emissions goals.

Shortening asset lives for new infrastructure to end in 2045, in line with the ACT's climate change policy, was estimated to add around $1.80 per customer each year. If applied to the entire ACT network (both new and existing infrastructure), additional annual costs were estimated at $57 per customer.[273]

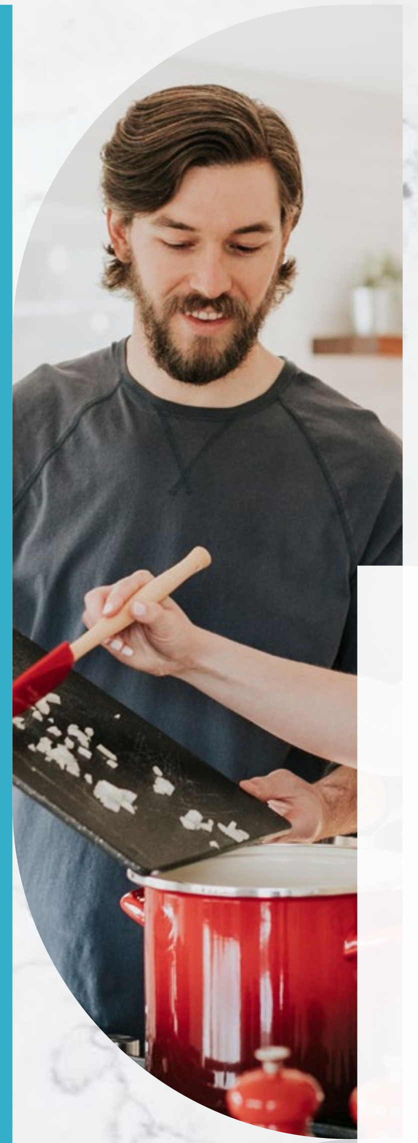
The economic case for new gas network infrastructure will become more challenging with shortened asset lives, demand uncertainty and potential renewable supply. Previous growth trends cannot be assumed going forward, and care will be needed when choosing to invest to avoid a risk of a stranded natural gas and/or stranded hydrogen asset.

The precise impacts of such policies in Victoria are unclear, particularly if seeking to limit connections where existing gas infrastructure has existing capacity.

271 ACT Government (2019) *ACT Climate Change Strategy 2019–25*

272 *Parliamentary and Governing Agreement*, 10th Legislative Assembly for the Australian Capital Territory

273 Evoenergy (2020) *Stranded Asset Risk Deep Dive Workshop Outcomes Report*



We considered whether the Victorian Government should follow a similar approach to the ACT, in prohibiting new gas networks and infill connections. Banning new network expansions would prevent new infrastructure being built, for example rolling out gas networks to new estates. Ending new infill development connections would halt connections in areas with an existing network that may have additional capacity but would mean that new developments would not be embedded with internal gas infrastructure that would need to be retrofitted in future (either for a hydrogen switch-over or conversion to all-electric).

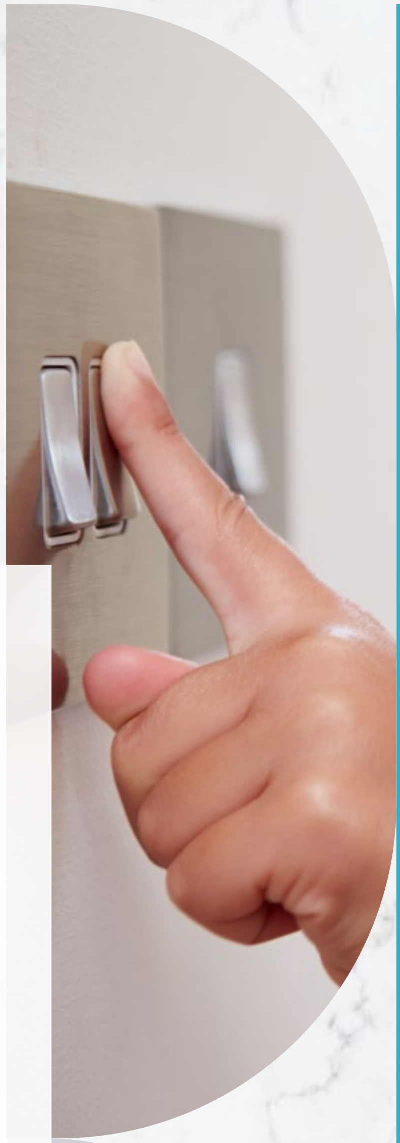
Further analysis will be needed to understand the full impact of any policy decision to prohibit new gas connections. Existing gas networks have been built and costed based on a forecast number of customers.[274] Any moves to limit the future customer base will have implications for network affordability. We have therefore focused in this advice on the immediate need to remove barriers to all-electric developments (see *Recommendation 7*). Removing any mandates, regulations and policies that encourage gas infrastructure and connections is a sensible first step which facilitates all-electric developments where this is a preference. Further policy direction may be needed from the Victorian Government if low or zero emission gases do not prove to be economically competitive or technically viable and pursuing all-electric new developments is the best way to achieve emission reductions in the medium term. This should therefore be revisited before the Victorian Gas Access Arrangements for the 2028–32 period commence, following consultation with relevant stakeholders to discuss further measures that could be introduced.

Prohibiting new gas connections would have implications for the electricity network, which is not yet ready to reliably assume Victoria's full energy load. Our scenario analysis has modelled energy futures where electricity demand increases more than threefold between 2020 and 2050, even in scenarios where low emissions gases remain part of the energy mix. Further analysis is needed to incorporate more dynamic power conditions including market dynamics and interconnection, as well as further investigation on electricity distribution capacity and preparedness to absorb further demand.

The electricity distribution network has highly localised impacts to changes in demand. In our *Advice on automated and zero emissions vehicles infrastructure*, we found that 114 out of 228 substations in Victoria would exceed their rated capacity based on modelling of potential electric vehicle charging.[275] Additional electrification of buildings would add to this impact. Mirvac's market testing of all-electric sustainable homes points to the need to better understand existing electrical distribution network capacity, and for electricity distribution planning to be better prepared for increased electrification of homes.

274 APA Group (2021) *Submission to Infrastructure Victoria's Gas Advice*

275 Infrastructure Victoria (2018) *Advice on Automated and Zero Emissions Vehicles Infrastructure*



Case Study

Mirvac tests opportunities for all-electric sustainable homes

The Australian Renewable Energy Agency has provided funding to development company Mirvac to design, market, sell and construct a net zero energy housing estate in Altona North. It is delivering 49 all-electric townhouses and apartments with a minimum 7-star Nationwide House Energy Rating.

The project aims to provide feedback on cost-effective design opportunities and live market testing of all-electric, sustainable homes. Features include solar panels, smart energy monitoring, all-electric appliances including induction cooking and provision for an electric vehicle charging point.

One of the key challenges Mirvac found was that the electrical appliances within the homes collectively drew significantly more electricity than a standard gas provided home. This meant that a significant upgrade was required to the electricity distribution network, potentially moving from a single phase 40 amp supply to a three-phase provision that is not standard in Victoria.[276] This effect would likely increase when considering potential future demand for homes with one or two electric vehicle charging points.

276 Mirvac (2021) *theFabric: Net Zero Energy Homes – Milestone 1 Knowledge Sharing Report*

4.4

Government has a key role in guiding the transition to net zero.

4.4.1 Clear, economy-wide policy direction is needed to achieve net zero emissions

The terms of reference for this advice asked Infrastructure Victoria to focus on the decisions which will need to be made regarding gas infrastructure in a future where Victoria's emissions reduction targets are achieved. However, a whole-of-economy approach will be needed for Victoria to achieve its net zero emissions goal.

A carbon pricing mechanism, where a cost is applied to emissions to encourage polluters to reduce the amount of greenhouses gases they release into the atmosphere, may be the most efficient way to achieve whole-of-economy emissions reductions. However, this is not currently an option that is being pursued in Australia. In its absence, strong policy action in every sector of the economy will be required.[277] This could include decarbonisation and energy demand reduction incentives and/or regulatory requirements for energy suppliers and users across all sectors, supported by the building of social licence and behaviour change.

Victoria's gas and electricity systems are interconnected within national systems. Victoria is historically an exporter of gas to other states. Changes to Victorian energy settings will need to consider implications for other states who are connected to and may rely on gas supplies from Victoria. In addition, increased electrification has implications for electricity system planning which is broader than Victoria. Both gas and electricity need to consider transport, as that sector's emissions reduction solution relies primarily on the decarbonisation of gas and electricity.

Natural gas planning in a net zero emissions future interacts with many sectors including electricity, renewable gases, manufacturing, transport, water, waste, agriculture, land use, the environment and cultural heritage. Various Victorian Government departments and agencies are responsible for planning for other sectors. This planning needs to consider the potential implications of switching away from natural gas to renewable energy.

Any future move towards large-scale repurposing or decommissioning of the gas network will require coordinated action across a range of sectors, organisations and consumers, both within Victoria and across jurisdictions. The Victorian Government will need to collaborate with industry and with Australian, state and territory governments to guide the transition. The need for clear policy direction and support from the Victorian Government, with a national approach where applicable, was a consistent message from stakeholders in developing this advice.

277 Wood T, Reeve A and Ha J (2021) *Towards Net Zero: Practical Policies to Offset Carbon Emissions*

Case Study

A whole-of-economy transition requiring strong policy agreement and leadership from all parts of the community

The Dutch Climate Accord, negotiated by civil society organisations at the instigation of government, agreed to cut natural gas use to zero by 2050 and transition gas infrastructure. Under the Climate Accord industrial heating processes will need to transition to net zero emissions by 2050, all buildings convert from gas-fired heating, and power generation will be 100% renewable.

Most buildings in the Netherlands are heated by gas through connection to the gas network. Existing buildings are therefore being removed from the gas network alongside a policy of no new gas network connections. By 2050, all 7.7 million dwellings should be disconnected from gas. The Dutch government aims to transition between 30,000 and 50,000 dwellings in 2021, accelerating to 200,000 dwellings a year before 2030.[278] It is also seeking to upscale biogas production by 2030, targeted towards buildings.

At the same time, the Netherlands is developing large-scale green hydrogen production with offshore wind. This is targeted towards industry, alongside industrial scale offshore carbon capture and storage in the Port of Rotterdam.

Gasunie, a public-private joint venture, owns the gas transmission network and is also a partner in the NorthH2 project – offshore wind to produce green hydrogen for Dutch industry. Gasunie plans to develop the hydrogen transmission network by repurposing existing natural gas pipelines, starting with the infrastructure within regional industrial clusters. Once complete, Gasunie will connect the clusters to each other, to storage facilities and to other countries.[279]

The Climate Accord includes long-term emissions reduction plans for industry and introduces a carbon tax from 2021 which will be progressively increased through to 2030. Some support is available to industry for carbon capture and storage, but this is time and capacity-limited and restricted to situations where no cost-effective alternative is available. The approach assumes industry will bear the largest part of the expense involved in its own energy transition.[280]

The transition away from natural gas, with supplementary roles for biogas and hydrogen, is a massive and complex transformation. The Dutch approach to removing homes from the gas grid is decentralised – local authorities determine the solutions in their regions. This process takes time, requires expertise and experience which some smaller municipalities are struggling with.[281] There are reports of high costs,[282] complex rules and inadequate subsidies. Recent reporting suggests that fewer than 10,000 houses have been renovated to become carbon-free.[283]

The Dutch gas industry is being proactive in responding to the energy transition and is seeking to redefine its role in a zero emissions energy sector. However, the transition is still at an early stage. Apart from Gasunie, no gas company has committed to invest substantially in 'new gas' activities, and progress will require cooperation with other sectors to realise projects.[284]

The Climate Accord shows that it is too early to be able to present a definitive blueprint for the energy future as too many uncertainties remain. The consensus approach adopted in developing Dutch energy policy has achieved progress, but there remains a strong need for the government to make clear-cut decisions on energy and climate policy. The Climate Accord is a significant achievement, but still requires a regulatory and policy framework if the Netherlands is to achieve far-reaching greenhouse gas emission reductions.[285]

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278 Accenture (2021) *Gas Infrastructure: International Comparisons*

279 NortH2 (2021) *NortH2 Happy with Dutch Government's Hydrogen Infrastructure Decision (media release)*

280 Beckman K and van den Beukel J (2019) *The Great Dutch Gas Transition*

281 DutchNews.nl (2021) *Just 206 Homes Have Been Made Gas Free, Two Years into Project: Volkskrant* (website)

282 Beckman K and van den Beukel J (2019) *The Great Dutch Gas Transition*

283 BBC (2021) *How the Netherlands is Turning its Back on Natural Gas* (website)

284 Beckman K and van den Beukel J (2019) *The Great Dutch Gas Transition*

285 Beckman K and van den Beukel J (2019) *The Great Dutch Gas Transition*

4.4.2 Governance and policy settings are not yet aligned with the transition to net zero

Victoria's *Climate Change Act 2017* provides Victoria with the legislative foundation to manage climate change risks and drive the transition to a net zero emissions economy by 2050.[286] Whichever pathway ultimately leads to a net zero emissions gas sector, the Victorian Government will need to ensure all legislation, regulations and standards are aligned with the state's net zero emissions target.

Earlier in this report we highlighted a range of land use planning and building regulations which continue to encourage new gas infrastructure despite its contribution to greenhouse gas emissions and uncertain long-term role in a net zero energy future (see section 4.3.4). Aligning policies and regulations across government will provide a strong framework to deliver net zero targets over time, and allow for all infrastructure and network investment decisions to be compatible with pathways towards net zero.

Regulatory frameworks can better incorporate emissions reduction objectives

Energy infrastructure is delivered, owned and managed by the private sector. Governments provide regulatory frameworks for these activities which aim to address market failures, manage risks, improve environmental and social outcomes and encourage competition in the interest of consumers. Victoria's energy sector operates under various legislative frameworks depending on the activity. It is a complex system, with national regulatory arrangements working alongside state-based regulation to address safety, environmental and development issues that require a local response. To date, decision-support tools, like Environmental Effects Statements, planning and operating licence applications, have considered acute impacts on people and the environment but have not always considered more diffuse and chronic impacts like indirect carbon emissions (i.e. the extent to which any given project will continue or increase carbon emissions across the economy, such as new fossil fuel supply). Where direct carbon emissions are considered, there has been limited focus on requiring reduction of these over time. Both within Victoria and in collaboration with the Australian Government, there are opportunities to refine existing frameworks to better address climate risk and achieve net zero emissions.

Access to natural gas pipeline services falls within the national energy market framework and is regulated through the National Gas Law and National Gas Rules. This framework provides for the economic regulation of infrastructure, market transparency and market facilitation. The National Gas Law is a schedule to the *National Gas (South Australia) Act 2008* (SA), and both the National Gas Law and National Gas Rules are applied as laws of Victoria by the *National Gas (Victoria) Act 2008* (Vic).[287] The Australian Energy Market Commission (AEMC) makes the National Gas Rules, while the Australian Energy Regulator (AER) regulates covered gas pipelines in accordance with the National Gas Rules.

The current economic regulatory framework for gas networks has provided significant benefit through encouraging efficient investment and ensuring consumers pay no more than is necessary. However, it was not designed to meet the challenges of technology change and reaching a net zero emissions future. The framework needs adapting.

The National Gas Objective as stated in the National Gas Law is *'to promote efficient investment in, and efficient operation and use of, natural gas services for the long-term interests of consumers of natural gas with respect to price, quality, safety, reliability and security of supply of natural gas.'* The AER, who approves access regimes for the Victorian Transmission System and the three distribution networks, must operate in a way that will contribute to achieving the National Gas Objective. Similarly, the AEMC must also have regard to the National Gas Objective when making rules.

The National Gas Objective does not explicitly incorporate long-term environmental or net zero emissions considerations. Current reforms are underway, including extending the national gas regulatory framework to hydrogen blends and renewable gases, and the AEMC has included a decarbonisation principle in its assessment of rule changes to support this.[288] This is a welcome step, but we consider that further guidance should be given to market bodies to explicitly consider emissions reduction objectives (see *Recommendation 10*).

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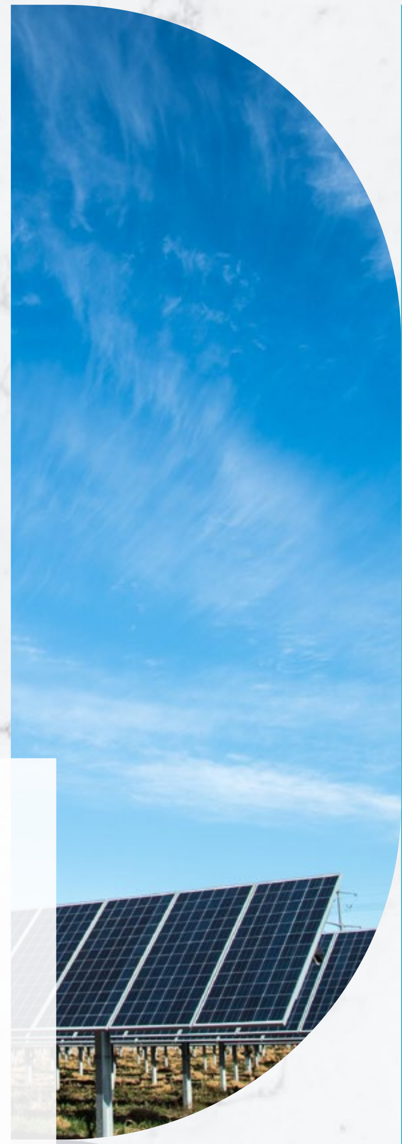
286 *Climate Change Act 2017* (Vic)

287 AEMC (2021) *National Gas Rules* (website)

288 Department of Industry, Science, Energy and Resources (2021) *Extending the National Gas Regulatory Framework to Hydrogen Blends and Renewable Gases* (website)



Case Study

British regulators are looking at similar issues

Great Britain's energy regulator, Ofgem, plays a significant role in supporting energy decarbonisation and acknowledges that its principal objective to protect both current and future consumers goes hand in hand with this. Its decarbonisation action plan sets out its initial approach and makes commitments to ensure its regulations keep pace with government policy.[289]

Similar to the Australian Energy Regulator, Ofgem operates within a multi-government system, where the UK Parliament has legislated a target of net zero by 2050, and the Scottish Government by 2045. The Welsh Government also intends to introduce legislation to amend its existing target to no later than 2050.[290]

The UK National Infrastructure Commission recommended that infrastructure regulators' duties need to be coherent, covering the environment as well as price, quality and resilience. Where these are missing, regulators should be required to ensure their decisions are consistent with, and promote the achievement of, legislated greenhouse gas emissions targets.[291] The UK Government supports legislated climate duties where applicable, and is considering the most appropriate measures to introduce to ensure regulators make the necessary contributions to achieving net zero emissions.[292] It is developing a policy paper on economic regulation, which will consider regulator duties and the benefits of a cross-sectoral strategic policy statement.[293]

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289 Ofgem (2020) *Ofgem's Decarbonisation Action Plan* (website)

290 Ofgem (2020) *Net Zero Advisory Group: Terms of Reference*

291 National Infrastructure Commission (2019) *Strategic Investment and Public Confidence*

292 HM Treasury (2020) *Response to the Regulation Study: Strategic Investment and Public Confidence*

293 HM Treasury (2020) *National Infrastructure Strategy*

Regulators need the tools and settings to manage a range of future scenarios

Regulators play an important role in delivering policy outcomes and require appropriate tools and settings, including clear objectives and functions, sufficient resourcing and expertise, and transparency to deliver accountability to the public for their decisions. Strong foundations already exist and can be built upon to accommodate the need to evolve from business-as-usual activity to one which manages different uncertainties and risks for an industry in transition.

Gas exploration and production activities will need to change to support a net zero emissions future. Our analysis identified the potential to repurpose existing production facilities, pipelines, processing and/or storage facilities in Gippsland and the Otway Basin for carbon capture and storage. Regulators will need tools and settings to manage decommissioning and rehabilitation for assets reaching later life, and actions to support repurposing.

Earth Resources Regulation, a branch within the Department of Jobs, Precincts and Regions, is Victoria's regulator of resources exploration, mining, quarrying, petroleum, extractives, geothermal and carbon storage activities in Victoria and offshore Victorian waters within three nautical miles of the coast. Its role is to ensure activities are conducted safely to protect people, property, infrastructure and the environment. Earth Resources Regulation administers the *Petroleum Act 1998* and *Offshore Petroleum and Greenhouse Gas Storage Act 2010* which govern gas exploration and production and carbon storage in Victoria and its offshore area. It also assesses and authorises earth resource projects and conducts compliance operations to ensure that licensed operators fulfil their regulatory obligations.

Beyond three nautical miles, gas exploration and production activities are regulated by the independent offshore energy regulator, the National Offshore Petroleum Safety and Environmental Management Authority (NOPSEMA). Titles and title transfers are by the National Offshore Petroleum Titles Administrator (NOPTA). Decisions by NOPTA are made jointly between the Commonwealth and state ministers.

Risks have emerged in recent times as resource industry assets age. This includes companies seeking to divest their more mature assets, to be acquired by companies with more risk appetite.[294] In the case of the Northern Endeavour, a floating production storage and offtake facility offshore northwest of Darwin, the company went into voluntary administration four years after it had acquired the petroleum title and associated assets. This followed numerous concerns raised by NOPSEMA.[295] The Australian Government subsequently stepped in to decommission the Northern Endeavour after its owner went into liquidation in 2020.[296] The Australian Government plans to impose a temporary levy on oil and gas producers to recover costs to ensure that taxpayers are not left to pay for decommissioning and remediation.[297] It is also enhancing the offshore oil and gas decommissioning framework.[298]

In another example from the mining sector, the Victorian Government assumed responsibility for rehabilitation works at the Benambra mine processing site in Gippsland after the former mine operator became bankrupt and defaulted on its obligations. Following this episode, Earth Resources Regulation, the Victorian regulator, released a strategy to drive better rehabilitation of mine, quarry and other resources sites.[299]

Recent compliance and enforcement actions also highlight risks emerging in Victoria's gas sector:

\ A former licensee who surrendered an exploration licence has now been issued with notices to decommission its redundant coal seam gas wells and infrastructure in Gippsland and to rehabilitate the site.

\ The regulator issued nine improvement notices to another Gippsland licence holder to improve maintenance and security at their onshore gas wells and sites.[300]

As the pace of change accelerates in the energy sector to reduce emissions, demand for fossil fuels declines and pressure increases for low emissions energy to come online, the risk of governments assuming liability for fossil fuel assets may increase as infrastructure owners seek to minimise costs or transfer liability to other companies. This risk could also present itself in repurposing infrastructure for other uses such as carbon capture and storage, and will need to be carefully managed so risks are securely transferred and remain with the private sector. Changes in legislation and regulations may be needed, and regulatory teams will need enhanced resources and capabilities to assess and identify new, complex risks associated with carbon dioxide storage operations.

Effective regulatory oversight will be essential to manage risks of potential repurposing, decommissioning and/or rehabilitation of assets. Some actions may include improving offshore pipeline decommissioning standards and guidelines across regulators to simplify the decommissioning and rehabilitation process to reduce the risk of regulatory gaps and make it easier for the private sector to undertake these activities. Another could be to review processes for transferring existing oil and gas wells to third parties, and consider a statutory transfer process between regulators should it be beneficial to leverage expertise. Further review of existing inactive (suspended) onshore gas wells could also be undertaken to minimise the risks to the public, the environment and any potential Victorian taxpayer liability. For instance, plug and abandonment costs may be significantly higher than current bonds.

As natural gas supply will need to decline in order to meet net zero emissions in the future, enhanced transparency of existing licences and performance will help with regulators' accountability to the public. NOPSEMA publishes information on projects and activities that have been approved, and directions, prohibition and improvement notices. Victoria could look to do something similar.

294 Department of Industry, Science, Energy and Resources (2020) *Enhancing Australia's Decommissioning Frameworkfor Offshore Oil and Gas Activities*

295 Walker S (2020) *Review of the Circumstances that Led to the Administration of the Northern Oil and Gas Australia (NOGA) Group of Companies*

296 Department of Industry, Science, Energy and Resources (2021) *Decommissioning the Northern Endeavour* (website)

297 Australian Treasury (2021) *Australian Budget 2021-22: Budget Measures*

298 Department of Industry, Science, Energy and Resources (2021) *Offshore Oil and Gas Decommissioning Framework Review*

299 Earth Resources (2020) *Rehabilitation Resumes at Former Mine Site* (media release)

300 Earth Resources (2021) *Gippsland Onshore Gas Licence Holder On Notice* (media release)

Gas exploration and production activities will need to change to support a net zero emissions future.

Preparing for hydrogen blending

Energy ministers have begun on extending the national gas regulatory framework to hydrogen blends and renewable gases. This includes national laws relating to the economic regulation of natural gas transmission and distribution pipelines, market transparency mechanisms such as the *Victorian gas planning report* and the operation of the Declared Wholesale Gas Market. Alongside the consultation, the AEMC is reviewing the National Gas Rules and National Energy Retail Rules, and the Australian Energy Market Operator is reviewing its procedures and instruments its uses for settlement and metering.[301]

A proposal is under consideration that jurisdictions remain responsible for licensing or authorising pipelines. This means Victoria would trigger the application of the national laws when it authorises hydrogen, biomethane and synthetic gases in gas pipelines. In Victoria, gas pipeline licensing and safety involves:

\ The Department of Environment, Land, Water and Planning (DELWP) which licences transmission pipelines through its responsibilities in administrating *Pipelines Act 2005*.[302] This Act governs the construction and operation of pipelines carrying liquid and gaseous fuels at high pressure in Victoria.

\ Energy Safe Victoria which provides technical advice to DELWP in transmission licensing, and is responsible for regulating safety management plans in compliance with licence conditions.[303] It is also responsible for electricity, gas and pipeline safety more broadly in Victoria through the *Gas Safety Act 1997*, and ensures gas and electrical appliances are approved and safe for use, investigates gas and electrical incidents and undertakes safety awareness campaigns.

\ The Essential Services Commission which licenses gas distribution businesses and applies the Gas Distribution Code.

These arrangements may need to be reviewed to ensure future regulatory frameworks are appropriate for authorising hydrogen blends, biomethane and synthetic gases in gas pipelines, considering pipeline and end user safety. Hydrogen in particular has a different chemical composition than natural gas and poses different risks to the public and environment, including in operations.

In addition, the 2017 *Review of Victoria's electricity and gas network safety framework* (the Grimes Review) identified some general concerns around the Essential Services Commission's limited technical capabilities in network operations. The Grimes Review suggested a review of the Gas Distribution Code to clearly define the technical elements and to consider the role that Energy Safe Victoria could play in compliance and enforcement.[304] The current *Memorandum of understanding* between the Essential Services Commission and Energy Safe Victoria could also be reviewed to ensure it remains current and fit for purpose, in line with the Grimes Review recommendation.

Preparing for more significant change

Some of the potential energy mixes we explored in our scenario analysis raise the prospect that parts of the gas network may not be needed in the future, or that there may be a sharp decline in energy gas use which could raise questions of commercial viability.

Under the current regulatory framework, network owners invest, maintain and operate gas infrastructure and recover the costs from customers. This is done through charging retailers who use the networks to deliver the gas supply to homes and businesses. Retailers then pass this cost through to their customers on their bills. Prices are determined through an access arrangement, which is approved and overseen by the AER for every five-year period.

Some of the National Gas Rules are based on a premise of continued customer growth. More customers on the network can share the costs, making it more affordable. Gas network businesses need to follow the National Gas Rules, and tensions can arise in seeking to meet the rules that assume growth when there is some decline. For example:

\ Rule 89(a) – the depreciation criteria should be designed so that reference tariffs will vary over time in a way that promotes efficient growth in the market for reference services. This rule highlights an underpinning assumption of increasing demand.

\ Rule 79(1)(a) – capital expenditure which can be incorporated into the regulatory asset base (and recovered from users) needs to be in accordance with accepted good industry practice, to achieve the lowest sustainable cost of providing services. This rule comes into conflict with a declining user base, and potentially with repurposing the network for hydrogen.[305]

The current mechanism for managing the risk of stranded assets is by accelerated depreciation, whereby an asset's economic life is shortened to allow faster cost recovery from customers. In the Australian Capital Territory, for example, the AER gave approval to the gas network owner to accelerate the depreciation on its network assets, in response to the government's policy of prohibiting new gas connections from 2023 (see ACT case study in section 4.3.4). This will allow the network owner to recover more of the costs for gas network services from current customers, compared to a smaller number of customers in future.[306]

Accelerated depreciation may go some way to helping network owners manage the risk of stranded assets, but it will not address distributional aspects, such as fewer future customers remaining on the network to meet the recovery costs of assets, affecting affordability.

301 Department of Industry, Science, Energy and Resources (2021) *Extending the national gas regulatory framework to hydrogen blends and renewable gases* (website)

302 Department of Environment, Land, Water and Planning and Energy Safe Victoria (2021) *Memorandum of Understanding*

303 Department of Environment, Land, Water and Planning and Energy Safe Victoria (2021) *Memorandum of Understanding*

304 Independent Review of Victoria's Electricity and Gas Network Safety Framework (2017) *Final Report*

305 AEMC (2021) *National Gas Rules Version 59*

306 Australian Energy Regulator (2021) *AER Allows Revenue to Support Gas Consumers in Transition to Renewables* (media release)

The AER is undertaking a review of regulatory issues arising from the uncertainty in long-term gas demand, which will include mechanisms through which this uncertainty can be managed and has published an issues paper for public consultation.[307] It discusses approaches to demand uncertainty and areas where the regulatory framework may need to be adapted. This includes potential amendments to the National Gas Law and National Gas Rules to provide network service providers with more flexibility to manage declining use of the network and the cost of maintaining and operating it, while protecting remaining customers during a transition with network shutdown.

The Victorian Government should seek review of the National Gas Law and National Gas Rules to allow, and help manage, alternative transition paths for network infrastructure such as decline, earlier retirement and decommissioning in parts, if needed. This is in addition to work underway to allow renewable gases. The government should also work with the AER on equity issues, so that those from low-income households do not face a disproportionate share of the costs of the gas sector transition (see also section 4.4.5). Actions that the Victorian Government takes should consider gas network businesses investment planning, which occurs in advance of access arrangement deliberation periods (see Figure 30).

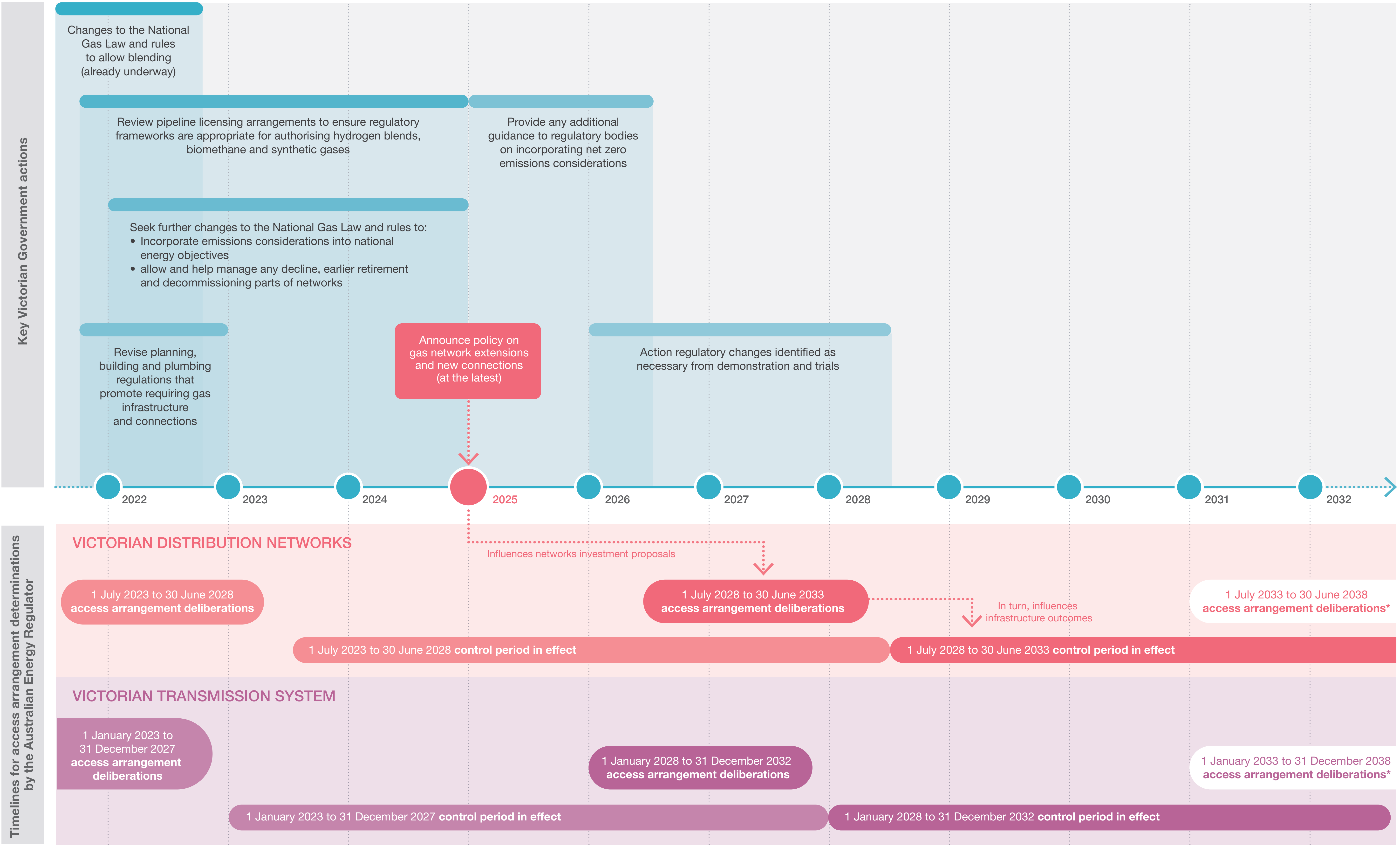
The Victorian Government should also look to apply relevant lessons from efficiency improvement and irrigation network rationalisation in northern Victoria.[308,309] This program was driven by climate change, declining water availability and the need to rebalance the available water supply between communities, agriculture and the environment. On-farm and network infrastructure measures were applied to massively increase efficiency but there have also been changes in the number of water users remaining on and paying for the system. There have been significant changes in farming practices and regional products as water has moved to higher value uses with associated social and economic change.

307 Australian Energy Regulator (2021) *Regulating Gas Pipelines Under Uncertainty*

308 Productivity Commission (2021) *National Water Reform 2020, Inquiry Report*

309 The Primary Agency (2016) *Report on the Community and Stakeholder Engagement for the GMW Connections Project Reset*

Figure 30: Victorian Government action and regulated network investment timelines



* Estimated timing

4.4.3 Emissions reduction policies need strengthening to support gas sector decarbonisation

Climate change is a global issue and requires strong leadership and action across the world. Australia is a signatory to the Paris Agreement, agreeing to work to hold the increase in global average temperature to well below 2, preferably to 1.5 degrees Celsius above pre-industrial levels. Countries are expected to progressively strengthen their emissions reduction ambition every five years.

Emissions reduction policies in general seek to encourage businesses and households to invest in technologies and adopt practices that reduce their emissions. Stable policy settings are needed to support investment in long-lived infrastructure, but it will be necessary to scale them up if possible. No single policy is a silver bullet, rather a policy toolkit will be required. The Australian and Victorian Governments have different levers, which can be complementary.

The Independent Expert Panel on Interim Emissions Reduction Targets for Victoria noted that strong policy action by both the Victorian and Australian Governments is needed to meet the higher end of Victoria's 2030 interim emissions reduction target.[310] It will be needed to meet future interim targets and the 2050 net zero target as well. More can be done to incentivise industry to reduce their emissions, including from natural gas use. The OECD identifies that in the absence of an economy-wide carbon price, existing instruments will need to be scaled up and new sector-based solutions considered, especially for energy, transport and agriculture.[311]

One of Australia's main levers for emissions reduction is the Emissions Reduction Fund (ERF), also known as the Climate Solutions Fund. It provides incentives to individuals and organisations to reduce emissions by earning Australian Carbon Credit Units (ACCUs) for registered emissions reduction projects. Each ACCU represents one tonne of carbon dioxide equivalent emissions avoided or removed from the atmosphere. ACCUs can be sold to the Australian Government through a carbon abatement contract, or other parties in a secondary market. They are a key part of Australia's offset framework.

The ERF has been successful in activating low-cost abatement from the agriculture, land and waste sectors in Australia, but has not contracted significant new amounts of abatement since 2017. Some reasons include price uncertainty and projects facing challenges in obtaining finance, high costs of participation in the scheme and the complexity, and lack, of methods for some activities.[312]

The ERF includes the safeguard mechanism, which aims to avoid increases in emissions beyond business-as-usual levels. The safeguard mechanism requires large greenhouse gas emitters to keep their net emissions below a baseline, and to offset any which are above it by surrendering ACCUs.[313]

The safeguard mechanism constrains industrial emissions growth, but it is not designed to reduce emissions. Several organisations have called for policies to go further, to incentivise emissions reduction and reduce baselines over time, including the Climate Change Authority,[314] the Grattan Institute,[315] the Business Council of Australia[316] and the OECD.[317] Declining baselines would further prompt the private sector to examine and invest in new technologies and processes, reduce emissions and help deepen Australia's carbon markets. In addition, developing emissions reduction activities within the ERF could further incentivise industry to invest in technologies that can reduce emissions from gas use (see ***Recommendation 2***). These need to keep pace with science and technology developments and any changes to emissions reduction targets, while also providing for a reasonably stable policy environment for investments.

310 Independent Expert Panel on Interim Emissions Reduction Targets for Victoria (2019) *Interim Emissions Reduction Targets for Victoria (2021-2030): Final Report*

311 OECD (2021) *OECD Economic Surveys: Australia 2021*

312 Climate Change Authority (2020) *Review of the Emissions Reduction Fund*

313 Clean Energy Regulator (2019) *The Safeguard Mechanism* (website)

314 Climate Change Authority (2020) *Prospering in a Low-Emissions World*

315 Wood T, Reeve A and Ha J (2021) *Towards Net Zero: Practical Policies to Reduce Industrial Emissions*

316 Business Council of Australia (2021) *Achieving a Net Zero Economy*

317 OECD (2021) *OECD Economic Surveys: Australia 2021*

Our scenario analysis has made limited use of offsets to balance emissions in some instances, taking into consideration that some hard-to-abate sectors will likely need offsets to reach net zero. We nominated agroforestry offsets for costing purposes in the scenarios, referring to offsets issued to projects targeting changes to vegetation and agriculture practices, including soil farming and reforestation. However, offsets can come in two broad forms:

- Avoidance offsets – from activities that reduce emissions by preventing their release into the atmosphere, such as energy efficiency or switching to renewable sources of energy. These can be used to offset emissions in other parts of the economy, for example through ongoing fossil fuel use, but they do not reduce current levels of carbon in the atmosphere when used this way.
- Removal offsets – from activities which pull carbon out of the atmosphere and sequester it.

There is much debate about the use of offsets, such as whether they are a distraction from reducing emissions from the source or a necessary tool for a cost-efficient transition. There is also debate about the reliability of the different types of offsets, with submissions to our interim report providing both negative and positive feedback on mechanisms such as carbon capture and storage and agroforestry offsets.

Overall, there is great benefit in avoiding emissions in the first place as only this will help mitigate climate change. Outlining a clear role that offsets should play in emissions reduction policy, and ensuring offsetting frameworks maintain high integrity, can assist the transition to net zero.[318]

Within Victoria, the *Climate Change Act 2017* sets a target of net zero greenhouse gas emissions by 2050. It prioritises reducing emissions to as close to zero as possible, but also makes provision for emissions to be removed through carbon sequestration activities within Victoria, followed by eligible offsets from outside Victoria to make up any difference.[319] Victoria's current climate change regulations do not yet describe what constitutes an eligible offset from outside of Victoria. While Victoria's climate change strategy projects that Victoria will meet the 2025 target, and that the sector pledges lay some foundations for meeting the 2030 target,[320] offsets from outside the state may be needed should Victoria not reach its interim emissions reduction targets from activities within Victoria. Offsets from outside of Victoria will need to be carefully considered to avoid any double counting, and to ensure Australia meets its overall emissions reductions commitments that form part of global efforts.

Victoria's land use, land use change and forestry sector removed 11.4 million tonnes of carbon dioxide equivalent (Mt CO_2e) in 2018. In 2019, it emitted 2.1 Mt CO_2e and sequestered 19.5 Mt CO_2e, providing a sink of 17.4 Mt CO_2e. Victoria's *Land use, land use change and forestry sector pledge* is estimated to reduce Victorian emissions by 1.4 Mt in CO_2e in 2030.[321] In our scenario analysis, around 3 Mt CO_2e is needed to offset emissions in 2050 alone, depending on the scenario. The scenarios were designed to use the least offsets possible, and do not consider changes to the land use and forestry sector's emissions profiles over time. As such, the offset figures are indicative only for the gas, electricity and road transport sectors. But they do provide a strong context for investing in the land use, land use change, and forestry sector as a natural sink.

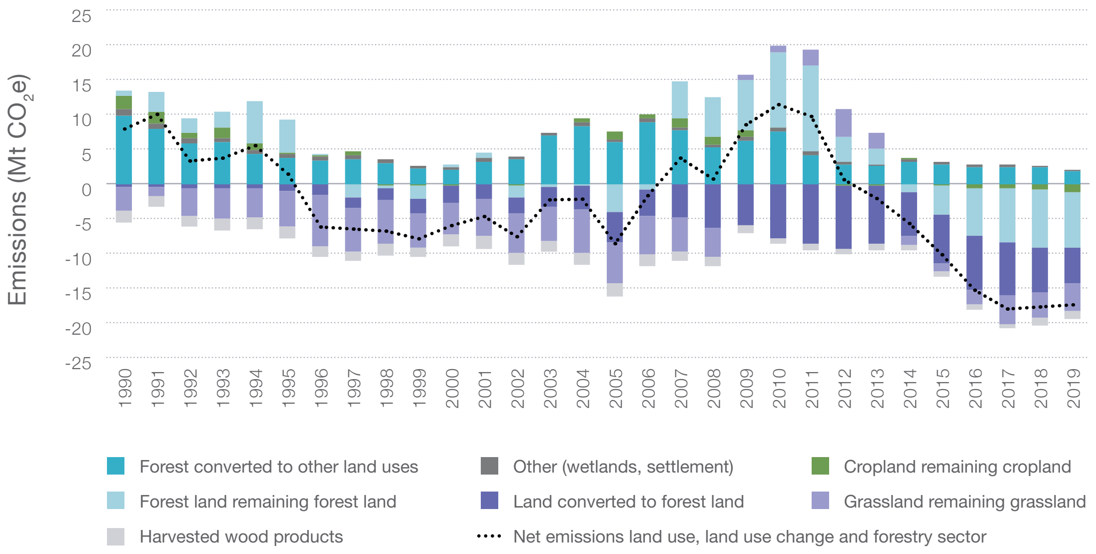
318 Wood T, Reeve A and Ha J (2021) *Towards Net Zero: Practical Policies to Offset Carbon Emissions*

319 Parliament of Victoria (2016) *Parliamentary Debates (Hansard): Legislative Assembly, Fifty-Eight Parliament, First Session*

320 Department of Environment, Land, Water and Planning (2021) *Victoria's Climate Change Strategy*

321 Department of Environment, Land, Water and Planning (2021) *Cutting Victoria's Emissions 2021–25: Land Use, Land Use Change and Forestry Sector Emissions Reduction Pledge*

Figure 31: Land use, land use change and forestry sector emissions – 1990 to 2019



Source: Department of Environment, Land, Water and Planning (2021) *Victorian greenhouse gas emissions report 2019*

The Victorian Government will need to protect and enhance natural environments, and this will increase even more over time. After 2050, it will be critical to maintain carbon sinks. This is challenging as Victoria will be impacted by climate change. By 2050, Victoria could experience average annual temperature increases of up to 2.4 degrees, declines in cool season rainfall and alpine snowfall which are largely responsible for recharging water reserves, more intense downpours and longer fire seasons with up to double the number of 'high' fire danger days.[322] Victoria is already one of the most fire prone places in the world.[323] Figure 31 illustrates how land use, land use change and forestry emissions can vary over time, including with drought and widespread bushfires, further adding to the emissions challenge.

While offsetting will be needed for hard-to-abate gas uses, more can be done now to reduce emissions. Other policy levers may also be needed. For example, Victoria's *Climate Change Act 2017* enables the Environment Protection Authority to regulate the emission or discharge of greenhouse gases to contribute to Victoria's long term and interim emissions reduction targets.[324] However, the Minister for Energy, Environment and Climate Change is yet to issue guidelines for how the Environment Protection Authority should consider the Act in its decision-making processes (see section 4.4.2), and this should be resolved.[325]

322 Department of Environment, Land, Water and Planning (2021) *Victoria's Climate Change Strategy*

323 Country Fire Authority (2021) *Am I at Risk?* (website)

324 Department of Environment, Land, Water and Planning (2017) *Climate Change Act 2017: Overview*

325 Environment Protection Authority Victoria (2021) *Climate Change Legislation* (website)

4.4.4 Decarbonisation will require sustained support and participation from gas users

Significant change will be required from consumers, regardless of which pathway ultimately leads to gas sector decarbonisation. Victorians will need to change the appliances they use to cook and heat their homes, and their means of transport will change. The International Energy Agency estimates that around 55% of cumulative emissions reductions outlined in their roadmap to net zero 2050 are linked to consumer choices such as buying an electric vehicle, energy efficiency upgrades or installing a heat pump, indicating that sustained participation and support will be needed from households and businesses for Victoria to achieve its emissions reduction targets.[326]

However, limited awareness and understanding of energy efficiency, as well as energy use and costs, is a barrier when it comes to changing behaviour. Households and businesses, as well as property managers, landlords, tradespeople and service sectors, would benefit from simple, accessible information on energy use and energy efficiency from an independent source to assist in understanding the various benefits and costs (for example investment payback, comfort and health), as well as the climate implications of the decisions they make.[327]

Research from Energy Consumers Australia indicates that less than 60% of Victorian consumers are confident they can find the tools and assistance they need to manage their energy use, or that there is enough easily understood information available to support decision-making about energy products and services.[328] In addition, research on energy efficiency in rental properties found that only 16% of landlords were aware of government incentives, indicating significant opportunities to raise awareness and increase uptake.[329] Education, training and behaviour change programs should therefore be targeted to specific audiences to ensure maximum impact.[330,331,332]

There is a role for government in providing clear, independent information, to help build this knowledge and prepare consumers for the changes ahead. This should be supported by a sustained communication campaign to build awareness of the climate impacts of different energy sources including natural gas, the benefits of energy efficient homes and available energy efficiency incentive programs.

In addition to information and awareness programs, a range of interventions can further influence energy behaviours, including feedback through real-time energy use data through digital devices, customer engagement and demand programs to steer changes in energy use over time, smart policy and program design to ensure that default usage options are also the cleanest and most energy efficient.[333] UK research has shown that providing regular feedback on energy use through measures such as feedback displays and better billing can result in household energy savings of up to 15%.[334] Targeted training programs for trades and services sectors (for example, plumbers, electricians, heating and cooling technicians, architects and real estate property managers[335]) will also be an important element in changing energy behaviours, as these are the sectors which plan for and deliver energy efficiency to consumers.[336]

The decarbonisation of our energy supply will require significant changes to energy infrastructure across the landscape and in people's homes. As a leader of the transition to net zero and with a significant role in planning, government will also need to build community acceptance of these changes, ensuring that negative impacts are minimised, any safety risks are addressed and that all Victorians can share in the benefits.

326 International Energy Agency (2021) *Net Zero by 2050: A Roadmap for the Global Energy Sector*

327 COAG Energy Council (2019) *COAG Report for Achieving Low Energy Existing Homes*

328 Energy Consumers Australia (2020) *Energy Consumer Sentiment Survey December 2020*

329 Newgate Research (2018) *Research Report on Energy Efficiency in Rental Properties*

330 White K, Habib R, and Hardisty DJ (2019) *How to SHIFT Consumer Behaviors to be More Sustainable: A Literature Review and Guiding Framework, in Journal of Marketing, Vol. 83(3) 22-49, 2019*

331 COAG Energy Council (2019) *COAG Report for Achieving Low Energy Existing Homes*

332 Department of State Development Business and Innovation (2014) *Business Impact Assessment Victorian Energy Efficiency Target*

333 International Energy Agency (2021) *The Potential of Behavioural Interventions for Optimising Energy Use at Home*

334 Martiskainen M (2007) *Affecting Consumer Behaviour on Energy Demand: Final report to EdF Energy*

335 Newgate Research (2018) *Research Report on Energy Efficiency in Rental Properties*

336 US Department of Energy and US Environmental Protection Agency (2006) *Energy Efficiency Program Best Practices, in National Action Plan for Energy Efficiency*

Case Study

Israeli campaign highlights water saving as a way of life, not just in drought

With an average annual rainfall of about 1.2 billion cubic metres or 555mm,[337] Israel is ranked number two behind Qatar in the World Resources Institute National Water Stress Rankings.[338]

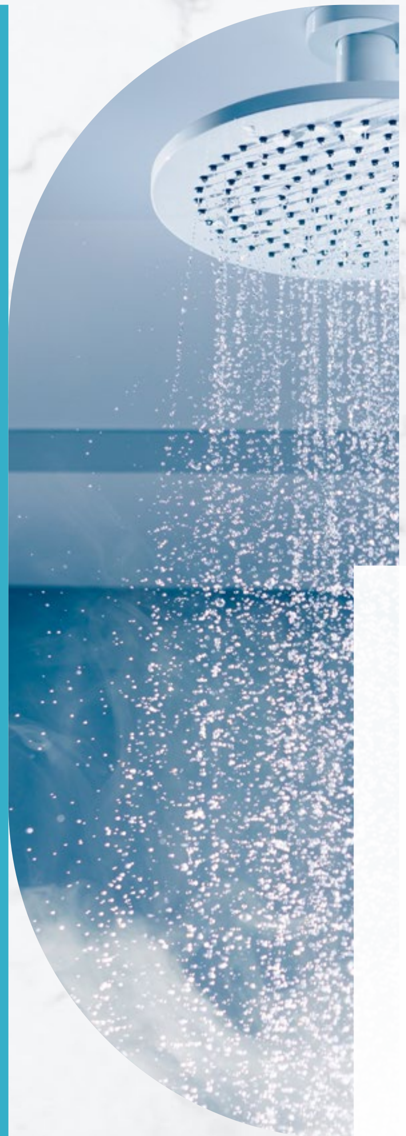
Through sustained water saving campaigns in the 1990s and 2000s, the Israeli Water Authority found it could save between 10-20% of water annually with a sustained behaviour change campaign. The authority found decreasing home water consumption by 7% is the equivalent of saving 50 million cubic metres of water, or approximately half of a new desalination plant – which are very expensive to build and require a lot of energy to run. However, as desalination plants came online and leaders started singing the praises of desalination, Israelis figured their days of water saving were over.

The campaign ceased in 2013 and average use rose again. In 2018, the Water Authority unveiled a large public information campaign entitled "Israel is drying out… again," aimed at reminding Israelis that saving water at home is still important, even if 70% of the country's drinking water comes from desalination plants. The goal of the latest campaign is to encourage Israelis to limit their use of water as a way of life, not just during drought.[339]

337 Schor U (2019) *Presentation to Liveability Victoria International Knowledge Exchange Series: Water Efficiency, Demand Management and Behaviour Change*

338 World Resources Institute (2019) *17 Countries, Home to One-Quarter of the World's Population, Face Extremely High Water Stress* (website)

339 Sedley D (2018) *Israel is Drying Out Again: Water Authority Relaunches Conservation Campaign, in The Times of Israel*



4.4.5 Targeted measures will be needed to manage the impact of the energy transition

The scale of the transition required, for both gas and electricity networks, is likely to result in increased energy costs for consumers in the future.[340] Future energy costs will be influenced by a range of factors, including the specific energy mix, production costs and demand. Energy prices are not explored in detail in this advice. However, our scenarios have sought to quantify the relative magnitude of energy infrastructure costs to 2050 in different future energy mixes.

Each of the scenarios we modelled saw an increase in infrastructure costs to 2050 relative to a more 'business as usual' control scenario that does not achieve net zero emissions. This enables us to estimate each scenario's cost of achieving net zero. Our scenario analysis also estimated, for example, that production costs for renewable gas could be up to three times the historical gas cost,[341] and higher production costs will likely flow through to end-users in their energy bills. Appropriate policy settings will need to be in place to manage these changes, supported by an immediate and sustained focus on energy efficiency to help consumers manage the impact of any increase in energy costs (see section 4.3.1).

Our review of energy efficiency measures in other jurisdictions has highlighted important principles for policy and program design

Maximising the benefits and outcomes achieved through energy efficiency will require a long-term policy focus and an emphasis on long-term benefits, both of which require ongoing funding certainty.

Retrofitting energy efficiency measures to existing buildings must ensure safety and effectiveness once installed. Accreditation and training for the service industry is critical to ensure measures are safe, effective and appropriate. Programs that are targeted and tailored to different market segments are more effective.[342] Partnerships can also enhance the effectiveness of energy efficiency efforts. Engagement and, ideally, co-designing initiatives with consumers (both households and businesses[343]) and utility providers will ensure consumer needs and priorities are addressed and facilitate maximum reach and effectiveness.

We consider that, at a minimum, energy efficiency programs should incorporate the following principles:

- Provide long-term benefits and ongoing funding certainty (i.e. avoid short-term funding that ceases).
- Ensure safety and appropriateness of products and installations
  - Include pre-installation inspections (e.g. for insulation)
  - Accreditation and training for the service industry
  - Post-installation inspection to ensure quality and appropriateness of installation.
- Engage with community, businesses and utility providers to develop and refine programs
  - Evaluate existing programs and use results to refine programs
  - Ensure that energy policies and interventions are consumer centred.
- Incorporate tailored measures which are targeted to different market segments.
- Include a strong communication strategy, supported by education initiatives to ensure broad community awareness and understanding.
- Include behavioural interventions to ensure longer-term behaviour change (and reduce the likelihood of consumers increasing their energy use in line with any cost savings realised through energy efficiency measures).
- Include a focus on low-income/disadvantaged cohorts (including renters) who are unable to afford the upfront investment but have the most to gain from saving money on energy bills.
- Incorporate an evaluation strategy from the outset.
- Work with other Australian governments to harmonise policies and programs where appropriate (for example, product registration).
- Consider the role of programs in developing a market for energy efficient products and services.

340 Energy Consumers Victoria (2021) *Submission to Infrastructure Victoria's Gas Advice*

341 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

342 Russell-Bennett R, McAndrew R, Gordon R, Mulcahy R and Letheren K (2019) *Effectiveness of Household Energy Efficiency Interventions in Advanced Economies – What Works and What Doesn't*

343 Singh J (2016) *Why Energy Efficiency Matters and How to Scale it Up, in Live Wire, 2016/53*

An equitable energy transition will require targeted measures

If there is a significant shift away from energy gas for Victorian households and businesses, those remaining on the gas network would face a greater share of the gas network costs. Fuel switching to low emissions gases such as hydrogen or to electricity would require households to change their appliances and could represent a significant upfront cost. Energy efficiency improvements can help consumers manage some of the impact of increased energy prices, however low-income households will be less able to afford the costs involved either in fuel switching or in energy efficiency upgrades. There is a risk that a greater share of the costs of the energy transition will be faced by those least able to afford them. Governments have a role in managing the affordability and equity issues associated with the gas sector's transition to net zero emissions.

Low-income households and many in rented homes are already more vulnerable to energy affordability stress.[344] They spend a greater proportion of their disposable income on energy than high-income households,[345] and this can be exacerbated if they live in poorer quality housing. There is evidence of significant health benefits from improvements to the thermal performance of houses, especially for low-income households.[346,347] Social housing tenants are highly vulnerable to energy price rises, and often cope with any cost increases by cutting their energy use.[348] This has potential adverse health impacts. Research from Sustainability Victoria found that around two-thirds of Victorians in public housing felt their home was too hot in summer and too cold in winter, while almost half have had to leave their home at some point because of extreme heat or cold.[349] This will be exacerbated with more extreme weather predicted in the decades ahead. Low-income renters have much to gain from energy efficiency upgrades.

The costs of energy efficiency measures are often a barrier for low-income households.[350] Renters face additional barriers, including short-term rental arrangements and split incentives, which occur when the person paying the energy bill is not the same as the person making energy efficiency investment decisions on the property. Landlords often do not see enough benefits to justify the investment.[351] They also cite tax arrangements as a disincentive to invest in energy efficiency. While repairs and maintenance are tax deductible, energy efficiency improvements are not.[352]

Building standards are an effective way of delivering energy efficiency improvements to buildings. In Victoria, better building standards have led to higher quality dwellings. The average Victorian home built before 1990 achieved around a 1.6 star energy rating while those built from 1990 to 2005, following the introduction of mandatory building standards for new homes, achieved an average of 3.1 stars.[353] However, building standards only apply to new homes and to some renovations. Encouraging adaptation in existing homes is more difficult and renters also need the consent of the landlord to make changes to their home. More attractive, better quality homes can also attract higher rents. Improving the energy efficiency of a rental property could lead to rent increases – meaning less affordability for low-income households.

The *Independent review into the future security of the National Electricity Market* found that existing energy policies are failing to effectively target households who are most vulnerable to energy affordability stress and in some cases are increasing inequity by subsidising those already able to afford upgrades.[354] Energy efficiency programs specifically designed and targeted to address the barriers faced by low-income households to improve their energy efficiency and to switch fuels will be critical to ensure that the transition to net zero is equitable. Subsidy programs which address the barriers, rather than subsidise the resulting costs, are recommended as government interventions should primarily address market failures. In addition to the features outlined for all energy efficiency programs outlined above, low-income energy efficiency programs should focus on market segmentation and targeted offerings, partnerships and consideration of non-energy benefits (which may mean supporting a greater range of energy efficiency measures such as insulation).[355]

Developing subsidy programs with an equity objective is especially challenging in relation to rental properties. This is due in part to the payback period of some energy efficiency upgrades relative to the length of tenancy agreements. The payback period for ceiling insulation upgrades can be over six years, for example, when considering only the direct energy benefits.[356] There is also the risk that energy efficiency improvements could encourage landlords to increase rents, outlined above, with government subsidies flowing directly to landlords while low-income renters are further disadvantaged.[357] However, despite these challenges the onus is on governments to ensure that the benefits associated with energy efficiency upgrades extend to all and that the costs of the energy transition are not shifted to those least able to afford them.[358]

Changes to the *Residential Tenancies Act 1997* made in 2018 introduced minimum standards for rental homes, including the power to include better energy and water efficiency requirements.[359] These currently contain only very basic standards, such as requiring a minimum 2-star heater.[360] The Victorian Government is planning to introduce further minimum energy efficiency standards for rental homes covering insulation, draught sealing and hot water, subject to a Regulatory Impact Statement.[361]

In *Victoria's infrastructure strategy 2021-2051*, we recommended that the Victorian Government increase minimum energy efficiency standards in the next three years to reduce energy use and costs in rented homes. During the next 15 years, we recommended the Victorian Government keep updating these standards to reflect new cost-effective measures, and improve renters' ability to make home energy efficiency improvements.[362] Our research has shown that upgrading space heaters to energy efficient heat pumps can deliver significant energy efficiency benefits.[363] As rented homes comprise around 29% of Victorian homes,[364] this could achieve significant energy and emissions savings in addition to reducing energy bills for renters and contributing to an equitable transition to net zero emissions. Energy efficiency programs such as the Victorian Energy Upgrades program could be used to support rental property owners in meeting these requirements.

344 COAG Energy Council (2019) *COAG Report for Achieving Low Energy Existing Homes*

345 ACCC (2017) *Retail Electricity Pricing Inquiry Preliminary Report*

346 Sustainability Victoria (2019) *Comprehensive Energy Efficiency Retrofits to Existing Victorian Houses*

347 Daly D, Halldorsson J, Kempton L and Cooper P (2018) *Targeted Review of Evidence of Direct and Co-benefits of Energy Efficiency Upgrades in Low Income Dwellings in Australia*

348 Daly D, Halldorsson J, Kempton L and Cooper P (2018) *Targeted Review of Evidence of Direct and Co-benefits of Energy Efficiency Upgrades in Low Income Dwellings in Australia*

349 Sustainability Victoria (2020) *Linking Climate Change and Health Impacts – Social Research Exploring Awareness Among Victorians and our Healthcare Professionals of the Health Effects of Climate Change*

350 Berg W, Cooper E and Molina M (2021) *Meeting State Climate Goals: Energy Efficiency Will Be Critical*

351 Newgate Research (2018) *Research Report on Energy Efficiency in Rental Properties*

352 HVAC HESS (2013) *Overcoming Split Incentives*

353 Sustainability Victoria (2016) *Energy Efficiency Upgrade Potential of Existing Victorian Houses*

354 COAG Energy Council (2019) *COAG Report for Achieving Low Energy Existing Homes*

355 Gille A, Nowark S and Drehobl A (2017) *Making a Difference: Strategies for Successful Low-Income Energy Efficiency Programs*

356 Sustainability Victoria (2019) *Comprehensive Energy Efficiency Retrofits to Existing Victorian Houses*

357 COAG Energy Council (2019) *COAG Report for Achieving Low Energy Existing Homes*

358 Berg W, Cooper E and Molina M (2021) *Meeting State Climate Goals: Energy Efficiency Will Be Critical*

359 Consumer and Other Acts Miscellaneous Amendments Bill 2020 – Amended Print Explanatory Memorandum, Clause 101

360 Residential Tenancies Regulations 2021 s.29 and Schedule 4 s.14

361 Department of Environment, Land, Water and Planning (2021) Energy Sector Emissions Reduction Pledge (website)

362 Infrastructure Victoria (2021) *Victoria's Infrastructure Strategy 2021–2051*

363 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

364 Australian Bureau of Statistics (2016) *2016 Census QuickStats – Victoria*

Victoria's concession program aims to make essential services more affordable for low-income households and those experiencing hardship. It includes a variety of benefits to assist with energy bills and energy affordability.[365] In the event energy costs for consumers rise during the transition to net zero, it is likely that increasing numbers of Victorians will need assistance to meet their energy costs and the concession program will need to be prepared for this.

The Victorian Government will also need to consider particular households that may be disadvantaged through the transition including consumers that are not connected to the electricity grid and rely on bottled gas. It will be important that the *Gas substitution roadmap* considers the impacts for these Victorians to ensure they are not excluded from transition plans.

The Victorian Government's Victorian Energy Saver program includes several initiatives aimed at low-income and rental households, including $335 million to deliver heating and cooling systems, $112 million for energy upgrades to social housing properties and $128 million for bonus payments to help concession card holders with bills.[366] The Victorian Government should increase the scope and scale of energy efficiency programs targeted to low-income and rental households, and increase minimum energy efficiency requirements in rental properties, to help them reduce their energy use and minimise the impact of increased energy costs on household energy bills (see *Recommendation 6*).

365 Department of Families, Fairness and Housing (2021) *Concessions & Benefits* (website)

366 Department of Environment, Land, Water and Planning (2021) *Victoria's Household Energy Savings Package* (website)

In the event energy costs rise during the transition to net zero, it is likely that increasing numbers of Victorians will need assistance to meet their energy costs.

There are opportunities to strengthen support for the commercial development of low emissions gases

Overseas experience indicates that consistent policy support, combined with industry partnerships, will be central to development of low emission gases at scale.[367,368] There are opportunities for the Victorian Government to strengthen support for the commercial development of renewable and low emissions gases to help lower production costs, working collaboratively with industry, researchers and the Australian Government. These include developing production targets and providing additional support for trials and demonstration projects.

Stakeholders have suggested other opportunities to foster development of renewable and low emissions gases, including a renewable gas target. This could take the form of a general target against which to track emissions reductions, or a blending target for gas networks which target a specific level of natural gas displacement with hydrogen and biomethane. A renewable gas target could be implemented in several different ways, for example:

- Placing a liability on retailers/wholesale purchasers of gas to purchase a certain level of renewable gas each year, creating a market for supply and demand through regulatory obligations
- A contract-for-difference arrangement, where the government auctions contracts for renewable gas suppliers that provide a guaranteed price for the renewable gas, providing more certain revenue for project finance
- Direct government subsidy for renewable gas projects, such as though a competitive grants allocation process

Any scheme would need to be supported by certification of renewable gases, such as the one currently under development by the Australian Government.[369] For instance, green hydrogen production will require renewable electricity to create the hydrogen. As the electricity grid is not fully decarbonised, a hydrogen producer would need to secure green electricity through Power Purchase Agreements with a renewable generator, accredited Green Power, or own-source renewable electricity. The certification scheme will set out the requirements for verification and provide transparency for the energy source used in producing renewable gases.

Before committing to a blending target policy, the government will need to consider whether the cost of infrastructure upgrades is included in such an arrangement, or only the cost of incentivising the technology. All schemes would need to consider who will bear the infrastructure upgrade costs and/or the risk of upgrading networks to be hydrogen-ready in the event hydrogen does not become cost competitive with other energy sources.

The need to upgrade networks to accommodate certain types of low emissions gas makes policy development more challenging. If policy objectives are linked to gas network decarbonisation, it can embed an infrastructure solution which has technical and implementation hurdles, including upgrading the network to support pure hydrogen and switching to hydrogen appliances. We consider that the aim of any policy should be to support emissions reduction, rather than directly link to use of gas infrastructure.

367 ENEA and Deloitte (2021) *Australia's Biogas Roadmap*

368 Accenture (2021) *Gas Infrastructure: International Comparisons*

369 Department of Industry, Science and Resources (2021) *Hydrogen Guarantee of Origin Scheme: Have Your Say* (website)

Consider measures to maximise benefits and manage localised workforce impacts

The transition of the gas sector to net zero will have implications for the nature and distribution of jobs and skills. The natural gas sector employs, directly and indirectly, many Victorians in production, supply, maintenance, appliance manufacture and servicing, including around 20,000 registered and licensed gasfitters.[370] Skills and capabilities in these workforces will need to adapt to meet the requirements of new technologies.

The energy transition will also bring new employment opportunities. Our scenario analysis has highlighted the potential for new job opportunities in all energy futures, in both metropolitan and regional areas, as new energy projects come on board. A more dispersed energy generation system is likely to benefit regional Victoria in particular. Estimates suggest that around 70% of renewable energy job opportunities to 2035 could be distributed across regional areas.[371]

The Victorian Government should provide support to maximise the benefits to the state from these opportunities through local content requirements under the *Local Jobs First Act 2003*, ensuring that government procurement is specified to maximise local industry participation and, if appropriate, providing additional support to establish and/or develop a local industry.

New energy sources will have a different distribution than current energy generation with renewable energy generation primarily located in places with good sun and wind resources. This will impact individual people and businesses (through direct and indirect employment impacts) as well as local communities. Given the scale of new projects likely to be undertaken within each Renewable Energy Zone (REZ), the Victorian Government should consider undertaking a 'strategic level assessment' for each REZ and for offshore wind (rather than just 'project-by-project assessments') to address and manage the cumulative impacts of these projects on particular locations and communities.[372]

The future energy mix will also require a workforce with different skill sets. The Victorian Government's Clean Economy Workforce Skills initiative aims to support Victorian workers, businesses and the training system as the economy transitions to net zero. It includes a Jobs and Skills Taskforce to help prepare for the workforce implications of the transition to net zero emissions. The taskforce will develop a 10-year workforce strategy exploring renewable energy, circular economy practices and climate change adaptation, to help ensure the gas sector workforce can develop the skills needed to support industry decarbonisation.[373]

The Victorian Government may need to consider targeted worker support for employees in the gas industry to aid their transition to new roles within the economy. This may be needed particularly if there is policy uncertainty, insufficient lead times, significant localised impacts and low adaptive capacity of impacted regions. Government support is likely to focus on retraining and, in addition to direct employment impacts, should also consider employees within the supply chain (including gas fitters and employees in gas appliance manufacturing). The Victorian Government may also need to consider support for impacted local communities, especially where there are concentrated economic impacts and low adaptive capacity.

370 Department of Environment, Land, Water and Planning (2021) *Victoria's Gas Substitution Roadmap Consultation Paper*

371 Clean Energy Council (2020) *Clean Energy at Work*

372 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

373 Premier of Victoria The Hon Daniel Andrews (2021) *Driving Force for New Skills Authority Announced* (media release)

4.4.6 Government can play a leadership role in demonstrating how net zero can be achieved

The Victorian Government has set interim emissions reduction targets to support the legislated net zero emissions goal by 2050, and developed pledges which outline the actions it will take to cut emissions from key sectors and from its own operations.[374] It has committed to reduce emissions by switching to clean energy sources and managing energy demand.[375]

The Victorian Government also supports local governments to address climate change impacts through local adaptation projects and activities.[376] Some local governments have set ambitious net zero emissions targets for all council operations by 2030, or for the local government area as a whole by 2040.[377,378,379]

Significant components of the Victorian Government's own natural gas use are not well understood. While there is a clear commitment to achieving net zero for electricity used in government operations by 2025,[380] similar plans have not been published for its gas use. The Victorian Government can play a key role in demonstrating how a net zero target can be achieved. A clearer position on the role of natural gas within its own emissions reduction actions will provide greater clarity and investment in future pathways for other stakeholders (see *Recommendation 9*).

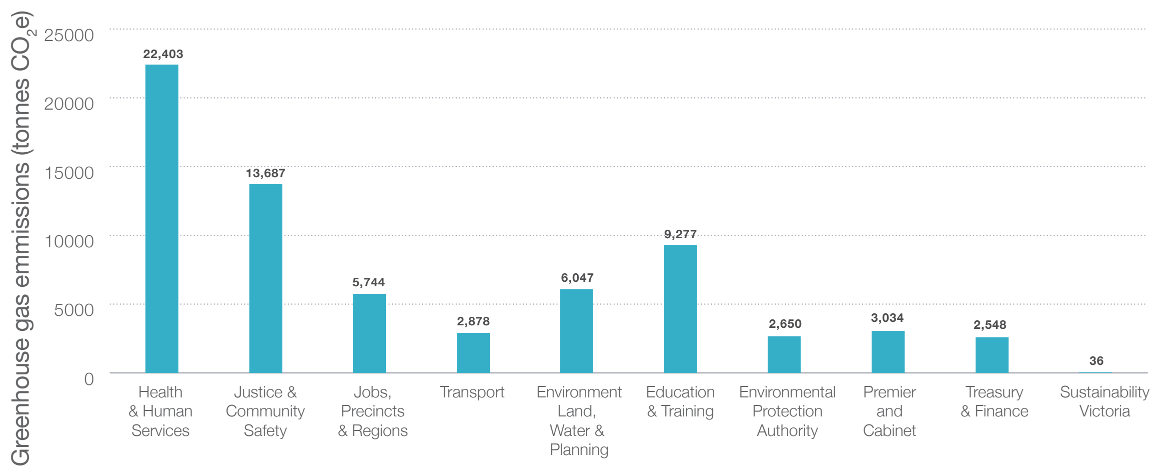
A clearer position on the role of natural gas within the government's own emissions reduction actions will provide greater clarity and investment in future pathways for other stakeholders.

There are opportunities to expand the scope of government energy use and emissions reporting

The Commissioner for Environmental Sustainability monitors how individual departments and agencies are improving environmentally sustainable practices through the annual *Strategic audit of environmental management systems*.[381] The audit covers mandatory annual reporting on energy use and greenhouse gas emissions associated with office-based activity by Victorian Government entities. Total office-based energy use of 0.3 PJ was reported in 2019-20, of which one-quarter was estimated to be natural gas. Greenhouse gas emissions associated with office-based energy were 68 kilotonnes (kt) CO_2e, as illustrated in Figure 32.[382]

However, as acknowledged in the audit, office-based emissions are only a small fraction of overall greenhouse gas emissions contributed by Victorian Government entities. For example, the Department of Health and Human Services reported greenhouse gas emissions associated with hospital operations (which are beyond the scope of mandatory reporting covered by the audit) of 871.7 kt CO_2e in 2019-20. Office-based emissions therefore represented less than 5% of the department's total emissions in this period. Energy use and associated emissions in schools are not included within the scope of mandatory reporting; prisons are also out of scope.[383] Expanding the scope of mandatory annual reporting to cover all government operations will increase transparency and assist in managing overall progress towards Victoria's net zero goals.

Figure 32: Victorian Government office-based emissions by entity – 2019-20 (tonnes CO_2e)



Source: Commissioner for Environmental Sustainability (2021) *Strategic audit 2019-20*

374 Department of Environment, Land, Water and Planning (2021) *Victorian Government Action on Climate Change* (website)
375 Department of Environment, Land, Water and Planning (2021) *Cutting Victoria's Emissions 2021-2025: Energy Sector Emissions Reduction Pledge*
376 Department of Environment, Land, Water and Planning (2021) *Victoria's Climate Change Adaptation Plan 2017–2020*
377 Moreland City Council (2019) *Zero Carbon Moreland – Climate Emergency Action Plan 2020/21–2024/25*
378 Yarra City Council (2020) *Yarra Council Commits to Ambitious Climate Emergency Plan* (website)
379 Bayside City Council (2020) *Climate Emergency Action Plan 2020–2025*
380 Department of Environment, Land, Water and Planning (2021) *Cutting Victoria's Emissions 2021-2025: Whole of Victorian Government Emissions Reduction Pledge*
381 Commissioner for Environmental Sustainability Victoria (2018) *Strategic Audit of Environmental Management System* (website)
382 Commissioner for Environmental Sustainability (2021) *Strategic Audit 2019-20*
383 Commissioner for Environmental Sustainability (2021) *Strategic Audit 2019-20*

Whole-of-government natural gas use is not well understood

Significant components of government natural gas use are not well documented or understood, hampering preparations to achieve net zero emissions. Victorian Government departments and entities, including hospitals, schools, TAFE institutes and public buildings are expected to align with emissions reduction targets. However, energy use and emissions reporting, and the implementation of net zero plans and strategies vary across the organisations.

Schools and TAFE institutes

The education sector is estimated to be one of the largest users of natural gas among Victorian Government entities, although specific data is unavailable. Our energy efficiency analysis estimated annual gas use in Victorian schools (including private and Catholic schools) to be around 4 PJ, with space heating comprising about three-quarters of the total.[384] There is no mandatory environmental management reporting of energy consumption and greenhouse gas emissions for schools, and no central database to provide a complete overview.[385] TAFE institutes collectively reported 0.1 PJ gas use in their 2020 annual reports, but this data was not consistently reported for all institutes.

The Victorian School Building Authority (VBSA) intends to phase out natural gas to new and existing school sites in the future, although no specific timeframe has been set. Current VBSA guidelines indicate that excluding gas usage should be considered when determining the best method of heating within a school.[386] Phasing out natural gas will be easier to implement as new schools are built; existing buildings may require capital-intensive upgrades and further work is needed to understand the costs and opportunities.

The Greener Government School Buildings program provides upfront funding for schools to install solar power systems, which is repaid in instalments over time.[387] This program does not support other energy efficiency activities or the reduction of natural gas use within schools. Sustainability Victoria's ResourceSmart Schools program guides Victorian schools in implementing energy saving and emissions reduction measures.[388] The program includes a school energy use audit which identifies energy savings opportunities through retrofits, upgrades and maintenance. However, the program does not include funding to implement audit findings.

Hospitals

The healthcare sector, including public hospitals, is also estimated to be one of the largest gas users among Victorian Government entities. Our analysis estimated annual natural gas use of 4.5 PJ across hospitals, healthcare and social services, including the private sector.[389] Victorian public health services (including hospitals) reported natural gas use of 2.1 PJ in 2020-21.[390] Gas use in hospitals includes space heating, hot water and generating steam for sterilisation.[391]

The Victorian Health Building Authority is moving to all-electric buildings to support the 2050 net zero target. Its sustainability guidelines for capital works outlines that smaller health facilities (up to 10,000 square metres) should be all electric, but notes electrification constraints for some larger hospital facilities (over 10,000 square metres). Instead, capital works for larger facilities should seek to minimise gas use as much as possible and future proof an all-electric design.[392] A shift to all-electric would significantly flatten a hospital's electrical demand profile, with a consistently high load over summer and winter. There may be a need to augment electrical supply to sites. Larger plant rooms will be required for electrical equipment than is currently the case for natural gas, leading to additional capital costs for building all-electric hospitals.

Social housing

Reported gas use among Victoria's housing services, which includes high-rise dwellings, disability and youth accommodation and other public housing, was 0.4 PJ in 2020-21.[393] Under Victoria's Big Housing Build package, new housing will meet 7-star energy efficiency standards and include solar PV and all-electric appliances where possible,[394,395] although all-electric developments are not mandatory.

There are several existing energy efficiency programs to reduce the gas consumption of existing public housing. The EnergySmart Public Housing program delivered energy-efficiency upgrades to 1,500 low-rise public housing properties. The program aims to reduce energy costs and improve thermal comfort for participating public housing tenants by replacing gas space and water heaters with heat pumps and upgrading the building thermal shell.[396] These and similar programs should be continued (see *Recommendation 6*).

Public buildings

Public buildings like law courts, museums, galleries and libraries largely use natural gas and bottled gas for heating and cooling. However, compared to schools and hospitals the gas use is relatively low, suggesting these organisations may not need be prioritised in the immediate term or addressed on a case by case basis.[397]

Local governments

Many local governments have set ambitious net zero emissions targets, aiming to reach net zero for all council operations by 2030 in some instances.[398,399,400] A key focus for some councils is to replace natural gas with renewable electricity, prioritising small sites for early adoption of all-electric appliances before moving on to larger, more complex facilities such as libraries, aquatic centres and town halls.[401] There is scope for the Victorian Government to review and apply the lessons learned by local councils to their own gas use, as well as to fund programs to encourage all local governments to reduce emissions.

Aquatic and recreation centres are typically the largest energy consuming facilities for local governments. Pool water heating typically accounts for 60% to 80% of an aquatic centre's energy usage, with gas boilers the most commonly-used heating technology. Electric heat pumps offer the best energy efficiency improvements to reduce natural gas use, but their use is not widespread in Victoria.[402]

Victorian Government departments and entities, including hospitals, schools, TAFE institutes and public buildings are expected to align with emissions reduction targets.

384 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

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398 Moreland City Council (2019) *Zero Carbon Moreland – Climate Emergency Action Plan 2020/21 – 2024/25*

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402 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

Case Study

Local councils move to phase out gas in aquatic and recreation centres

Local councils across Melbourne are improving energy efficiency and phasing out gas across their operations. In Melbourne's north, Darebin City Council has committed to reaching net zero greenhouse gas emissions across the municipality by 2030. By switching to air source heat pumps at Northcote Aquatic Centre, and choosing 100% Green Power, the council will reduce its emissions by 10-15%. The new carbon neutral centre will include a high-performance building envelope and double glazing. It will be the first indoor aquatic facility in Australia to reach the highest Green Star Rating of 6 stars.[403]

Neighbouring Moreland City Council is committed to zero carbon by 2040. Moreland has a long history of actively decarbonising council operations, recently focusing on energy efficiency improvements and renewable energy generation,[404] and supporting the community to do the same. Since 2012, the council has reduced its emissions by 70% with a range of initiatives including rolling out solar on its facilities, electrifying over a third of its light vehicle fleet and, more recently, sourcing 100% renewable electricity for all council buildings.[405] Of remaining emissions, 60% are due to transport fuels used by council's own fleet and contractors, and 30% from natural gas used for heating aquatic centres and buildings. Four heated aquatic centres account for 89% of council's gas consumption. The remaining gas is consumed by council's civic and community centres. Around 80% of gas consumption at aquatic centres is used for pool water heating, while the rest is used for air conditioning and domestic hot water.[406]

Moreland City Council aims to transition its facilities away from gas to electric heat pumps. Complementary measures to increase energy efficiency include upgrading the thermal building performance for indoor pools and using pool blankets to trap heat. Moreland has installed heat pumps at six sports pavilions, two community centres and administrative offices. After carrying out feasibility studies for all of Moreland's aquatic centres, an all-electric design for the planned refurbishment of Moreland's Fawkner Aquatic Centre is currently out for public consultation.[407] Moreland is also encouraging the community and private sector to electrify, with all-electric developments encouraged through the Design Excellence Scorecards initiative and the soon to be launched, Go electric campaign. When combined with 100% renewable electricity, electric heat pumps guarantee emissions savings and avoid locking in future gas use.

Other examples of switching to heat pumps include the St Albans Leisure Centre in Brimbank and the Carnegie Swim Centre in Glen Eira. Heat pumps are a mature technology and cheap to run,[408] however the up-front costs of moving an aquatic centre with an outdoor pool off gas is expensive, at between $1 million and $4 million. Heat pumps also require extra plant room, which can be an issue if there are heritage restrictions. Another key barrier is the need to upgrade electrical infrastructure to deal with the higher electricity demand. Moving an aquatic centre off gas can incur costs of up to $350,000 to upgrade local electric sub-stations. However, modelling does suggest that all-electric aquatic centres are slightly cheaper to run than gas-powered centres. Purchasing 100% Green Power ensures they are also carbon neutral.

403 Darebin City Council (2021) *Find Answers to our Frequently Asked Questions Relating to the Proposed New Facility* (website)

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407 Moreland City Council (2021) *Moreland Council to Phaseout Gas in Fawkner Leisure Centre* (website)

408 Moreland City Council (2021) *Submission to Infrastructure Victoria's Gas Advice*

▽ **Figure 33:** Brunswick Baths outdoor heated pool
Source: Provided by Moreland City Council

Better data would support efforts to reduce emissions associated with natural gas use

Timely, reliable and detailed data on energy use and associated emissions will be a critical tool for governments, the private sector and consumers in managing the transition to net zero emissions. Reliable data can inform policy and program design, corporate strategy and consumer choices.

Our experience in developing this advice has highlighted many examples where improvements could be made to data quality and completeness, including:[409,410]

- Detailed energy consumption data, with breakdowns provided for each user group, industry sector, and energy type
- Energy demand forecasts with breakdowns by user group, industry sector, and energy type
- Detailed emissions data, with breakdowns provided by industry sector and energy type
- Uptake and fuel consumption forecasts for low emissions road vehicles (including light and heavy vehicles)
- The scale of energy efficiency improvements in the residential and commercial sector
- Agreed definitions for emissions offset factors
- Data on concession household composition, home and appliance age, energy use and spending.

The technical studies which inform this advice have through necessity relied on estimates and simplifying assumptions in completing the analysis. Further details are available in the technical reports, available on our *website.*

409 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

410 Northmore Gordon and Energeia (2021) *Cost Benefit Analysis of Energy Efficiency Activities in the Gas Sector*

5.

What stakeholders told us

Infrastructure Victoria is committed to meaningful consultation with community and industry stakeholders. We develop our advice and recommendations through an open, evidence-based and transparent process.

The consultation program for this advice included two main phases. The first phase ran from March to May 2021. Engagement activities included targeted questionnaires to key stakeholders, with questions tailored to each stakeholder group (universities and think tanks; government; consumer groups; industrial users; producers and distributors). The questionnaires were supplemented with one-on-one meetings with individual stakeholders.

We captured a broad representation of views from organisations and individuals across the gas sector, business, industry and government. Their valuable input helped us to refine the scope of our research and analysis. We also considered relevant submissions from stakeholders that were provided in response to *Victoria's draft 30-year infrastructure strategy r*eleased by Infrastructure Victoria in December 2020.

We released our evidence base report *Towards 2050: gas infrastructure in a zero emissions economy – interim report* for consultation in July 2021. This report discussed the findings of technical research we undertook and commissioned in developing the evidence base. Public consultation on the interim report was invited from 19 July 2021 to 16 August 2021.

The feedback we received from stakeholders has provided valuable insights on stakeholders' priority issues and concerns and has informed our final advice and recommendations. Infrastructure Victoria would like to thank everyone who contributed to this work.

In our interim report we posed nine questions for response:

1. Do you have any further information, evidence or concerns that you wish to raise in relation to the scenario design and analysis?
2. Do you have any further information or evidence that can help identify an optimum scenario for a net zero emissions gas sector in 2050?
3. What policies and/or regulations, if any, are needed to support the development of low carbon pathways such as biogas, green hydrogen, and carbon capture and storage?
4. What is your view on the best ways to maintain the reliability and affordability of Victoria's gas supply if natural gas use declines?
5. What else can you tell us about the implications of decarbonisation pathways for the electricity generation, transmission and distribution networks?
6. How can the use of Victoria's existing gas infrastructure be optimised during the transition to net zero emissions, over the short (10 years), medium (20 years) and long-term (30+ years)? How can the Victorian Government assist in this?
7. What principles should apply or what measures will be needed to manage the impacts of gas decarbonisation on households and businesses?
8. What policies, programs and/or regulations should the Victorian Government consider or expand to encourage households, commercial buildings and small businesses to reduce their gas use?
9. What policies, regulations or other support, if any, do you think are needed to support industrial users to switch from natural gas to lower emissions energy sources or chemical feedstocks?

We received 121 submissions from individuals, organisations, businesses and local governments. Submissions reflected a diversity of opinions, as would be expected from such a wide range of stakeholders on an issue which directly affects so many Victorians. However, there were several key themes that emerged in the feedback we received.

A summary of the most common issues and how they relate to our final advice to the Victorian Government is below. Public submissions are available at *infrastructurevictoria.com.au*

In October 2021, we hosted workshops with key stakeholders representing the energy sector, consumers, industry and the environment. Attendees provided input into our findings and advice covering the future of energy gas, the increased interaction between electricity and gas supply, and energy efficiency.

The feedback we received from stakeholders has provided valuable insights on stakeholders' priority issues and concerns and has informed our final advice and recommendations. Infrastructure Victoria would like to thank everyone who contributed to this work.

Victoria's transition to net zero emissions

The need to accelerate the transition to net zero emissions as an urgent response to climate change was a strong theme in many submissions, particularly those from local governments and the community. Many cited the sixth assessment report from the Intergovernmental Panel on Climate Change to support their position.

Many submissions and subsequent input at stakeholder workshops acknowledged, however, the importance of balancing speed with a managed approach to avoid unintended consequences. Some stakeholders highlighted the benefits of focusing on known solutions and technologies in the short term, to allow time for emerging technologies to be further developed. This approach has informed our approach to energy efficiency measures and aligns with our thinking on the importance of keeping Victoria's options open rather than locking in a single approach.

The net zero 2050 scenarios used for our analysis

Stakeholders provided considerable feedback on the four net zero gas sector scenarios presented in our interim report and analysed by DORIS Engineering. A broad range of views was represented from all stakeholder groups. *Scenario A: full electrification, no natural gas* received the strongest support, particularly among community responses. The complexity of the issue was reflected in many of these submissions, however, with recognition that this would be a long-term process and that electrification may not be achievable for all current users of gas.

Energy security was raised as a key issue in Scenario A, as an increasing proportion of electricity was generated from renewable sources. Some submissions saw an ongoing role for natural gas in electricity generation, to balance variations in supply from renewable sources and to meet peak demand (aligned with *Scenario B: partial electrification supported by natural gas*). Others saw the benefits of the diversified energy supply outlined in *Scenario C: zero emissions hydrogen with biogas and electrification*, particularly in the potential for green hydrogen development.

We received suggestions for additional scenarios to be explored in the second phase of our analysis, for example, increased use of existing gas infrastructure, a greater role for biogas in the energy mix, further exploration of hydrogen blending and a stronger role for energy efficiency and demand management measures. Where possible, we incorporated these suggestions in the second iteration of our scenario analysis.[411]

Several submissions suggested a role for nuclear energy in our scenario analysis as it is a zero emissions fuel. We did not pursue this suggestion as nuclear power generation is prohibited by both Victorian and Commonwealth legislation. We recognise that the scenarios provide a simplified view of Victoria's energy market. The scenarios are designed to be illustrative and to test key variables and uncertainties regarding the potential future energy mix. They are not intended to represent an optimal scenario.

A role for gas in the future energy mix

Views varied on a potential role for gas – either natural gas or renewable gases such as green hydrogen or biomethane – in the future energy mix. Many submissions supported a move to increased electrification and a rapid phase-out of natural gas use. However, others pointed out that too rapid a transition to electricity could increase emissions in the short term, given the proportion of Victoria's electricity currently produced by coal-fired power stations.

Some stakeholders expressed concerns that full electrification from renewable sources would threaten Victoria's energy security. Several submissions supported an ongoing role for natural gas in electricity generation, to balance variations in supply from renewable sources of electricity. Others could see a future where Victoria's reliance on natural gas declines over time, to be replaced by renewable gases such as green hydrogen – helping to ensure a diversified energy supply.

Hydrogen, particularly hydrogen produced using renewable energy, received a lot of interest in the submissions we received. Submissions were generally positive about its future potential, particularly as a replacement for natural gas in industry, for heavy transport, or in situations where electrification may not be possible. Some submissions anticipated widespread future hydrogen uptake in households and businesses as the gas distribution network switches to full hydrogen supply. The potential role for biogas or biomethane received much less attention. Submissions discussing biogases were generally positive about its future potential, but as a localised option rather than a system-wide solution due to likely constraints in supply.

411 DORIS Engineering (2021) *IV128 Net Zero Emissions Scenario Analysis Stage 2 – Study Report*

The future for gas infrastructure

Views on the future for gas infrastructure were aligned with stakeholder opinions on the role gas could play in the future. Many of those who supported electrification advocated immediate halting of new gas connections, followed by targeted retirement of sections of the gas network over time. A phased approach was proposed to minimise the impact on gas users and to allow additional time to transition hard-to-abate industries.

On the other hand, stakeholders who foresaw an ongoing role for gas (either natural gas or substitutes) flagged the importance of retaining choice, flexibility and future optionality for consumers. Concerns were raised about locking households out of future technologies should household hydrogen use become a reality.

We received feedback that our interim report over-simplified gas infrastructure, rather than differentiating between types such as production, transmission and distribution infrastructure. Submissions also suggested that our assumptions on the remaining utility of gas infrastructure should be revisited. The second phase of our work included a strategic assessment by Advisian of the different categories of gas infrastructure in Victoria, its condition, configuration and adaptability for future use. The next iteration of the scenario analysis, carried out by DORIS Engineering, also looked at the implications of significant ongoing use of existing natural gas infrastructure, in line with our *Terms of reference*. This work has helped shape our final recommendations and is summarised in the *technical reports* which accompany this advice.

Views varied on a potential role for gas – either natural gas or renewable gases such as green hydrogen or biomethane – in the future energy mix.

The importance of government action

Almost two-thirds of the submissions we received indicated that the Victorian Government will have a significant role in supporting decarbonisation of the energy sector and in providing policy certainty to industry and the community. In addition to Victorian Government action, however, several stakeholders stressed the importance of state and Australian governments working together to develop a coordinated national approach to decarbonise Australia's energy sector.

A wide range of potential policy levers were suggested, including regulatory reforms to enable hydrogen and other renewable gases. These included a renewable gas target to encourage technology development, a renewable gas certification scheme to help develop a market for renewable gas, and mandated introduction of 'hydrogen-ready' appliances.

The benefit of financial incentives to stimulate innovation was emphasised by some stakeholders. Examples included funding for biogas project hubs, continued use of trials to test emerging decarbonisation technologies and funding for gas blending demonstration projects.

Others raised a potential leadership role for government in publishing its own emissions reduction targets for all government buildings and operations, to demonstrate to the broader community how the transition to net zero emissions can be achieved. We have assessed all suggestions alongside other potential policy and regulation levers, to build our final advice to the Victorian Government.

Energy efficiency

Energy efficiency was an area of consensus among the submissions we received. Almost half of the submissions we received highlighted the importance of policies and programs to support energy efficiency and reduce overall energy demand, agreeing with our position that energy efficiency is a 'no regrets' measure which can reduce energy costs for consumers as well as contribute to emissions reduction targets.

There was broad support for the Victorian Government's Victorian Energy Upgrades program, alongside suggestions for expanding the program further – to include insulation, for example, or encourage fuel switching. Others referenced the former Environment and Resource Efficiency Plans program as an example of where energy efficiency measures had been successfully encouraged in industry.

Energy efficiency has been a major focus of our work since releasing our interim report, explored in detail in the work carried out for us by *Northmore Gordon and Energeia,* and reflected in *Recommendation 5* in this advice.

Implications of the energy transition for gas users

Many submissions and attendees at the stakeholder workshops focused on the significant change that will be required for natural gas users, whichever pathway ultimately leads to gas sector decarbonisation. A wide range of potential support measures were identified, including incentives, subsidies and rebates as well as community education and behaviour change programs. Stakeholders stressed that natural gas users will need clear and unbiased information on the various options available, to help them determine how they can contribute to achieving Victoria's net zero 2050 targets.

The potential cost to gas users was also an area of concern, for example the cost of switching from gas to electric appliances or of installing energy-efficient solutions such as insulation. Almost half the submissions we received stressed the importance of providing additional support for low-income and vulnerable households during the transition to net zero emissions, since they may face disproportionate barriers in the move to other solutions.

Several stakeholders pointed out that if a smaller proportion of households are connected to the gas network, network costs will be borne by a smaller number of consumers – likely to include those least able to afford the upfront costs of alternatives. The equity considerations of the energy transition have been a significant focus in our work, reflected in *Recommendation 6*.

6.

Methodology

We developed our advice to the Victorian Government in two phases of stakeholder engagement and technical analysis.

The first phase of the project was the delivery of our *interim report* in July 2021. This report combined findings from our initial stakeholder consultation with detailed modelling and analysis, supported by international examples for comparison.

The second phase, the focus of this report, articulates our advice and recommendations to the Victorian Government based on the evidence we have gathered, our further technical work and feedback we have received from stakeholders. This phase includes a second round of technical analysis, an open public submissions process and phase 2 stakeholder workshops which sought detailed feedback on our *interim report* and subsequent technical work.

Our technical work packages, summarised below, consider the infrastructure and policy settings for Victoria's gas sector in a net zero emissions future.

The full versions of all technical work undertaken to inform this advice are available at infrastructurevictoria.com.au or in the links below.

Literature review

A summary of key issues and opportunities identified in current literature sourced from academia, industry, think-tanks and governments to contribute to our understanding of the potential pathways towards net zero emissions for Victoria's gas infrastructure. This *literature review* was undertaken by Infrastructure Victoria.

Interjurisdictional analysis

Accenture undertook an *assessment of other states, territories and countries* currently transitioning away from a high reliance on natural gas to understand the potential for the Victorian Government to adopt and adapt similar policies and approaches.

Scenario analysis

We worked with a consortium of technical experts led by DORIS Engineering to undertake scenario analysis for a net zero emissions gas sector in Victoria in 2050. This work was progressed in two stages:

- Development and *qualitative analysis* of the relative economic, social and environmental impacts of four illustrative 2050 net zero gas sector scenarios for Victoria. The scenarios and underlying assumptions were designed to be plausible but also to be different from each other to enable identification and discussion of trade-offs and decisions that the community, Government and businesses of Victoria will need to make to meet the legislated emissions reduction targets.
- Identification and *in-depth analysis of hybrid scenarios* designed to meet or exceed the Victorian Government's interim and 2050 emissions reduction targets. This includes the infrastructure provision, upgrade and decommissioning decisions that need to be made, and the timing of those decisions, as well as an assessment of the potential costs and impact on Victorian consumers and businesses.

We looked at key trigger points and interdependencies associated with the infrastructure decisions and identified scenario elements that would be resilient in an uncertain future to allow Victoria's net zero outcomes to be achieved. In both stages of the scenario analysis, the scenarios aim to illustrate the performance of key variables but are not intended to be definitive or reflect an optimal scenario.

Asset life and adaptability review

Advisian carried out a *review of Victoria's existing gas infrastructure* to provide greater understanding of whether and how it can be repurposed to support a net zero gas sector. The age and condition of existing assets were assessed at a strategic level alongside the potential for upgrades to support clean energy sources and the key risks and benefits of repurposing.

The study has strategically assessed all infrastructure across the value chain, including producing facilities and pipelines, processing facilities and storage, transmission pipelines and distribution pipelines. In doing so, it has estimated which infrastructure may be repurposed for lower carbon gases and the likely requirements to do so.

This has allowed us to develop advice on required upgrades or decommissioning in line with the decisions needed for the gas sector to reach Victoria's emissions reduction targets.

Advisian's results are the result of a high level strategic assessment. Gas infrastructure owners and operators are undertaking their own more detailed assessments in collaboration with research organisations. Therefore, actual compatibility for use of specific transmission and distribution pipelines with hydrogen or other renewable gases remains the subject of ongoing investigations, and will likely vary with the age, steel type and construction of the pipelines in different locations.

The study has strategically assessed all infrastructure across the value chain, including producing facilities and pipelines, processing facilities and storage, transmission pipelines and distribution pipelines.

Energy efficiency analysis

Northmore Gordon and Energeia undertook detailed modelling to understand the *energy efficiency activities with the highest potential* to target natural gas use and reduce gas demand in Victoria's residential, commercial and industrial sectors.

This helped us to identify additional energy efficiency measures which could be adopted as a 'no regrets' measure to help reduce emissions associated with Victoria's natural gas use.

Consumer research

Research was undertaken to inform Infrastructure Victoria's understanding of the *barriers and enablers to reducing gas-related emissions in Victoria at a household level*. We examined knowledge of and attitudes towards household gas use, the extent to which households have taken actions to reduce their gas use, attachment to natural gas for specific household uses, and community support for reducing household gas use.

Consultation

Consultation ran throughout this advice project. This has included public consultation, as well as targeted questionnaires to key stakeholders, and meetings and workshops with the gas industry, businesses, regulators, all three levels of government, consumer advocates and environmental groups. Submissions reprinted with permission from their authors are available **here**. We received 121 responses in total.

7.

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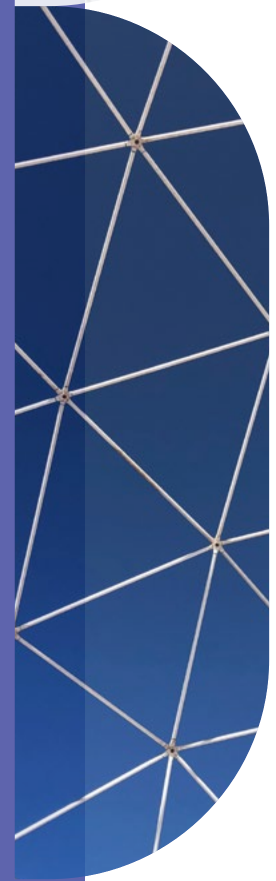

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